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SITE

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Technology Profiles
Sixth 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. 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 eighth 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 refine their innovative technologies at bench- or pilot-scale and may demonstrate them, with support from EPA, at hazardous waste sites. 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, the states, 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 sixth 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 23,000 copies of the fifth edition, published in 1992, have been distributed.

This document profiles 170 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 1993 and October 1993, 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 specific SITE technology 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.

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SITE PROGRAM DESCRIPTION

The U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program, now in its eighth 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 interrelationship between the programs.

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 level. The program compares the applicability of particular technologies to Superfund site waste characteristics and supports promising technologies that, within two years, may be ready to be evaluated under in the Demonstration Program. The technology's performance is documented in a final report, project summary, and bulletin.

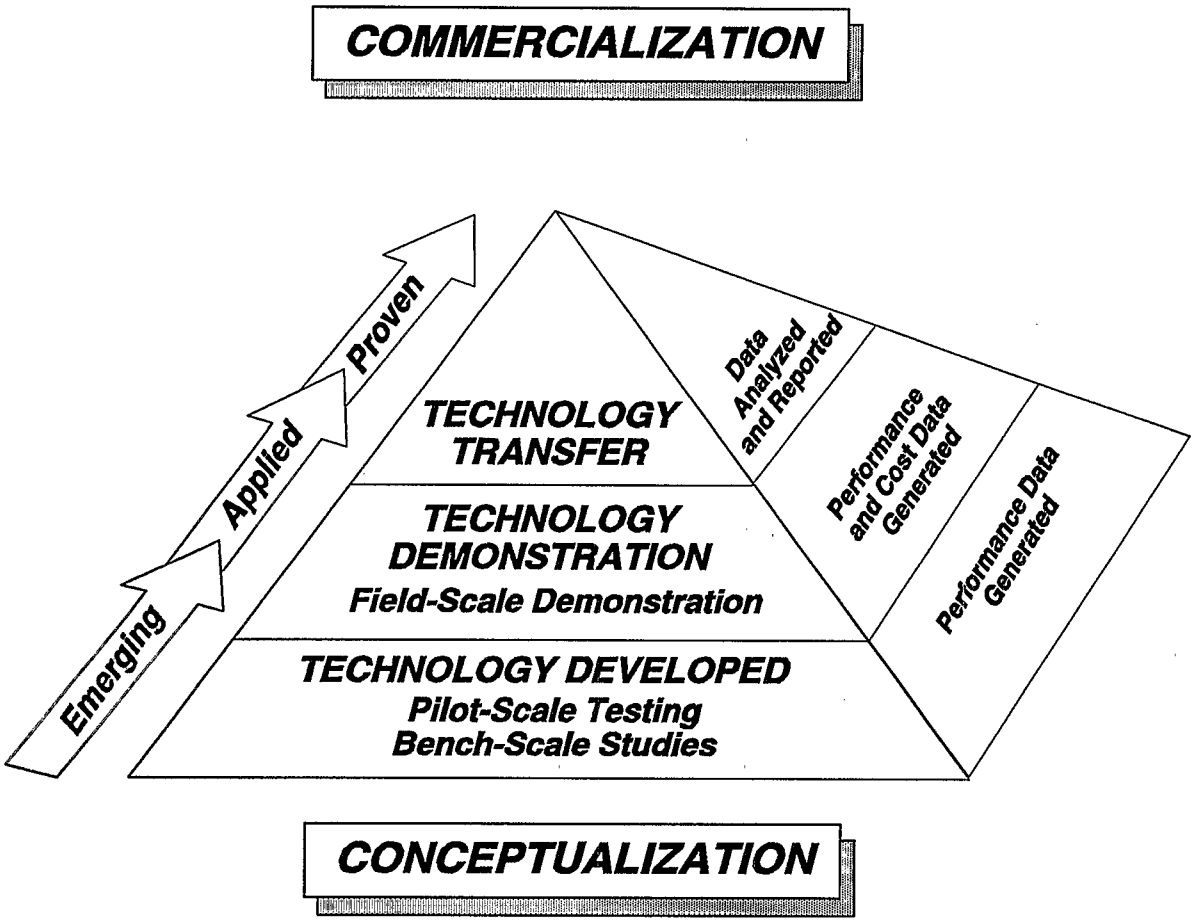

Figure 1: Development of Innovative Technologies

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.

In the past, EPA prepared an Applications Analysis Report (AAR) and a Technology Evaluation Report (TER) at the conclusion of a SITE demonstration. To better meet the information needs of the environmental community, EPA will begin to prepare an Innovative Technology Evaluation Report (ITER) and Technology Capsule at the end of a demonstration. These reports will 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 will also be presented. Over time, AARs and TERs will be phased out in favor of ITERs and Technology Capsules.

ITERs, Technology Capsules, other demonstration documents, and videotapes are distributed to provide reliable technical data for environmental decision–making and to promote the technology's commercial use.

EPA has provided technical and financial support to 64 projects in the Emerging Technology Program. Of these projects, 29 are completed, 34 are ongoing in the program, and one has exited the program. These technologies are divided into the following categories: thermal destruction (9), physical/chemical treatment (34), biological degradation (15), and materials handling (6). Figure 2 displays the breakdown of technologies in the Emerging Technology Program.

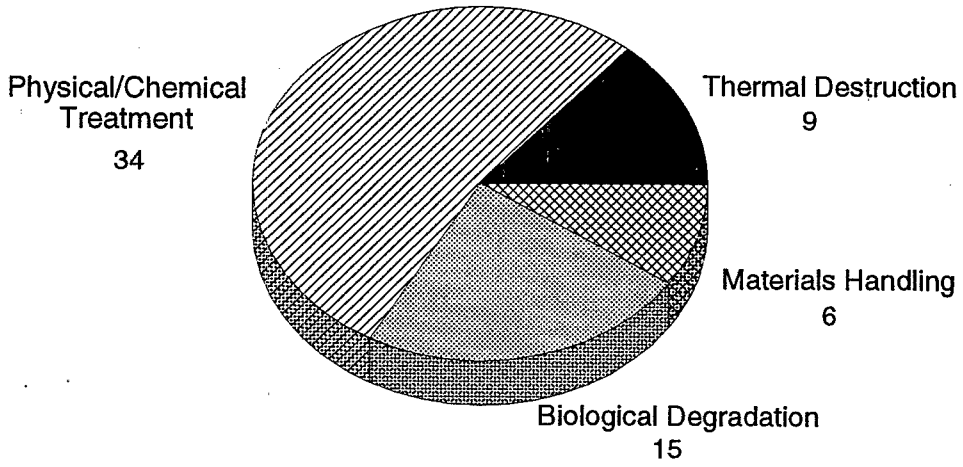

Figure 2: Innovative Technologies in the Emerging Technology Program

The Demonstration Program currently has 87 developers providing 98 demonstrations. Of these projects, 57 have completed demonstrations and 41 are ongoing. The projects are divided into the following categories: thermal destruction (10), biological degradation (19), physical/chemical treatment (37), solidification and stabilization (9), radioactive waste treatment (2), thermal desorption (15), materials handling (4), and other (2). Several technologies combine these treatment categories. Figure 3 shows the breakdown of technologies in the Demonstration Program.

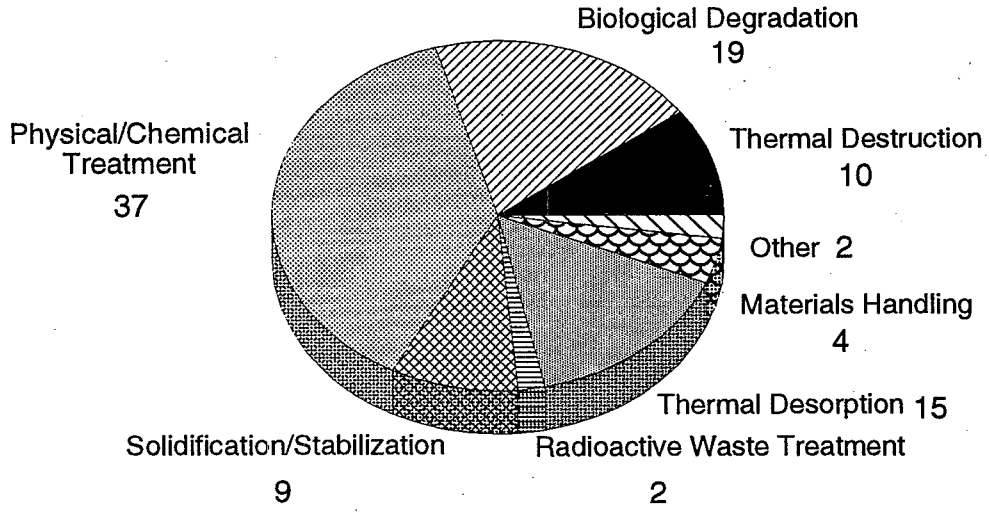

Figure 3: Innovative Technologies in the Demonstration Program

The Monitoring and Measurement Technologies Program's (MMTP) goal is to assess innovative and alternative monitoring, measurement, and site characterization technologies. During fiscal year 1993, six technologies were demonstrated. Additionally, the MMTP plans two demonstrations, each evaluating one or more monitoring and measurement technologies, in fiscal year 1994.

To date, 79 technology demonstrations have been completed (57 in the Demonstration Program and 22 in the MMTP); many reports have been published, and others are in various stages of production.

In the Technology Transfer Program, technical information on innovative technologies in the Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs 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
- Demonstration videotapes
- Project-specific fact sheets
- Innovative Technology Evaluation Reports
- 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: 301-670-6294 or 908-321-6677

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

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 at 513-569-7562. Additional SITE documents become available throughout the year. To find out about newly published documents or to be placed on the SITE mailing list, telephone or write to:

ORD Publications
26 West Martin Luther King Drive (G72)
Cincinnati, OH 45268
513-569-7562

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

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, eight solicitations have been completed — SITE 001 in 1986 through SITE 008 in 1993. The RFP for SITE 009 will be issued in January 1994.

The SITE demonstration process typically consists of five steps: (1) matching an innovative technology with an appropriate site; (2) preparing a Demonstration Plan that includes 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 87 developers and 98 projects. These projects are organized into two sections, one for completed projects and one for 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 1993

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 (ECRA) site in Hillsborough, NJ	Harry Moscatello 908-739-6444	Uwe Frank 908-321-6626	Soil, Rock	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
American Combustion, Inc., Norcross, GA (001) *Demonstration Date:* November 1987 - January 1988	PYRETRON® Thermal Destruction/EPA's Incineration Research Facility in Jefferson, AK 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	Lawrence King 216-829-7576	Laurel Staley 513-569-7863	Solids, Soil, Sludges	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	Sediment, Soil	Heavy Metals	PCBs, Nonspecific Organics
BioGenesis Enterprises, Inc., Des Plaines, IL (005) *Demonstration Date:* November 1992	BioGenesis℠ Soil Washing Process/Refinery site in Minnesota	Charles Wilde 703-250-3442 Mohsen Amiran 708-827-0024	Annette Gatchett 513-569-7697	Soil	Not Applicable	Volatile and Nonvolatile Hydrocarbons, PCBs

* Solicitation Number

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Bio-Rem, Inc., Butler, IN (007) *Demonstration Date:* May 1992 - June 1993	Augmented In Situ Subsurface Bioremediation Process/ Williams AFB in Phoenix, AZ	David O. Mann 219-868-5823 800-428-4626	Kim Lisa Kreiton 513-569-7328	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	Dennis Chilcote 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	Dennis Chilcote 612-942-8032	Mary Stinson 908-321-6683	Soil	Metals	High Molecular Weight Organics, PAHs, PCP, PCBs, Pesticides
Brice Environmental Services Corporation, Fairbanks, AK (007) *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
Canonie Environmental Services Corporation, Porter, IN (007) *Demonstration Date:* September 1992	Low Temperature Thermal Aeration (LTTA)/Pesticide Site in Phoenix, AZ	Chetan Trivedi 219-926-7169	Paul dePercin 513-569-7797	Soil, Sediment, Sludge	Not Applicable	VOCs, SVOCs, OCPs, OPPs, TPHs
CeTech Resources, Inc. (A Subsidiary of Chemfix Technologies, Inc.), St. Rose, LA (002) *Demonstration Date:* March 1989	Solidification and Stabilization/Portable Equipment Salvage Company 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

TABLE 1 (continued)
Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
CF Systems Corporation, Woburn, MA (002) *Demonstration Date:* September 1988	Solvent Extraction/New Bedford Harbor Superfund Site in New Bedford, MA	Chris Shallice 617-937-0800	Laurel Staley 513-569-7863	Soil, Sludge, Wastewater	Not Applicable	PCBs, VOCs, SVOCs, Petroleum Wastes
Chemical Waste Management, Inc., Schaumburg, IL (005) *Demonstration Date:* September 1992	PO*WW*ER™ Technology/ Developer'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
Chemical Waste Management, Inc., Anderson, SC (003) *Demonstration Date:* May 1992	X*TRAX™ Thermal Desorption/ Re-Solve, Inc., Superfund Site in North Dartmouth, MA	Carl Palmer 803-646-2413	Paul dePercin 513-569-7797	Soil, Sludge, Other Solids	Not Applicable	VOCs, SVOCs, PCBs
Dehydro-Tech Corporation, East Hanover, NJ (004) *Demonstration Date:* August 1991	Carver-Greenfield Process® for Solvent Extraction of Oily Waste/EPA Research Facility in Edison, NJ	Theodore Trowbridge 201-887-2182	Laurel Staley 513-569-7863	Soil, Sludge, Sediments	Not Applicable	PCBs, Dioxins, Oil-Soluble Organics
E.I. DuPont de Nemours and Co. and Oberlin Filter Co., Newark, DE and Waukesha, WI (003) *Demonstration Date:* April - May 1990	Membrane Microfiltration/ Palmerton Zinc Superfund Site in Palmerton, PA	Ernest Mayer 302-366-3652	John Martin 513-569-7758	Groundwater, Leachate, Wastewater, Electroplating Rinsewaters	Heavy Metals, Cyanide, Uranium	Organic Particulates, Volatile Organics
ECOVA Corporation, Golden, CO (006) *Demonstration Date:* May - September 1991	Bioslurry Reactor/EPA Test and Evaluation Facility in Cincinnati, OH	William Mahaffey 303-273-7177	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, Gases	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
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, Gases	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols
EPOC Water, Inc., Fresno, CA (004) *Demonstration Date:* May 1992	Precipitation, Microfiltration, and Sludge Dewatering/Iron Mountain Superfund Site in Redding, CA	Gary Bartman 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/Rocky Flats Plant in Golden, CO	Tod Johnson 713-334-6080	Annette Gatchett 513-569-7697	Groundwater, Industrial Wastewater	Heavy Metals, Radionuclides	Not Applicable
Funderburk & Associates (formerly HAZCON, Inc.), Oakwood, TX (001) *Demonstration Date:* October 1987	Dechlorination and Immobilization/Former Oil Processing Plant in Douglassville, PA	Ray Funderburk 903-545-2004	Paul dePercin 513-569-7797	Soil, Sludge, Sediments	Heavy Metals	Nonspecific Organics
General Atomics (formerly Ogden Environmental Services), San Diego, CA (001) *Demonstration Date:* March 1989	Circulating Bed Combustor/Ogden's Facility in La Jolla, 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
GIS/Solutions, Inc., Concord, CA (007) *Demonstration Date:* August 1993	GIS/Key™ Environmental Data Management Software/San Francisco, CA	Asad Al-Malazi 510-827-5400	Dick Eilers 513-569-7809	Not Applicable	Not Applicable	Not Applicable

TABLE 1 (continued)
Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Gruppo Italimpresse (developed by Shirco Infrared Systems, Inc.), Rome, Italy (001) (2 Demonstrations) *Demonstration Dates:* Florida: August 1987 Michigan: November 1987	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
Horsehead Resource Development Co., Inc. (HRD), 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 Richards 513-569-7783	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., Manhattan Beach, CA (005) *Demonstration Date:* August 1991 - September 1993	Steam Enhanced Recovery Process/Fuel Spill Site in Huntington Beach, CA	Ron Van Sickle 310-616-6634	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs
Illinois Institute of Technology Research Institute/Halliburton NUS, Oak Ridge, TN (007) *Demonstration Date:* August 1993	Radio Frequency Heating/Kelly Air Force Base in San Antonio, TX	Paul Carpenter 904-283-6022 Clifton Blanchard 615-483-9900 Guggliam Sresty 312-567-4232	Laurel Staley 513-569-7863	Soil	Not Applicable	VOCS and SVOCs
International Waste Technologies/ Geo-Con, Inc., Wichita, KS and Monroeville, PA (001) (2 Demonstrations) *Demonstration Date:* April - May 1988	In Situ Solidification and Stabilization Process / General Electric Service Shop in Hialeah, FL	Jeff Newton 316-269-2660 Chris Ryan 412-856-7700	Mary Stinson 908-321-6683	Soil, Sediment	Nonspecific Inorganics	PCBs, PCP, Other Nonspecific Organics

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
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	Dick Eilers 513-569-7809	Groundwater, Wastewater	Not Applicable	Nonspecific Organic Compounds
NOVATERRA, Inc. (formerly Toxic Treatments USA, Inc.), Torrance, CA (003) *Demonstration Date:* September 1989	In Situ Steam and Air Stripping/Annex Terminal, San Pedro, CA	Philip LaMori 310-843-3190	Paul dePercin 513-569-7797	Soil	Nonspecific Inorganics, Heavy Metals	VOCs, SVOCs, Hydrocarbons
Peroxidation Systems, Inc., Tucson, AZ (006) *Demonstration Date:* September 1992	**perox-pure**™ Advanced 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
Resources Conservation Company, Ellicott City, MD (001) *Demonstration Date:* July 1992	B.E.S.T. Solvent Extraction Technology/Grand Calumet River in Gary, IN	Lanny Weimer 301-596-6066	Mark Meckes 513-569-7348	Soil, Sludge, Sediment	Not Applicable	Oil, PCBs, PAHs, Pesticides, Herbicides
Retech, Inc., Ukiah, CA (002) *Demonstration Date:* July 1991	Plasma Arc Vitrification/DOE Component Development and Integration Facility in Butte, MT	Ronald Womack or Leroy Leland 707-462-6522	Laurel Staley 513-569-7863	Soils, Sludge	Metals	Nonspecific Organics
Risk Reduction Engineering Laboratory, Cincinnati, OH (006) *Demonstration Date:* August 1993	Base-Catalyzed Dechlorination Process/Koppers Company Superfund Site in Morrisville, NC	Charles Rogers 513-569-7626 Yei-Shong Shieh 215-832-0700	Terrence Lyons 513-569-7589	Soils, Sediments	Not Applicable	PCBs, PCPs, Halogenated Compounds
Risk Reduction Engineering Laboratory, Cincinnati, OH (007) *Demonstration Date:* November 1992	Volume Reduction Unit/ Escambia Wood Preserving Site in Pensacola, FL	Richard Griffiths 908-321-6629	Teri Richardson 513-569-7949	Soil	Metals	Creosote, PCPs, PAHs, VOCs, SVOCs, Pesticides

TABLE 1 (continued)
Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Risk Reduction Engineering Laboratory and IT Corporation, Cincinnati, OH (004) *Demonstration Dates:* September 1988, December 1989, and August 1990	Debris Washing System/ Superfund Sites in Detroit, MI; Hopkinsville, KY; and Walker County, GA	Michael Taylor or Majid Dosani 513-782-4700	Naomi Barkley 513-569-7854	Debris	Nonspecific Inorganics	Nonspecific Organics, PCBs, Pesticides
Risk Reduction Engineering Laboratory and University of Cincinnati, Cincinnati, OH (005) *Demonstration Date:* July 1991 - September 1992	Hydraulic Fracturing/Feasibility Studies conducted in Oakbrook, IL and Dayton OH	Larry Murdoch 513-556-2526	Naomi Barkley 513-569-7854	Soil, Groundwater	Nonspecific Inorganics	Nonspecific Organics
Risk Reduction Engineering Laboratory and USDA Forest Products Laboratory, Cincinnati, OH (006) *Demonstration Date:* September 1991 - November 1992	Fungal Treatment Technology/ Brookhaven Wood Preserving in Brookhaven, MS	Richard Lamar 608-231-9469 John Glaser 513-569-7568	Kim Lisa Kreiton 513-569-7328	Soil	Not Applicable	PCPs, PAHs, Chlorinated Organics
SBP Technologies, Inc., Stone Mountain, GA (005) *Demonstration Date:* October 1991	Membrane Filtration and Bioremediation/American Creosote Works in Pensacola, FL	David Drahos 404-498-6666	Kim Lisa Kreiton 513-569-7328	Groundwater, Soils, Sludges	Not Applicable	Organic Compounds, PAHs, PCBs, TCE, PCP
Silicate Technology Corporation, Scottsdale, AZ (003) *Demonstration Date:* November 1990	Chemical Fixation/Solidification Treatment Technologies/Selma Pressure Treating Site in Selma, CA	Stephen Pelger or Scott Larsen 602-948-7100	Edward Bates 513-569-7774	Soil, Sludge, Wastewater	Metals, Cyanide	High Molecular Weight Organics
J.R. Simplot Company,** Pocatello, ID (007) *Demonstration Date:* July 1993	Biodegradation of Dinoseb/ Bowers Field in Ellensburg, WA	Dane Higdem 208-234-5367	Wendy Davis-Hoover 513-569-7206	Soil	Not Applicable	Nitroaromatics

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1993

Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
J.R. Simplot Company,** Pocatello, ID (007) *Demonstration Date:* September 1993 - October 1993	Biodegradation of Trinitrotoluene/U.S. Department of Defense site in St. Louis, MO	Dane Higdem 208-234-5367	Wendy Davis-Hoover 513-569-7206	Soil	Not Applicable	Nitroaromatics
SoilTech ATP Systems, Inc., Englewood, CO (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	Roger Nielson 303-290-8336 Joseph Hutton 219-926-8651	Paul dePercin 513-569-7797	Soil, Sludge, Refinery Wastes	Not Applicable	PCBs, Chlorinated Pesticides, VOCs
Soliditech, Inc., Houston, TX (002) *Demonstration Date:* December 1988	Solidification and Stabilization/ Imperial Oil Company/ Champion Chemical Company Superfund Site in Morganville, NJ	Bill Stallworth 713-497-8558	Jack Hubbard 513-569-7507	Soil, Sludge	Metals, Nonspecific Inorganics	Nonspecific Organics
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 and SVOCs
Toronto Harbour Commission, Toronto, Ontario, Canada (007) *Demonstration Date:* April - May 1992	Soil Recycling/Toronto Port Industrial District in Toronto, Ontario	Dennis Lang 416-863-2047	Teri Richardson 513-569-7949	Soil	Nonspecific Inorganics	Nonspecific Organics
Ultrox International, 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 Hydrocarbons, VOCs, Pesticides, PCBs
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 415-744-2241	Jack Hubbard 513-569-7507	Soil	Volatile Inorganics	Volatile Organics

** From Emerging Technology Program

TABLE 1 (continued)

Completed SITE Demonstration Program Projects as of October 1993

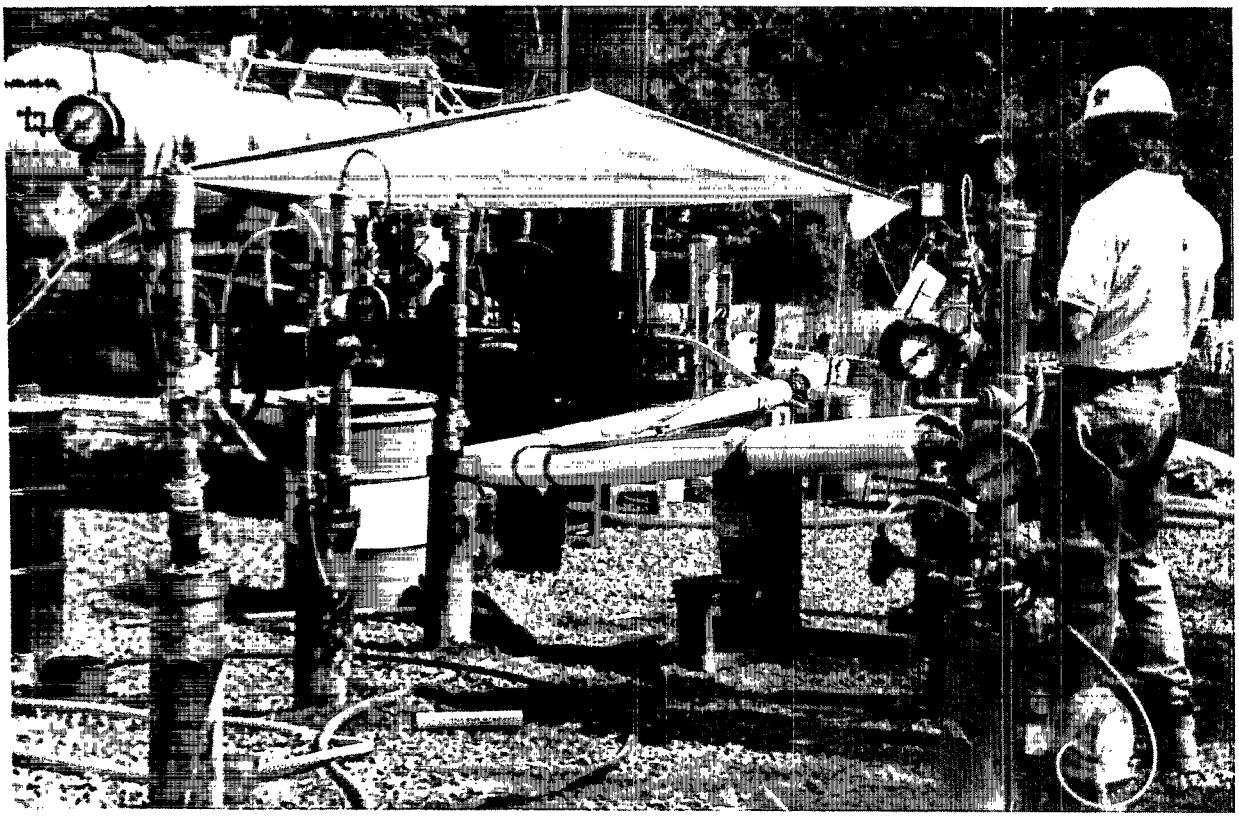
Developer	Technology/ Demonstration Location	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
WASTECH Inc., Oak Ridge, TN (004) *Demonstration Date:* August 1991	Solidification and Stabilization/ Robins AFB in Warner Robins, GA	Benjamin Peacock 615-483-6515	Terrence Lyons 513-569-7589	Soil, Sludge, Liquid Waste	Nonspecific Radioactive Inorganics	Nonspecific Organics
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 215-430-7423	Paul dePercin 513-569-7797	Soil, Sludge	Not Applicable	VOCs, SVOCs, Petroleum Hydrocarbons, PAHs
Roy F. Weston, Inc./IEG Technologies, Woodland Hills, CA (007) *Demonstration Date:* May - November 1993	UVB - Vacuum Vaporizing Well/March Air Force Base, CA	Jeff Bannon or Ron Chu 818-596-6900 Eric Klingel 704-357-6090	Michelle Simon 513-569-7469	Groundwater	Not Applicable	VOCs

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

TECHNOLOGY DESCRIPTION:

An integrated treatment system incorporating Pneumatic Fracturing Extraction(SM) (PFE(SM)) with hot gas injection (HGI) has been jointly developed by Accutech Remedial Systems, Inc. (Accutech), and the Hazardous Substance Management Research Center located at the New Jersey Institute of Technology in Newark, New Jersey. The system (see photograph below) provides a cost-effective, accelerated remedial approach to low-permeability formations contaminated with halogenated and nonhalogenated volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC). 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 through the formation, which can greatly improve the rates of contaminant mass removal. PFE(SM) also increases the effective area that can be influenced from each extraction well while intersecting new pockets of contamination that were previously trapped in the formation. Thus VOCs are removed faster and from a larger section of the formation.

This process can be combined with a catalytic destruction unit equipped with special atalytes to destroy halogenated organics. The heat thus generated can be recycled to the formation, significantly raising the vapor pressure of the contaminants. Thus, the VOCs volatilize faster, which makes cleanups more efficient.



Pneumatic Fracturing Extraction and Catalytic Oxidation

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

PFE(SM) can be coupled 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 integrated treatment system of PFE(SM) with HGI is cost-effective for treating soil and rock formations where conventional in situ technologies have limited effectiveness because of low-permeability 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 low-permeability 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 (NSDEPE) Environmental Cleanup Responsibility Act (ECRA) site in Hillsborough, New Jersey, where trichloroethene (TCE) and other VOCs were removed from a siltstone formation. Results of this demonstration were published in the following documents available from CERI:

- 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 results indicate that the PFE(SM) technology increased the effective vacuum radius of influence nearly threefold and 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.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
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2890 Woodbridge Avenue
Edison, NJ 08837
908-321-6626
Fax: 908-906-6990

TECHNOLOGY DEVELOPER CONTACT:
Harry Moscatello
Accutech Remedial Systems, Inc.
Cass Street and Highway 35
Keyport, NJ 07735
908-739-6444
Fax: 908-739-0451

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

AMERICAN COMBUSTION, INC.
(PYRETRON® Thermal Destruction)

TECHNOLOGY DESCRIPTION:

The PYRETRON® thermal destruction technology (see figure below) controls the heat input into an incineration process by using the PYRETRON® oxygen-air-fuel burners and controlling the level of excess oxygen available for oxidation of hazardous waste. The PYRETRON® combustor relies on a new technique for mixing auxiliary fuel, oxygen, and air to (1) provide the flame envelope with enhanced stability, luminosity, and flame core temperature and (2) reduce the combustion volume per million British thermal units (Btu) 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 volatilization rate of contaminants from the waste.

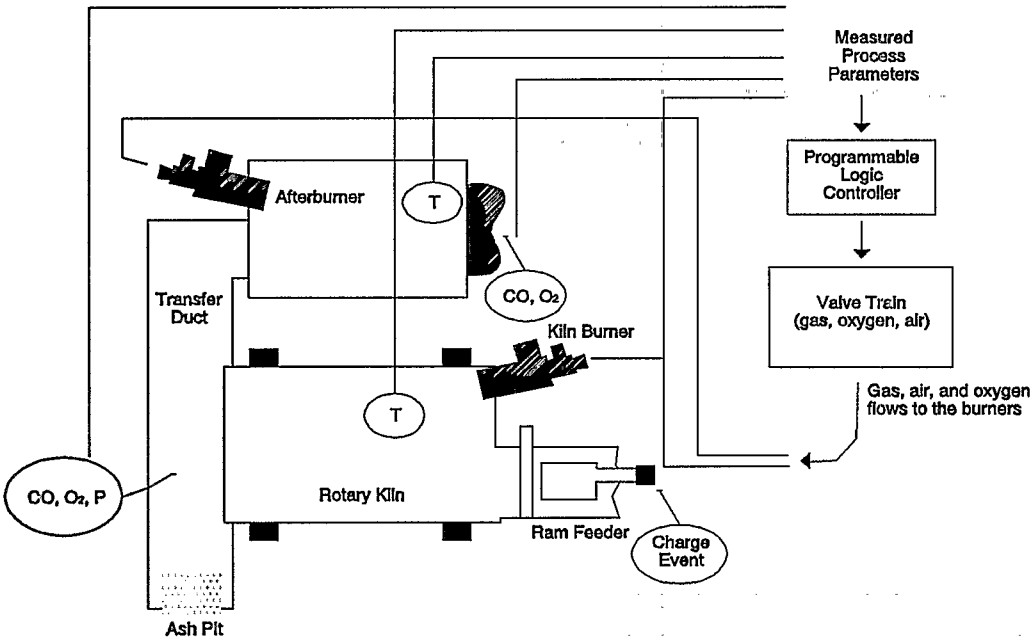
The technology can be fitted onto any conventional incineration unit to burn liquids, solids, and sludges. Solids and sludges can also be coincinerated when the burner is used with a rotary kiln or similar equipment.

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 (RCRA) heavy metal wastes, or inorganic wastes.

STATUS:

A demonstration was conducted at EPA's Incineration Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund



PYRETRON® Thermal Destruction System

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

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 (PAH) were selected as the principal organic hazardous constituents (POHC) for the test program -- naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene.

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

- The PYRETRON® technology with oxygen enhancement achieved double the waste throughput possible with conventional incineration.
- All particulate emission levels in 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.
- 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 can be achieved 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.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
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U.S. EPA
Risk Reduction Engineering Laboratory
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513-569-7863
Fax: 513-569-7620

TECHNOLOGY DEVELOPER CONTACT:
Gregory Gitman
American Combustion, Inc.
4476 Park Drive
Norcross, GA 30093
404-564-4180
Fax: 404-564-4192

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

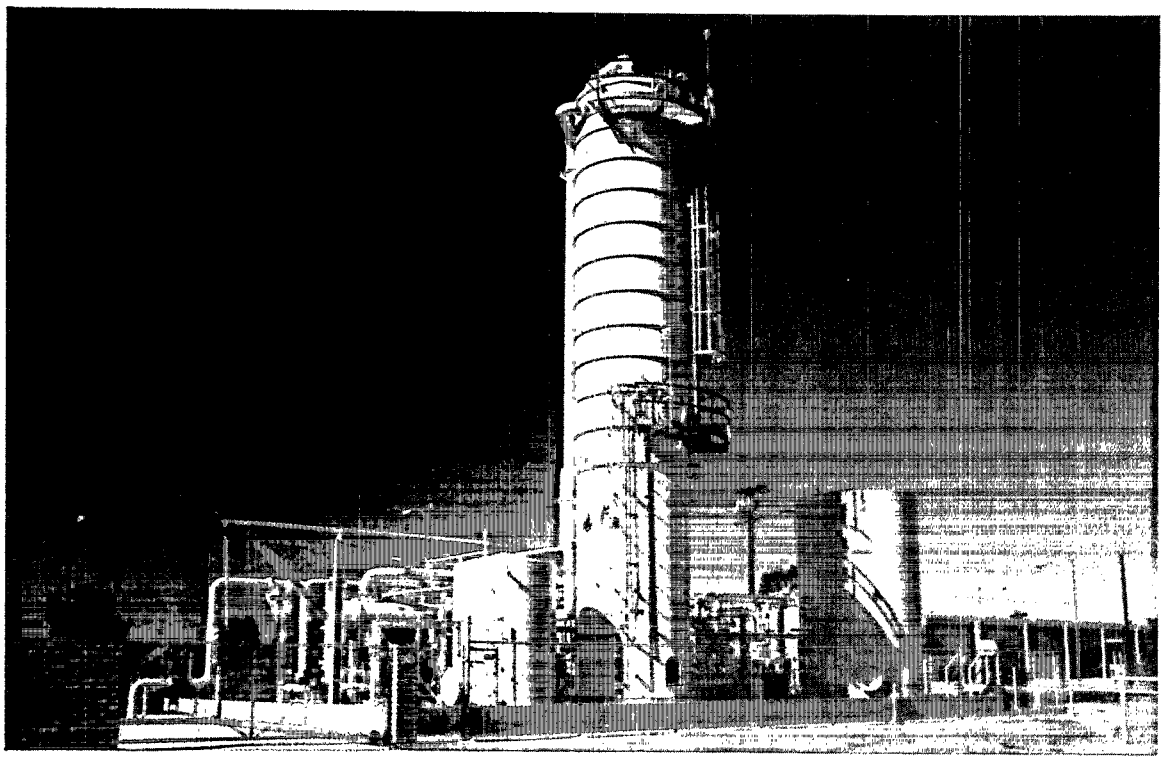
AWD TECHNOLOGIES, INC.
(Integrated Vapor Extraction and Steam Vacuum Stripping)

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 up to 99.99 percent of VOCs in water. 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.

FOR FURTHER INFORMATION:

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Cincinnati, OH 45268
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Fax: 513-569-7620

TECHNOLOGY DEVELOPER CONTACT:
David Bluestein
AWD Technologies, Inc.
49 Stevenson Street, Suite 600
San Francisco, CA 94105
415-227-0822

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

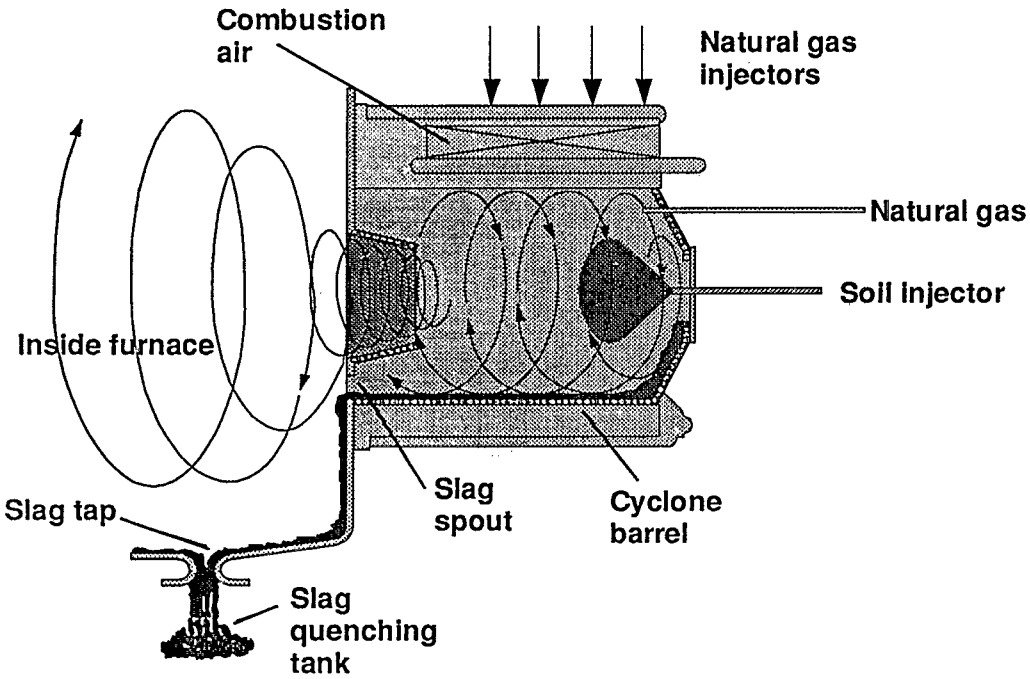
BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed for the combustion of high inorganic content (high-ash) coal. The combination of high heat-release rates (45,000 British thermal units [Btu] per cubic foot of coal) and high turbulence in cyclones assures achievement of 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 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 (820 °F) 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 is captured and melted, and organics are destroyed in the gas phase or in the molten slag layer 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 is dropped 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

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

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 in the form of solids, 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, an important application is treatment of soils that contain lower-volatility radionuclides such as strontium and transuranics.

STATUS:

This 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.

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, greater than 88 percent of the strontium, and greater than 97 percent of the zirconium were captured in the slag. Volume was reduced 28 percent on a dry weight basis. Destruction and removal efficiencies (DRE) 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 is below the Resource Conservation Recovery Act (RCRA) limit of 0.08 gr/dscf. 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:

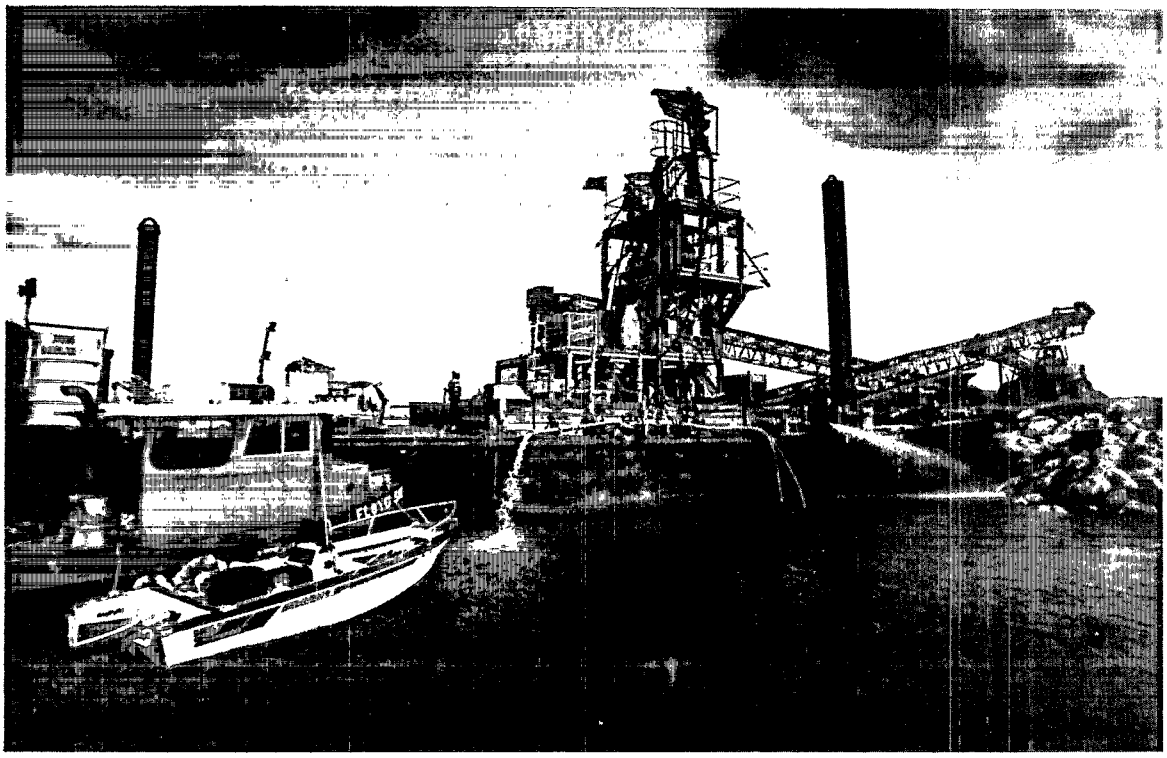
The Bergmann USA Soil and Sediment Washing technology separates contaminated particles by density and grain size (see photograph below). The technology operates on the hypothesis that most contamination is concentrated in the fine particle fraction (-63 micron fines), and that contamination of larger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

In this technology, 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. Rotary trommel screen, dense media separators, cyclone separators, and other equipment create mechanical and fluid shear stress, removing contaminated silts and clay from granular soil particles. Different separation processes then create output streams consisting of granular soil particles, silts and clays, and wash water.

Upflow classification and separation, also known as elutriation, is used to separate light contaminated specific gravity materials such as contaminated leaves, twigs, roots, or wood chips.

WASTE APPLICABILITY:

This technology is suitable for treating soils and sediment contaminated with polychlorinated biphenyls (PCB). The technology has been applied to soils and sediments contaminated with organics and heavy metals, including cadmium,



Bergmann USA Soil and Sediment Washing

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

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 field evaluated in Toronto, Ontario in April 1992 (see Toronto Harbour Commission profile in this document), and Saginaw, Michigan in May 1992. Twenty-three 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 at Saginaw, Michigan will be available in late 1993.

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

BIOGENESIS ENTERPRISES, INC.
(BioGenesis℠ Soil Washing Process)

TECHNOLOGY DESCRIPTION:

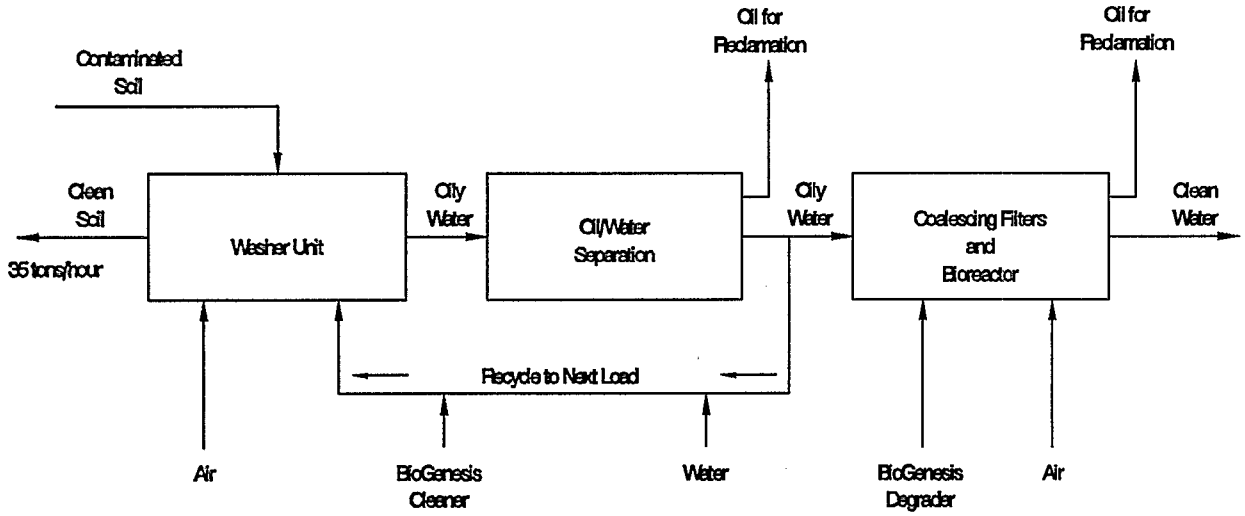
The BioGenesis℠ process uses a specialized truck, a complex surfactant, and water to clean soil contaminated with organics. Ancillary equipment includes gravity oil and water separators, coalescing filters, and a bioreactor. All equipment is mobile, and treatment normally occurs on site. The cleaning rate for oil contamination of 5,000 parts per million (ppm) is 25 to 35 tons per hour. A single wash removes 85 to 99 percent of hydrocarbon contamination, up to 15,000 ppm. High concentrations may require additional washes depending on the cleanup objective.

The figure below shows the soil washing procedure. Up to 35 tons (22 cubic yards) of contaminated soil are loaded into a washer unit containing water and BioGenesis℠ cleaner. The BioGenesis℠ cleaner is a light alkaline mixture of natural and organic materials containing no hazardous or petrochemical ingredients. For 15 to 30 minutes, aeration equipment agitates the mixture, washing the soil and encapsulating oil with BioGenesis℠ cleaner. After washing, the extracted oil is reclaimed, wash water is recycled or treated, and the soil is dumped from the soil washer. Hazardous organics, such as polychlorinated biphenyls (PCB), can be extracted in the same manner and processed using compound-specific treatment methods.

Advantages of BioGenesis℠ include (1) treatment of soils containing both volatile and nonvolatile oils, (2) treatment of soil containing up to 50 percent clays, (3) high processing rates, (4) on-site operation, (5) production of reusable oil, treatable water, and soil suitable for on-site backfill, (6) absence of air pollution, except during excavation, (7) and accelerated biodegradation of oil residuals in the soil.

WASTE APPLICABILITY:

This technology extracts volatile and nonvolatile oils, chlorinated hydrocarbons, pesticides, and other organics from most types of soils,



Soil Washing Process

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

including clays. Treatable contaminants include asphalteens, heating oils, diesel fuel, gasoline, PCBs, and polynuclear aromatic hydrocarbons.

STATUS:

The BioGenesis℠ technology was accepted into the SITE Demonstration Program in June 1990. The process was demonstrated in November 1992 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. Treatability tests were conducted in May 1992 at Santa Maria, California. Full commercial operations began in Wisconsin in October 1992. The technology was modified in June 1993 to treat polynuclear aromatic hydrocarbons (PAH) in harbor sediment, in conjunction with testing for Environment Canada in Wastewater Technology Centre's Contaminated Sediment Treatment Technology Program.

Research continues to extend application of the technology to acid extractables, base and neutral extractables, pesticides, and acutely hazardous materials.

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

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.

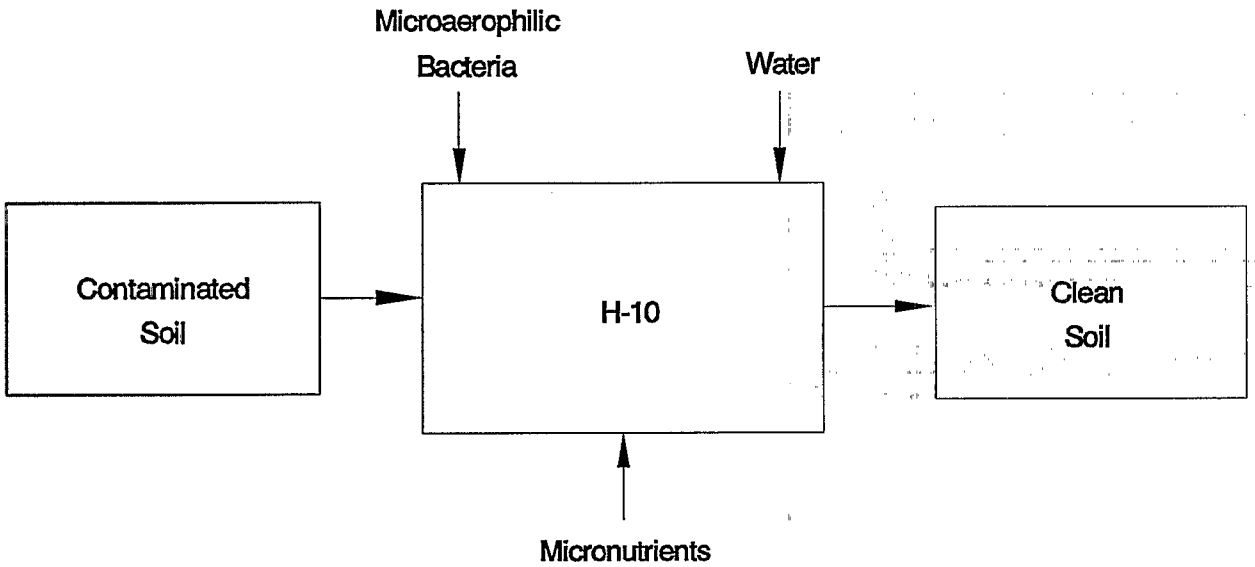
The bioremediation process consists of four steps: (1) defining and characterizing the contamination plume; (2) selecting a site-specific application methodology; (3) initiating and propagating the bacterial culture; and (4) cleanup monitoring and reporting.

WASTE APPLICABILITY:

This technology treats soil and water contaminated with hydrocarbons, halogenated hydrocarbons, and chlorinated compounds. About 240 compounds which can be successfully treated by this process have been identified.

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 will be available after January 1, 1994.



Augmented In Situ Subsurface Bioremediation Process

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

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

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

BIOTROL, INC.
(Biological Aqueous Treatment System)

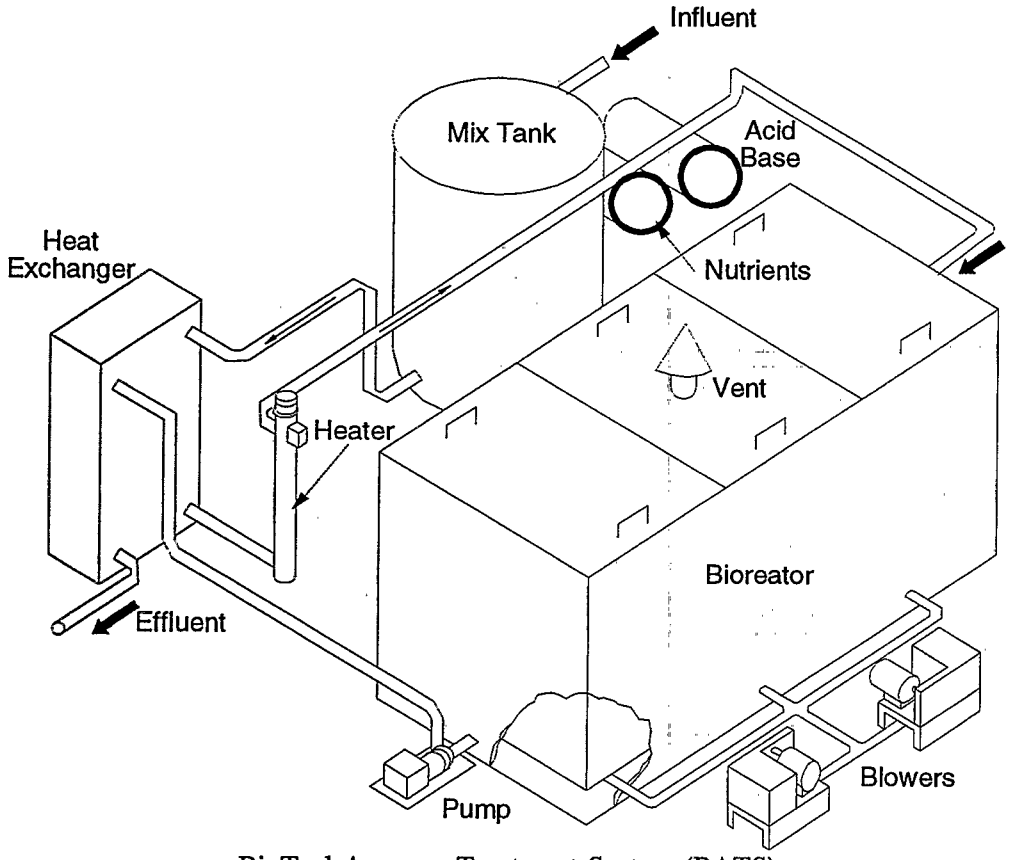
TECHNOLOGY DESCRIPTION:

The BioTrol Aqueous Treatment System (BATS) is a patented biological treatment system that effectively treats contaminated groundwater and process water. The system uses naturally occurring microbes; however, in some instances 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, using both 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 perform the degradation 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 the 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 (POTW) or



BioTrol Aqueous Treatment System (BATS)

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

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

WASTE APPLICABILITY:

This technology may be applied to a wide variety of wastewaters, including groundwater, lagoons, and process water. Contaminants amenable to treatment include pentachlorophenol, 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 technology 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 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 SITE demonstration of the BATS technology took place from July 24 to September 1, 1989, at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. The system was 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 NTIS (Order No. PB92-110 048/AS).

DEMONSTRATION RESULTS:

The SITE demonstration yielded the following results:

- Reduced pentachlorophenol concentrations from ~45 to 1 ppm or less in a single pass
- Achieved 96 to 99 percent removal of PCP
- Produced minimal sludge and no air emissions of pentachlorophenol
- Mineralized chlorinated phenolics
- Eliminated biotoxicity in the groundwater
- Appeared to be unaffected by low concentrations of oil and grease (~50 ppm) and heavy metals in groundwater
- Required minimal operator attention
- Operating costs of treatment given in dollars per 1,000 gallons were $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 fraction of soil (silt, clay, and soil organic matter) or to contamination associated with the coarse (sand and gravel) soil fraction.

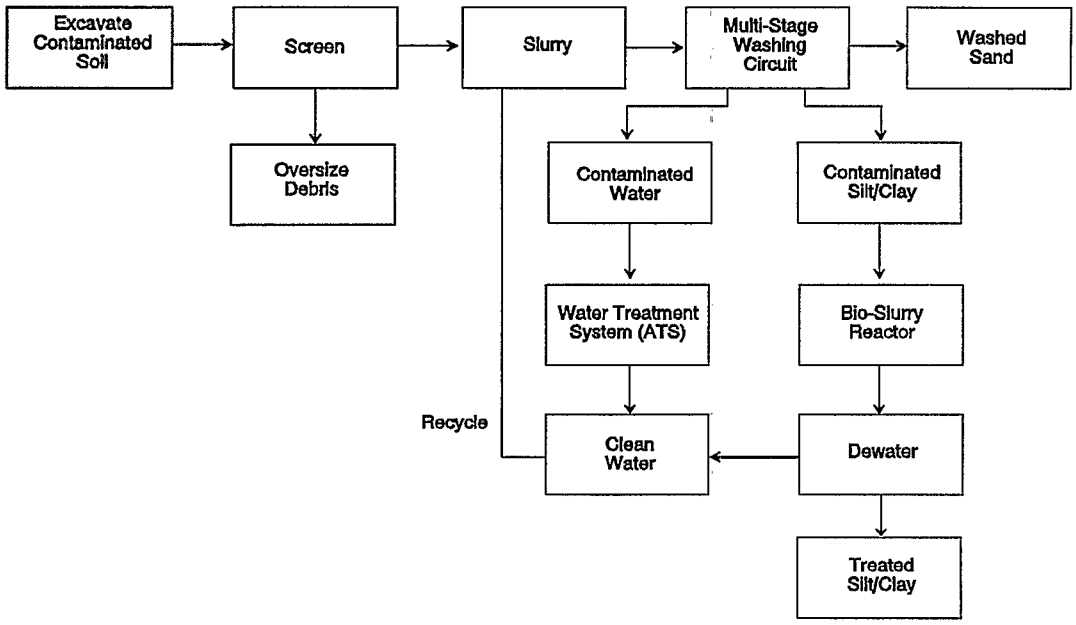
As a part of the process, debris is removed from the soil, and the soil is mixed with water and subjected to various unit operations common to the mineral processing industry. These operations can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, 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.

Residual products that are contaminated can be treated by other methods. Process water is normally recycled after biological or physical treatment. Options for the contaminated fines include off-site disposal, incineration, stabilization, and biological treatment.

WASTE APPLICABILITY:

This technology was initially developed to clean soils contaminated with wood preserving wastes, such as polynuclear aromatic hydrocarbons (PAH) and pentachlorophenol (PCP). The technology may also be applied 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 SITE demonstration of the Soil Washing System took place from September 25 to October 30, 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 was 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. During the second phase (7 days), soil containing 680 ppm PCP and 404 ppm total PAHs was fed to the system.

Contaminated process water from soil washing was treated biologically in a fixed-film reactor and was recycled. A portion of the contaminated fines generated during soil washing 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 NTIS (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; while 90 percent of the feed soil contamination was contained within the woody residues, fines, and process wastes.
- The soil washer removed up to 89 percent of PCP and 88 percent of the total PAHs, based on the difference between ppm levels in the contaminated (wet) feed soil and the washed soil.
- The system degraded up to 94 percent of the 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:

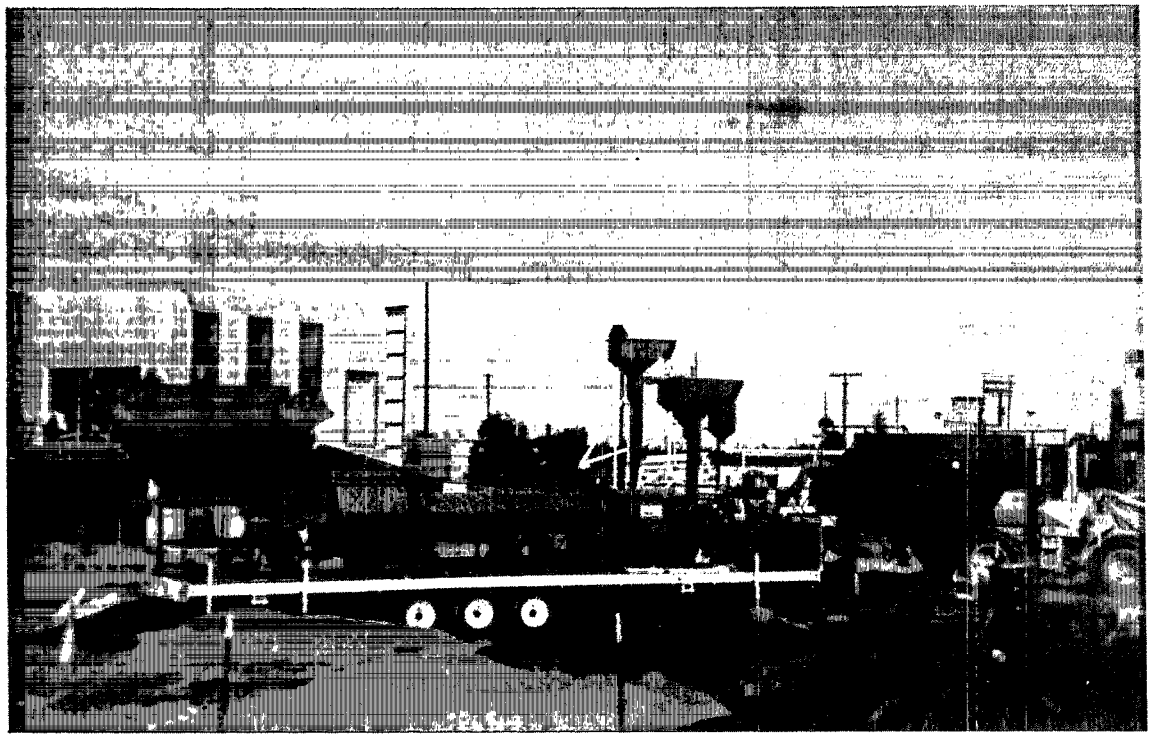
The Brice Environmental Services Corporation (BESCORP) soil washing plant is a highly portable, cost-effective, aboveground process for reducing the overall volume of contaminated soil requiring treatment.

The demonstration plant is contained on an 8-by-40-foot trailer and transported with a pickup truck. The processing rate depends on the percentage of soil fines in the feed material. During the SITE demonstration, the BESCORP system processed between 2.5 and 5 tons of contaminated soil per hour; however, the unit can operate at up to 20 tons per hour. The system uses conventional mineral processing equipment for deagglomeration, density separation, and material sizing, centered around a patented process for effective fine particle separation. By use of high attrition and wash water, soil contaminants are partitioned to fine soil fractions. Oversized coarse soil fractions are washed in clean water before exiting the plant for redeposition on site. Process water is containerized, recirculated, and treated to remove suspended and dissolved contaminants. Fine contaminated soil fractions are containerized automatically during plant operation.

The BESCORP system can be upscaled; a 150-ton-per-hour plant, built in 1989 for mining gold, processed 47,000 cubic yards (71,400 tons) of material.

WASTE APPLICABILITY:

The BESCORP technology can be used to treat soil contaminated with radioactive and heavy metals. Metals concentration does not influence



BESCORP Soil Washing Plant

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

system throughput. Currently BESCORP is designing a soil washing plant for remediation of hydrocarbon-contaminated soil.

The BESCORP technology recirculates all process water and containerizes the entire waste stream; the only noncontainerized products leaving the plant are washed, clean coarse soil fractions.

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 using lead-contaminated soil at the Alaskan Battery Enterprises (ABE) Superfund site in Fairbanks, Alaska. Results of the demonstration are scheduled for publication in late 1993.

The ABE site was added to the National Priorities List because of high levels of lead found in site soils and the potential for groundwater contamination. The lead contamination resulted from past manufacturing and recycling of batteries at the site. EPA removed some contaminated soil from the site in 1988 and 1989. Further site testing in 1990 revealed that additional contaminated soil remained on site.

BESCORP was selected primarily because the site soil is gravelly to sandy soil with a minimum of clay and silt. These soil characteristics make the site highly amenable to the BESCORP soil washing system. Analysis of the excavated soil revealed large quantities of metallic lead and contaminated battery casings; BESCORP quickly modified its process to separate these additional contaminants.

The demonstration at the ABE site established two precedents for the SITE Program:

- Volume Processed
  Over 100 cubic yards of material was processed.

- Contaminant Recycling
  BESCORP's unique approach for isolating and automatically containerizing three lead contaminant types (contaminated soil fines, elemental lead, and battery casings and chips) with an in-line process recovered metallic lead and enabled washed battery casings to be recycled.

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

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

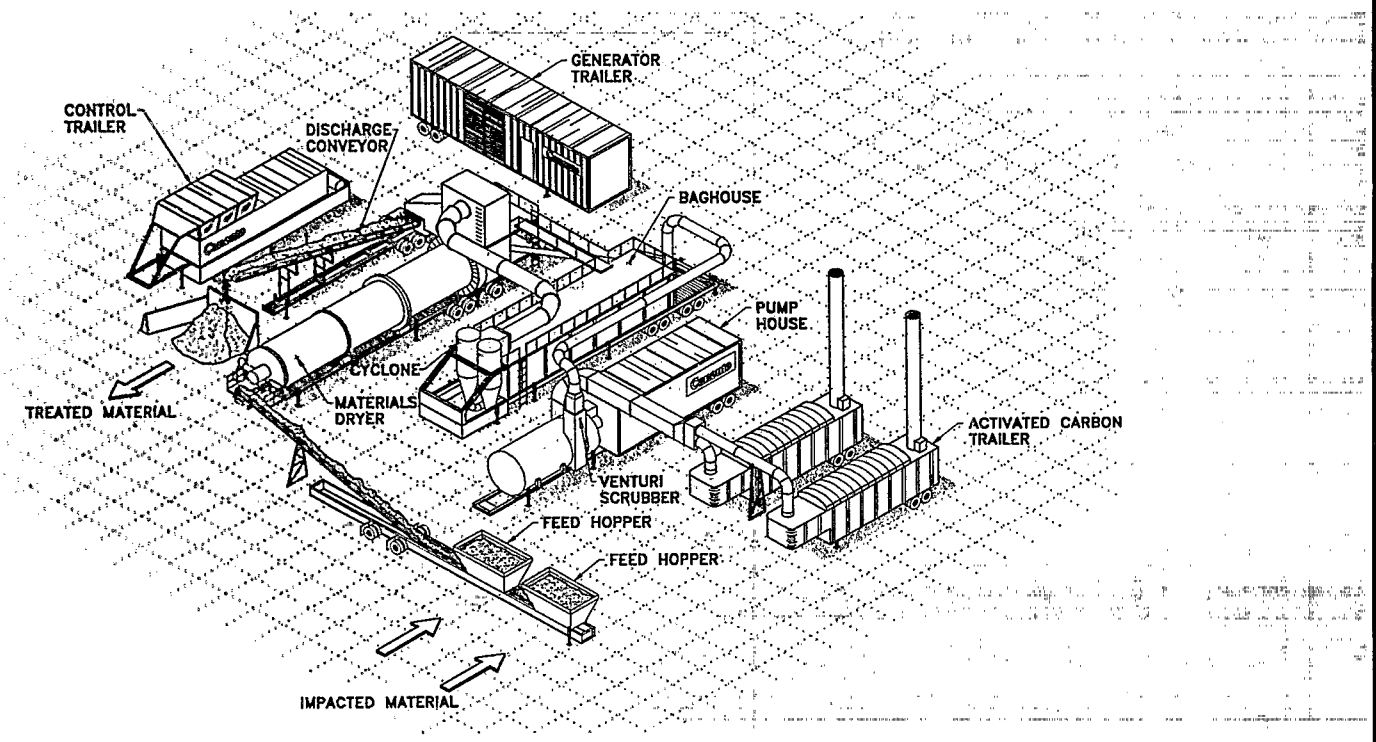
TECHNOLOGY DESCRIPTION:

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

A direct-fired rotary dryer is used to heat an air stream which, by direct contact, desorbs water and organic contaminants from the soil. Soil can be heated to up to 800 °F. The processed soil is quenched to cool it and to mitigate dust problems. It is then discharged into a stockpile. The hot air stream containing 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; (3) GAC adsorption beds for organic removal.

The second air stream treatment system can treat soils containing high concentrations of petroleum hydrocarbons. It 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; (5) wet scrubber for acid gas removal.

The LTTA® process generates no wastewater or waste soils. Cyclone fines and baghouse dust are combined with treated soil and quenched with treated scrubber water. The treated soil,



Low Temperature Thermal Aeration

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

once verified to meet the treatment criteria, can be 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 (PCE), trichloroethene (TCE), and dichloroethene (DCE); SVOCs such as acenaphthene, chrysene, naphthalene, and pyrene; OCPs such as DDT and its 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. A demonstration was performed on soils contaminated with OCPs at a pesticide site in Arizona during September 1992, during full-scale site remediation. Demonstration results show that LTTA® removed toxaphene, DDT, DDD, dieldrin, endosulfan I, and endrin with a minimum efficiency of 99.9 percent. It removed endrin aldehyde and DDE with a minimum efficiency of 98 percent and 90 percent respectively. These results will be published in an Applications Analysis Report.

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.

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

CETECH RESOURCES, INC.
(A Subsidiary of CHEMFIX TECHNOLOGIES, INC.)
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

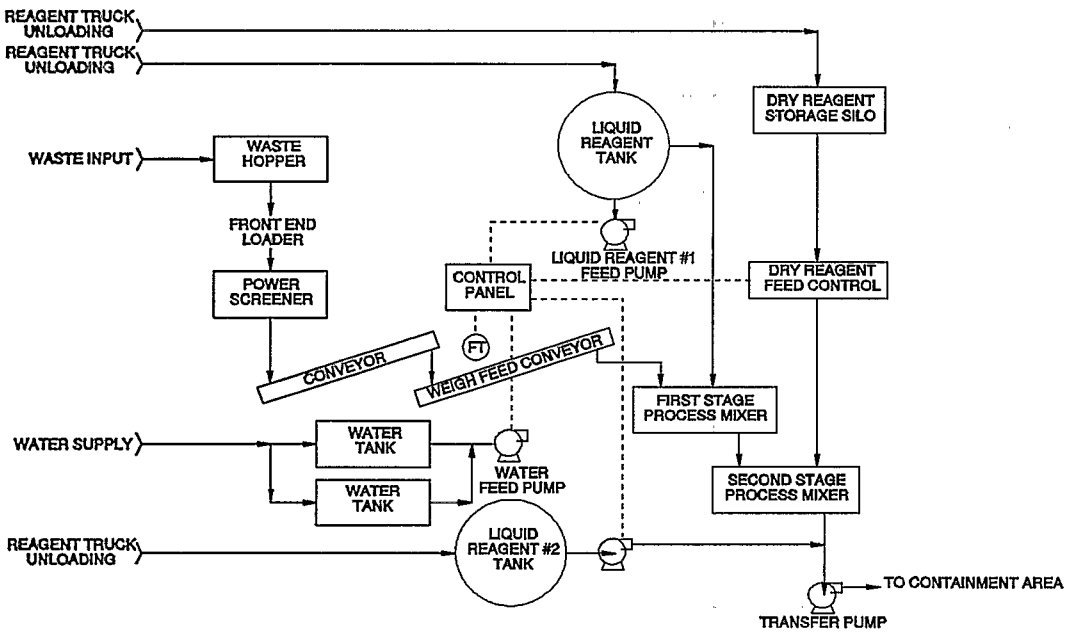
In this solidification and stabilization process, pozzolanic materials react with polyvalent metal ions and other waste components to produce a chemically and physically stable solid material. Optional accelerators and precipitators may include soluble silicates, carbonates, phosphates, and borates. 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 containing calcium hydroxide, which is 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 either prior to the dry binder or after the 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 assisting in the fixation of 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.

The system shown below, with modifications, may be applied to wastes containing solids between 10 to 100 percent.

WASTE APPLICABILITY:

This technology is suitable for contaminated soils, sludges, ashes, and other solid wastes. The process is particularly applicable to wastes



Process Flow Diagram

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

such as 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. Heavy metals, such as antimony, arsenic, lead, cadmium, hexavalent chromium, mercury, copper, and zinc, are effectively treated using this technology. In addition, when combined with specialized binders and additives, this technology can be used to stabilize low-level nuclear wastes.

STATUS:

The technology was demonstrated in March 1989 at the Portable Equipment Salvage Co. 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, Chemfix Technologies, Inc., has applied a high solids CHEMSET® reagent protocol approach to the treatment of about 30,000 cubic yards of hexavalent chromium-contaminated waste with a high solids content. The average chromium level after treatment was less than 0.15 milligram per liter (mg/L) and met toxicity characteristic leaching procedure (TCLP) criteria. The final product permeabilities were less than 1×10^{-4} centimeters per second (cm/sec).

DEMONSTRATION RESULTS:

The demonstration yielded the following results:

- The technology effectively reduced concentrations of copper and lead 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 the excavated waste material increased between 20 to 50 percent.
- In 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 (UCS) 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 (PCB) during the treatment process.
- The cost of the treatment process was estimated at approximately $73 per ton of raw waste treated, not including excavation, pretreatment, and disposal.

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

CF SYSTEMS CORPORATION
(Solvent Extraction)

TECHNOLOGY DESCRIPTION:

The CF Systems Corporation technology uses liquified gases as solvent to extract organics from sludges, contaminated soils, and wastewater. Propane is the solvent typically used for sludges and contaminated soils, while carbon dioxide is used for wastewater streams. The system is available as either a continuous flow unit for pumpable wastes or a batch system for nonpumpable soils and sludges. Typical costs for contaminated soils treatment range from $80 to $250 per ton, excluding excavation and disposal.

Contaminated solids, slurries, or wastewaters are fed into the extraction system (see figure below) along with solvent. Typically, more than 99 percent of the organics are extracted from the feed. Following phase separation of the solvent and organics from the treated feed, the mixture of solvent and organics 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.

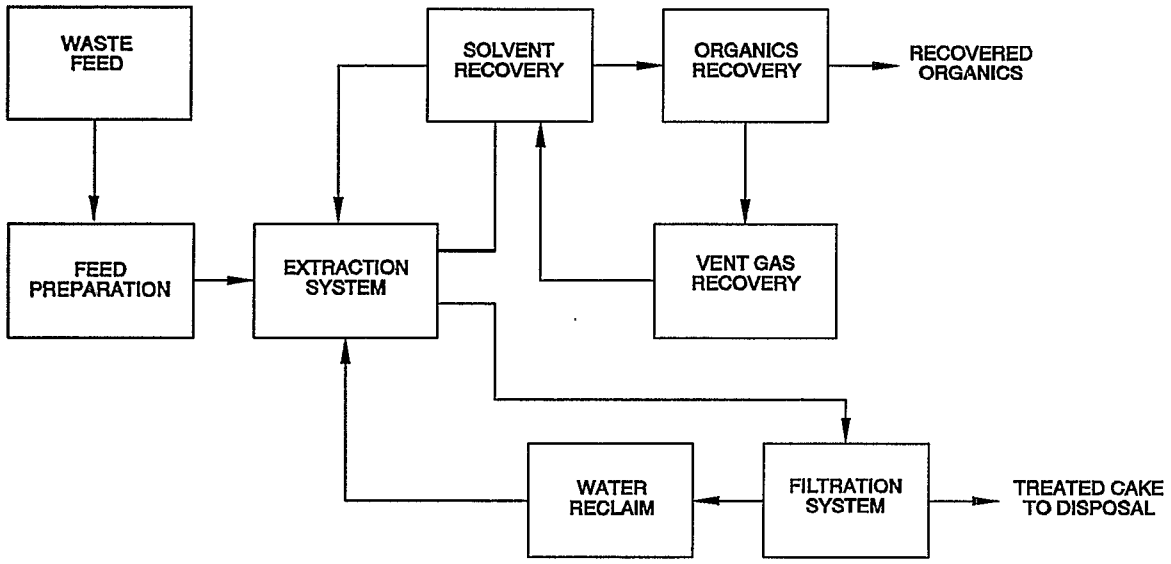
The extraction system design is different for contaminated wastewaters and semisolids. A tray tower contactor is used for wastewaters, and a series of extractor/decanters is used for solids and semisolids.

WASTE APPLICABILITY:

This 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 (PAH), polychlorinated biphenyls (PCB), dioxins, and pentachlorophenol (PCP). This process can also treat refinery wastes and wastewater contaminated with organics.

STATUS:

Under the SITE Program, a mobile demonstration unit was tested on PCB-laden sediments from the New Bedford (Massachusetts) Harbor Superfund site during September 1988. PCB



Solvent Extraction Remediation Process

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

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.

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 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 fixation for heavy metals, the treated solids were disposed of in a Class I landfill.

During operation, 100 percent of the feed material treated met land-ban specifications. Multiple feeds, including API separator solids, slop oil emulsion solids, slop oils, and contaminated soils, were treated.

The technology has been selected by EPA Region 6 and the Texas Water Commission on a sole-source basis for cleanup of 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 1993.

Other ongoing demonstrations and applications of this technology include on-site pilot demonstrations and new a SITE Program demonstration with process improvements.

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 Cleanup 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:

- Extraction efficiencies of 90 to 98 percent were achieved on sediments containing PCBs between 360 and 2,575 ppm. PCB concentrations were as low as 8 ppm in the treated sediment.
- In the laboratory, extraction efficiencies of 99.9 percent were obtained for volatile and semivolatile organics in aqueous and semisolid wastes.
- Operating problems included solids retention in the system hardware and foaming in receiving tanks. The problems were corrected in the full-scale commercial units.
- Projected costs for PCB cleanup are estimated at approximately $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.

CHEMICAL WASTE MANAGEMENT, INC.
(PO*WW*ER™ Technology)

TECHNOLOGY DESCRIPTION:

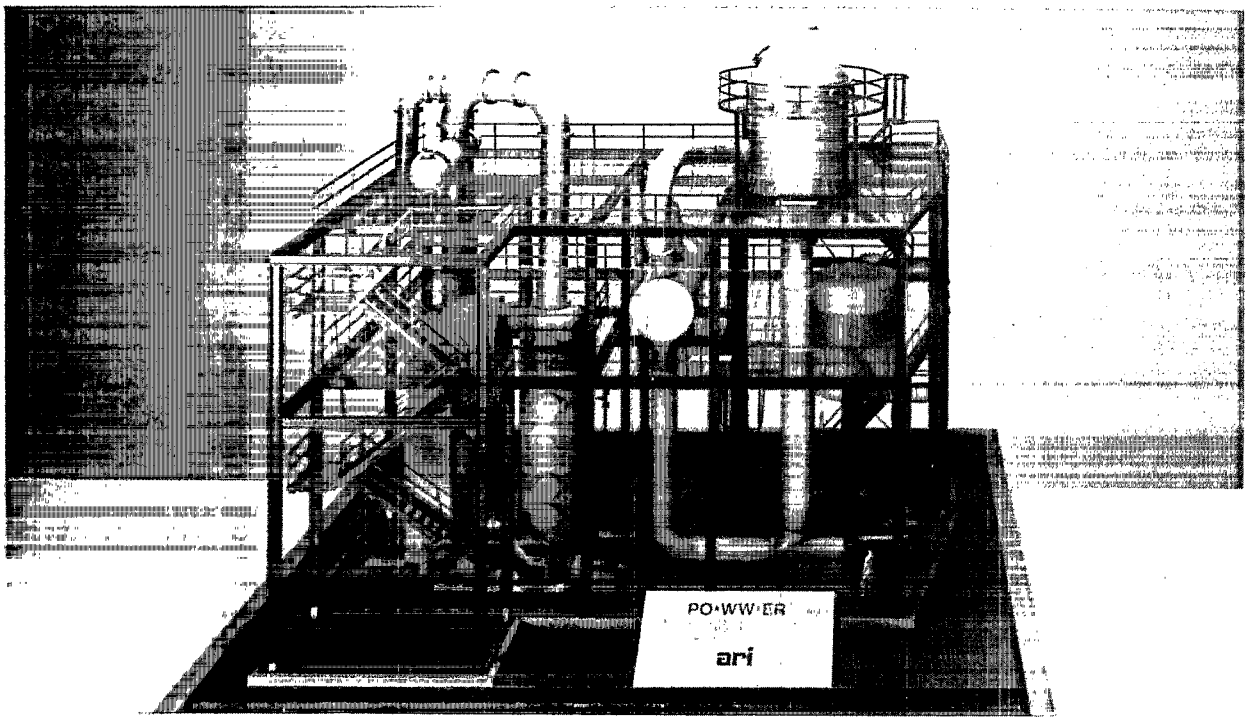
The PO*WW*ER™ technology is used for treatment and volume reduction of complex industrial and hazardous wastewaters containing mixtures of inorganic salts, metals, volatile and nonvolatile organics, volatile inorganics, and radionuclides. The proprietary technology combines evaporation with catalytic oxidation to concentrate and destroy contaminants, producing nontoxic product condensate.

Wastewater is first taken 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 that can be used as either boiler or cooling tower make-up water, if appropriate. The 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 semivolatiles • Organic pesticides/herbicides • Solvents • BTEX • 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. It 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/R-93/506) are available from EPA.

A commercial system (50-gpm capacity) is in operation at Ysing Yi Island, Hong Kong. A pilot-scale unit (1 to 1.5 gallons per hour) available at Clemson Technical Center can treat both radioactive, hazardous, and mixed waste streams.

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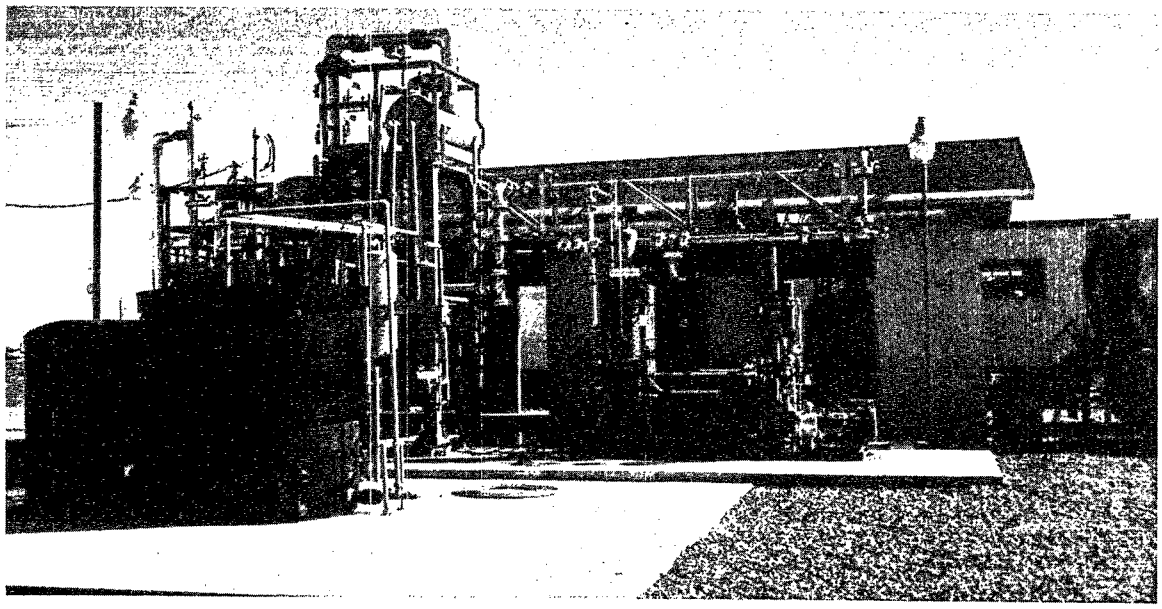
NOTE: This technology has been purchased by ARI Technologies, Inc.



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.

CHEMICAL WASTE MANAGEMENT, INC.
(X*TRAX™ Thermal Desorption)

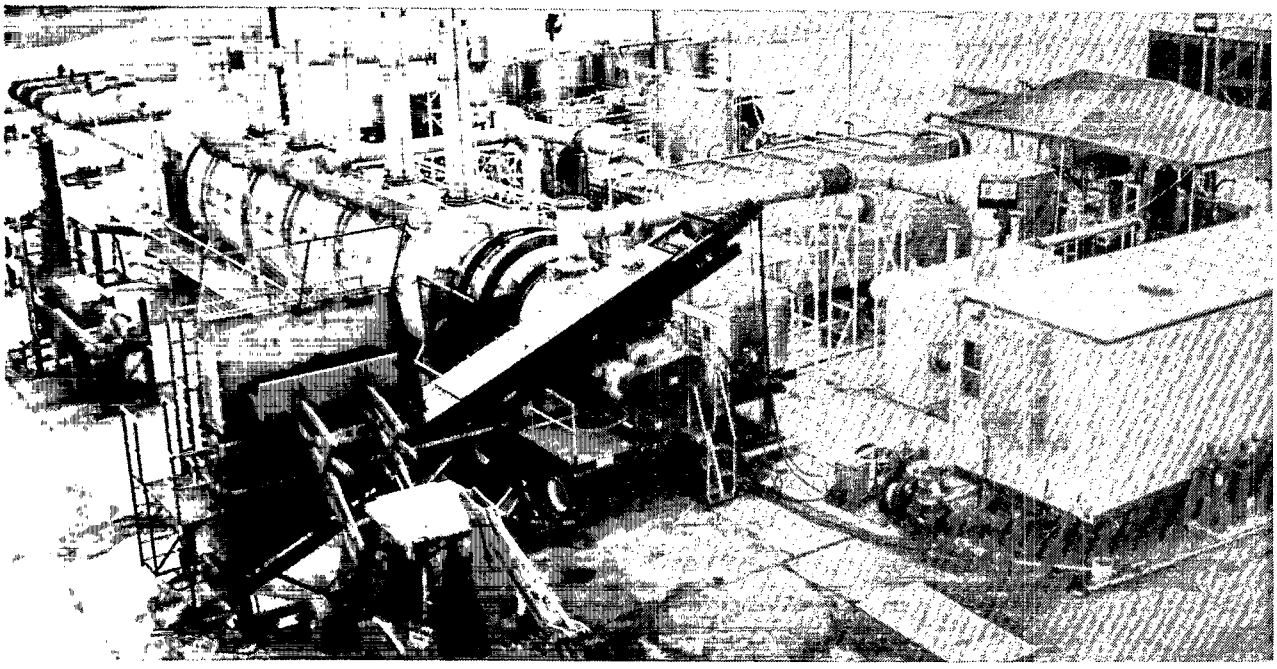
TECHNOLOGY DESCRIPTION:

The X*TRAX™ technology (see photograph below) is a thermal desorption process that removes organic contaminants from soils, sludges, and other solid media. It is not an incinerator or a pyrolysis system. Chemical oxidation and reactions are not encouraged, and no combustion by-products are formed. The organic contaminants are removed as a condensed liquid, characterized by a high heat rating, which may then be either destroyed in a permitted incinerator or used as a supplemental fuel. Because of low operating temperatures (200 to 900 °F) and gas flow rates, this process is less expensive than incineration.

An externally-fired rotary dryer volatilizes the water and organic contaminants into an inert carrier gas stream. The processed solids are then cooled with treated condensed water to eliminate dusting. The solids can then be placed and compacted in their original location.

An inert nitrogen carrier gas transports the organic contaminants and water vapor out of the dryer. The carrier gas 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. It then passes through two condensers in series, where it is cooled to less than 40 °F.

Most of the carrier gas is reheated and recycled to the dryer. About 5 to 10 percent is passed through a particulate filter and a carbon adsorption system and discharged. This discharge helps maintain a small negative pressure within the system and prevents potentially contaminated



Full-Scale X*TRAX™ System

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

gases from leaking. The discharge also allows make-up nitrogen to be added to the system, to keep oxygen concentrations below 4 percent. The volume of gas released from this process vent is approximately 100 to 200 times less than an equivalent capacity incinerator.

WASTE APPLICABILITY:

The process removes volatiles, semivolatiles, and polychlorinated biphenyls (PCB). It has been demonstrated on a variety of soils ranging from sand to very cohesive clays. 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 6,000 ppm PCB have been reduced to 2 to 25 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.

Minimal feed pretreatment is required. The feed material must be screened to a particle size of less than 2 inches. For economic reasons, a single location should have a minimum of 5,000 cubic yards of material. For most materials, the system can process 120 to 180 tons per day at a cost of $125 to $225 per ton.

This technology was accepted into the SITE Demonstration Program in summer 1989. The full-scale system is being used to remediate 35,000 tons of PCB-contaminated soil at the Re-Solve, Inc., Superfund site in Massachusetts. The unit has treated 240 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. The Applications Analysis Report will be published in early 1994.

Rust Remedial Services (RRS) currently has laboratory-, pilot-, and full-scale X*TRAX™ systems. Two laboratory-scale systems are available for treatability studies. Both systems are operated at RRS's Clemson Technical Center in South Carolina: one treats mixed (Resource Conservation and Recovery Act [RCRA]/radioactive) wastes; the other treats RCRA and Toxic Substances Control Act (TSCA) wastes. More than 94 tests have been completed since January 1988.

A 7-ton per day, pilot-scale system was operated at the CWM Kettleman Hills facility in California. During 1989 and 1990, 10 different PCB-contaminated soils were processed under a TSCA research and development permit. The system was then operated under EPA RCRA permits to test three different wastes. The first Model 200 full-scale X*TRAX™ system, shown on the previous page, was completed in early 1990.

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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 Oily Waste)

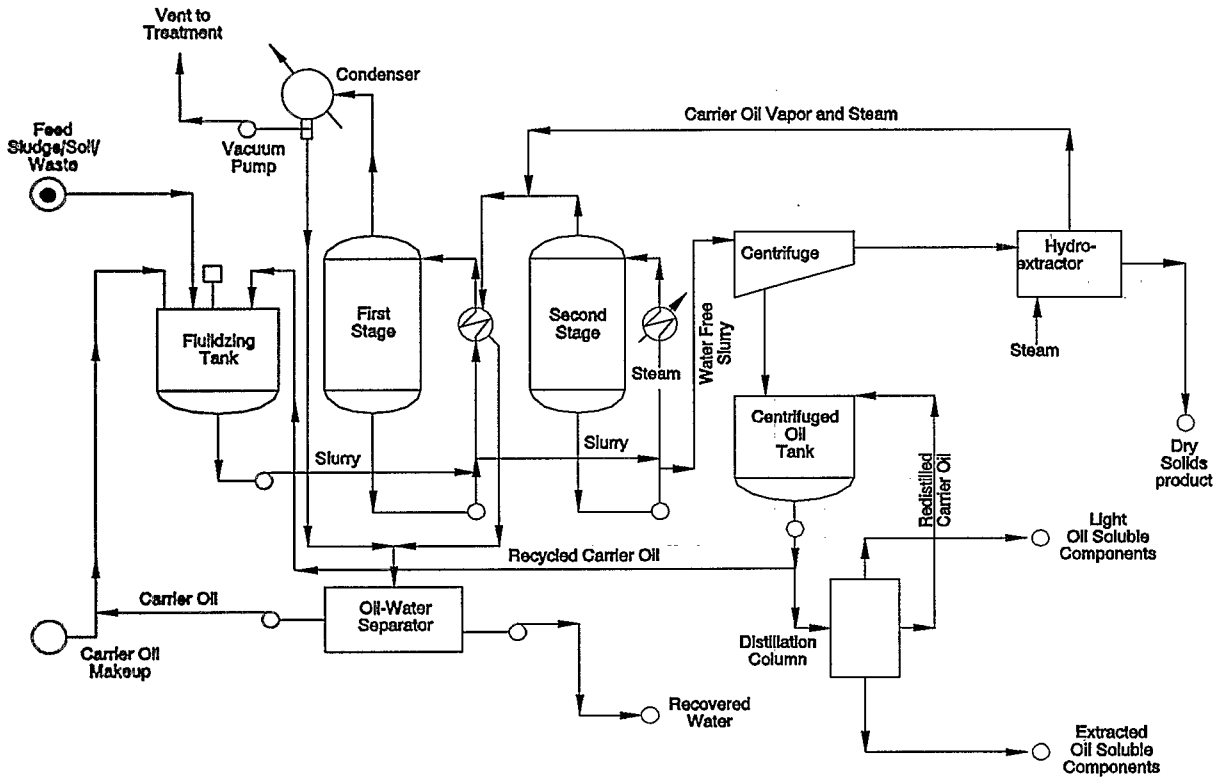
TECHNOLOGY DESCRIPTION:

The Carver-Greenfield Process® (C-G Process®) for solvent extraction of oily waste is designed to separate materials into their constituent solid, oil (including hydrocarbon-soluble substances), and water phases. The process is intended mainly for soils and sludges contaminated with hydrocarbon-soluble hazardous compounds. The technology uses a food-grade hydrocarbon solvent or carrier oil to extract the hydrocarbon-soluble contaminants (see figure below). Pre-treatment is necessary for particle sizes greater than 0.25 inch.

The solvent, with a boiling point of 400 °F, is mixed with waste sludge or soil; the mixture is then introduced to an evaporation system to remove water. The solvent fluidizes the mix and maintains a low slurry viscosity to ensure efficient heat transfer, allowing virtually all water to evaporate.

Hydrocarbon-soluble contaminants are extracted from the waste by the solvent. Volatile compounds present in the waste are also stripped in this step and condensed with the solvent and water. After the water is evaporated from the mixture, the resulting dried slurry is sent to a centrifuging section that removes most of the solvent and contaminants from the solids. This step is repeated as necessary to completely extract contaminants from the solids.

After final centrifuging, residual solvent is removed from the solids by a process known as "hydroextraction" which includes evaporation and steam stripping. The hazardous constituents



Carver-Greenfield Process® Schematic Diagram

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

are removed from the recovered solvent by distillation. The contaminants can be incinerated or reclaimed.

WASTE APPLICABILITY:

The C-G Process® can be used to treat sludges, soils, sediments, and other water-bearing wastes containing hydrocarbon-soluble hazardous compounds, including polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), 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 SITE demonstration of this process technology on a pilot scale 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 were issued in 1992.

DEMONSTRATION RESULTS:

Based on SITE demonstration results, the following conclusions can be made about the C-G Process®:

- 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 (TPH) are present in the final solid product.
- The final solid product is a dry powder similar in character to bentonite. The food-grade solvent comprises the bulk of the residual hydrocarbon content (about 1 percent) in the solid.
- Values for all metals and organics are well below the Resource Conservation and Recovery Act (RCRA) Toxicity Characteristic Leaching Procedure (TCLP) limits for characteristic hazardous wastes. The process does not remove metals bound to the solid phase.
- The resulting water product requires treatment due to the presence of small amounts of light organics and solvent. In some cases, the wastewater product may be disposed of at a local publicly owned treatment works (POTW).
- A full scale C-G Process® can process drilling fluid wastes at technology-specific costs of $100 to $220 per ton of wet feed, exclusive of disposal costs of the residuals. Site-specific costs, which include the cost of residual disposal, can range from minimal amounts (less than $10 per ton) to more than $300 per ton of feed and are very dependent on site characteristics and treatment objectives.

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

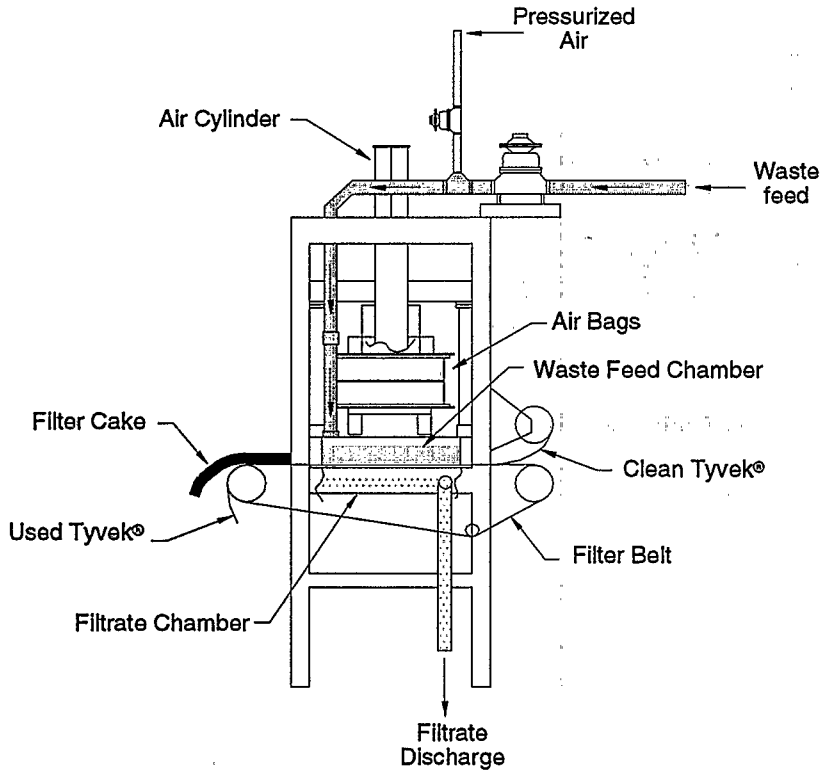
E.I. DUPONT DE NEMOURS AND COMPANY, and OBERLIN FILTER COMPANY
(Membrane Microfiltration)

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 (see figure below) uses an automatic pressure filter (developed by Oberlin Filter Company), combined with a special Tyvek filter material (Tyvek T-980) made of spunbonded olefin (invented by E.I. DuPont De Nemours and Company). The filter material is a thin, durable plastic fabric with tiny openings (about 1 ten-millionth of a meter in diameter) that allows water or other liquids, along with 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 is collected in the lower chamber. Following filtration, air is fed into the upper chamber at a pressure of about 45 pounds per square inch. Air is used to remove any liquid remaining in the upper chamber and to further dry the cake. When the cake is dry, the upper



DuPont/Oberlin Microfiltration System

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

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 prior to disposal, if necessary.

WASTE APPLICABILITY:

This treatment technology 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 is capable of treating liquid wastes containing volatile organics.

STATUS:

This technology was demonstrated at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania. Groundwater from the shallow aquifer at the site, contaminated with dissolved heavy metals (such as cadmium, lead, and zinc), was selected 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 also been completed.

Two commercial installations of the technology began operation 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 (RCRA) 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 (EPtox) and toxicity characteristic leaching procedure (TCLP) tests for metals.

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

ECOVA CORPORATION
(Bioslurry Reactor)

TECHNOLOGY DESCRIPTION:

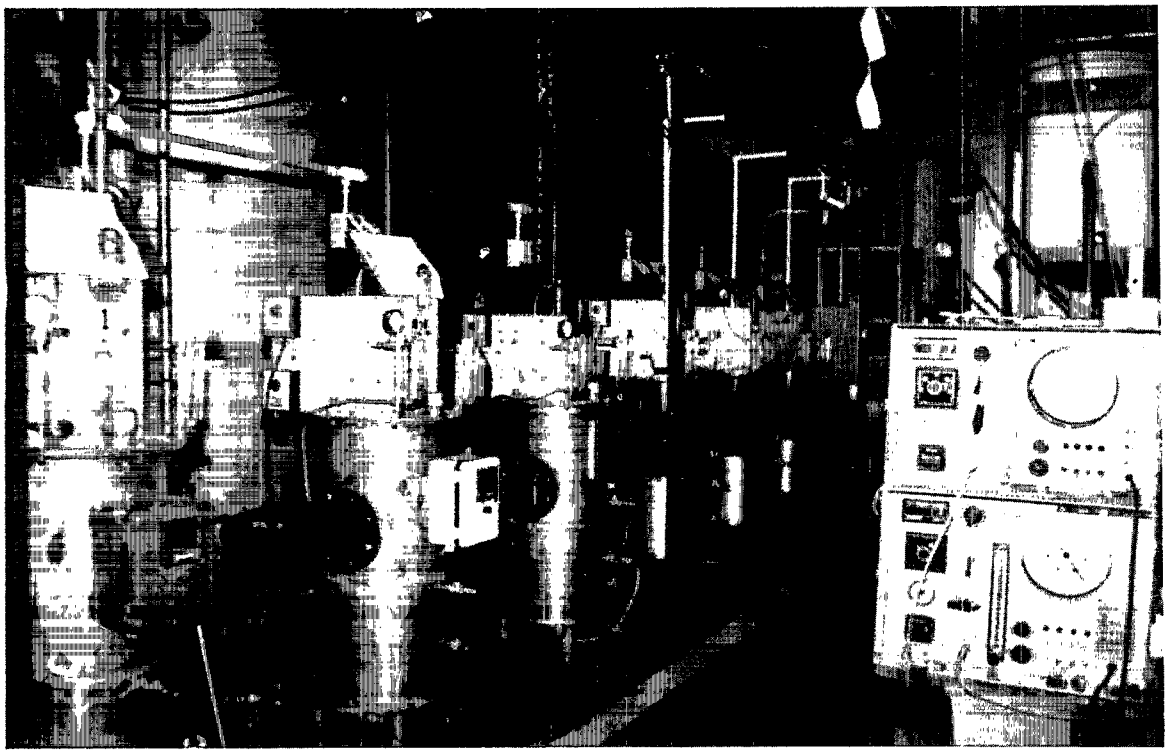
ECOVA Corporation's slurry-phase bioremediation (bioslurry) technology biodegrades creosote-contaminated materials through aerobic degradation. The technology uses batch and continuous flow bioreactors to process polynuclear aromatic hydrocarbon (PAH)-contaminated soils, sediments, and sludges. The bioreactors are supplemented with oxygen, nutrients, and a specific inocula 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 biological treatment 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.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1991. From



Bioslurry Reactor

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

May through September 1991, EPA conducted a SITE demonstration using six bioslurry reactors at EPA's Test and Evaluation Facility in Cincinnati, Ohio.

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 performed prior to 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 (BDAT) program.

DEMONSTRATION RESULTS:

Slurry-phase biological treatment significantly improved biodegradation rates of carcinogenic 4- to 6-ring PAHs. The pilot-scale bioslurry reactor reduced 82 ± 15 percent of the total soil-bound PAHs in the first week. After 14 days, total PAHs had been biodegraded by 96 ± 2 percent. An overall reduction of 97 ± 2 percent was seen 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 ± 3.2 percent to 501 ± 103 milligrams per kilogram (mg/kg) from levels of 5,081 ± 1,530 mg/kg.

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

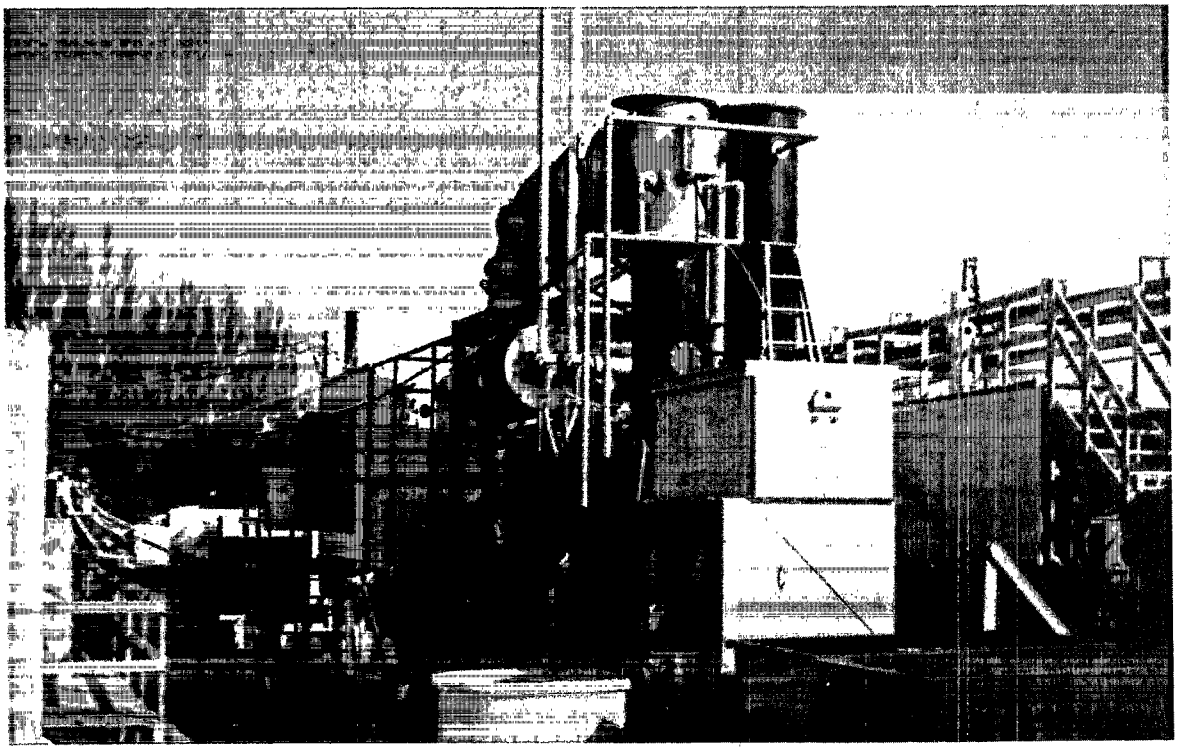
ELI ECO LOGIC INTERNATIONAL INC.
(Gas-Phase Chemical Reduction Process)

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.

The gas-phase reduction reaction takes place within a specially-designed reactor. Nozzles inject a mixture of 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 °C. The reduction reaction takes place as the gases enter the ceramic tube and travel up toward the scrubber. The scrubber removes hydrogen chloride, heat, water, and particulate matter.

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 disposal.



Gas-Phase Chemical Reduction Process

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

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

WASTE APPLICABILITY:

The Eco Logic Process is designed to treat aqueous and oily waste streams contaminated with polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), chlorinated dioxins and dibenzofurans, chlorinated solvents, chlorobenzenes, and chlorophenols. Wastes with high water content can be easily handled by the Eco Logic 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 (TSCA) research and development permit. The test program was conducted in cooperation with Environment Canada and the Ontario Ministry of the Environment. Testing was performed using two waste feeds:

- Wastewater with an average PCB concentration of 4,600 ppm
- A waste oil containing an average of 24.5 percent PCBs

Both feeds were tested in triplicate. In addition, a 72-hour engineering performance test was conducted.

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 (DRE) for PCBs during all test runs
- A 99.99 percent destruction efficiency for tetrachloroethene, 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.

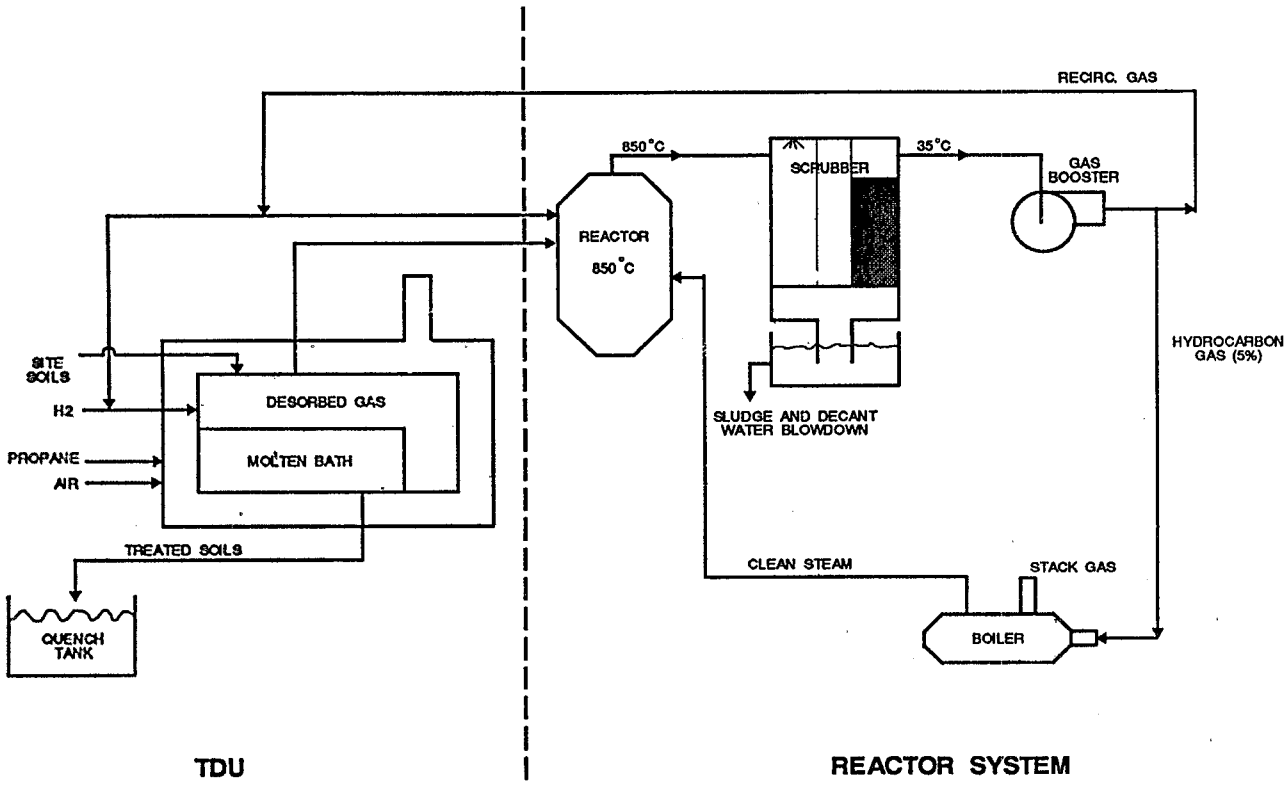
ELI ECO LOGIC INTERNATIONAL, INC.
(Thermal Desorption Unit)

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 process.

The TDU consists of an externally-heated bath of molten tin metal, blanketed in a hydrogen gas atmosphere. Tin is used for several reasons: tin and hydrogen are nonreactive; tin's density allows soils to float on the molten bath; molten tin is a good fluid for heat transfer; tin is non-toxic 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 °C, 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.



Thermal Desorption Unit Schematic

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

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 fuel or compressed for later analysis and disposal. 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 treat soils and sludges contaminated with polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), 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 (TSCA) research and development permit. The formal test program consisted of processing soil containing an average 627 ppm PCBs. The test plan called for three analytical test runs. Shakedown and material handling problems in run 1 caused Eco Logic to make significant adjustments prior to run 2. Feed throughput was reduced for run 2 to increase soil residence time on the tin bath, so that clumps of soil that formed in the system could be adequately heated. Run 3 was cancelled because of TSCA permit time constraints.

DEMONSTRATION RESULTS:

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

- Desorption efficiencies for PCBs from the soil of 93.5 percent in run 1 and 98.8 percent in run 2
- Desorption efficiencies for hexachlorobenzene (a tracer compound) 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.

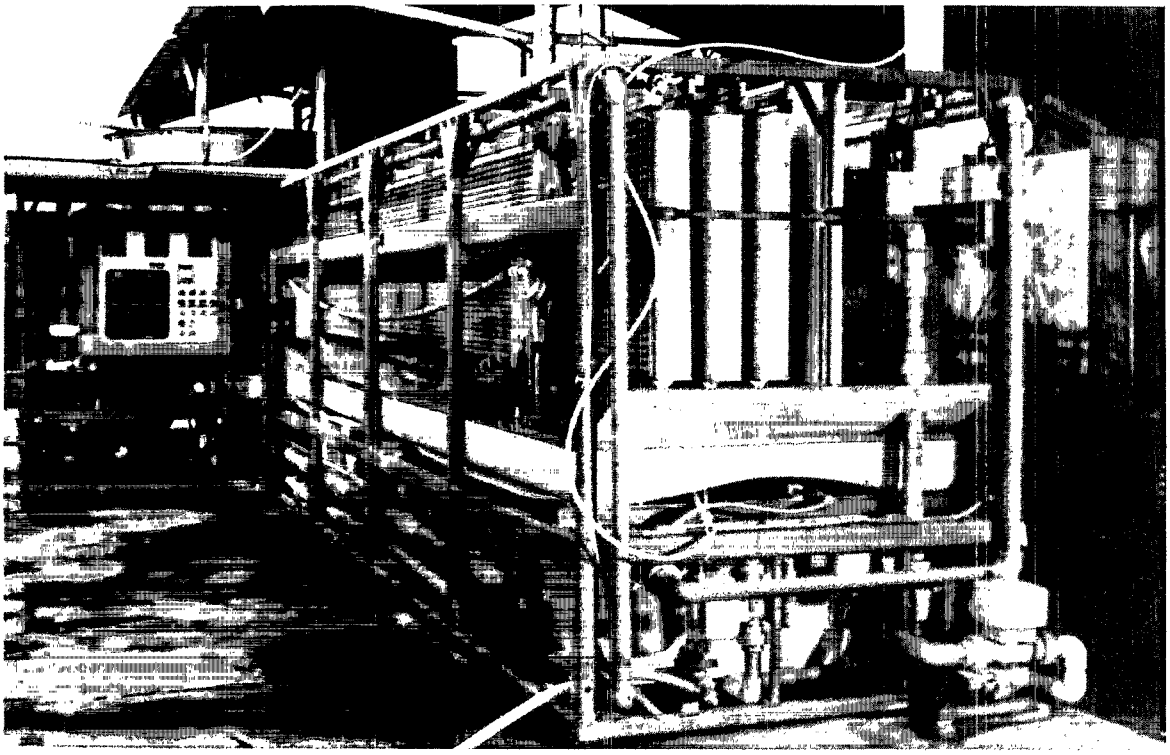
EPOC WATER, INC.
(Precipitation, Microfiltration, and Sludge Dewatering)

TECHNOLOGY DESCRIPTION:

The Precipitation, Microfiltration, and Sludge Dewatering treatment process developed by EPOC Water, Inc., 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 to 0.1 micron are filtered through a unique tubular fabric 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 to 0.1 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 50 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



EXXFLOW/EXXPRESS Demonstration Unit

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

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 organics and solvents can be removed using activated carbon or powdered ion-exchange adsorbents.

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/EXPRESS 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, pesticides, oil and grease, bacteria, suspended solids, and constituents that can be precipitated to particle sizes greater than 0.1 micron. The 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 using this process.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. Bench-scale tests were conducted in 1990, and the SITE demonstration was conducted in May 1992 on highly acidic mine drainage 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. The Applications Analysis Report and Technology Evaluation Report will be published in late 1993.

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. Applications include the following: industrial laundries, circuit board shops, ceramics, agricultural chemicals, oil produced water, oil field waste, scrubber waste, municipal waste, water purification, water softening, clarifier sludge dewatering, wine and juice filtration, surface finishing, and vehicle wash water.

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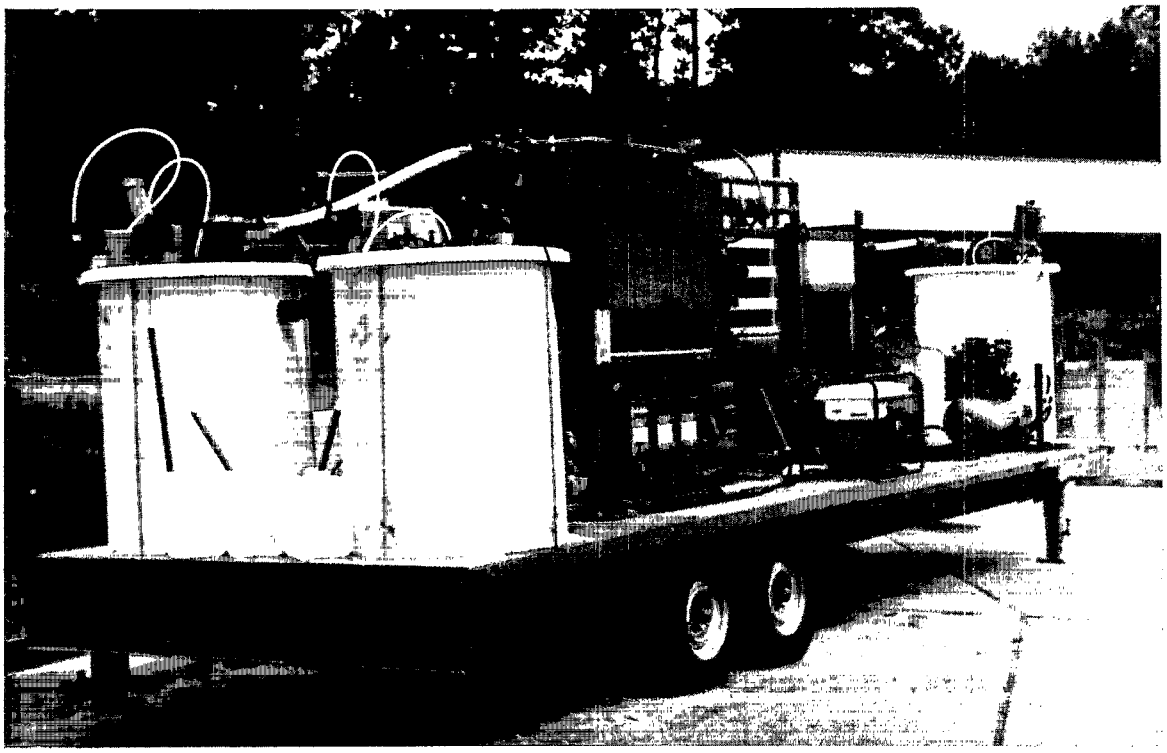
The SITE Program assesses but does not approve or endorse technologies.

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

TECHNOLOGY DESCRIPTION:

The Colloid Polishing Filter Method (CPFM) is a sorption and chemical complexing phenomena based filtration methodology that removes colloidal (and ionic) heavy metals and nontritium radionuclides from water. The CPFM cost effectively removes inorganic metallic pollutants in groundwater, wastewater, or in soil washing secondary wastewater following primary treatment for organics destruction, bulk solids, or soil washing. The methodology uses a polishing filter to remove heavy metals, naturally occurring radioactive materials, and manmade uranium, transuranic, and low-level radionuclides. The technology involves pumping and treating the contaminated water and performing specific, prechemical conditioning and pH adjustment in mixing tanks. Prefiltration is used to remove total suspended solids (TSS) to prolong bed life prior to removing metallic pollutants using multiple sorption beds. A specially designed filtration apparatus contains the inorganic, insoluble sorption bed material (Filter Flow-1000) and provides fluid control. Optional single-use, disposable and reusable bed material designs have been developed, with emphasis on easy, safe handling and removal of the spent bed material. Both batch (50- to 1,000-gallon-per-cycle) and continuous (5- to 500-gallon-per-



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

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

minute) treatment systems have been designed for application in both mobile field equipment and fixed installations.

WASTE APPLICABILITY:

The CPFM efficiently removes heavy metals and nontritium radionuclides from water to parts per million or parts per billion levels. The system can also achieve maximum contaminant level compliance standards for water use or environmental water discharge. This simple methodology can be used separately to treat low-TSS water or in a treatment train downstream from other technologies such as soil washing, organic oxidation, or conventional wastewater treatment using flocculation and solids removal. Major advantages of the CPFM include high performance and low cost to treat a wide range of inorganic metallic pollutants in water including mono- and divalent forms, multivalent and high valence forms existing as colloids, and ionic, chelated, and complexed forms. The same equipment can be used to treat water at different sites, but the preconditioning chemistry and pH must be optimized for each site using bench and field testing.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. EPA and Department of Energy (DOE) are cosponsoring the technology evaluation. Bench tests were conducted at the DOE Rocky Flats Plant, Golden, Colorado removing uranium-234, uranium-238, plutonium-239, and americium-241 from interceptor trench pump house (ITPH) groundwater collected from a french drain surrounding solar evaporative ponds at the Rocky Flats Plant. The SITE demonstration was carried out at the Rocky Flats Plant in early September 1993 under a cooperative memorandum of understanding between EPA and DOE. ITPH water was tested for the removal of uranium, radium, and gross alpha. Despite the successful removal of plutonium-239 and americium-241 from the ITPH water in the bench tests, these isotopes could not be analyzed in the demonstration due to low activity.

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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 underwater. 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.

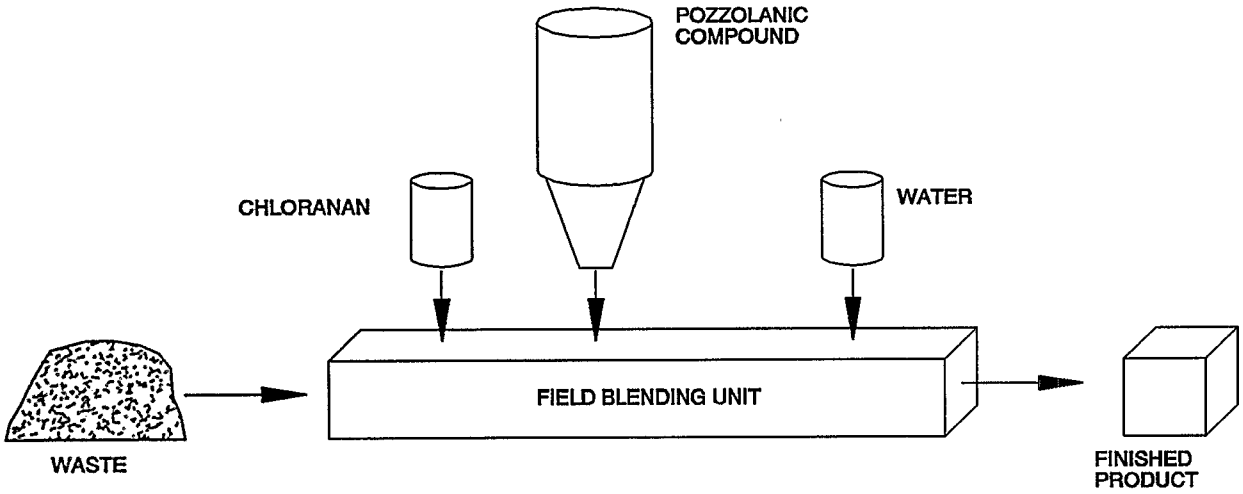
The treatment process (see figure below) begins by adding Chloranan and water to the blending unit. Waste is then added and mixed for 2 minutes. Cement or fly ash is added and mixed for a similar time. After 12 hours, the treated material hardens into a concrete-like mass that exhibits unconfined compressive 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 is 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.

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



Dechlorination and Immobilization Treatment Process

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

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 (EDC), trichlorethene (TCE), and pentachlorophenol.

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
(formerly OGDEN ENVIRONMENTAL SERVICES)
(Circulating Bed Combustor)

TECHNOLOGY DESCRIPTION:

The 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 combustion chamber (36 inches in diameter) can treat up to 150 tons of contaminated soil daily, depending on the heating value of the feed material.

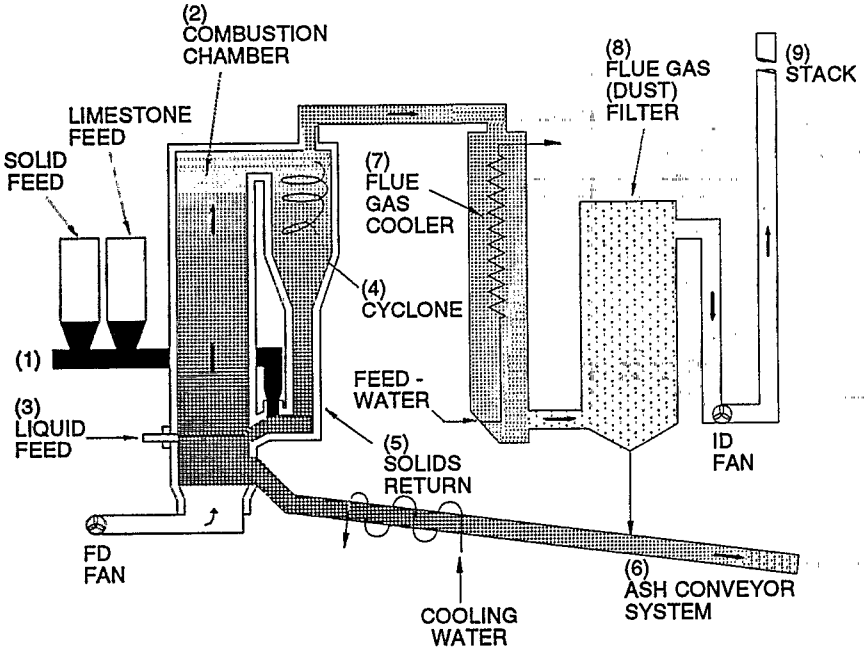
The CBC operates at relatively low temperatures (1,450 to 1,600 °F), reducing operating costs and potential emissions such as nitrogen oxides (NO_x) and carbon monoxide. Auxiliary fuel can be natural gas, fuel oil, or diesel. No auxiliary fuel is needed for waste streams with a net heating value greater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

The CBC's high turbulence produces a uniform temperature around the combustion chamber and hot cyclone. It also completely mixes the waste material during combustion. The effective mixing and relatively low combustion temperature also reduce emissions of carbon monoxide and nitrogen oxides.

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 gases produced during combustion pass through a convective gas cooler and baghouse before being 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 site cleanups, and con-



Circulating Bed Combustor (CBC)

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

taminated military sites. The CBC is permitted under the Toxic Substance Control Act to burn PCBs in all 10 EPA regions, 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 technology (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 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 the 16-inch-diameter CBC.

DEMONSTRATION RESULTS:

The demonstration successfully achieved the desired goals, as follows:

- Obtained DRE values of 99.99 percent or greater for principal organic hazardous constituents and minimized the formation of products of incomplete combustion;
- Met the Research Facility permit conditions and California South Coast Basin emission standards;
- Controlled sulfur oxide emissions by adding limestone and showed that the residual materials (fly ash and bed ash) were nonhazardous. No significant levels of hazardous organic compounds left the system in the stack gas or remained in the bed and fly ash. The CBC minimized emissions of sulfur oxide, nitrogen oxide, 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.

GIS/SOLUTIONS, INC.
(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.

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 Francisco, California. The Demonstration Bulletin and Applications Analysis Report will be published in early 1994.

CHEMISTRY	GEOLOGY	HYDROLOGY
• Isopleth maps of soil or water quality — plan or section view • Chemical concentration time series graphs • Chemical versus chemical graphs inter- and intra-well • Trilinear Piper diagrams • Chemical concentration versus distance graphs • 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 • Graphical summary of statistics • Presentation-quality data tables	• Boring logs with company logos • Geologic cross-section maps • Isopach maps • Structure maps • Modflow integration	• Density-corrected water level contour maps • Floating product contour maps • Hydraulic conductivity contour maps • Water elevation versus time graphs • Floating product thickness versus time graphs • Extraction well graphs - Flow verus time - Concentration versus time - Chemical flux versus time • Modflow integration

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

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GIS/Solutions, Inc.
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Concord, CA 94520
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The SITE Program assesses but does not approve or endorse technologies.

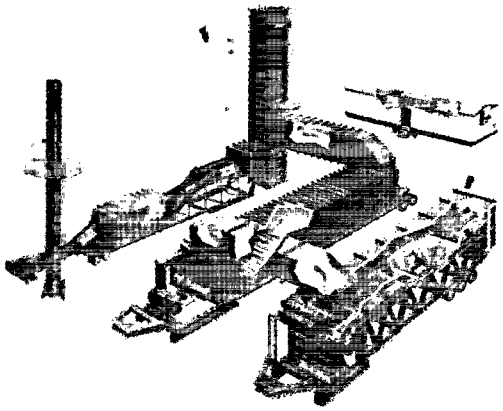
GRUPPO ITALIMPRESSE
(Developed by SHIRCO INFRARED SYSTEMS, INC.)
(Infrared Thermal Destruction)

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 °F) 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 (POTW) 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 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 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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This technology is no longer available through vendors in the United States.

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

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

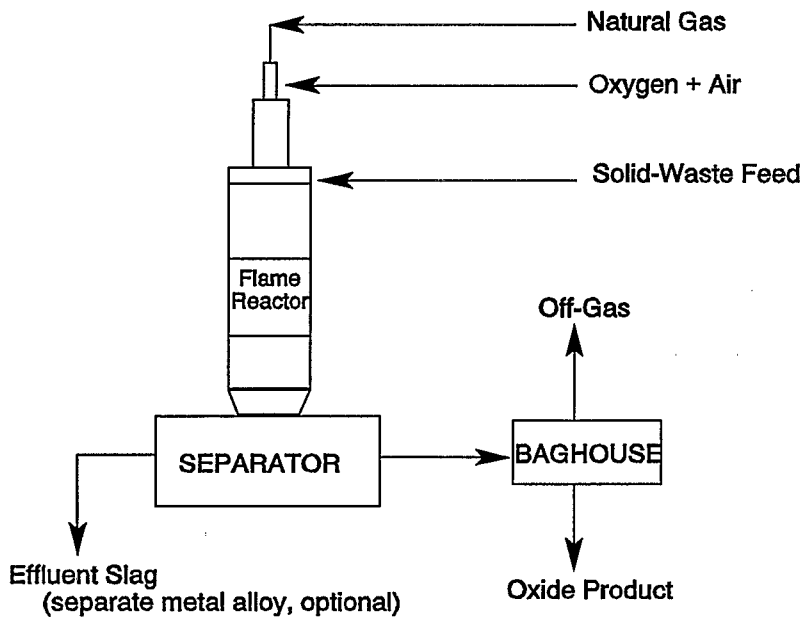
TECHNOLOGY DESCRIPTION:

The flame reactor system (see figure below) is a patented, hydrocarbon-fueled, flash-smelting system that treats residues and wastes containing metals. The reactor processes wastes with a hot (greater than 2,000 °C) reducing gas produced by the combustion of 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 nonleachable slag (a glass-like solid when cooled), a potentially recyclable, heavy metal-enriched oxide, and, in some cases, a metal alloy. The achieved 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 report to the slag or may be separated as a molten alloy. The remaining trace levels of metals are encapsulated in the slag. Organic compounds are destroyed at the elevated temperature of the flame reactor technology. In general, the system requires that wastes be dry enough (up to 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 current system 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 technology can be applied to granular solids, soil, flue dusts, slags, and sludges containing heavy metals. Electric arc furnace dust, lead blast furnace slag, soil, iron residues, primarily copper flue dust, lead smelter nickel matte, zinc plant leach residues and purification residues, and brass mill dusts and fumes have been successfully treated.

Metal-bearing wastes containing zinc (up to 40 percent), lead (up to 10 percent), chromium (up



HRD Flame Reactor Process Flow

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

to 4 percent), cadmium (up to 3 percent), arsenic (up to 1 percent), copper, cobalt, and nickel have been successfully treated.

The process can 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 the developer's facility in Monaca, Pennsylvania. EPA and the developer 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 (NSR) Company Superfund site in Atlanta, Georgia. The test was conducted at the Monaca facility under a Resource Conservation and Recovery Act (RCRA) research, development, and demonstration permit that allows the treatment of Superfund wastes containing high concentrations of metals, but only negligible concentrations of organics. The major objectives of the SITE technology demonstration were to (1) investigate the reuse potential of the recovered metal oxides, (2) evaluate the levels of contaminants in the residual slag and their leaching potential, and (3) determine the efficiency and economics of processing.

An additional SITE demonstration with feed containing organics is tentatively planned for the near future.

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 became active June 1, 1993 and is successfully operating at design capacity.

DEMONSTRATION RESULTS:

Approximately 72 tons of NSR waste material was 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

All effluent slag passed toxicity characteristic leaching procedure (TCLP) 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.

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

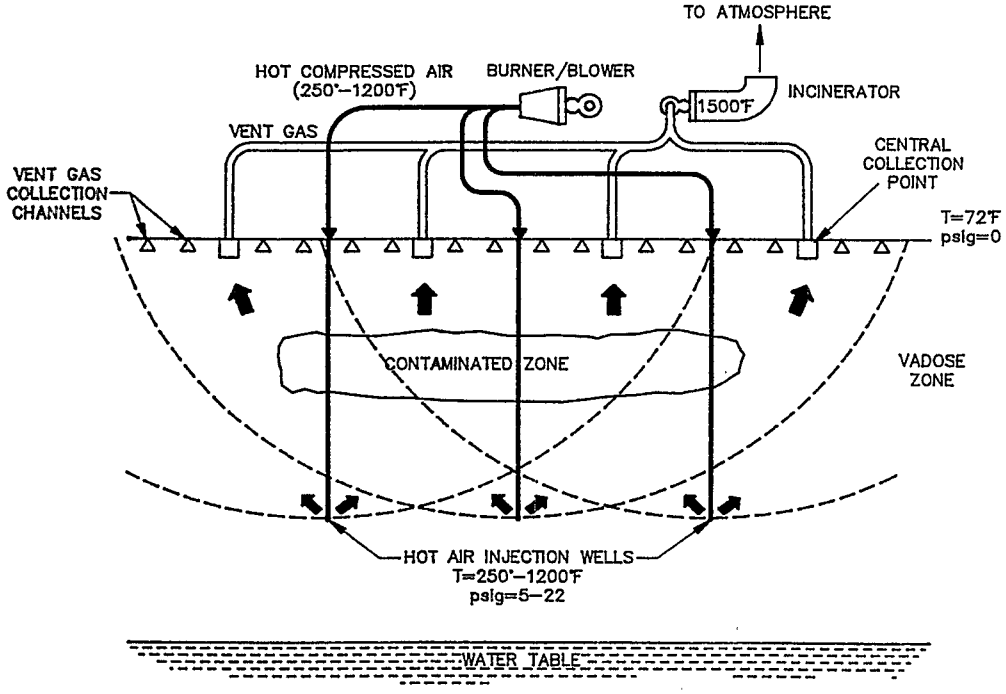
HRUBETZ ENVIRONMENTAL SERVICES, INC.
(HRUBOUT® Process)

TECHNOLOGY DESCRIPTION:

The HRUBOUT® process is a thermal, in situ treatment process designed to remove volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils. As part of the process, heated air is injected into the soil below the zone of contamination, evaporating the soil moisture, and removing volatile and semivolatile hydrocarbons. As the water evaporates, soil porosity and permeability is increased, further facilitating the air flow at higher temperatures. Nonvolatiles are removed in place by slow oxidation at the higher temperature ranges.

As part of the process, injection wells are drilled in predetermined distribution patterns to a depth below the contamination. The wells are equipped with steel casing, perforated at the bottom, and cemented into the hole above the perforations. This base is then cemented into the hole. Heated, compressed air is introduced at temperatures up to 1,200 °F, and the pressure is slowly increased to force the soil water up uniformly. 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 a 2.9-million-Btu/hour adiabatic burner. 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 either



HRUBOUT® Process

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

by natural gas or propane. All equipment is mounted on custom-designed mobile units and operates 24 hours per day.

WASTE APPLICABILITY:

According to the developer, the process is capable of treating soils in the vadose zone that are contaminated with organic halogenated or nonhalogenated volatiles and semivolatiles at a wide concentration range. Gasoline, solvents, diesel oil, jet fuel, heating oil, crude oil, lubricating oil, creosotes, and hydraulic oils are the primary applicable hydrocarbon compounds suitable for treatment.

There is no residual output from the treatment site, thereby eliminating any potential future liability.

STATUS:

The technology was accepted into the SITE Demonstration Program in July 1992 and was demonstrated at Kelly Air Force Base, San Antonio, Texas. Preliminary results from the demonstration have been published in a demonstration bulletin (EPA/540/MR-93/524). This document is available from EPA. In 1988, approximately 80,000 gallons of jet fuel (JP-4) spilled from a ruptured, high-pressure fuel pipeline on Kelly Air Force Base. The fuel spilled into the alluvial clay sediment at the site, where infiltration occurred.

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. The demonstration began on January 15, 1993 and ended February 6, 1993, which was the maximum time period that the Air Force allowed operations to be conducted.

Additional research and development conducted by Hrubetz has 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. A containerized version of the above process has also been developed. Future containers may be large enough to treat 40 cubic yards of contaminated soil.

Additional patents for the broadened applications of the HRUBOUT® process are pending. The process was approved by the Texas Water Commission in December 1991.

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

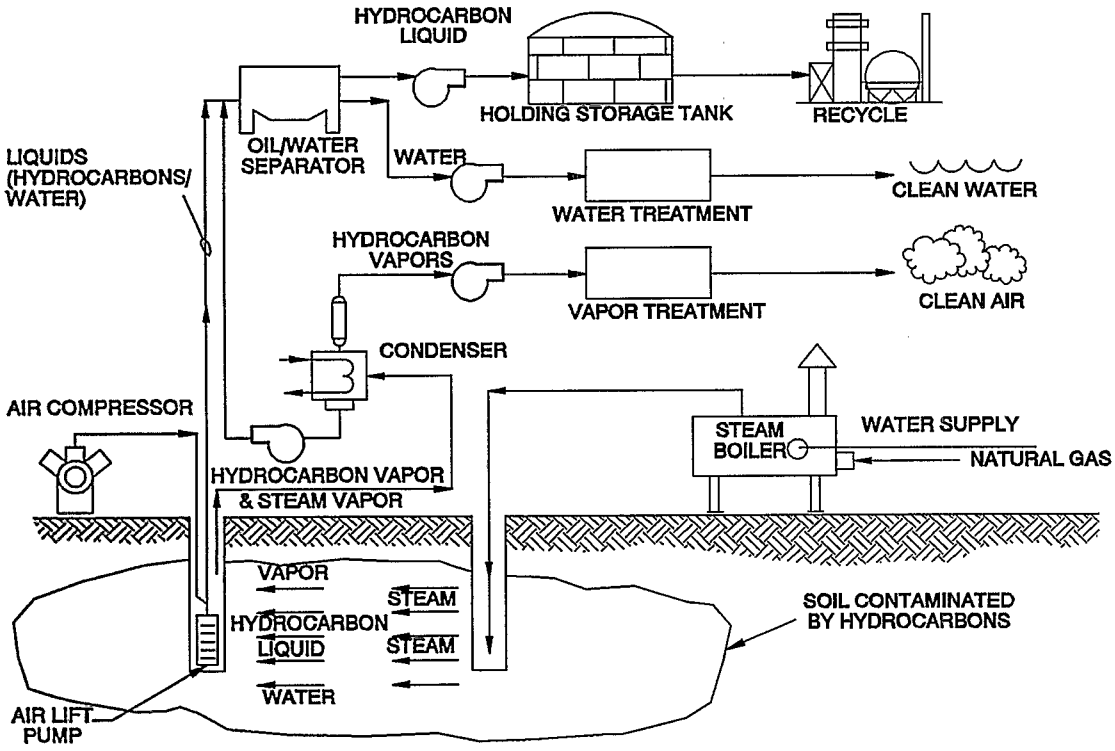
HUGHES ENVIRONMENTAL SYSTEMS, INC.
(Steam Enhanced Recovery Process)

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 can be used to treat 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 be used to 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 (TCE), trichloroethane (TCA), and dichlorobenzene



Steam Enhanced Recovery Process

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

(DCB); 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-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 at a site in Huntington Beach, California began in August 1991 and was completed in September 1993. Soil at the site was contaminated by a large diesel fuel spill.

For more information regarding this technology, see the Udell Technologies, Inc., profile in the Demonstration Program (active projects) section.

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

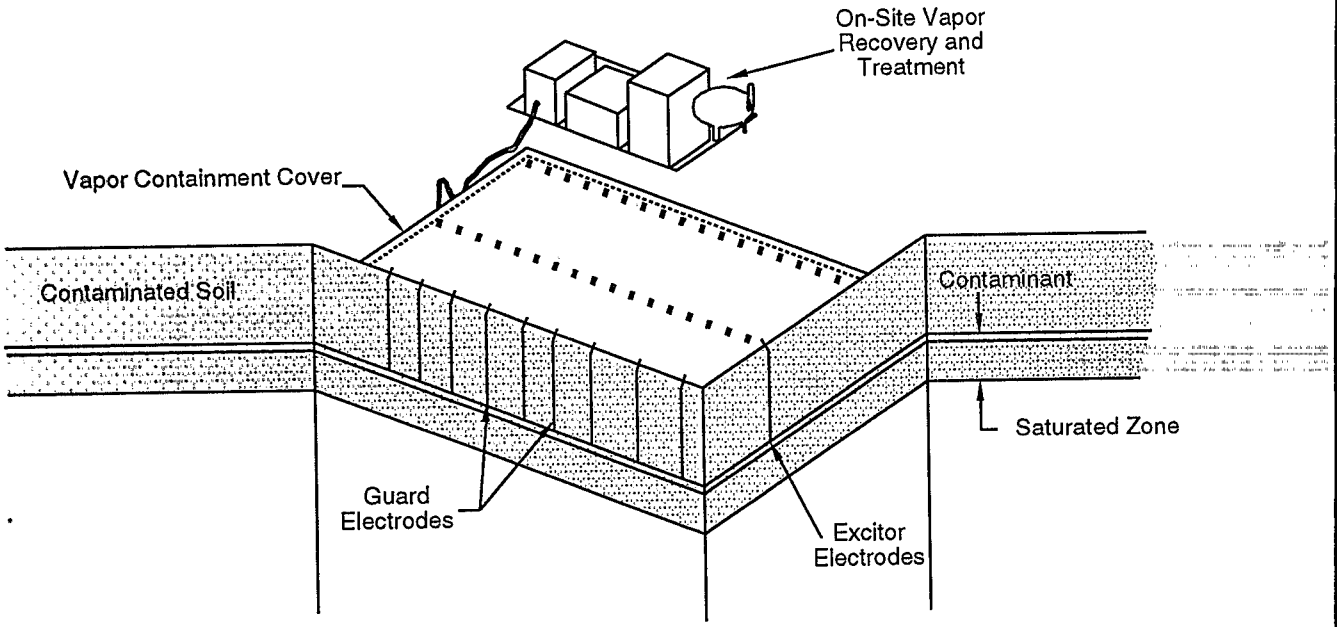
ILLINOIS INSTITUTE OF TECHNOLOGY RESEARCH INSTITUTE/HALLIBURTON NUS
(Radio Frequency Heating)

TECHNOLOGY DESCRIPTION:

Radio frequency (RF) heating is an in situ process that uses electromagnetic energy to heat soil to enhance the removal of volatile and semivolatile contaminants. The technology developed by Illinois Institute of Technology Research Institute (IITRI) can heat soil to temperatures up to 600 °C using an array of electrodes embedded in the soil. Volatilization and mobility of organic contamination and native soil moisture are enhanced. Contaminants are removed by conventional soil vapor extraction methods. Extracted vapor can then be treated by a variety of existing technologies, such as granular activated carbon or incineration.

WASTE APPLICABILITY:

RF heating can be used with soil vapor extraction to remove petroleum hydrocarbons, volatile and semivolatile organics, and pesticides from



Radio Frequency In Situ Heating Process

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

soils. The technology is most efficient in subsurface areas with low groundwater recharge. The technology, in theory, should be applicable to any volatile or semivolatile hydrocarbon compound.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. The demonstration occurred during the summer of 1993 at Kelly Air Force Base, Texas, as part of a joint project with the U.S. Air Force. Results will be available in 1994.

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

INTERNATIONAL WASTE TECHNOLOGIES/GEO-CON, INC.
(In Situ Solidification and Stabilization Process)

TECHNOLOGY DESCRIPTION:

This in situ solidification and stabilization 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), a system to deliver and mix the chemicals with the soil in situ; and (2) a batch mixing plant to supply the 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, the building of macromolecules continues 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 (rpm). Two conduits in the auger inject the additive slurry and supplemental water. Additives are injected on the downstroke; further mixing takes place 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.

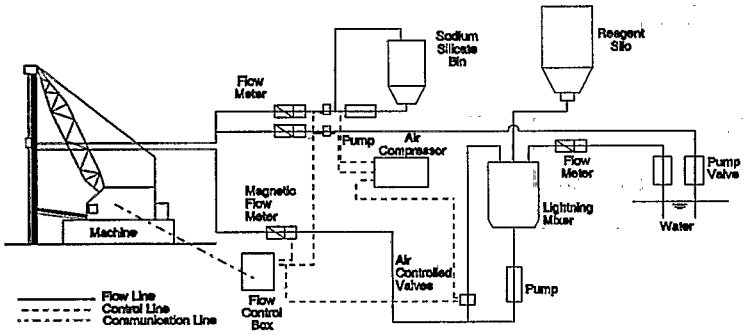
WASTE APPLICABILITY:

The IWT technology treats soils, sediments, and sludge-pond bottoms contaminated with organic compounds and metals. The technology has been laboratory-tested on soils containing polychlorinated biphenyls (PCB), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons. Geo-Con's soil mixing technology can treat any waste for which a physical or chemical reagent is applicable.

STATUS:

A SITE demonstration was conducted at a PCB-contaminated 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 Applications Analysis Report (EPA/540/A5-89/004) and Technology Evaluation Report (EPA/540/5-89/004a) have been published. The process was used to remediate the PCB-contaminated site in Hialeah, Florida during the winter and spring of 1990.

Geo-Con has completed over 12 in situ stabilization projects using soil mixing. The equipment has been scaled up to diameters as large as 12 feet. Typical production costs are $40 per cubic yard plus the cost of reagents, which may be lower than the cost estimated in



In Situ Solidification Batch Mixing Plant Process Flow

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

the SITE demonstration. To date, over 250,000 cubic yards of contaminated soils and sludges has been treated using Geo-Con's process.

DEMONSTRATION RESULTS:

The SITE demonstration of the process yielded the following results:

- Immobilization of PCBs 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 not available to evaluate the performance of the system with regard to 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 bulk density of the soil increased 21 percent after treatment. This increased the volume of treated soil by 8.5 percent and caused a small ground rise of 1 inch per treated foot of soil.
- The UCS of treated soil was satisfactory, with values up to 1,500 pounds per square inch (psi).
- The permeability of the treated soil was satisfactory, decreasing four orders of magnitude compared to the untreated soil, or 10^{-6} and 10^{-7} compared to 10^{-2} centimeters per second.
- The wet and dry weathering test on treated soil was satisfactory. The freeze and dry weathering test of treated soil was unsatisfactory. Because the project took place in Florida, freeze-thaw testing was not considered as a design criterion.
- Data provided by IWT indicate some immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the IWT reagent. Data are insufficient to confirm this immobilization.
- Performance data are limited outside of the SITE Program. The developer modifies the binding agent for different wastes. Treatability studies should be performed for specific wastes.
- Cost of the process is $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 has reduced process costs to about $140 per cubic yard.

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

MAGNUM WATER TECHNOLOGY
(CAV-OX® Process)

TECHNOLOGY DESCRIPTION:

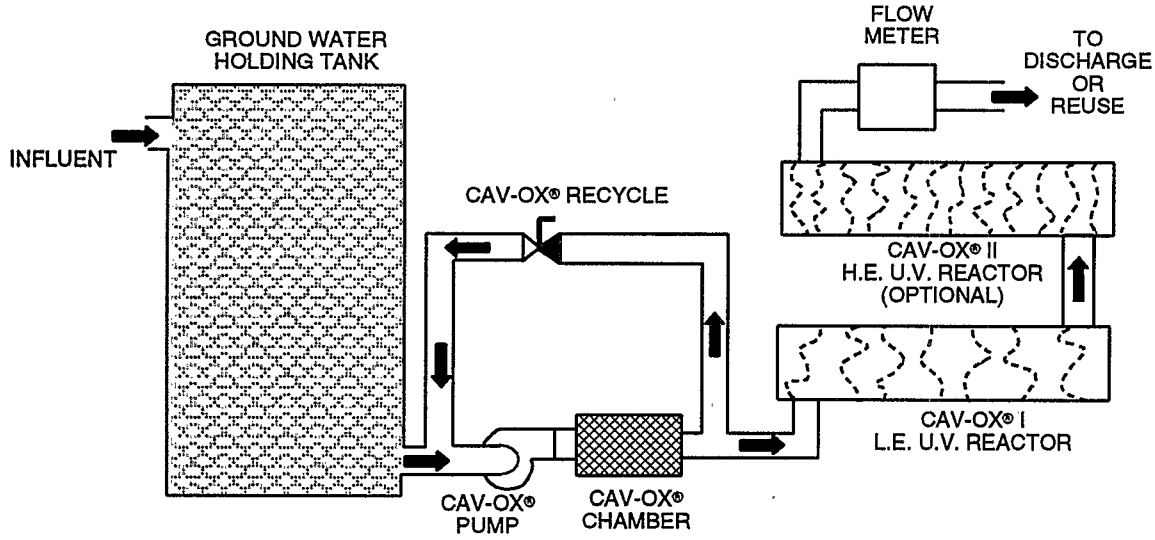
The CAV-OX® process uses a synergistic combination of hydrodynamic cavitation and ultraviolet (UV) radiation to oxidize contaminants in water. The process is designed to remove organic contaminants from waste streams and groundwater without releasing volatile gaseous organic compounds. Aqueous contaminants can be reduced to levels meeting most discharge specifications. The CAV-OX® process cannot handle free product or highly turbid waste streams, because these conditions tend to lower the efficiency of the UV reactors; however, the CAV-OX® cavitation chamber itself is unaffected in such cases.

Free radicals are generated and maintained by the system's combination of cavitation, UV excitation, and, where necessary, the 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 contaminant stream.

Magnum Water Technology estimates the cost of using the CAV-OX® process to be about half the cost of 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. Quartz tube scaling, common with other UV equipment, has not occurred in CAV-OX® systems. 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



The CAV-OX® Process

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

biphenyls; explosives; benzene, toluene, ethylbenzene, and xylenes; methyl tertiary butyl ether, cyanide and other organic compounds are suitable for this treatment process. Concentrations can range from a few thousand milligrams per liter to one microgram per liter or lower. Organics such as benzene can be treated to nondetectable levels; others such as 1,1-dichloroethane are typically reduced by 96 percent. Living organisms such as *Salmonella* and *E. Coli* are also significantly reduced.

STATUS:

The CAV-OX® process has been tested at several private and public sites, including the San Bernardino and Orange County California, Water Departments. 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 has successfully treated cyanide contamination. The process has also been used to remediate a former gasoline station site over a 2-year period. A second gasoline station site is currently being decontaminated.

This technology was accepted into the SITE Demonstration Program in summer 1992, and was demonstrated in March 1993 at Edwards Air Force Base in Edwards, California. The Demonstration Bulletin (EPA/540/MR-93/524) has been published and is available from EPA. The Applications Analysis Report and the Technology Evaluation Report will be published in late 1993.

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

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

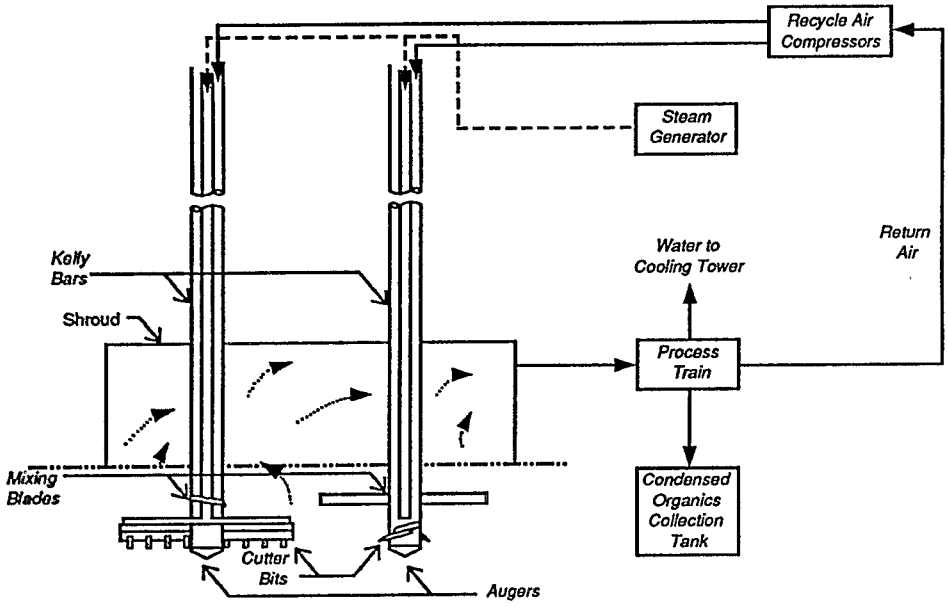
TECHNOLOGY DESCRIPTION:

This technology uses a transportable treatment unit called the Detoxifier™ for in situ steam and air stripping of volatile organics 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 27-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-fired boiler at 450 °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 is delivered to the top of the drills and injected through the cutting blades. The steam heats the soils, increasing the vapor pressure of the volatile contaminants, and thereby increasing the rate at which they can be stripped. 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, collects the volatile contaminants, and ducts them 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 water for a wet cooling tower. Steam is used to regenerate 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 a fuel in an incinerator.

The Detoxifier™ is also used to treat contaminated soil by injecting a wide range of reactive chemicals. Chemical injection processes include stabilization/solidification plus



Detoxifier™ Process Schematic

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

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 volatile organic compounds (VOC), such as 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 process can also significantly reduce the concentration of semivolatile organic compounds (SVOC) in soil. In regard to stabilization and solidification, this technology also treats inorganics, heavy metals, and mixed wastes.

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 from the process during operation, and the operating procedures were closely monitored and recorded. Posttreatment soil samples were analyzed by EPA methods 8240 and 8270. 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.

DEMONSTRATION RESULTS:

The SITE technology demonstration yielded the following results:

- More than 85 percent of the VOCs in the soil were removed.
- Up to 55 percent of the SVOCs in the soil were removed.
- 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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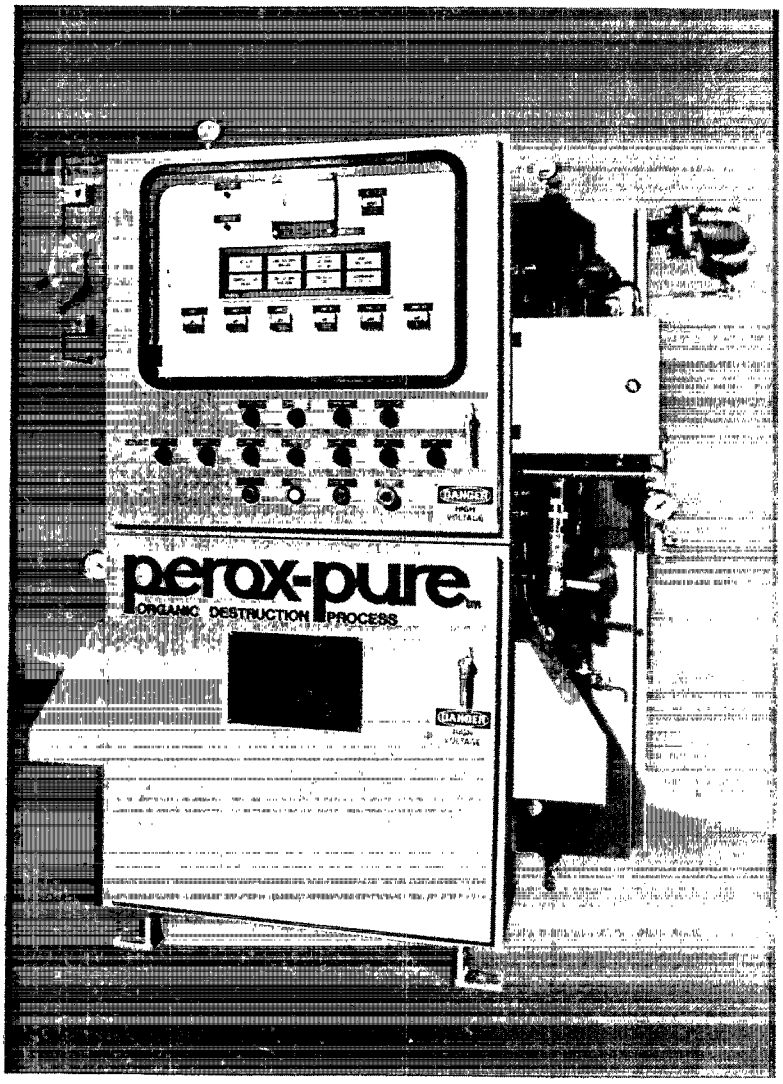
The SITE Program assesses but does not approve or endorse technologies.

PEROXIDATION SYSTEMS, INC.
(perox-pure™ Advanced Oxidation Technology)

TECHNOLOGY DESCRIPTION:

The **perox-pure™** technology is designed to destroy dissolved organic contaminants in groundwater or wastewater through an advanced chemical oxidation process using 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 contains one or more compartments in the oxidation chamber. 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.

UV light catalyzes chemical oxidation of organic contaminants in water by its combined effect upon the organics and reaction with hydrogen peroxide. First, many organic contaminants that absorb UV light may undergo a change in their



perox-pure™ Model SSB-30

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

chemical structure or may become more reactive with chemical oxidants. Second, and more importantly, UV light catalyzes the breakdown of hydrogen peroxide to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with organic contaminants, destroying them and producing harmless by-products such as carbon dioxide, halides, and water. The process produces no hazardous by-products or air emissions.

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.

WASTE APPLICABILITY:

This 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 process can be combined with air stripping, steam stripping, or biological treatment for optimal treatment results.

STATUS:

This 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. The purpose of this demonstration was to measure how well the **perox-pure**™ technology removes volatile organic compounds (VOC) from contaminated groundwater at the site.

This technology has been successfully applied at over 80 sites throughout the United States, Canada, and Europe. The 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 was operated at a variety of operating conditions. Three reproducibility tests were performed at the optimum operating conditions, having been selected from the initial test runs.

The **perox-pure**™ technology reduced trichloroethene and tetrachloroethene to below analytical detection limits. For each organic contaminant, the **perox-pure**™ technology achieved compliance with California action levels and federal drinking water contaminant levels at the 95 percent confidence level. The quartz tube wipers were effective in keeping the tubes clean and eliminating 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.

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

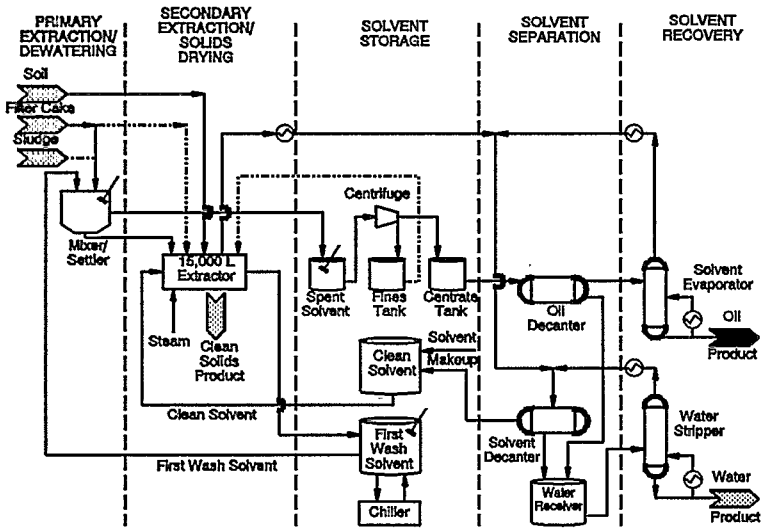
TECHNOLOGY DESCRIPTION:

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 by separating the waste matrix 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 leaving the solid and water fractions virtually free of contaminants.

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 °C and hydrophilic below 20 °C. This property allows the process to extract both aqueous and nonaqueous compounds by simply changing the temperature of the solvent, resulting in a contaminant free, distilled aqueous phase as a product stream.

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 pH of the waste material must be raised to greater than 10, so that triethylamine will be conserved for recycling through the process. The pH may be adjusted by adding sodium hydroxide. Pretreatment also includes screening the waste to remove oversize 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). 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 allowed to settle by gravity. The solvent mixture is decanted from the solids and centrifuged to remove fine par-



B.E.S.T. Solvent Extraction Technology

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

ticles. Solids from the cold extraction tank are then transferred to the extractory dryer vessel.

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 is passed to a steam stripping column where residual solvent is recovered for recycling. The water is typically discharged to a local wastewater treatment plant and the solids fraction can be used as backfill for the site.

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

WASTE APPLICABILITY:

The B.E.S.T. technology can be used to remove most hydrocarbon contaminants in sediments, sludges, or soils, including PCBs, PAHs, pesticides and herbicides. Performance can be influenced by the presence of detergents and emulsifiers, low pH materials, and reactivity of the organics with the solvent.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1987. The SITE demonstration was completed in July 1992 at the Grand Calumet River 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 the Alcoa site in Massena, New York. It 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 of the PCBs (treated solids contained less than 2 mg/kg PCBs) found in river sediments without the use of 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)

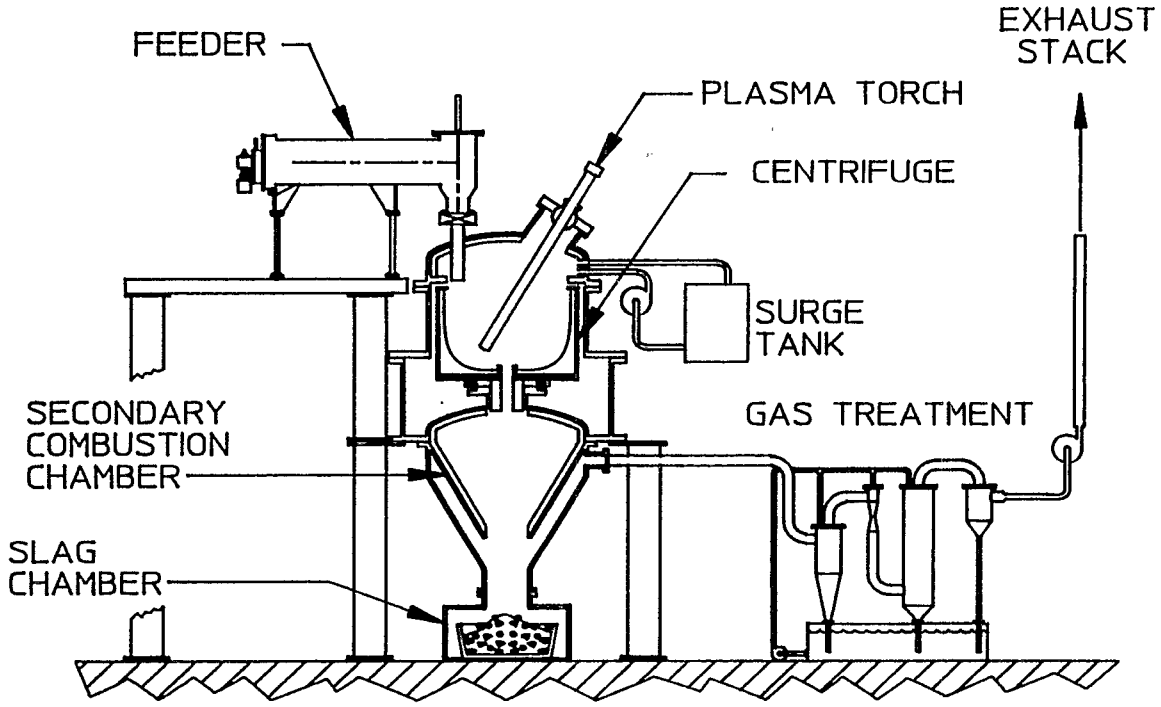
TECHNOLOGY DESCRIPTION:

Plasma arc treatment vitrification 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 at 2,800 to 3,000 °F. 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 it is heated to 1,800 °F by the plasma torch. Organic material is evaporated and destroyed. Off-gas travels through a gas-slag separation chamber to a secondary combustion chamber where the temperature is maintained at over 2,000 °F for more than 2 seconds. .The gas then flows 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 is slowed, 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.



Plasma Arc Centrifugal Treatment (PACT) Furnace

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

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.

WASTE APPLICABILITY:

The technology can process organic and inorganic wastes. It is most appropriate for mixed waste, transuranic waste, chemical plant waste, soil containing both heavy metals and organics, incinerator ash, 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: liquids, sludges, 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 and 1,000 ppm hexachlorobenzene and mixed in a 90-to-10 weight ratio with No. 2 diesel oil. All feed and effluent streams were sampled. The Applications Analysis Report (EPA/540/A5-91/007) has been published.

DEMONSTRATION RESULTS:

During testing at the Component Development and Integration Facility, the PACT-6 furnace achieved the following:

- Hexachlorobenzene was at or below detection limits in all off-gas samples. The minimum destruction removal efficiency (DRE) ranged from 99.9968 percent to 99.9999 percent.
- The treated material met TCLP standards for organic and inorganic constituents.
- The treated material contained a high percentage of the 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 the PACT-8 furnace in Muttenz 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 Muttenz was reduced in a catalytic system to 19 ppm.

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

RISK REDUCTION ENGINEERING LABORATORY
(Base-Catalyzed Dechlorination Process)

TECHNOLOGY DESCRIPTION:

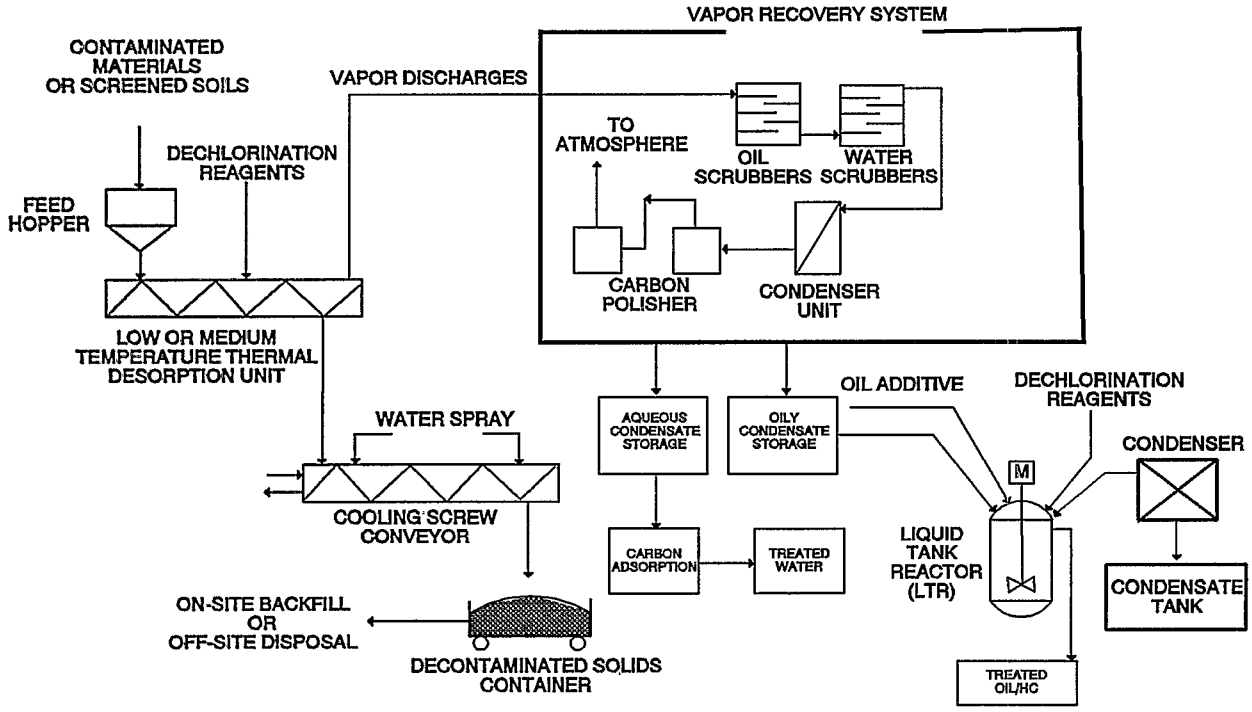
The base-catalyzed dechlorination (BCD) process was developed by the Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. This process, which does not use polyethylene glycol (PEG), is a clean and inexpensive way to remediate soils and sediments contaminated with chlorinated organic compounds, including polychlorinated biphenyls (PCB). The process strips off chlorine from PCB or other halogenated material, to produce a nonhalogenated organic and sodium chloride.

ETG Environmental, Inc., and Separation and Recovery Systems (SRS) developed the THERM-O-DETOX system to treat contaminated soils, based on the BCD process chemistry. The combined process (see figure below) begins by mixing chemicals with contaminated soil or sediment. This mixture is heated at 300 to 340 °C for 1 to 3 hours. Off-gases are treated and released. The treated residuals are nonhazardous and can be either disposed of using standard methods or further processed to separate components for reuse.

WASTE APPLICABILITY:

This process can treat soils and sediments contaminated with the following chlorinated compounds:

- Halogenated VOCs
- Halogenated SVOCs, including herbicides and pesticides



Base-Catalyzed Dechlorination (BCD) Process

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

- Polychlorinated biphenyls (PCB)
- Pentachlorophenol (PCP)
- Dioxins and furans

STATUS:

The BCD technology was demonstrated at the Koppers Company Superfund Site in Morrisville, North Carolina during August 1993. The technology was demonstrated in conjunction with the SAREX® THERM-O-DETOX™ System developed by ETG Environmental, Inc., and Separation and Recovery Systems, Inc. (SRS). For information on the SAREX® THERM-O-DETOX™ system, see the SRS profile in this document.

The purpose of this demonstration was to determine how effectively the technology removed PCP and dioxins from the soil at the site. Results will be published in 1994.

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

RISK REDUCTION ENGINEERING LABORATORY
(Volume Reduction Unit)

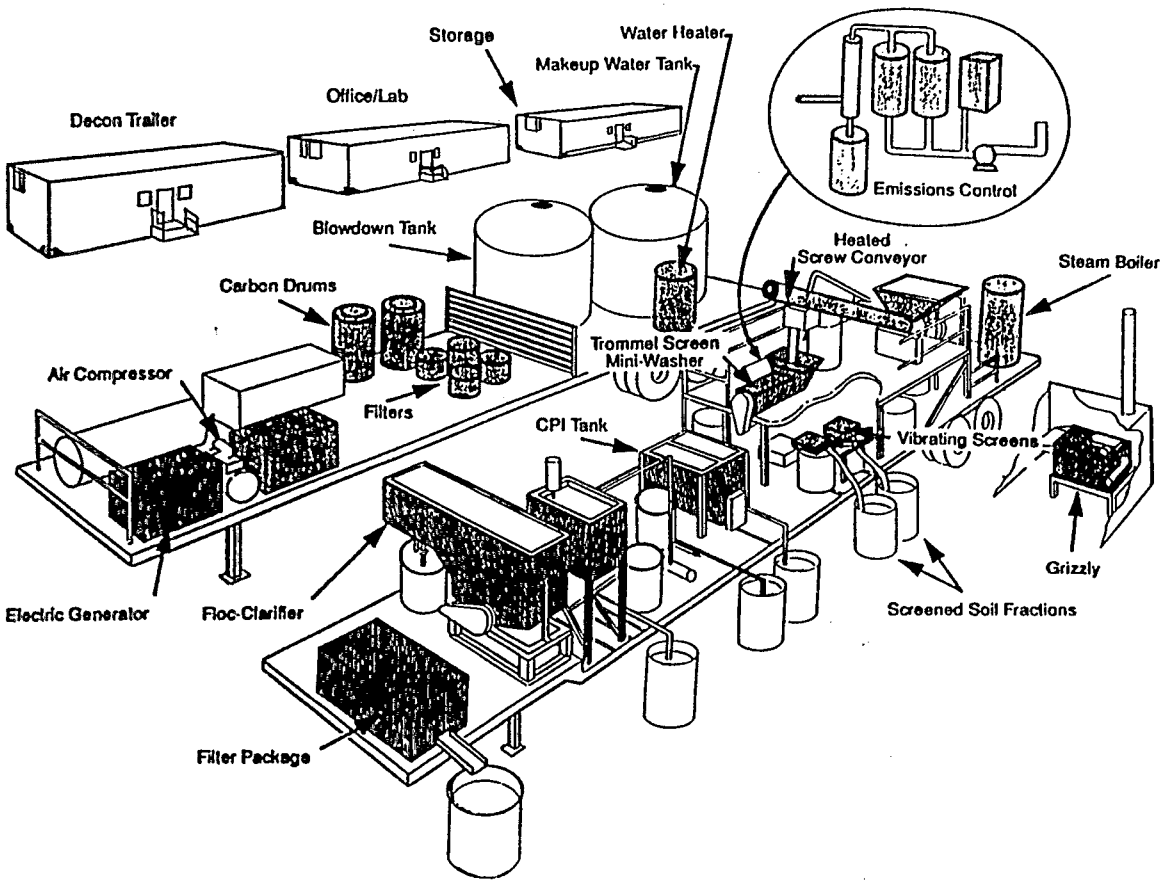
TECHNOLOGY DESCRIPTION:

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, floc-culation/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:

This technology 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 pentachlorophenol (PCP) and creosote (polynuclear aromatic hydrocarbons (PAH) 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 physical condition of the wash water was modified 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), and Condition 3 (surfactant addition, pH adjustment, and temperature adjustment). The table below summarizes the preliminary 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

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

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

TECHNOLOGY DESCRIPTION:

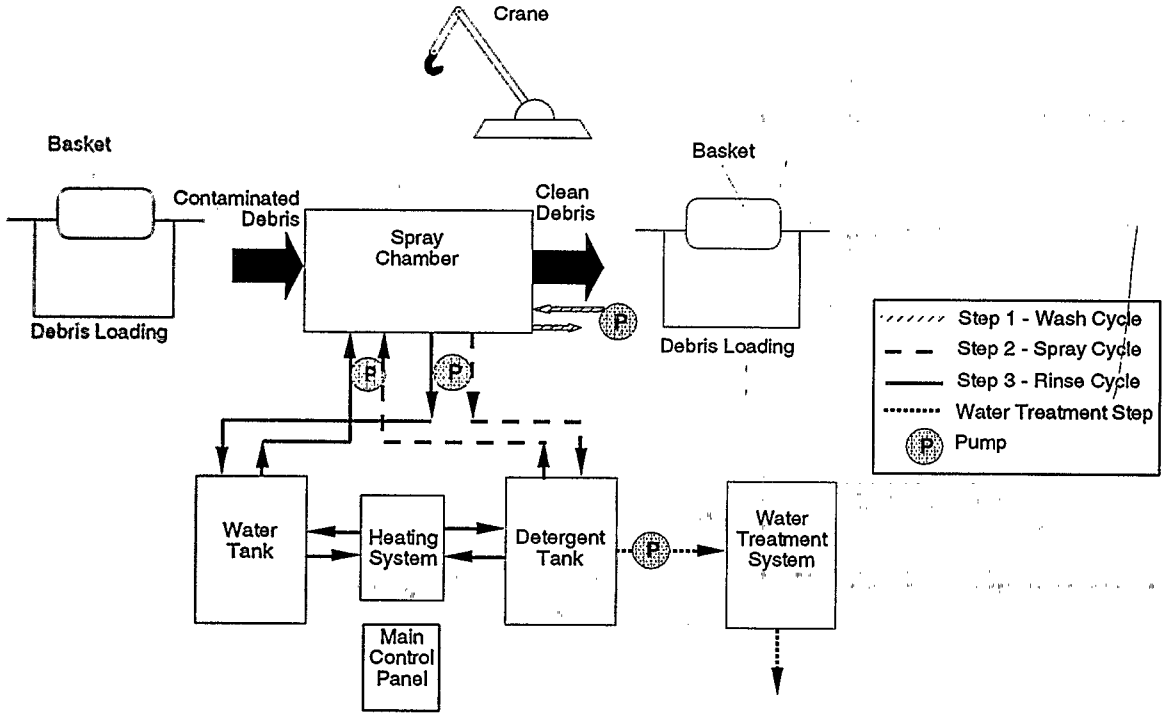
This technology was developed by EPA's Risk Reduction Engineering Laboratory (RREL) and IT Corporation (IT) for on-site decontamination of metallic and masonry debris at CERCLA sites. The full-scale debris washing system (DWS) consists of dual 4,000-gallon spray-wash chambers that are connected to a detergent solution holding tank and rinse water holding tank. Debris is paced 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 the chamber. Process water is heated to 160 °F 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 two 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.

STATUS:

The first pilot-scale tests were performed in September 1988 at the Carter Industrial Superfund site in Detroit, Michigan (EPA Region 5). PCB reductions averaged 58 percent



Pilot-Scale Debris Washing System

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

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 (EPA Region 4), 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 (EPA Region 4). 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 (EPA Region 5).

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 ready for deployment to a CERCLA site 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 THE UNIVERSITY OF CINCINNATI
(Hydraulic Fracturing)

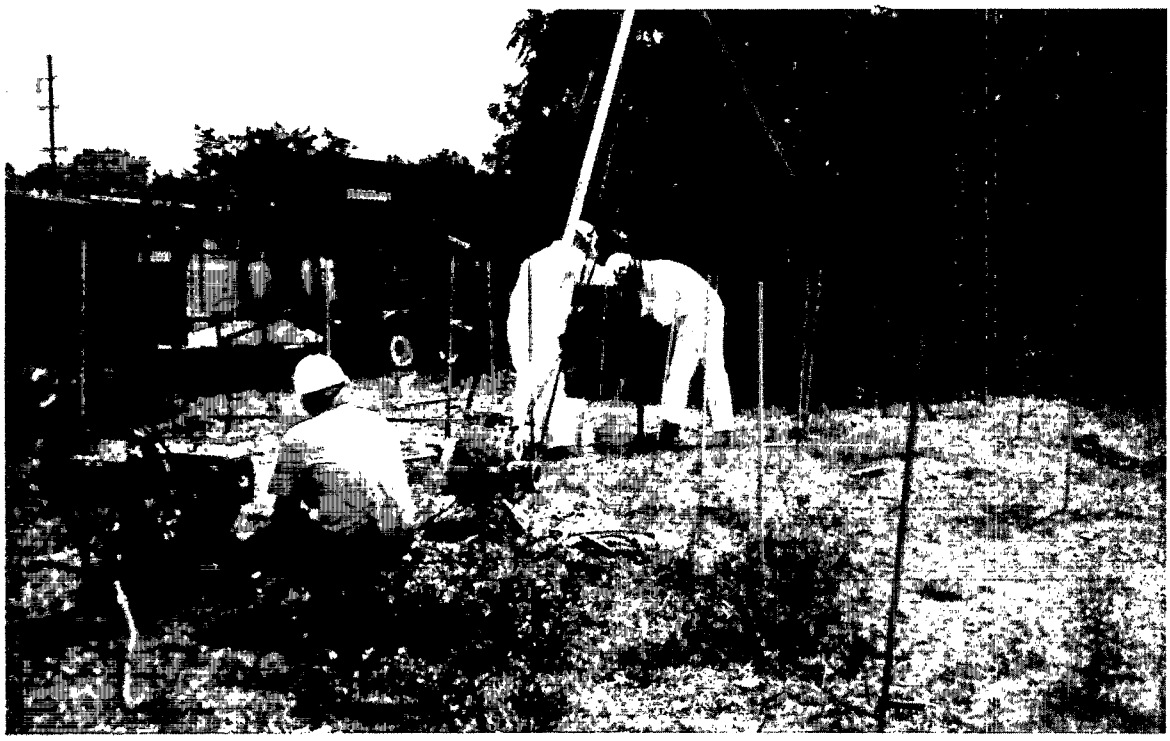
TECHNOLOGY DESCRIPTION:

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 through 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 low-permeability geologic formations.

The fracturing process (see photograph below) begins with the injection of water into a sealed borehole until the pressure of the water exceeds a critical value and a fracture is nucleated. A slurry composed of a coarse-grained sand and guar gum gel is then injected as the fracture grows away from the well. After pumping, the sand 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 delivery or recovery of a vapor or liquid.

These fractures function as pathways for vapor extraction or fluid introduction, potentially increasing the effective area available for remediation.

The hydraulic fracturing process can be used in conjunction with soil vapor extraction technology to enhance the recovery of contaminated soil vapors. Hydraulically-induced fractures are used to place fluids and nutrients during in situ bioremediation. The technology has the potential to deliver solids useful in bioremediation to



Hydraulic Fracturing Process (Well is at Center of Photograph)

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

the subsurface. Solid nutrients or oxygen-releasing compounds can be injected as granules into the fractures.

Techniques for measuring deformation of the ground surface in real time have been developed to monitor the position of the fractures in the subsurface.

WASTE APPLICABILITY:

Hydraulic fracturing is appropriate for enhancing remediation of soil and groundwater. The technology can be applied to contaminants or wastes associated with remediation by soil vapor extraction, bioremediation, or pump and treat systems.

STATUS:

The hydraulic fracturing technology entered the SITE Demonstration Program in July 1991. Pilot-scale feasibility studies 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 have been published under one cover (EPA/540/R-93/505). The Technology Demonstration Summary (EPA/540/SR-93/505) is also available.

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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 and other unknown enzyme systems, the fungi also break down contaminants in the soil.

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

WASTE APPLICABILITY:

This technology was initially developed to treat soil contaminated with chemicals found in the wood preserving industry. Contaminants include chlorinated organics and polynuclear aromatic hydrocarbons (PAH). Different contaminants and combinations of contaminants may have varied degrees of success. In particular, the SITE Demonstration Program is evaluating how well white rot fungi degrades pentachlorophenol.

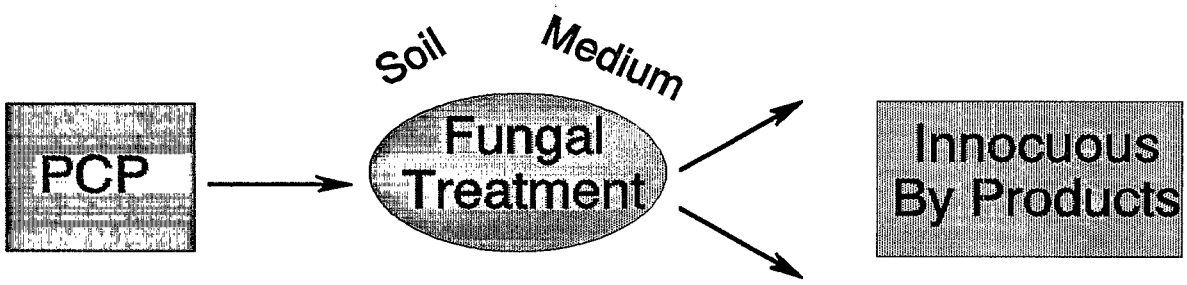
STATUS:

This technology 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 an 89 percent removal of PCP and a 70 percent removal of total PAHs during a 2-month period, by one lignin-degrading fungus.

A full-scale demonstration using this fungus was recently completed to obtain economic data. 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 during mid-June 1993. No woodchips or other bulking agents were added to the prepared soil.

Field activities included tilling and watering all plots. No nutrient addition was undertaken.

Air emissions data have shown no significant hazards to field technicians due to soil tilling activities. Contaminated soil, underlying sand,



In Situ White Rot Fungal Treatment of Contaminated Soil

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

and leachate are being sampled for the contaminants and for toxicity responses.

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.

The project was completed in November 1992. Initial reports will be available in late 1993.

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

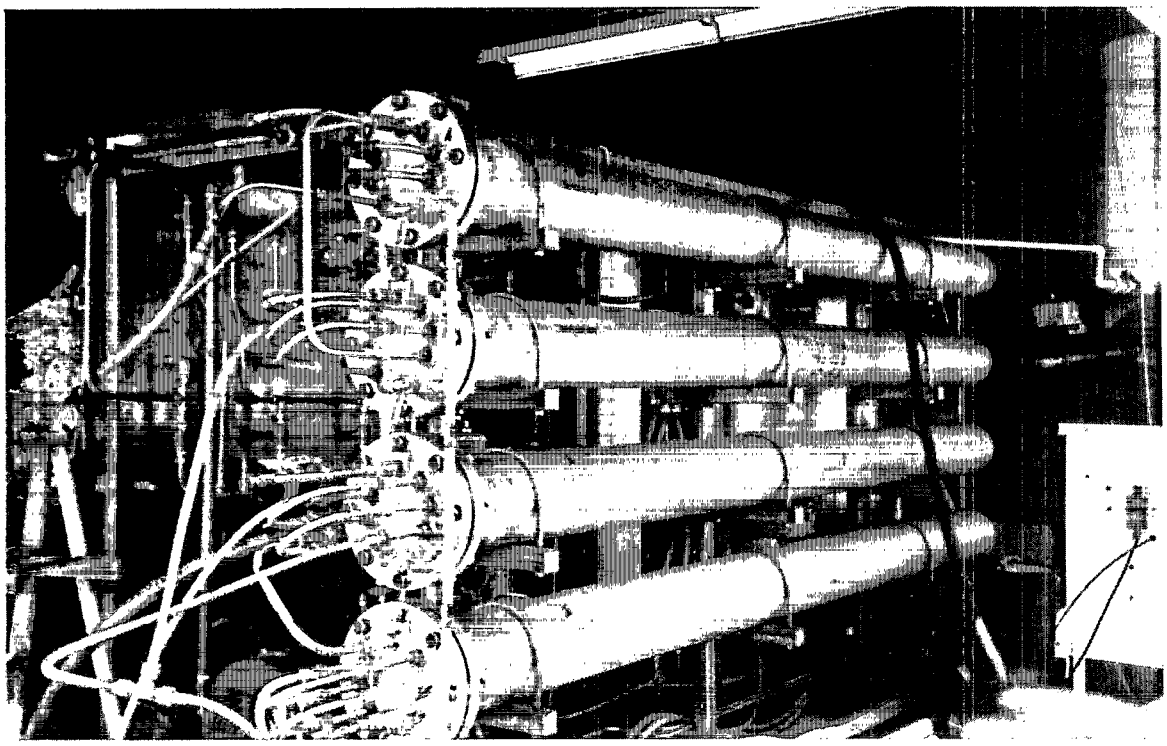
SBP TECHNOLOGIES, INC.
(Membrane Filtration and Bioremediation)

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 a part 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.

Contaminated water or slurry can also be fed directly into the bioreactor and then polished with the membrane filtration unit. The bioreactor, or series of bioreactors, are inoculated with proprietary (specially selected, usually indigenous) microorganisms to produce effluent with low to nondetectable levels of contaminants. Integrating the two units allows many contaminants to be removed and destroyed on site.



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 solvent contamination. The system, with modifications, can also treat polynuclear aromatic hydrocarbons (PAH) (such as creosote and coal tar); pentachlorophenol (PCP); petroleum hydrocarbons; and chlorinated aliphatics, such as trichloroethene (TCE).

The two technologies can be used separately or together, 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.

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

STATUS:

The membrane filtration system was demonstrated under the SITE Program during October 1991 at the American Creosote Works in Pensacola, Florida. Results confirmed that this membrane system removed 95 percent of the PAH concentrations and 25 to 30 percent of smaller phenolic compounds, reducing creosote constituents in the contaminated feed by 80 percent overall. PAH removal was sufficient to pass local POTW discharge standards. Full-scale demonstration of the bioremediation system through the SITE Program was cancelled. However, a smaller-scale field study was performed at the site. Results are available through the developer. A final report describing the membrane filtration performance is also available (EPA/540/AR-92/014).

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

SILICATE TECHNOLOGY CORPORATION
(Chemical Fixation/Solidification Treatment Technologies)

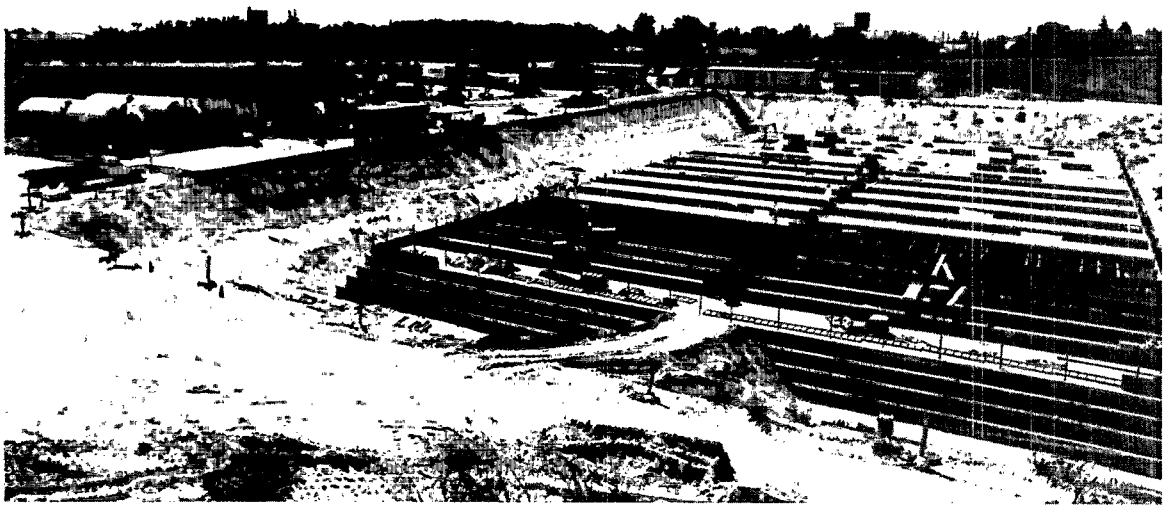
TECHNOLOGY DESCRIPTION:

Silicate Technology Corporation (STC) has developed both chemical organic destruct and chemical fixation/solidification technologies for the treatment of inorganic and organic solid hazardous wastes.

STC's chemical organic destruct 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's inorganic contaminant chemical fixation/solidification technology involves the formation of insoluble chemical compounds, reducing leachable contaminant concentrations of inorganic contaminated soils and sludges. STC's inorganic treatment technologies are more efficient and often less costly than generic cementitious processes.

STC'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 as well as industrial sites across the United States and in Italy.

STC 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 as well as placement and conveying systems for handling treated material. Mixing systems include various batching plants, pug mills and high-shear batch mix-



Pretreatment of Contaminated Soil

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

ing systems for proper metering and mixing of reagents with contaminated soils. STC provides full on-site technical support to ensure proper application of the treatment technologies, documentation, and quality assurance/quality control procedures to assure the effectiveness of the treatment process.

WASTE APPLICABILITY:

STC'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's demonstration project was completed in November 1990 at the Selma Pressure Treating (SPT) Superfund site in Selma, California. STC was subsequently selected for the full-scale remediation of the SPT site. The SPT site is contaminated with both organics, mainly pentachlorophenol (PCP), and inorganics, mainly arsenic, chromium, and copper. 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 chemical destruct process reduced total PCP concentrations up to 97 percent. The STC chemical fixation process stabilized the residual PCP concentrations to very low leachable levels (less than 0.3 milligrams per liter)
- STC's technology immobilized arsenic as well as chromium and copper.
- Unconfined compressive strength testing of the treated wastes after 28 days was moderately high, averaging 260 to 360 pounds per square inch.
- 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 costs of treatment using STC's technologies depends on the specific waste characteristics.

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

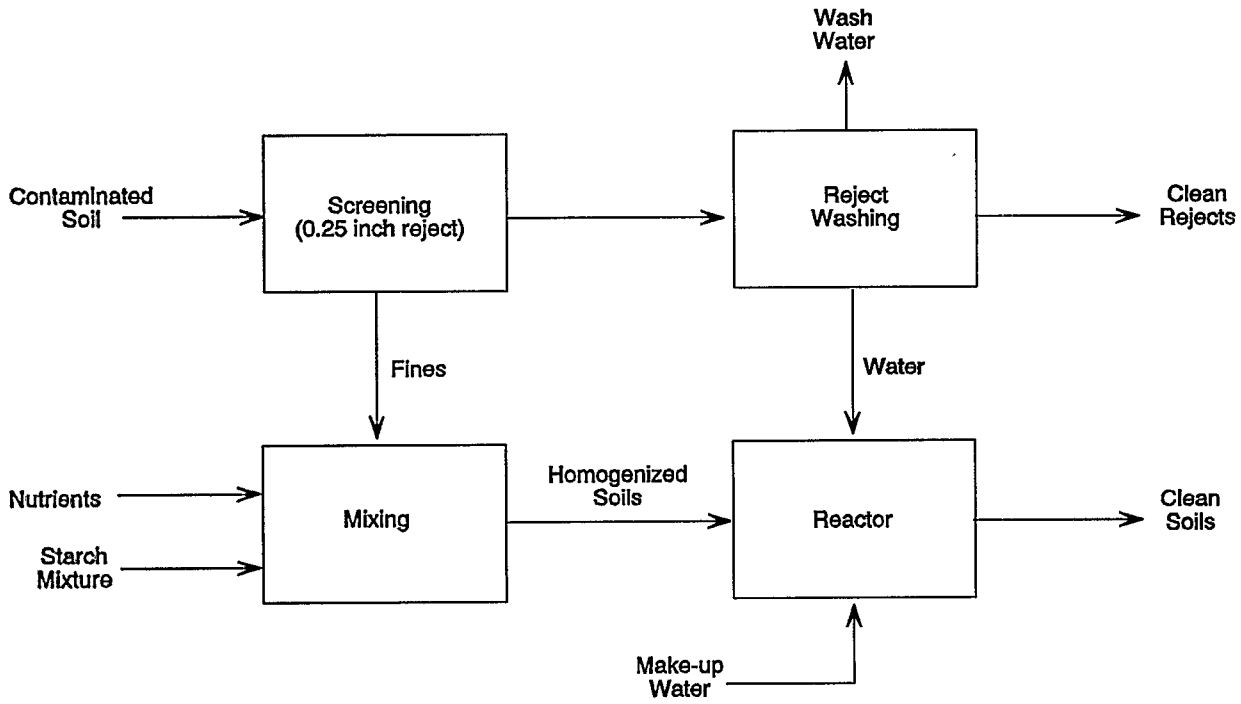
J.R. SIMPLOT COMPANY
(Biodegradation of Dinoseb)

TECHNOLOGY DESCRIPTION:

Anaerobic microbial mixtures have been discovered which degrade both dinoseb (2-sec-butyl-4,6-dinitrophenol) and trinitrotoluene (TNT). These mixtures completely degrade their target molecules to simple nonaromatic products within a few days forming reduced intermediates (such as aminonitrotoluenes) and hydroxylated intermediates (such as methylphlorglucinol and p-cresol). The microbial consortia function at Eh's of -200 mV or more.

This technology bioremediates soils contaminated with the pesticide dinoseb. Treatment units (see figure) consist of simple vessels that contain static soil slurries (50 percent soil and 50 percent water). The units contain about 50 cubic meters of soil. The biodegradation process involves adding starch to flooded soils and sludges. Anaerobic, starch-degrading bacteria may also be introduced. After anaerobic conditions are established (at Eh equal to -200 millivolts [mV]), an anaerobic microbial consortium is inoculated which degrade the nitroaromatics. In some soils, inoculations are not necessary because native consortia are able to degrade the dinoseb.

This technology treats soils contaminated with nitroaromatic pollutants. Anaerobic microbial mixtures for dinoseb can reduce this pollutant to less than its detection limit. This technology has achieved removal rates of greater than 99.88 percent.



Pilot-Scale Treatment Unit

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

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Bench-scale processes have been developed for both dinoseb and TNT under the SITE Emerging Technology Program.

A pilot-scale system treated dinoseb-contaminated soils from a site in Idaho, with the largest reactors holding 4 cubic meters (m^3) of soil. With three replicates per treatment, up to 12 m^3 of soil were treated at one time. The procedure's efficacy was confirmed at a small scale (50 kilograms), using dinoseb-contaminated soil from a spill site in Washington state.

During bench-scale tests, soil contaminated with 2 percent TNT was treated to below detectable limits. Degradation intermediates were identified using gas chromatography/mass spectrometry techniques.

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

The dinoseb demonstration occurred at Bowers Field in Ellensburg, Washington and was completed in July 1993. The results are being analyzed. In the field, dinoseb was reduced from 28 parts per million to below the detection limit (a greater than 99.88 percent removal). Other pesticides were also degraded in this process. The process took less than 22 days under conditions that were less than optimum (18 °C instead of 35 to 37 °C).

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

J.R. SIMPLOT COMPANY
(Biodegradation of Trinitrotoluene)

TECHNOLOGY DESCRIPTION:

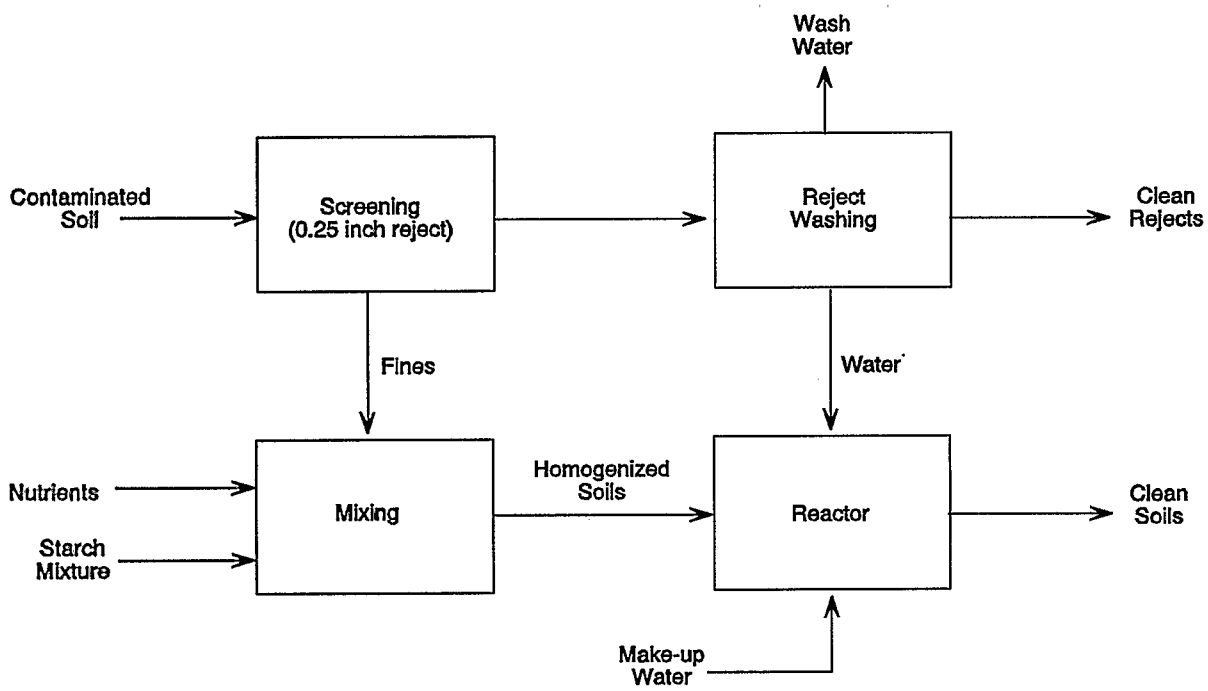
This technology bioremediates soils and sludges contaminated with nitroaromatics. Nitroaromatics have become serious environmental contaminants at military locations nationwide. Examples of nitroaromatics include nitrotoluenes, used as explosives, and pesticides.

Anaerobic microbial mixtures have been discovered, that degrade both the pesticide dinoseb (2-sec-butyl-4,6-dinitrophenol) and trinitrotoluene (TNT). These mixtures completely degrade their target molecules to simple nonaromatic products within a few days forming reduced intermediates (such as aminonitrotoluenes) and hydroxylated intermediates (such as methylphlorglucinol and p-cresol). The microbial consortia function at Eh values of -200 millivolts (mV) or more.

Treatment units (see figure) consist of simple vessels that contain static soil slurries (50 percent soil and 50 percent water). The units hold about 50 cubic meters of soil. The biodegradation process involves adding starch to flooded soils and sludges. Anaerobic, starch-degrading bacteria may also be introduced. After anaerobic conditions are established (at Eh values equal to -200 mV), an anaerobic microbial consortium is inoculated which degrades the nitroaromatics. In some soils, inoculations are not necessary, because native consortia are able to degrade the TNT.

WASTE APPLICABILITY:

This technology is designed to treat soils contaminated with nitroaromatic pollutants. Anaerobic microbial mixtures have been developed for the pesticide dinoseb and for TNT.



Pilot-Scale Treatment Unit

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

These pollutants can be reduced to less than their detection limit.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Bench-scale processes have been developed for both dinoseb and TNT under the SITE Emerging Technology Program.

A pilot-scale system treated dinoseb-contaminated soils from a site in Idaho, with the largest reactors holding 4 cubic meters (m^3) of soil. With three replicates per treatment, up to 12 m^3 of soil was treated at one time. The procedure's efficacy was confirmed at a small scale (50 kilograms), using dinoseb-contaminated soil from a spill site in Washington state.

During bench-scale tests, soil contaminated with 2 percent TNT was treated to below detectable limits. Degradation intermediates were identified using gas chromatograph/mass spectrograph techniques.

Based on these results, this technology was accepted into the SITE Demonstration Program in winter 1992.

The TNT demonstration occurred from September 1993 through October 1993 at a U.S. Department of Defense (DOD) site in St. Louis. The process was tested on soils with clay and a high concentration of contaminant. The concentration of dinoseb was reduced to less than its analytical detection limit in 22 days in 18 °C (optimum would have been 35 to 37 °C). Percent removal was greater than 99.8 percent. The samples are currently being analyzed. These results will be discussed at a Visitors' Day scheduled for November 1993.

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

SOILTECH ATP SYSTEMS, INC.
(Anaerobic Thermal Processor)

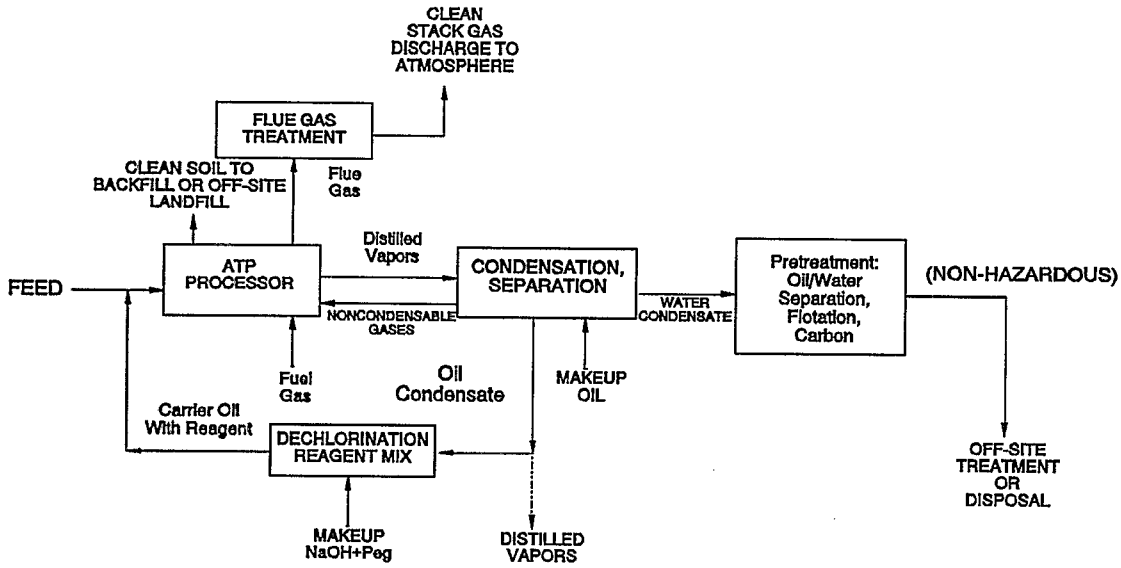
TECHNOLOGY DESCRIPTION:

The SoilTech ATP Systems, Inc. (SoilTech), anaerobic thermal processor (ATP) is a thermal desorption process. A rotary kiln unit desorbs, collects, and recondenses contaminants from the fed material. The unit also can be used in conjunction with a dehalogenation process to destroy halogenated hydrocarbons through a chemical process conducted 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 the passage of solids and inhibits the passage of gases, including contaminants, 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 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 shell of the kiln. 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.



Anaerobic Thermal Processor (ATP)

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

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.

When the ATP system is used to dechlorinate 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 technology was originally developed to recover oil from tar sands and shales. It 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 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 technology has been demonstrated at two sites. At the first demonstration, in May 1991, a full-scale unit dechlorinated soils contaminated with PCBs 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.

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.
- No volatile or semivolatile organic degradation products were detected in the treated soil. Also, no leachable metals, VOCs, or semivolatile organic compounds 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.

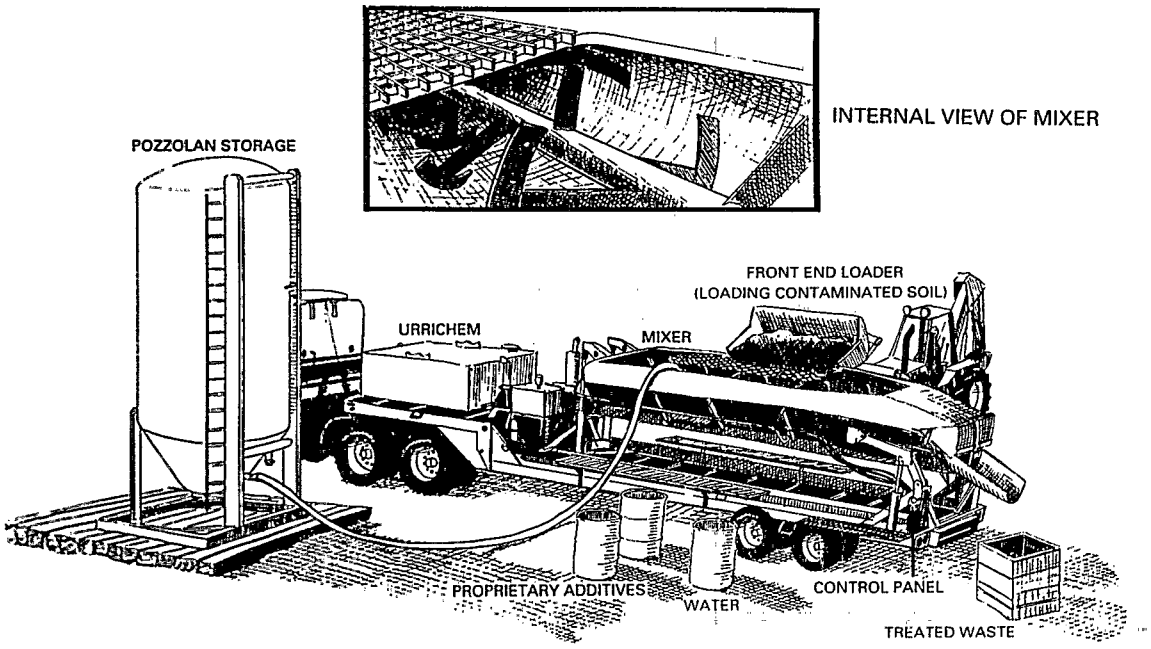
Contaminated waste materials are collected, screened to remove oversized material, and introduced to the batch mixer (see figure below). The waste material is then mixed with (1) water, (2) Urrichem —— a proprietary chemical reagent, (3) proprietary additives, and (4) pozzolanic material (fly ash), kiln 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 technology treats soils and sludges contaminated with organic compounds, metals, inorganic compounds, and oil and grease. Batch mixers of various capacities are available to treat different volumes of waste.

STATUS:

The 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 tank were treated during the demonstration. These wastes were contaminated with petroleum hydrocarbons,



Soliditech Processing Equipment

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

polychlorinated biphenyls (PCB), other organic chemicals, and heavy metals.

DEMONSTRATION RESULTS:

Key findings from the Soliditech demonstration are summarized below:

@^F@^F^T nalyses of extracts and leachates 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.
- 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)]. Oil and grease content of the TCLP extracts of 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 of 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.

A Technology Evaluation Report was published in February 1990 in two volumes. Volume I (EPA/540/5-89/005) is the report; Volume II (EPA/540/5-89/005) contains supplemental data. An Applications Analysis Report was published in September 1990 (EPA/4540/A5-89/005).

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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 the process of removing and treating volatile organic compounds (VOC) from the vadose or unsaturated zone of soils. These compounds can often be removed from the vadose zone before they contaminate groundwater. This process is patented and licensed to Terra Vac, Inc. (Terra Vac), and others.

The technology uses readily available equipment, such as 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.

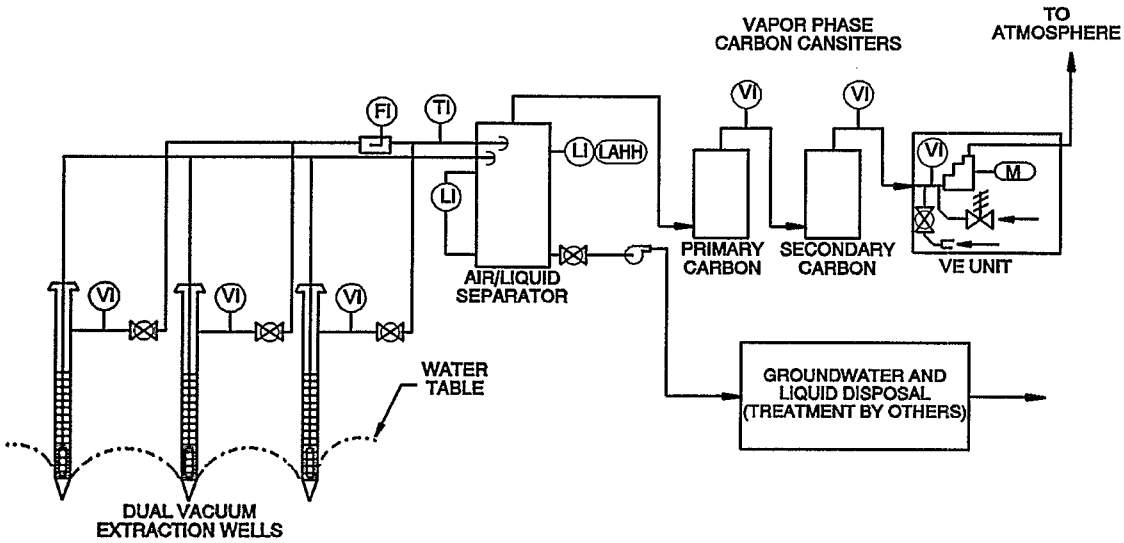
A vacuum pump draws the subsurface contaminants from the extraction wells to the liquid/gas separator. The contaminants are then treated using an activated carbon adsorption filter or a catalytic oxidizer before the gases are discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations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

The technology is effective in virtually all hydrogeological settings and can reduce soil contaminant levels from saturated conditions to nondetectable. The process works in low permeability 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 methods of remediation, 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 contamination at the site.

WASTE APPLICABILITY:

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, including 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 nine 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:

The Groveland Wells demonstration used four extraction wells to pump 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 low permeability clays. The process achieved nondetectable levels of VOCs 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 concentrations of VOCs in the treated soils usually remained.
- Major considerations in applying this technology are volatility of the contaminants and site soils. 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 but can range from $10 to $150 per ton, 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.

TORONTO HARBOUR COMMISSION
(Soil Recycling)

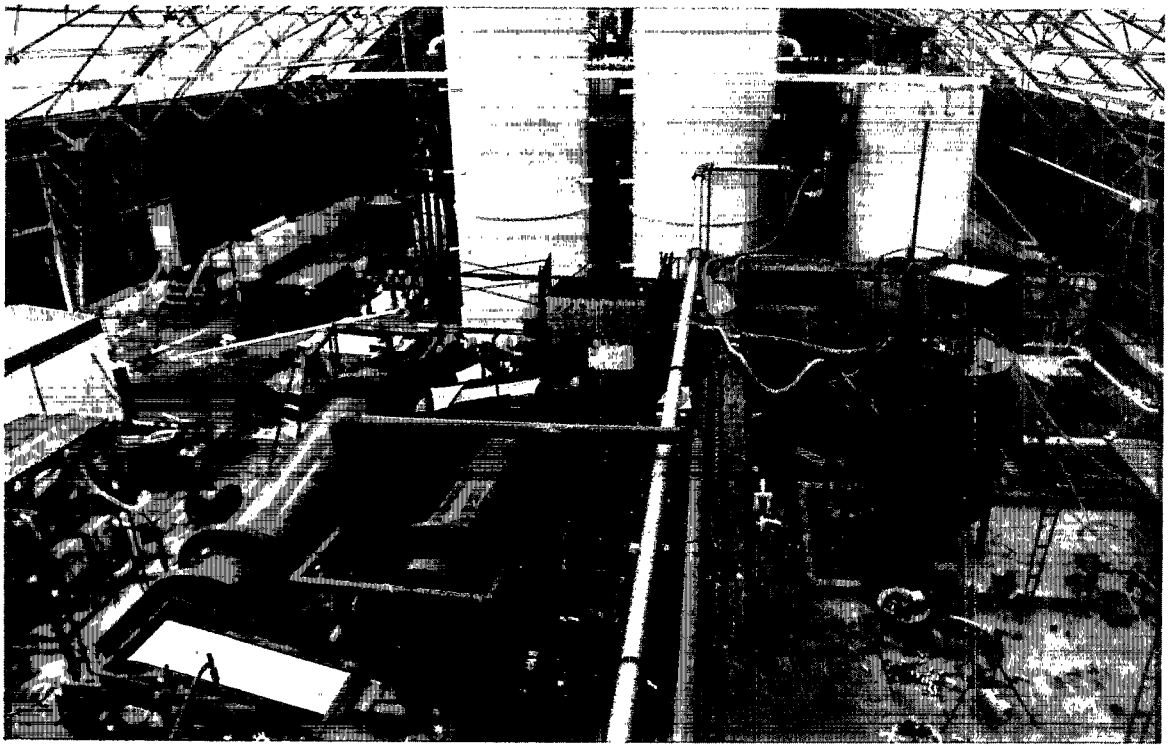
TECHNOLOGY DESCRIPTION:

The Toronto Harbour Commission's soil recycling process involves three technologies operating in series. The process removes inorganic and organic contaminants in soil to produce a reusable fill material. The first technology involves a soil washing process that reduces the volume of material to be treated by concentrating contaminants in a fine slurry mixture. The second technology removes heavy metals from the slurry through a process of metal dissolution. Using acidification and selective chelation, the metal dissolution process recovers all metals in their pure form. 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. The following reports are available from EPA:

- Applications Analysis Report (EPA/540/AR-93/517)
- Technology Evaluation Report (EPA/540/R-93/517)
- Technology Demonstration Summary (EPA/540/SR-93/517)

WASTE APPLICABILITY:

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



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

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

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 and petroleum storage. Demonstration sampling took place in April and May 1992. The objective of the SITE demonstration was to evaluate the ability of the process to achieve the modified Ontario Ministry of the Environment (MOE) criteria for commercial and industrial sites.

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

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 from the Anaconda copper mine in Butte, Montana.

The chemical treatment process and bioslurry reactors achieved a 90 percent reduction in simple 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.

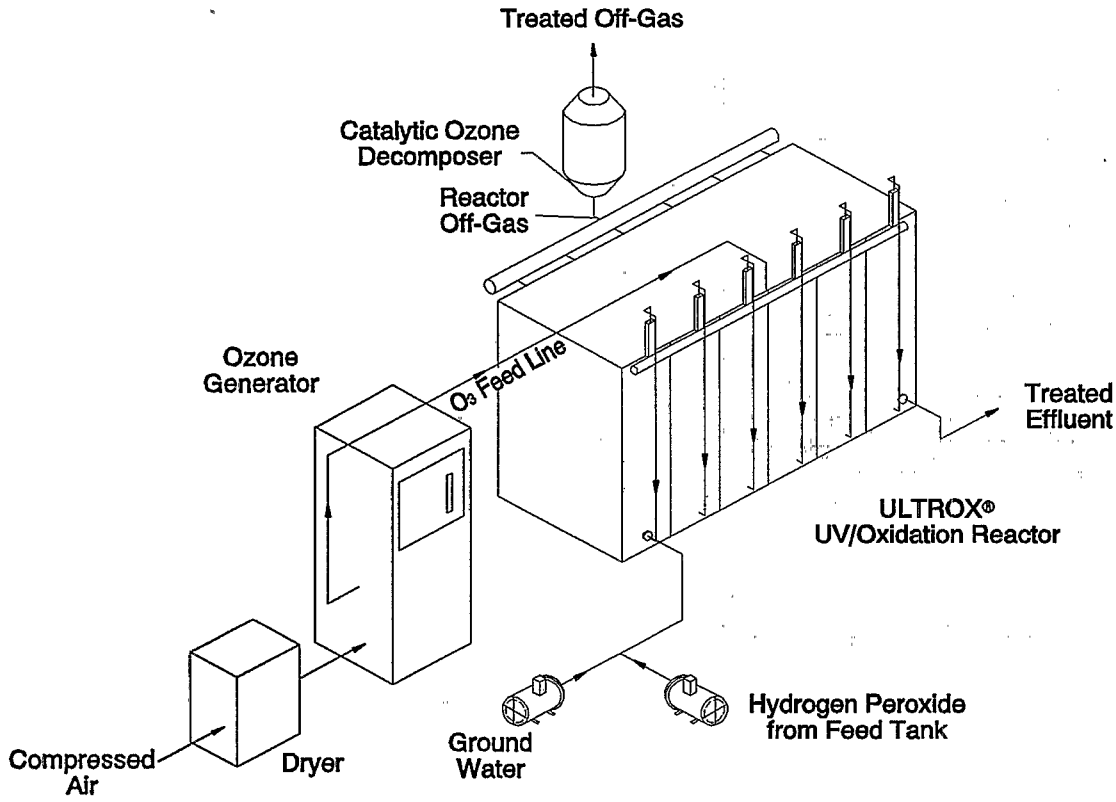
ULTROX INTERNATIONAL
(Ultraviolet Radiation and Oxidation)

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) in concentrations of parts per million or parts per billion.

The system (see figure below) consists of a treatment tank module, an air compressor and ozone generator module, and a hydrogen peroxide feed system. It is skid-mounted and portable, and permits on-site treatment of a wide variety of liquid wastes, such as industrial wastewater, groundwater, and leachate. The 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.

Influent to the treatment tank (see figure below) 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:

Contaminated groundwater, industrial wastewaters, and leachates containing halogenated solvents, phenol, pentachlorophenol, pesticides; polychlorinated biphenyls; explosives; benzene, toluene, ethylbenzene, and xylene; methyl tertiary butyl ether; and other organic compounds are suitable for this treatment process.

STATUS:

A field-scale demonstration was completed in March 1989 at a hazardous waste site in San Jose, California. The test program was designed to evaluate the performance of the Ultrox system at 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 25 systems installed. Flow rates ranging from 5 gallons per minute (gpm) to 1,050 gpm are being used in various industries and site cleanup activities, including aerospace, U.S. Department of Energy (DOE), 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 are to be used.

DEMONSTRATION RESULTS:

Contaminated groundwater treated by the Ultrox 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 part per million, 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.

Very low total organic carbon removal was found, implying partial oxidation of organics without complete conversion to carbon dioxide and water.

FOR FURTHER INFORMATION:

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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:

This technology was 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.

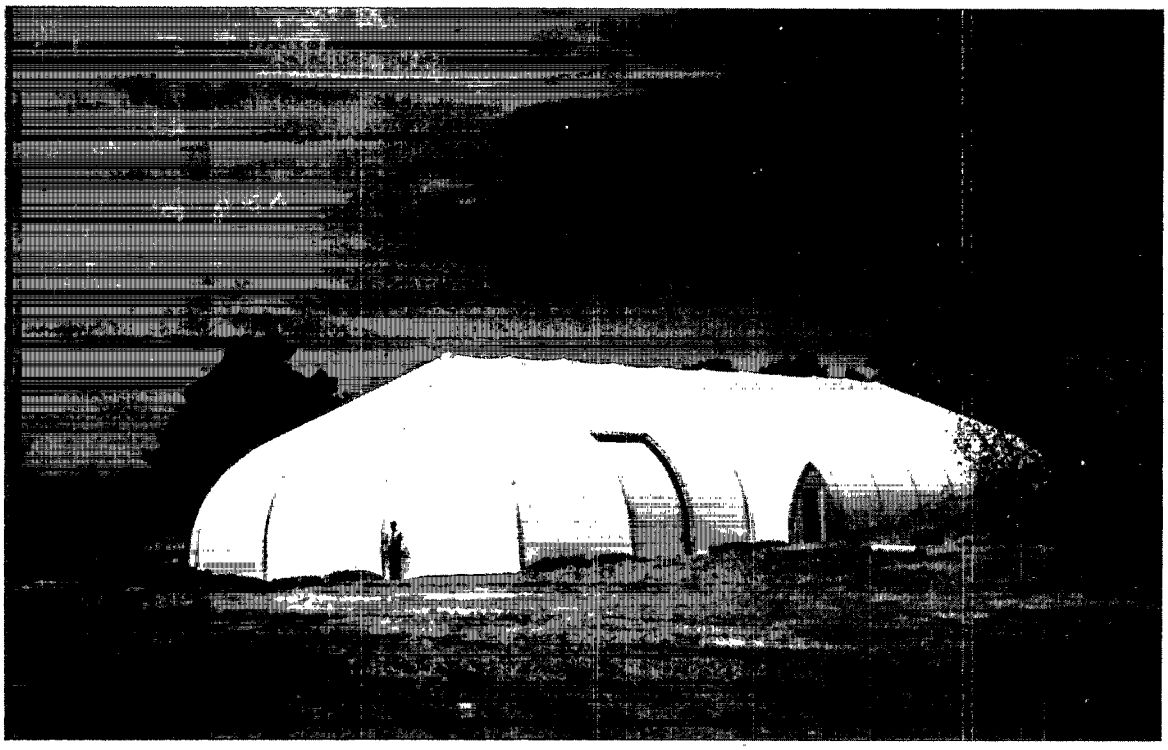
In general, excavating soil contaminated with volatile organic compounds (VOC) results in fugitive air emissions. The area to be excavated is surrounded by a temporary enclosure (see photograph below). Air from the enclosure is vented through an emission control system before being released to the atmosphere. 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 dioxide. A backhoe was used to remove of the



Excavation Area Enclosure

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

overburden and excavate 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 CERI:

- 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 contaminants in the air inside the enclosure were higher than expected. This was due in part to the vapor suppressant foam's 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.

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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 the characteristics of the waste to be treated. Treated material is a nonleaching, high-strength, stabilized end-product.

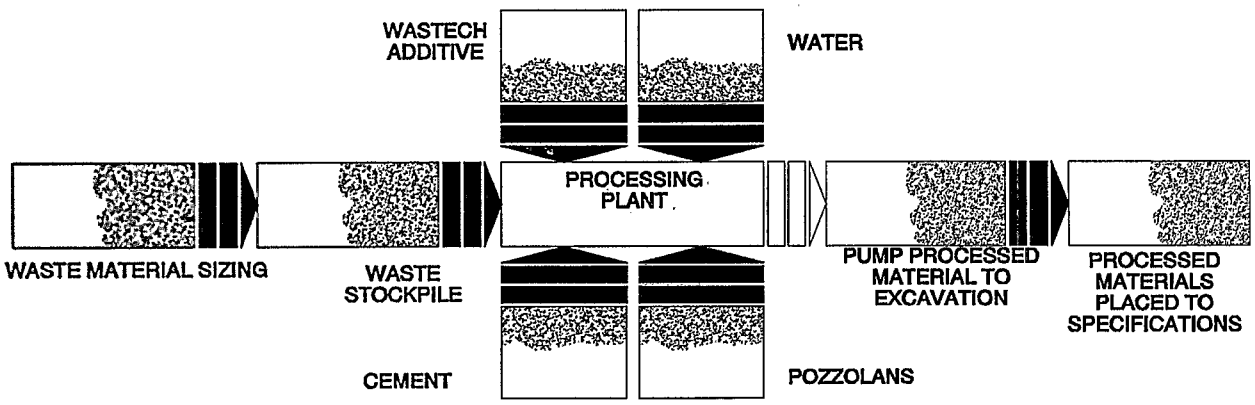
The process uses standard engineering and construction equipment. Because the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula.

Treatment usually begins with excavation of waste. Waste containing large pieces of debris must be pre-screened to remove the debris from the waste. The waste is then placed into a high shear mixer (see figure below), along with premeasured quantities of water and SuperSet®, WASTECH, Inc.'s (WASTECH) proprietary reagent.

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, such as 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



WASTECH Solidification and Stabilization Process

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

by many other chemical manufacturing and industrial processes. WASTECH's technology 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 bench-scale evaluation of the process has been completed. A field demonstration at Robins Air Force Base in Warner Robins, Georgia was completed in August 1991, where the WASTECH technology was used to treat high level organic and inorganic wastes at an industrial sludge pit. WASTECH conducted an abbreviated demonstration with a detailed mass balance evaluation in fall 1992. The technology is being commercially applied to treat hazardous wastes contaminated with various organics, inorganics, and mixed wastes.

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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)

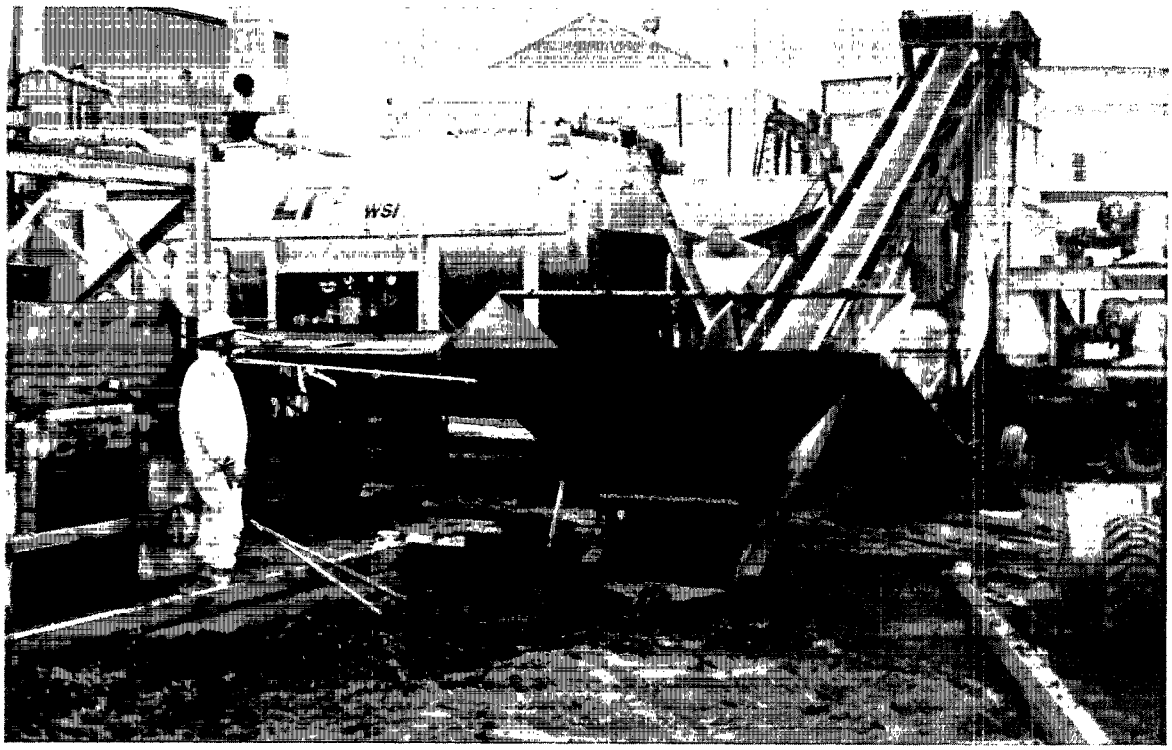
TECHNOLOGY DESCRIPTION:

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 (shown below) consists of three segments: soil treatment, emissions control, and water treatment.

The LT³® thermal processor consists of two jacketed troughs, one above the other. Each trough houses four intermeshed screw conveyors. A front-end loader feeds soil (or sludge) onto a conveyor that discharges into a surge hopper above the thermal processor. Circulating hot oil is used to heat the soil to 400-500 °F, 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. It is then passed through a second, refrigerated condenser and treated by carbon adsorption.

Condensate streams are typically treated in a three-phase oil-water separator to remove light



Low Temperature Thermal Treatment System

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

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 technology treats soils contaminated with volatile and semivolatile organic compounds (VOC and SVOC). Bench-, pilot-, or full-scale LT³® systems have treated soil contaminated with the following wastes: coal tar, drill cuttings (oil-based mud), No. 2 diesel fuel, JP4 jet fuel, leaded and unleaded gasoline, petroleum hydrocarbons, halogenated and nonhalogenated solvents, VOCs, SVOCs, and polynuclear aromatic hydrocarbons.

STATUS:

This technology 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, MI. The system was tested on lagoon sludge from the ADC site. This sludge was contaminated with VOCs, SVOCs, and 4,4-methylene bis(2-chloroaniline) (MBOCA).

DEMONSTRATION RESULTS:

The SITE demonstration yielded the following preliminary 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; 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 in relation to the decrease in chlorobenzene.
- 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 Applications Analysis Report (EPA/540/AR-92/019) is available from EPA. The Technology Evaluation report will be available in 1994.

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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:

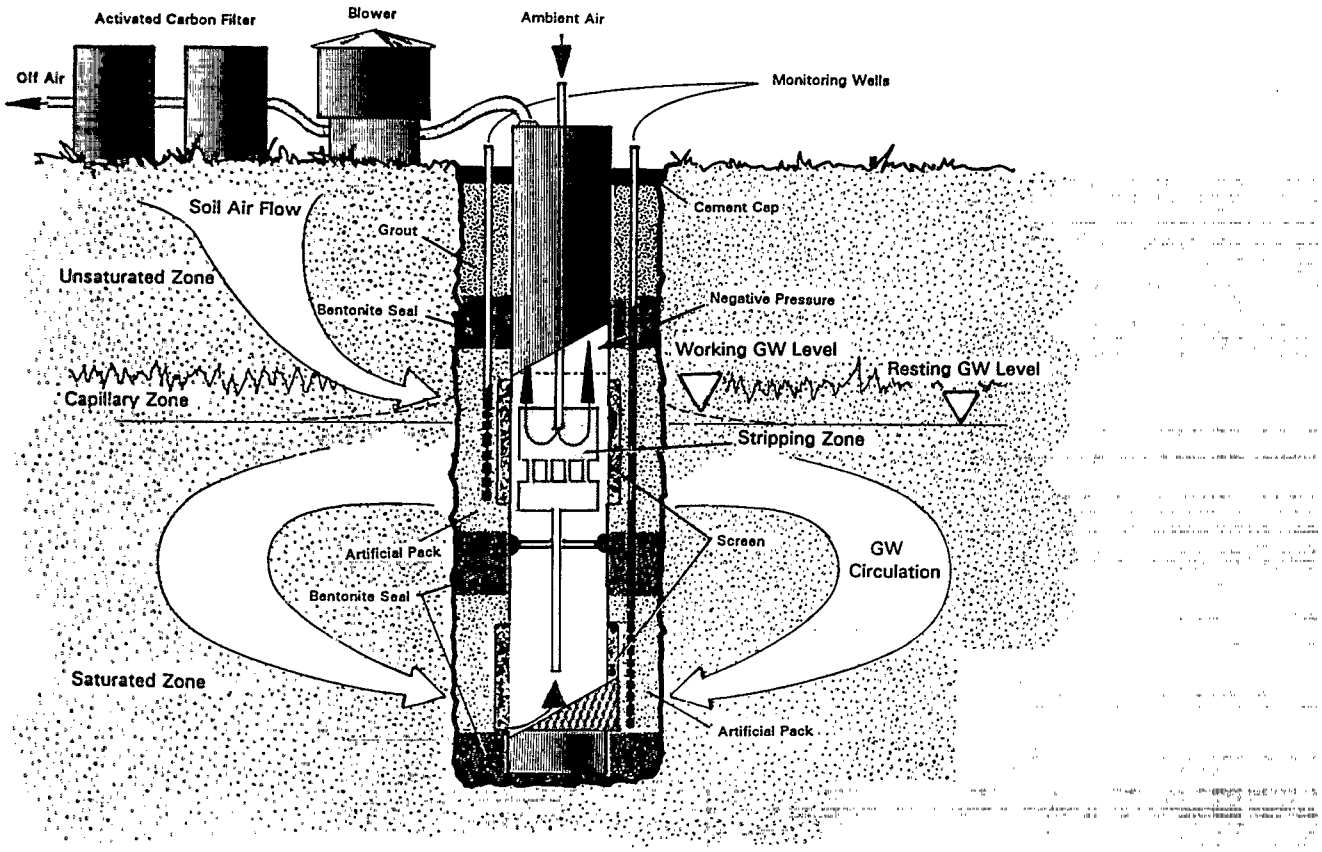
The Unterdruck-Verdampfer Brunnen (UVB) is an in situ system for remediation of contaminated aquifers, especially those contaminated with volatile and semivolatile hydrocarbons or heavy metals, and uses a combination of chemical, physical and biological processes.

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 granular activated carbon filters.

The water level rises inside the well (approximately 1 foot) 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 (air-lift-pump).

As a result of the concentration gradient, the contaminants vaporize into the air bubbles and are removed from the well by the air flow.

A specific flow direction can be induced by adding a support pump to produce a vertical flow either upward or downward within the well. The oscillating hydraulic pressure forces the water horizontally into the aquifer through the top screened segment of the well. In the



UVB Standard Circulation

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

surrounding aquifer, a circulation system develops in which water enters at the base of the well and leaves through the upper screened segment, or vice versa, depending on the desired flow direction.

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 is capable of extracting 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, including trichloroethene and 1,1-dichloroethane from groundwater.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. The 6-month demonstration at March Air Force Base, California will be completed in November 1993.

FOR FURTHER INFORMATION:

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

TABLE 2

Ongoing SITE Demonstration Program Projects as of October 1993

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	Harry Moscatello 908-739-6444	Uwe Frank 908-321-6626	Soil, Rock	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
AlliedSignal, Inc., Des Plaines, IL (003)	ICB Biotreatment System	Steve Lupton 708-391-3224 Conrad Kempton 201-455-5531	Ronald Lewis 513-569-7856	Groundwater, Wastewater	Not Applicable	Readily Biodegradable Organic Compounds
Andco Environmental Processes, Inc., Amherst, NY (007)	Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization	Michael Brewster or Gary Peck 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	Metals	Not Applicable
ASI Environmental Technologies, Inc./ Dames & Moore, St. Petersburg, FL (005)	Hydrolytic Terrestrial Dissipation	Stoddard Pickrell 812-822-7477	Ronald Lewis 513-569-7856	Soil	Not Applicable	Low-Level Toxaphene and Other Pesticides
Billings and Associates, Inc., Albuquerque NM (007)	Subsurface Volatilization and Ventilation System (SVVS®)	Gale Billings 505-345-1116 Don Brenneman 713-575-4693	Kim Lisa Kreiton 513-569-7328	Soil, Sludges, Groundwater	Not Applicable	BTEX, VOCs, SVOCs
Bio-Recovery Systems, Inc.,*** Las Cruces, NM (005)/(E01)	Biological Sorption	Mike Hosea 505-523-0405 800-697-2001	Naomi Barkley 513-569-7854	Groundwater, Electroplating Rinse water	Heavy Metals	Not Applicable
CF Systems Corporation,* Woburn, MA (008)	Solvent Extraction	Chris Shallice 617-937-0800	Mark Meckes 513-569-7348	Soil, Sludge, Wastewater	Not Applicable	PCBs, VOCs, SVOCs, Petroleum Wastes
Clean Berkshires, Inc., Lanesboro, MA (008)	Mobile Thermal Desorption System	James Maxymillian 413-499-9862	Ronald Lewis 513-569-7856	Soil	Not Applicable	VOCs, SVOCs, PAHs and Coal Tars

* An additional demonstration is planned for this technology. Refer to the profile in the Demonstration Program (completed projects) section for more information on this technology.

** Solicitation Number

*** From Emerging Technology Program

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Colorado Department of Health (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
Dynaphore, Inc., Richmond, VA (006)	FORAGER® Sponge	Norman Rainer 804-288-7109 Lou Reynolds 703-713-9000	Carolyn Esposito 908-906-6895	Industrial Discharge, Municipal Sewage Process Streams, Acid Mine Drainage Wastes	Metals	Not Applicable
Ensotech, Inc., Sun Valley, CA (007)	Mobile Environmental Treatment System	Inderjit Sabherwal 818-767-2222	Naomi Barkley 513-569-7854	Soil	Heavy Metals	Hydrocarbons, Chlorinated Organics
EnviroMetal Technologies, Inc., Guelph, Ontario, Canada (008)	In Situ Metal Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater	John Quayle 519-824-0432	Chien Chen 908-906-6985	Groundwater	Not Applicable	Vinyl Chloride, 1,1,1-Trichloroethane, 1,2-Dichloroethene, TCE and PCE
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
Geosafe Corporation, Richland, WA (002)	In Situ Vitrification	James Hansen 509-375-0710	Teri Richardson 513-569-7949	Soil, Sludge	Nonspecific Inorganics	Nonspecific Organics
GRACE Dearborn, Inc., Mississauga, Ontario, Canada (008)	Daramend™ Bioremediation Technology	Alan Seech Igor Marvan 416-279-2222	Teri Richardson 513-569-7949	Soils, Sediments	Not Applicable	PAHs, PCP, Total Petroleum Hydrocarbons
High Voltage Environmental Applications, Inc.,*** Miami, FL (008)	High-Energy Electron Irradiation	William Cooper 305-593-5330	Franklin Alvarez 513-569-7631	Water Streams and Sludges	Not Applicable	Most Organics

*** From Emerging Technology Program

TABLE 2 (continued)
Ongoing SITE Demonstration Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Horsehead Resource Development Co., Inc.,* Monaca, PA (008)	Flame Reactor	Regis Zagrocki 412-773-2289	Marta Richards 513-569-7783	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
In-Situ Fixation Company, Chandler, AZ (005)	Deep In Situ Bioremediation Process	Richard Murray 602-821-0409	Edward Opatken 513-569-7855	Soil, Sludge	Not Applicable	Biodegradable Organics
International Environmental Technology, Perrysburg, OH (005)	Geolock and Bio-Drain Treatment Platform	Rebecca Sherman 419-856-2001 419-255-5100	Randy Parker 513-569-7271	Soil	Not Applicable	Biodegradable Organics
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, TCE, Benzene, Chloroform
North American Technologies Group, Inc., Sacramento, CA (008)	BioTreat™ System	Cathryn Wimberly 916-366-6165	Mary Stinson 908-321-6683	Sludges, Soil, and Mixed Media	Not Applicable	Gasoline, Jet Fuel, Diesel Fuel, Motor Oil, Crude Oil, PAHs, BTEX, Methyl Isobutyl Ketone, TCE, PCP, Creosotes
North American Technologies Group, Inc., Sacramento, CA (008)	Oleophilic Amine-Coated Ceramic Chip Hydrocarbon Recovery	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
Praxis Environmental Technologies, Inc., San Francisco, CA (008)	In Situ Steam Enhanced Extraction Process	Lloyd Stewart 415-641-9044	Paul dePercin 513-569-7797	Soils, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Purus, Inc., San Jose, CA (006)	Vapor Treatment Process	Paul Blystone 408-955-1000	Norma Lewis 513-569-7665	Groundwater, Soil	Not Applicable	Fuel Hydrocarbons, VOCs, SVOCs, Chlorinated Solvents
Remediation Technologies, Inc., Seattle, WA (002)	Liquid and Solids Biological Treatment	Merv Coover 206-624-9349	Ronald Lewis 513-569-7856	Soil, Sludge, Sediments	Not Applicable	Biodegradable Organics, Creosote, PCP, PAHs

* An addtional demonstration is planned for this technology. Refer to the profile in the demonstration program section (completed projects) for more information on this technology.

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Risk Reduction Engineering Laboratory, Cincinnati, OH (006)	Bioventing	Paul McCauley 513-569-7444	Kim Lisa Kreiton 513-569-7328	Soil	Not Applicable	Biodegradable Organics
Rochem Separation Systems, Inc., Torrance, CA (006)	Rochem Disc Tube Module System	David LaMonica 310-370-3160	Douglas Grosse 513-569-7844	Liquids	Nonspecific Inorganics	Organic Solvents
S.M.W. Seiko, Inc., Hayward, CA (004)	In Situ Solidification and Stabilization	David Yang 510-783-4105	Jack Hubbard 513-569-7507	Soil	Metals	SVOCs, PCBs, PAHs, Phenols, Pesticides
Separation and Recovery Systems, Inc., Irvine, CA (002)	SAREX Chemical Fixation Process	Brad Miller 714-261-8860	Jack Hubbard 513-569-7507	Sludge, Soil	Low-Level Metals	Nonspecific Organics
Sonotech, Inc., Atlanta, GA (007)	Frequency Tunable Pulse Combustion System	Zin Plavnik 404-525-8530	Marta Richards 513-569-7783	Soil, Medical Waste	Nonspecific Inorganics	Nonspecific Organics
TechTran Environmental, Inc., Houston, TX (005)	Combined Chemical Precipitation, Physical Separation, and Binding Process for Radionuclides and Heavy Metals	E.B. (Ted) Daniels 713-688-2390	Annette Gatchett 513-569-7697	Aqueous Solutions, Sludge, Soil	Heavy Metals, Radionuclides	Not Applicable
Terra-Kleen Corporation, Oklahoma City, OK (006)	Soil Restoration Unit	Alan Cash 405-728-0001	Mark Meckes 513-569-7348	Soil	Not Applicable	PCBs, PCP, Creosote, Chlorinated Solvents, Naphthalene, Diesel Oil, Used Motor Oil, Jet Fuel, Grease, Organic Pesticides
Texaco Syngas Inc., White Plains, NY (006)	Entrained-Bed Gasification	Richard Zang 914-253-4047	Marta Richards 513-569-7783	Soils, Sludges, Sediments	Nonspecific Inorganics	Nonspecific Organics
Udell Technologies, Inc., Berkeley, CA (005)	In Situ Steam Enhanced Extraction Process	Kent Udell 510-644-4474	Paul dePercin 513-569-7797	Soils, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Western Research Institute,*** Laramie, WY (005) (E01)	Contained Recovery of Oily Wastes (CROW™)	Lyle Johnson 307-721-2281	Eugene Harris 513-569-7862	Soil	Not Applicable	Coal Tar Derivatives, Petroleum By-products, PCP

*** From Emerging Technology Program

TABLE 2 (continued)

Ongoing SITE Demonstration Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Wheelabrator Technologies Inc., Hampton, NH (008)	WES-PHix Stabilization Process	Mark Lyons 603-929-3000	Esperanza Piano Renard 908-906-4355	Municipal Waste Combustion Ash, Soils, Sludges	Heavy Metals, Lead, Cadmium, Copper, Zinc	Not Applicable
Zenon Environmental Systems, Inc.,*** Burlington, Ontario, Canada (007)	Cross-Flow Pervaporation System	Philip Canning 905-639-6320	Ronald Turner 513-569-7775	Groundwater, Lagoons, Leachate, Rinse water	Not Applicable	Solvents, Degreasers, Gasoline
Zenon Environmental Systems, Inc., Burlington, Ontario, Canada (007)	ZenoGem™ Process	Tony Tonelli 416-639-6320	Daniel Sullivan 908-321-6677	Groundwater, Leachate	Not Applicable	Nonspecific Biodegradable Organics
Zimpro Passavant Environmental Systems, 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, INC.
(ICB Biotreatment System)

TECHNOLOGY DESCRIPTION:

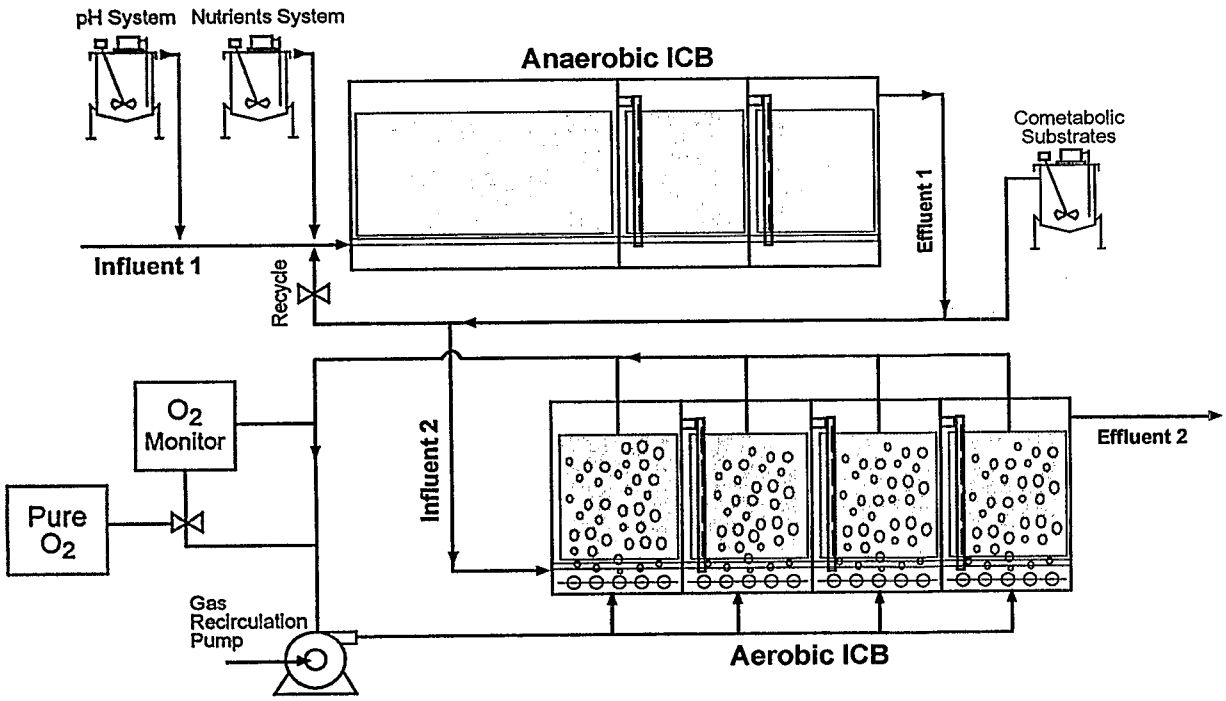
The immobilized cell bioreactor (ICB) biotreatment system is an aerobic, anaerobic, or combined aerobic/anaerobic fixed-film bioreactor system designed to remove organic contaminants (including nitrogen-containing compounds and chlorinated solvents) from process wastewater, contaminated groundwater, and other aqueous streams. The system offers improved treatment efficiency through the use of (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.

WASTE APPLICABILITY:

The ICB biotreatment system has been successfully applied to industrial wastewater and groundwater containing a wide range of organic contaminants, including polynuclear aromatic hydrocarbons (PAH), phenols, gasoline, chlorinated solvents, diesel fuel, and chlorobenzene.



Dual Anaerobic/Aerobic ICB Flow Diagram

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

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 also be used to retrofit existing bioreactors by adding the necessary internal equipment and proprietary media. The table below summarizes recent applications.

Applications	Contaminants	Scale
• Pipeline Terminal Wastewater	• COD, Benzene, 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 trichloroethene (TCE)-contaminated site in St. Joseph, Michigan.

This 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 sometime thereafter.

FOR FURTHER INFORMATION:

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26 West Martin Luther King Drive
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513-569-7856
Fax: 513-569-7620

TECHNOLOGY DEVELOPER CONTACT:
Steve Lupton
AlliedSignal Research & Technology
50 E. Algonquin Road
Des Plaines, IL 60017
708-391-3224
Fax: 708-391-3776

TECHNOLOGY VENDOR CONTACT:
C. Conrad Kempton
AlliedSignal Tar Products
101 Columbia Road
Morristown, NJ 07962
201-455-5531

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

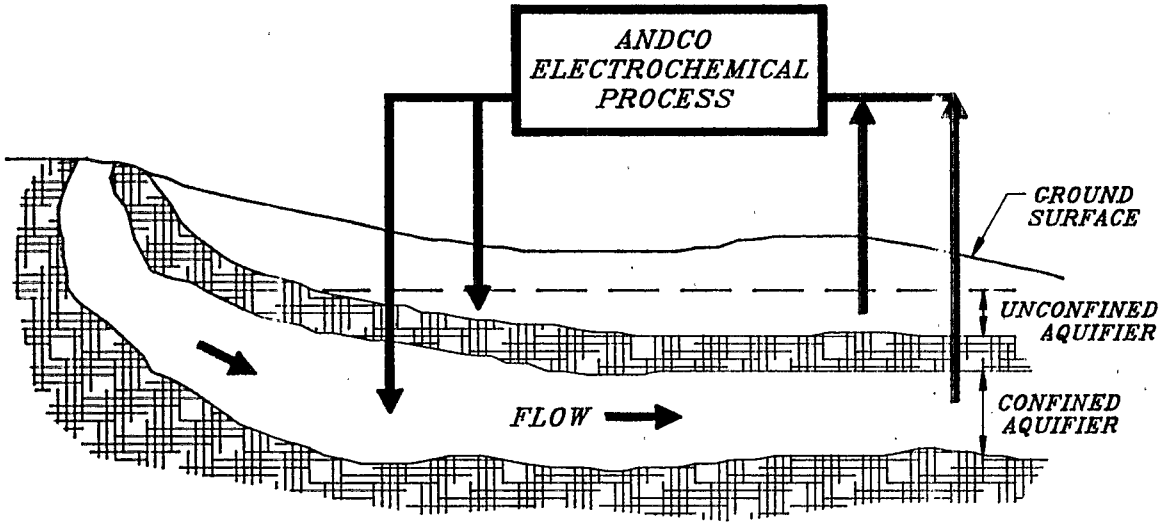
ANDCO ENVIRONMENTAL PROCESSES, INC.
(Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization)

TECHNOLOGY DESCRIPTION:

The Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization process uses electrochemical reactions to generate ions for removal of hexavalent chromium and other metals from groundwater. As contaminated water is pumped from an aquifer though the treatment cell (see figure below), electrical current passes from electrode to electrode though 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 reduction of hexavalent chromium almost instantaneously. Depending on the pH, various solids may form. They 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 concentration is determined based on the hexavalent chromium concentration in the groundwater, site-specific hydraulics, and the desired rate of site cleanup. Dilution is avoided by introducing ferrous ions in situ and using the aquifer's water to convey them. Following their injection, soluble ferrous ions circulate until they contact either 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 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, complete chromate reduction can be achieved without the need for sludge handling. As chromate reduction occurs, iron and chromium solids are filtered out and stabilized in the soil. When 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 system life and mini-



Electrochemical In Situ Chromate Reduction and Heavy Metal Immobilization Process

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

mizes 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 method is that hydrous iron oxide adsorbs heavy metals. When iron solids are immobilized in the soil, the concentrations of other contaminants in the groundwater decrease significantly because of adsorption and coprecipitation.

WASTE APPLICABILITY:

The pilot plant is designed to treat groundwater contaminated with hexavalent chromium in concentrations of 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 site-specific and designed to achieve all remediation objectives.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1992. Screening of candidate sites for the demonstration began in early 1993. The demonstration is scheduled for Spring 1994. Although the process can be used for remediation of 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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595 Commerce Drive
Amherst, NY 14228-2380
716-691-2100

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Amherst, NY 14228-2380
716-691-2100

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

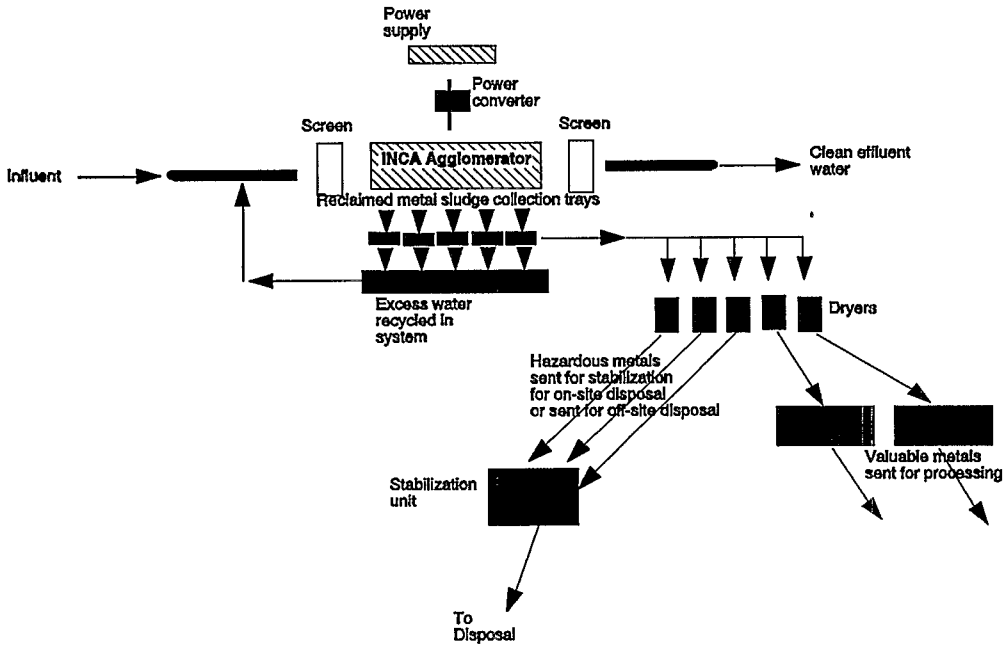
APROTEK
(Ion Conduction Agglomeration System)

TECHNOLOGY DESCRIPTION:

The high tension Ion Conduction Agglomeration (INCA) system is an electrolytic recovery process that selectively removes or recovers soluble and particulate metals from aqueous solutions such as mining effluents, process waters, waste waters and sludges. Each INCA module is individually configured to recover each desired element in a separate stream. This is particularly important when the waste stream contains a combination of valuable and hazardous materials such as is common in mining effluent. The standard flow-through system is a modular unit which 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, the INCA system cathodes are made of a specially designed substrate. Proprietary coatings specific to the metals to be collected are grafted on the tubular collection units. When power is applied, metallic ions in the solution relative to the types of coatings on the tubes are destabilized and agglomerate. 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 material, a 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 and, in fact, could turn the treatment system into a profit center.



INCA System

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

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. It 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 1993 using mine drainage from the Argo Tunnel and the National Tunnel in Colorado.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
Cathryn Wimberly
Aprotek
3316 Corbin Way
Sacramento, CA 95827
916-366-6165

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

ASI ENVIRONMENTAL TECHNOLOGIES, INC./ DAMES & MOORE
(Hydrolytic Terrestrial Dissipation)

TECHNOLOGY DESCRIPTION:

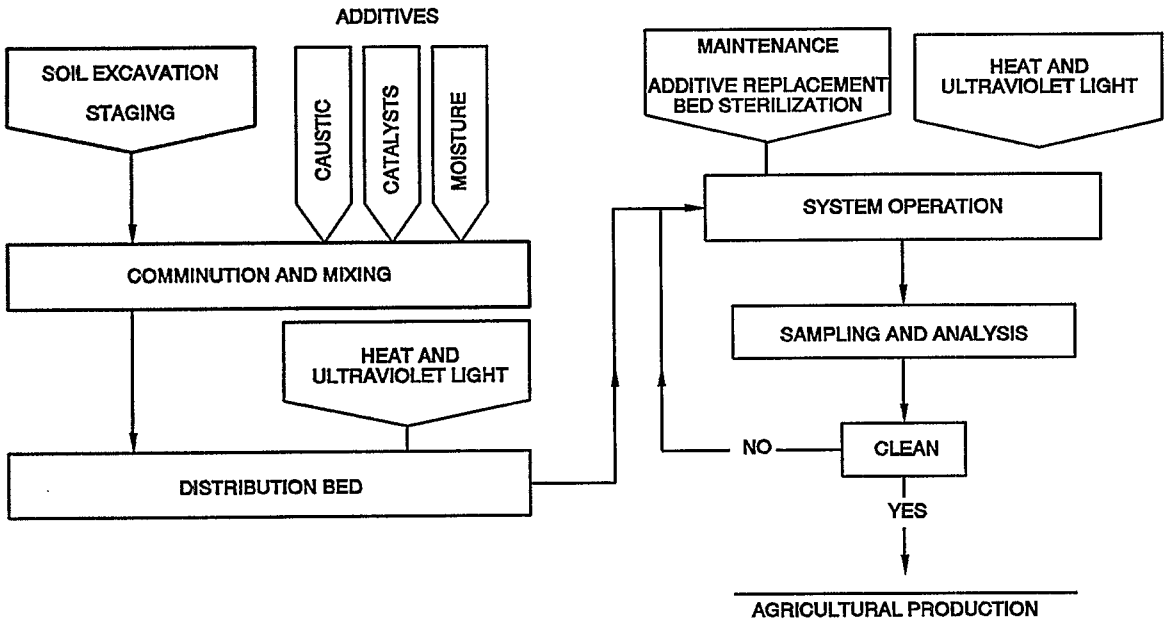
The Hydrolytic Terrestrial Dissipation (HTD) process was developed for use at the Chemairspray site in Palm Beach County, Florida. An estimated 11,500 cubic yards of surface soils at the site is contaminated with toxaphene (a chlorinated pesticide) and metal fungicides, primarily copper.

After excavation, the HTD process comminutes (mixes and cuts) 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. Sodium metabisulfite (a reducing agent) is added at intervals to catalyze the process.

The prepared mixture is then distributed in a thin veneer (4 to 7 centimeters) over a soil bed and exposed to heat and ultraviolet light from the sun to facilitate dissipation. Lighter weight toxaphene compounds are reported to be volatile. Under HTD conditions, the toxaphene's volatility increases as heavier compounds are dehalogenated to lower molecular weights. Ultraviolet light also dechlorinates toxaphene, so more volatile toxaphene moieties at the surface will slowly degrade to still lower molecular weights.

HTD uses the metal-catalyzed alkaline hydrolysis reactions, catalyzed by sodium metabisulfite, to liberate chlorine ions that form various metal salts, depending on the characteristics of the contaminated media. Dehalogenation reduces toxaphene to camphene ($C_{10}H_{16}$), which ultimately degrades to water and carbon oxides (CO_x). The figure below illustrates the process.

Soils in the distribution bed are periodically sampled to evaluate any residual contamination. Also, the quality of underlying groundwater is



Hydrolytic Terrestrial Dissipation

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

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 can treat large quantities of soil contaminated by small amounts of toxaphene or other pesticides. Depending on the pesticide, metal catalysts other than copper and iron may be effective. The process involves a hydrolysis reaction; however, flash points, vapor pressures, and other physical properties can enhance dissipation. Although it may have such application, this method was not developed for highly concentrated soil contaminants.

STATUS:

This technology 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 will validate laboratory results.

Soil moisture may play a major role in the release of toxaphene from its bound state and allow degradation to occur. Treatability studies were conducted with soil moisture of about 50 percent, soil pH at 8.5, air temperature at 102 to 105 °F, and a UV wavelength of 356 nanometers. These studies also showed that under simulated conditions, HTD methods reduce organochlorine pesticide concentrations in soils.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Allied Environmental
42 First Street NE
St. Petersburg, FL 33701
813-822-7477

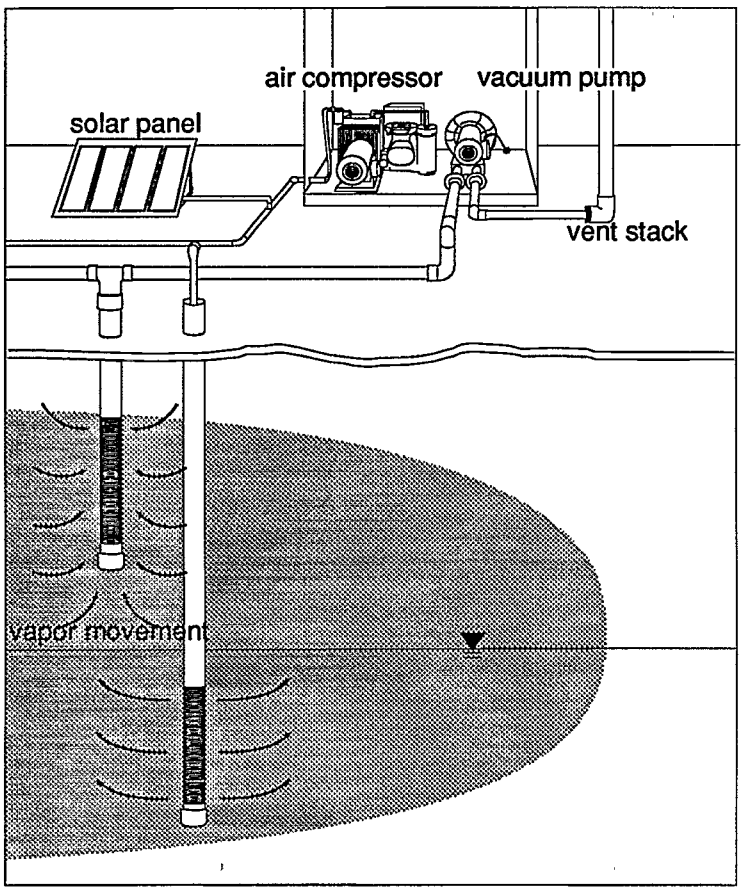
The SITE Program assesses but does not approve or endorse technologies.

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

TECHNOLOGY DESCRIPTION:

The SVVS® (Patent Number 5,221,159), developed by Billings and Associates, Inc. (BAI), and operated by Brown & Root Environmental, a division of Halliburton NUS Corporation under a licensing agreement, uses a network of injection and extraction wells (collectively, a reactor nest) to treat subsurface organic contamination via 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. The number and spacing of the wells depend upon the modeling results of applying a design parameter matrix, as well as the physical, chemical, and biological characteristics of the site. One or more vacuum pumps create negative pressure to extract contaminant vapors, while an air compressor simultaneously creates positive pressure across the 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, extraction wells are placed above the water table and injection wells are placed below the groundwater. 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



Subsurface Volatilization and Ventilation System (SVVS)

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

nest lines (radials) or, at some sites, on individual well points. Depending upon groundwater depths and fluctuation, horizontal vacuum screens, "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 be used to 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 be used to remove nitrate from groundwater. The aerobic SVVS® raises the redox potential of groundwater, to precipitate and remove heavy metals.

STATUS:

The SVVS® has been implemented at 75 UST sites in New Mexico, North Carolina, South Carolina, and Florida. 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 on July 20, 1992. The SVVS® will be used to remediate BTEX, tetrachloroethene (PCE), trichloroethene (TCE), and dichloroethene (DCE) at the site. The demonstration began in March 1993 and will require 12 months to complete. Intermediate results may be available throughout the project.

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

BIO-RECOVERY SYSTEMS, INC.
(Biological Sorption)

TECHNOLOGY DESCRIPTION:

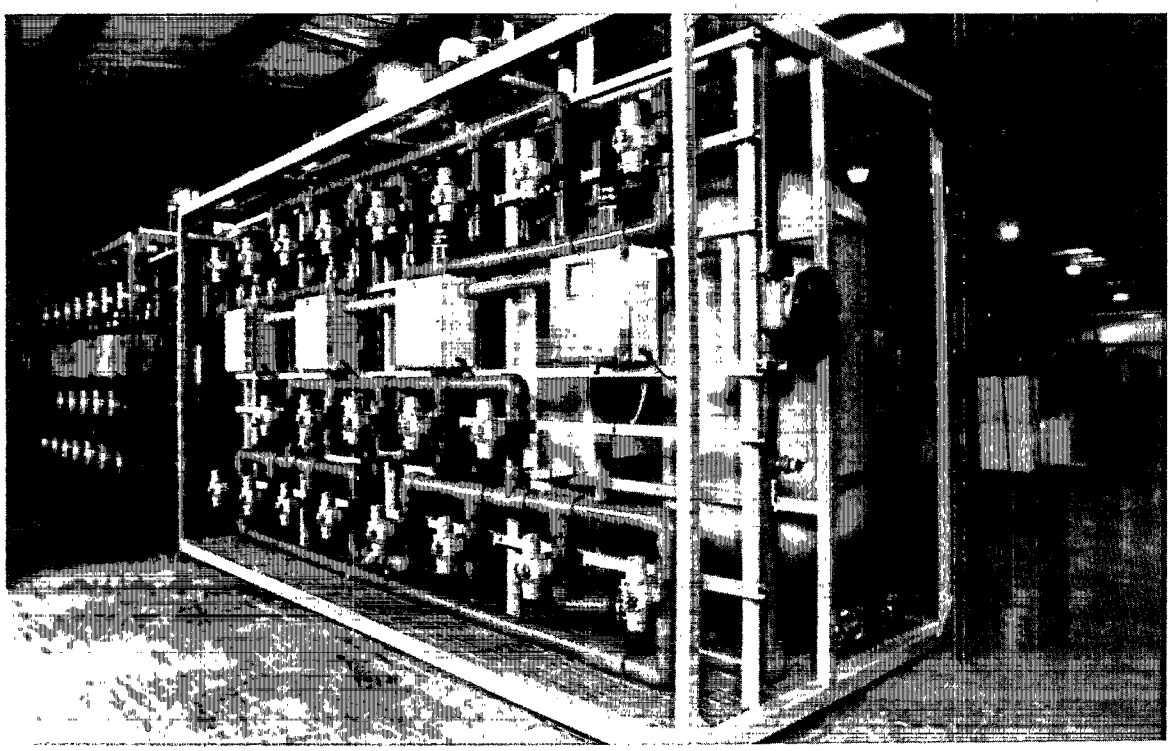
The AlgaSORB® sorption process is designed to remove heavy metal ions from aqueous solutions. The process is based on the natural affinity of algae cell walls for heavy metal ions. In many applications, AlgaSORB® is highly selective in capturing the metal of interest without being saturated by large concentrations of salts. AlgaSORB® seems particularly effective in removing mercury and uranium from groundwater.

The sorption medium comprises 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 (large, complex, oxygen-containing ions with a negative charge, 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, the components of hard water (calcium, Ca^{+2}, and magnesium, Mg^{+2}) or monovalent cations (sodium, Na^{+}, and potassium, K^{+}) do not significantly interfere with the binding of toxic heavy metal ions to the algae-silica matrix.

After the media are saturated, the metals are stripped from the algae using acids, bases, or other suitable reagents. This produces a small



Ion Exchange System

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

volume of very concentrated metal-containing solutions that must be further treated.

The photograph on the previous page shows a 100-gallon-per-minute (gpm) ion-exchange system designed to operate with either AlgaSORB® or conventional chemical resins. Smaller and larger systems have been designed and manufactured.

WASTE APPLICABILITY:

This technology is useful for removing metal ions from groundwater or surface leachates that are "hard" or contain high levels of dissolved solids. Rinse waters from electroplating, metal finishing, and printed circuit board manufacturing industries can also be treated. Variations of the technology, some using other adsorbents, may be used to recover spent acid from metal pickling lines and maintain the purity of chemical baths that use heavy metals.

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. The final report (EPA/540/5-90/005a) is available. Based on the test results, Bio-Recovery Systems, Inc. was invited to participate in the Demonstration Program.

Further work, supported by the U.S. Department of Energy (DOE) and Argonne National Laboratory, was conducted on groundwater containing mercury and uranium from the Oak Ridge, Savannah River, and Hanford DOE sites. The final report, "Remediation of Groundwater containing Radionuclides, Heavy Metals, Inorganic Ions, and/or Organics using the AlgaSORB® Biosorbent System" has been submitted to Argonne National Laboratory.

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.

CLEAN BERKSHIRES INC.
(Mobile Thermal Desorption System)

TECHNOLOGY DESCRIPTION:

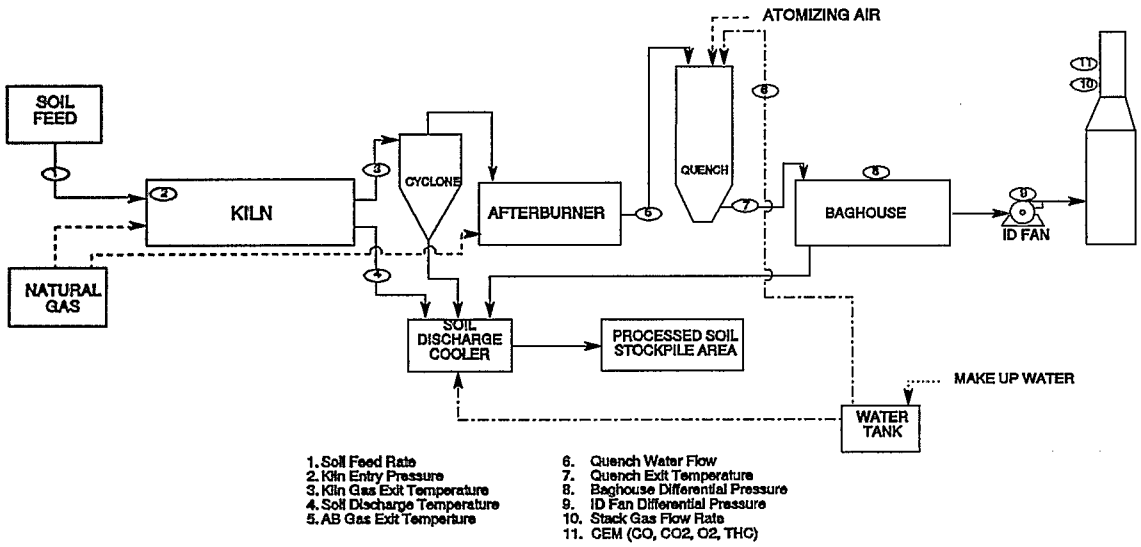
Clean Berkshires Inc.'s Mobile Thermal Desorption System (TDS) uses rotary kiln technology to remove contaminants from soils. The TDS can be used to remediate soils contaminated with volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and polynuclear aromatic hydrocarbons (PAH). It 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 conisistency soil, including sands, silts, clay 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

The thermal treatment process involves two steps: volatilization of contaminants followed by gas treatment. During the volatilization step, contaminated materials are exposed to temperatures ranging from 600 °F to 1,000 °F in a co-current flow rotary kiln drum desorber, causing contaminants to volatilize to the gas phase. Clean soils are then discharged through a multistage dust suppression system for re-moisturization and stacked for testing.

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 °F to 2,000



Mobile Thermal Desorption System

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

°F. The gas stream is then cooled by quenching before passing through a high-efficiency baghouse where fine particles are removed. The gas is then released to the atmosphere through a 60-foot stack.

Soil pretreatment consists of shredding, crushing, and screening to achieve a uniform particle size of less than 0.75 inch. Feed soils are also processed to achieve uniform moisture content and heating value. Processed soil, after discharge from the dust suppression system, is stockpiled and allowed to cool prior to sampling.

The TDS offers the following advantages:

- The kiln and afterburner are separate chambers; thus the system temperature can be optimized to volatilize contaminants while ensuring destruction in the afterburner.
- The entire system operates under negative pressure, preventing fugitive emissions.
- The baghouse is located downstream of the afterburner. This prevents airborne contaminants from recondensing onto dust particles, because contaminants are destroyed in the afterburner before gas temperatures are reduced.
- Co-current flow within the kiln assures decontamination of dust particles.

WASTE APPLICABILITY:

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

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. The demonstration will be conducted at the Niagara Mohawk Power Corporation's Harbor Point site in Utica, New York.

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

COLORADO DEPARTMENT OF HEALTH
(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 (see figure below) to accumulate and remove metals from influent waters. The treatment system incorporates principal ecosystem components found in wetlands, including organic soils, microbial fauna, algae, and vascular plants.

Influent waters, with high metal concentrations and low pH, flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by filtration, ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. In filtration, metal flocculates and metals that are adsorbed onto fine sediment particles settle in quiescent ponds, or are filtered out as the water percolates through the soil or the plant canopy. 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, play a major role in removing metals as hydroxides and sulfides.

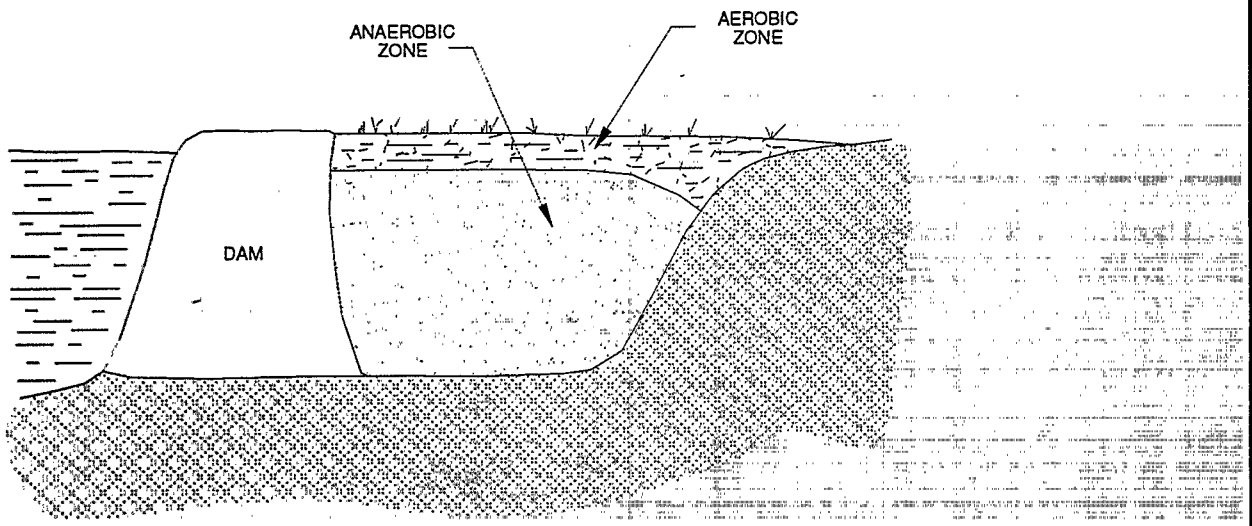
WASTE APPLICABILITY:

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 are acidic. 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 results from the SITE Emerging Technology Program, this process has been selected for the SITE Demonstration Program.

The project's final year under the Emerging Technology Program was 1991. Results of a



Typical Wetland Ecosystem

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

study of drainage from the Big Five Tunnel near Idaho Springs, Colorado showed that removal efficiency of heavy metals can approach the removal efficiency of chemical precipitation treatment plants.

One final goal of the Emerging Technology Program project was the development of 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 will be available from NTIS in 1993. A copy of an earlier version of the manual can be purchased from BiTech Publishing (604-277-4250).

The Demonstration Program will evaluate the effectiveness of a full-scale wetland. The proposed demonstration site is the Burleigh Tunnel near Silver Plume, Colorado. The Burleigh Tunnel is part of the Clear Creek/Central City Superfund site in Colorado. Construction of the demonstration wetland system is scheduled for September or October 1993. Evaluation will require 1 to 2 years.

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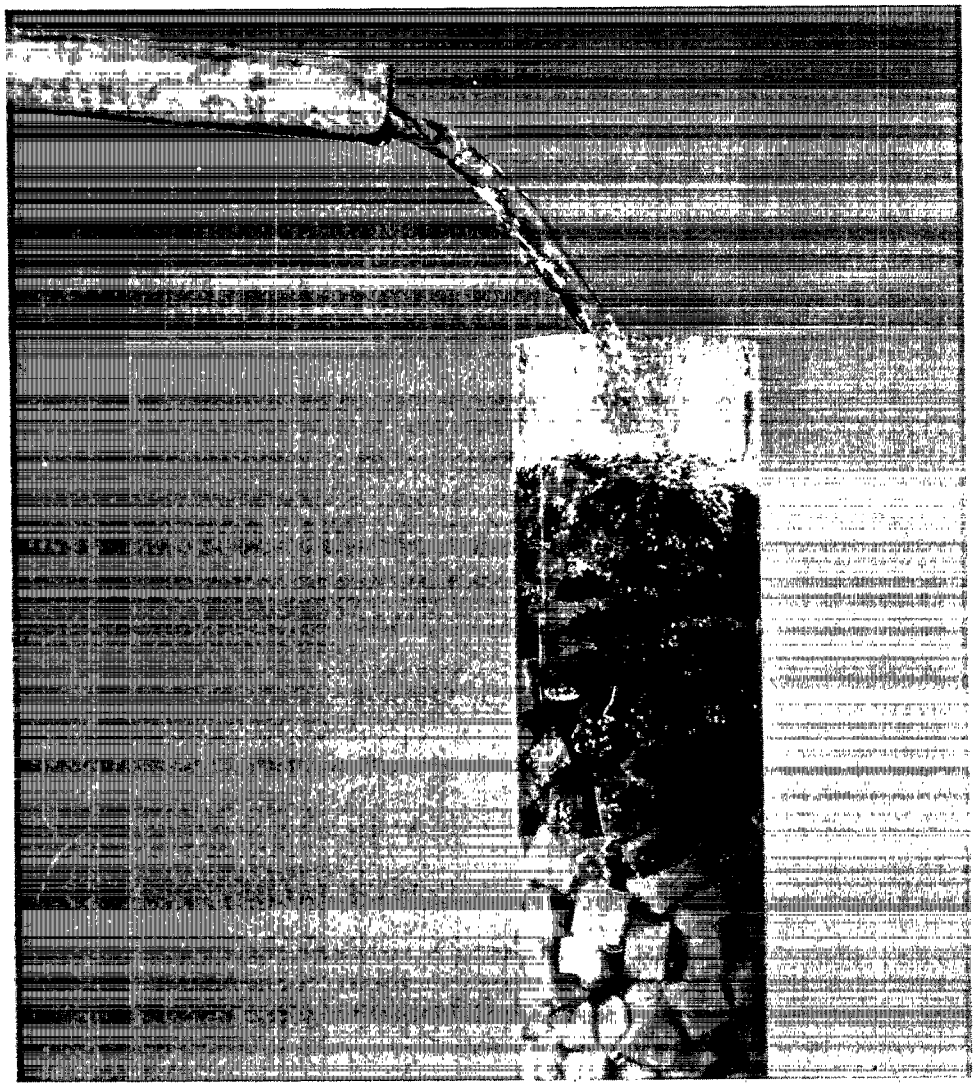
The SITE Program assesses but does not approve or endorse technologies.

DYNAPHORE, INC.
(FORAGER® Sponge)

TECHNOLOGY DESCRIPTION:

The FORAGER® sponge is an open-celled cellulose sponge incorporating an amine-containing polymer that has a selective affinity for aqueous heavy metals in both cationic and anionic states. The polymer prefers 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:

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



FORAGER® Sponge

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

The removal efficiency for transition-group heavy metals is about 90 percent at a flow rate of one bed volume per minute. The highly porous nature of the sponge speeds diffusional effects, thereby promoting high rates of ion absorption. The sponge can be used in columns, fishnet-type enclosures, or rotating drums. When using column operations, 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.

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, it may be preferable to compact the sponge by drying it to an extremely small volume to facilitate disposal.

The photograph on the previous page depicts water being treated in an unattended column using the FORAGER® sponge.

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.

When remediating groundwater, elongated nets that confine the sponge are placed in wells and removed when saturated. Alternatively, the groundwater can be treated in a packed column configuration.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. The sponge has been found effective in removing trace heavy metals from acid mine drainage water at three locations in Colorado.

In bench-scale tests, mercury, lead, nickel, cadmium, and chromium in groundwater have been reduced to below detectable levels at Superfund locations.

In a field-scale installation at a photoprocessing operation that generates an aqueous effluent containing 6 pounds of chromate and 0.8 pound of silver per day, 75 percent reductions were achieved at a cost of $1,100 per month.

The FORAGER® sponge will be demonstrated in October 1993 at the National Lead Industry site in Pedricktown, NJ. Treatability tests have shown over 90 percent removal of cadmium, lead, copper, and vanadium at flow rates of 2 to 3 gallons per minute.

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

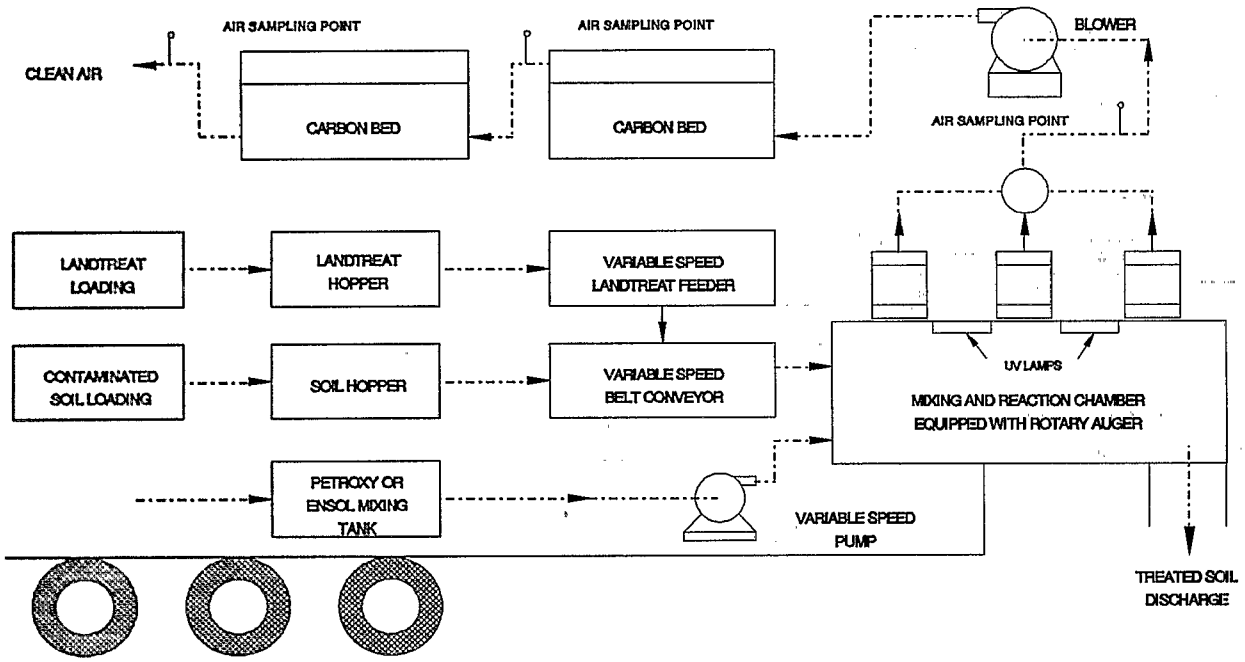
ENSOTECH, INC.
(Mobile Environmental Treatment System)

TECHNOLOGY DESCRIPTION:

The Mobile Environmental Treatment System (METS) is a multipurpose transportable treatment unit that can continuously treat soils contaminated with organics, heavy metals, and mixed wastes. The METS trailer-mounted unit can process up to 35 tons of soil per hour (see figure below). It is fitted with an ultraviolet radiation source and a vacuum suction system that uses granular activated carbon (GAC).

The technology uses a patented polysilicate powder, LANDTREAT, as well as PETROXY, a stabilized hydrogen peroxide product of Ensotech, Inc. (Ensotech). The large surface area provided by LANDTREAT, which is added to soil before it enters the reaction chamber, adsorbs PETROXY and assists in destroying hydrocarbon contaminants. Carbon dioxide and water are treatment by-products. The system is designed to ensure maximum dispersion of the additives though the soil matrix. PETROXY is sprayed directly onto the soil to ensure complete mixing. The vapors are continuously removed while oxidation is in progress; the vapors are then passed though the GAC drums. The process is completed in a few minutes.

For heavy metals treatment, the treatment process involves chemical fixation. The PETROXY solution is replaced by ENSOL, a chemical fixing agent that combines with heavy metals to form a highly unleachable residue in soil. The reaction is rapid and is essentially irreversible because of the low solubility and high stability of the metal hydroxide silicate complex. This complex is further solidified to produce a non-leachable final product by the addition of LANDTREAT. This additive retains the surplus chelating agent to prevent metals from leaching from the treated soil. The process does not change the physical properties of the soil. This process is designed to meet the criteria for the



Mobile Environmental Treatment System (METS)

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

soluble threshold limit concentrations (STLC) of the target metals. However, if the surface area must be decreased, solidification/stabilization agents such as portland cement, fly ash, and limestone may be added.

For mixed wastes, treatment can be carried out in two phases: chemical oxidation followed by chemical fixation.

WASTE APPLICABILITY:

METS can treat soil contaminated with hydrocarbons, chlorinated organics, heavy metals, and mixed wastes.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. A site for the demonstration has not yet been determined. Ensotech has conducted treatability studies on samples from several potential sites that have both chlorinated organic compounds and metals. Additional sites are being investigated for this demonstration.

Over 300 sites have been remediated using this technology, including gasoline stations; oil refineries; abandoned hazardous waste dumps; chemical manufacturing plants; plating shops; lead acid battery plants; and radiator/transformer, circuit board, and hardware manufacturing facilities. Ensotech products have been successfully used to decontaminate lagoons, ponds, wastewater, and groundwater.

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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., removes aqueous-phase halogenated organic compounds from groundwater by using an in situ permeable wall installed across a contaminated plume. As the water passes through the wall, the halogenated organics are degraded, thus preventing further downstream migration of contaminants.

Recent research has indicated that certain zero-valence metals, notably iron, can promote degradation of a wide variety of dissolved halogenated solvents. The permeable reaction wall contains a specially prepared mixture of iron and an inert support material. Observed rates of degradation are several times higher than those reported for natural abiotic degradation processes.

In most in situ applications of the technology, groundwater moves through the permeable wall naturally or is directed through the wall by flanking impermeable sections such as sheet piles or slurry walls. This passive method of remediation is a cost-effective alternative to conventional pump-and-treat method. Because contaminants are degraded in situ and not transferred to another medium, this process eliminates the need for treatment or disposal of wastes. Future applications are expected to include aboveground reactor vessels, which may be used as a replacement for, or an addition to, conventional pump-and-treat systems.

Process residuals may include dissolved methane, ethane, ethene, hydrogen gas, and small amounts of chloride and dissolved ferrous iron.

WASTE APPLICABILITY:

The process was developed to treat dissolved halogenated organic compounds in groundwater. It has been shown to degrade a wide variety of chlorinated alkanes and alkenes, including vinyl chloride, 1,1,1,-trichloroethane, 1,2-dichloroethene, trichloroethene (TCE), and tetrachloroethene (PCE). Current studies indicate that other

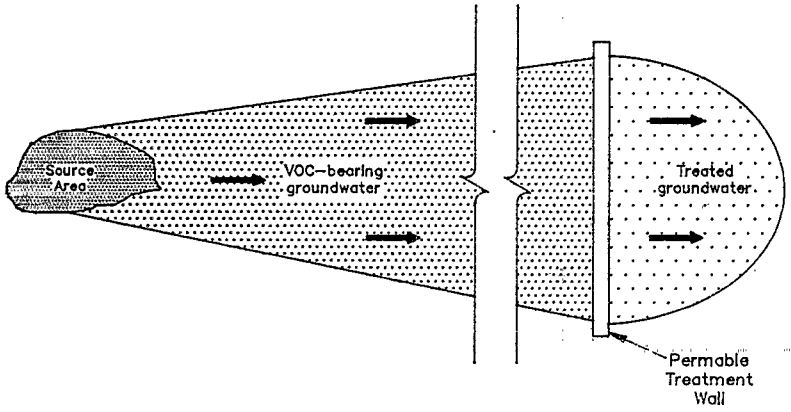

Figure 1: Schematic View of an In Situ Permeable Treatment Wall

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

organic contaminants, including Freon-113, ethylene dibromide, and n-nitrosodimethylamine are also degraded by the process.

STATUS:

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. Monitoring of a second wall installed in late 1992 is ongoing. Successful bench-scale feasibility tests that simulate flowing in situ conditions have been completed using groundwater from industrial facilities in California, Wisconsin, and New Jersey.

This technology was accepted into the SITE Demonstration Program in spring 1993. A pilot-scale demonstration of the technology is scheduled for fall 1993 at an industrial facility in New Jersey once construction issues are resolved. The overburden and shallow fractured bedrock beneath the facility contain dissolved TCE and PCE. The flow system prevents the installation of a "standard" in situ reactive wall; consequently, groundwater collected via trenches installed in the shallow bedrock will be passed through a treatment unit containing a high percentage of iron at a velocity of 5 feet per day. Groundwater discharge or disposal will be approved by New Jersey Department of Environmental Protection and Energy.

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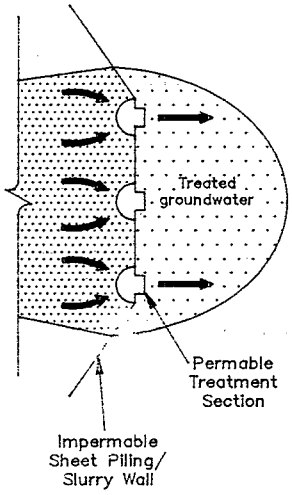


Figure 2: Schematic View of In Situ Permeable Treatment Section Installed in Conjunction with an Impermeable Barrier

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

GEOCHEM, A Division of Terra Vac
(In Situ Remediation of Chromium in Groundwater)

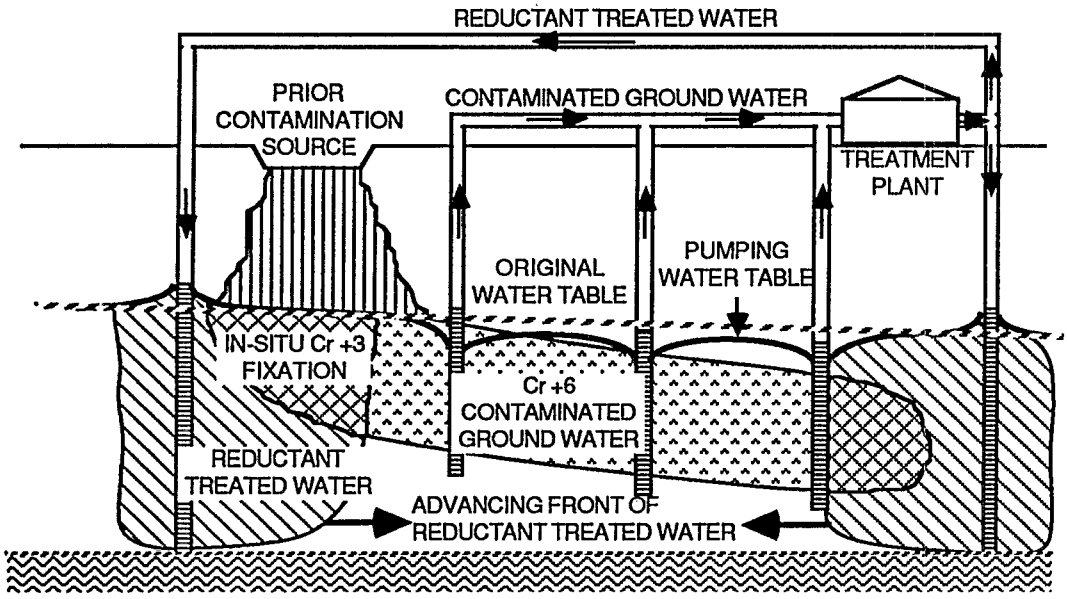
TECHNOLOGY DESCRIPTION:

The GEOCHEM treatment process removes chromium from contaminated groundwater using a variation on traditional pump-and-treat methods. As part of GEOCHEM's approach, contaminated groundwater is brought to the surface and treated using conventional treatment systems (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 achieves better hydrodynamic control by building a "barrier" of elevated water levels around the plume, thereby 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 as a result of the natural crustal abundance of chromium. The precipitation of residual chromium from the water does not materially add to the concentration of chromium in the aquifer solids, because most contaminated zones contain only a few milligrams per liter (mg/L) of chromium; the precipitation of such material onto the aquifer solids does not change the overall aquifer concentration. 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 is the more effective method.

WASTE APPLICABILITY:

The GEOCHEM process is capable of treating dissolved hexavalent chromium in groundwater at concentrations ranging from the detection limit to several hundred mg/L. The technique 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 demonstration of GEOCHEM's technology. The technology will be demonstrated at the Valley Wood Treating site in Turlock, California.

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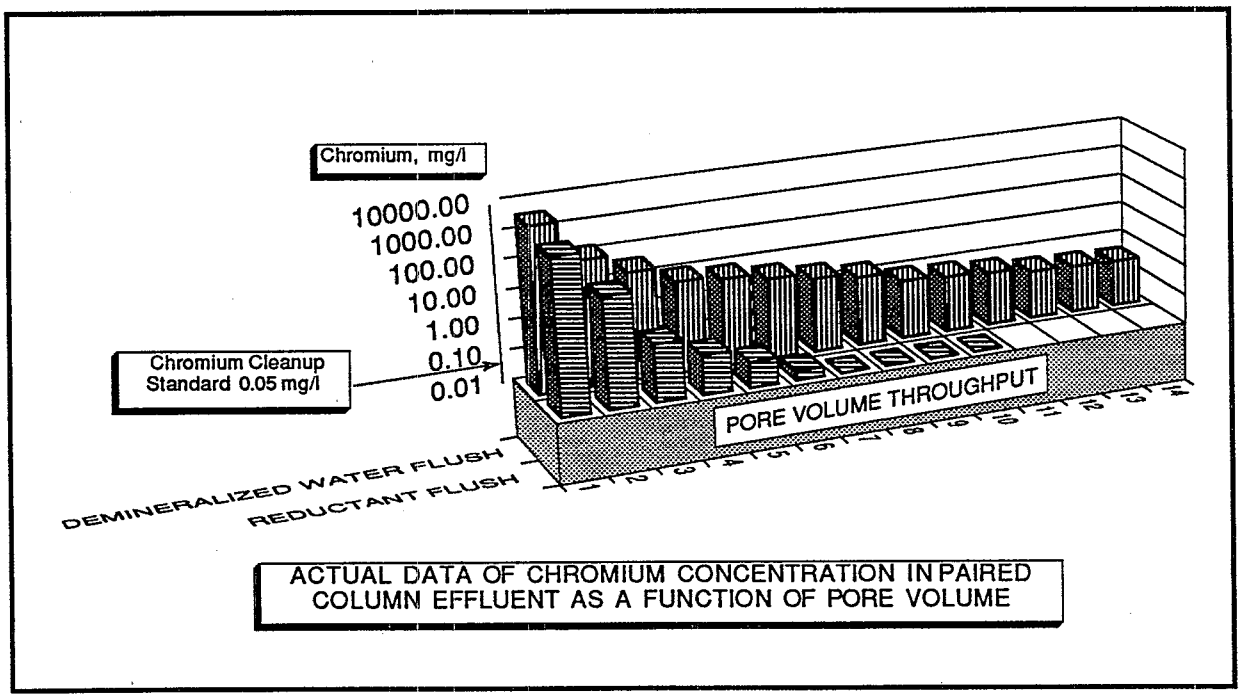


Chromium Reduction as a Function of Water Flush Method and Pore Volume Throughput

GEOSAFE CORPORATION
(In Situ Vitrification)

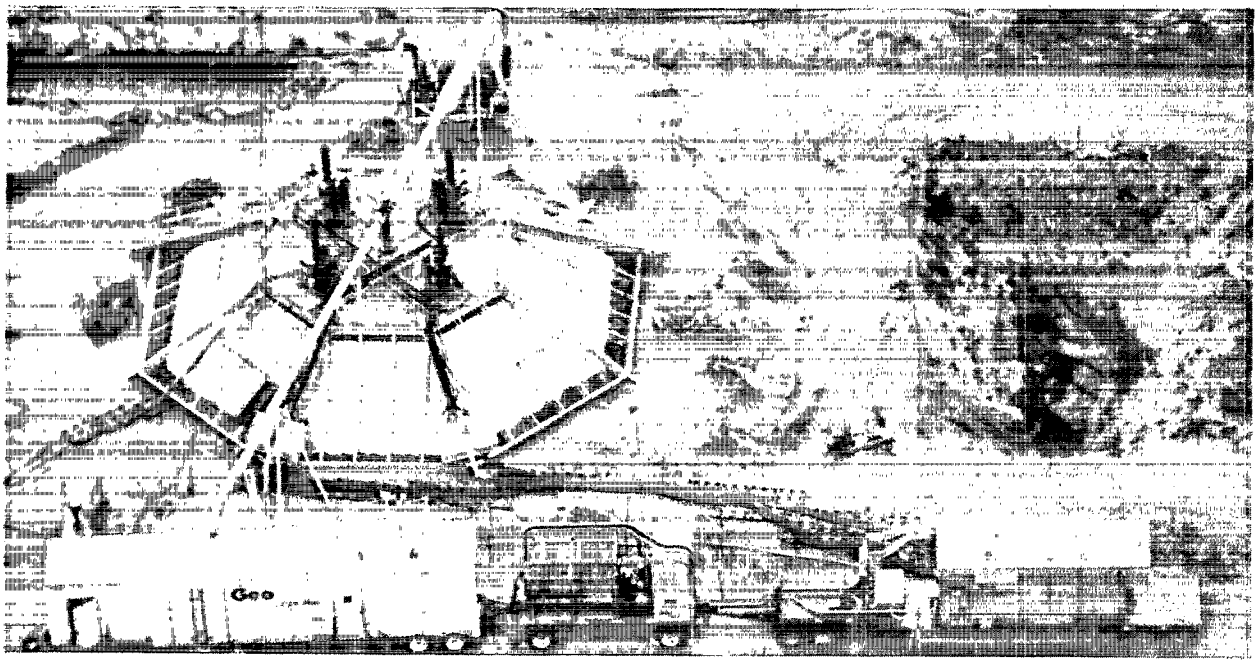
TECHNOLOGY DESCRIPTION:

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

The vitrification process begins by inserting an array (usually square) of four large electrodes slightly 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 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 a 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 results, 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 (1) quenching, (2) pH-controlled scrubbing, (3) dewatering (mist elimination), (4) heating (for dew point control), (5) particulate filtration, and (6) activated carbon adsorption.

Individual melt settings (each single placement of electrodes) may encompass a total melt mass of up to 1,000 tons and a maximum width of 40 feet. Single-setting depths as great as 25 feet



In Situ Vitrification Process

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

below ground surface are considered possible. Large-scale ISV equipment has achieved depths exceeding 22 feet below ground surface. Adjacent settings can be positioned to fuse to each other, completely processing the desired volume at a site. Special settings to reach deep contamination are also possible. The void volume in particulate materials (20 to 40 percent for typical soils) and volatile materials are removed during processing, greatly reducing the waste volume.

The mobile ISV system is mounted on three semitrailers. 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 soil processed. 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, 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, and on most priority pollutant metals and radionuclides. In most saturated 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 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 weight percent, depending on the heating value. Processing of contamination below the water table may require some means to limit recharge.

STATUS:

The ISV process has been operated for test and demonstration purposes at the pilot scale 22 times, and at large scale 10 times at the following sites: (1) Geosafe Corporation's test site, (2) the U.S. Department of Energy's (DOE) Hanford Nuclear Reservation, (3) DOE's Oak Ridge National Laboratory, and (4) DOE's Idaho National Engineering Laboratory. More than 170 tests at various scales have been performed on a broad range of waste types in soils and sludges. The SITE demonstration will take place at the Parsons/ETM site in Grand Ledge, Michigan, where the process is currently operating. The process is scheduled for use at EPA Superfund, private, U.S. Department of Defense (DOD), and other DOE sites.

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TECHNOLOGY DEVELOPER CONTACT:
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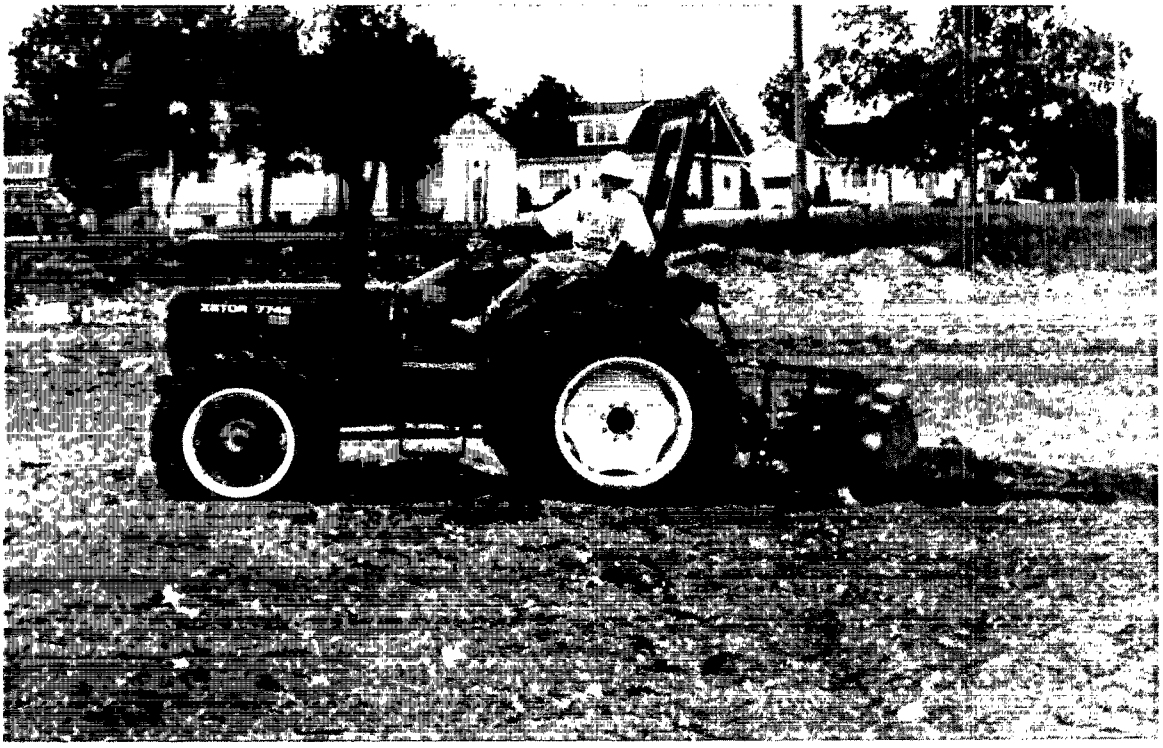
The SITE Program assesses but does not approve or endorse technologies.

GRACE DEARBORN, INC.
(Daramend™ Bioremediation Technology)

TECHNOLOGY DESCRIPTION:

GRACE Dearborn, Inc.'s organic amendment-enhanced bioremediation technology (Daramend™) is designed to degrade chlorinated phenols, including pentachlorophenol (PCP), creosotes, and petroleum hydrocarbons in industrial soils and sediments. The method is based upon addition of solid-phase organic soil amendments of specific particle size distribution and nutrient content. Soil amendments increase the ability of the soil matrix to supply water and nutrients to the microorganisms that degrade the hazardous compounds. Also, the amendments can transiently bind contaminants, thereby reducing the acute toxicity of the soil aqueous phase. This allows microorganisms to survive in soils containing very high concentrations of toxic compounds.

The technology can remediate soils both in situ and ex situ. In situ treatment involves breaking up soils with excavation equipment to reduce compaction and aid in the removal of debris, such as rocks or metal from the treatment zone. The soil is then tilled with a rotary tiller to reduce the variation in soil properties and contaminant concentrations. Tilling also incorporates the required soil amendments and aids in the delivery of oxygen to contaminant-degrading microorganisms. Ex situ treatment involves excavation and screening of contaminated soils.



Daramend™ Bioremediation Technology

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

A contained treatment area covered by a waterproof temporary structure is prepared. Screened soil is then deposited to a depth of approximately 2 feet and homogenized with a rotary tiller. The full-scale demonstration is expected to take 12 months.

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

WASTE APPLICABILITY:

The Daramend™ technology is applicable to a wide range of organic contaminants in soils or sediments. The technology has been proven effective on soils with total polynuclear aromatic hydrocarbon (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 and chlorophenols have been reduced to Canadian Council of Minister of the Environment guideline levels. Bench- and pilot-scale investigations indicate that the technology is also applicable to PAH-contaminated sediment. The technology's ability to treat chlorinated pesticide contamination is being evaluated.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1993. The Domtar Wood Preserving facility in Trenton, Ontario has been selected as the demonstration site.

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

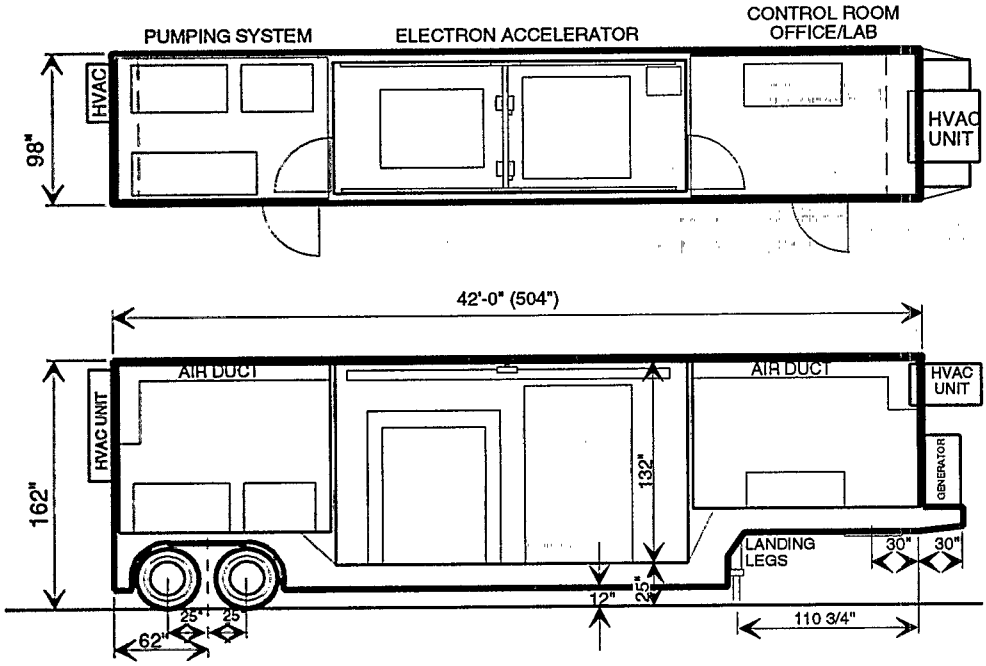
HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.
(formerly ELECTRON BEAM RESEARCH FACILITY, FLORIDA INTERNATIONAL UNIVERSITY AND UNIVERSITY OF MIAMI)
(High-Energy Electron Irradiation)

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 ($H\cdot$), and the hydroxyl radical ($OH\cdot$). These short-lived intermediates react with organic contaminants, transforming them to nontoxic by-products. The principal reaction that e^-_{aq} undergoes is electron transfer to halogen-containing compounds, which breaks the halogen-carbon bond and liberates the halogen anion [for example, 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 are formed at very low concentrations in some cases. These compounds are biodegradable end products.

In the electron beam treatment process, electricity is used to generate 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 as it falls through the beam. All reactions are complete in less than 0.1 seconds.

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. The facility is equipped to handle tank trucks carrying up to 6,000 gallons of waste. High Voltage Environmental Applications, Inc. has 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 process (see figure).

WASTE APPLICABILITY:

This system has been found to effectively treat a large number of common organic chemicals. These include (1) trihalomethanes (such as chloroform), which are found in chlorinated drinking water; (2) chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromochloropropane, hexachlorobutadiene, and hexachloroethane; (3) aromatics found in gasoline, including benzene, toluene, ethylbenzene, and xylene; (4) chlorobenzene and dichlorobenzenes; (5) phenol; (6) dieldrin, a persistent pesticide; (7) polychlorinated biphenyls; and (8) a variety of other organic compounds.

The technology is considered appropriate for removing various hazardous organic compounds from aqueous waste streams and sludges with up to 8 percent solids.

STATUS:

This technology 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. The reaction by-products have been determined for all six compounds. It appears, for the most part, that these compounds are converted. Trace quantities (several micrograms per liter) of formaldehyde and other low molecular weight aldehydes have been detected. Formic acid has also been detected at low concentrations; however, these compounds are not toxic at these concentrations. Papers are being prepared summarizing the results of these studies.

Additional studies are underway to determine destruction efficiencies and to characterize reaction by-products of carbon tetrachloride and methylene chloride.

The process will be demonstrated at the U.S. Department of Energy (DOE) Savannah River site in early 1994.

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

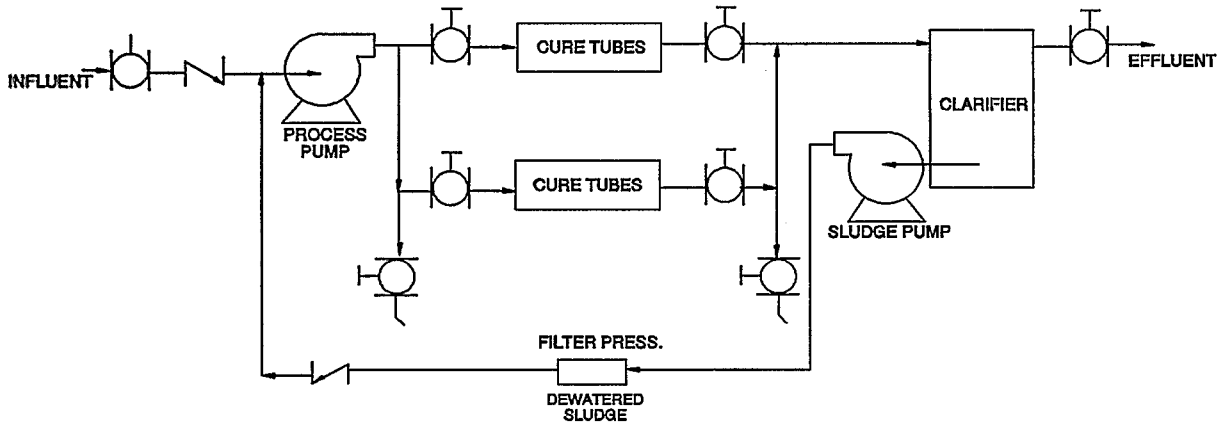
HYDROLOGICS, INC.
(CURE-Electrocoagulation Wastewater Treatment System)

TECHNOLOGY DESCRIPTION:

The CURE-Electrocoagulation (CURE) system is designed to remove ionic metal species and other charged particles in water. Because many toxic metal ions such as nickel, lead, chromates, and other metals are held in solution by electrical charges, they can be induced to precipitate out of solution if they are neutralized with oppositely charged ions. The process is very effective at breaking oil emulsions and removing suspended solids. This technology is an improvement over previous electrocoagulation methods due to a unique geometrical configuration.

The patented geometry of the CURE system 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, causing a direct current to pass uniformly through the 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 using 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 a very stable acid-resistant sludge. Tests have shown that sludges produced



Schematic Diagram of the CURE-Electrocoagulation System

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

by the CURE system pass the toxicity characteristic leaching procedure and can often be disposed of as nonhazardous waste.

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 be used to 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. Potential demonstration sites are being evaluated.

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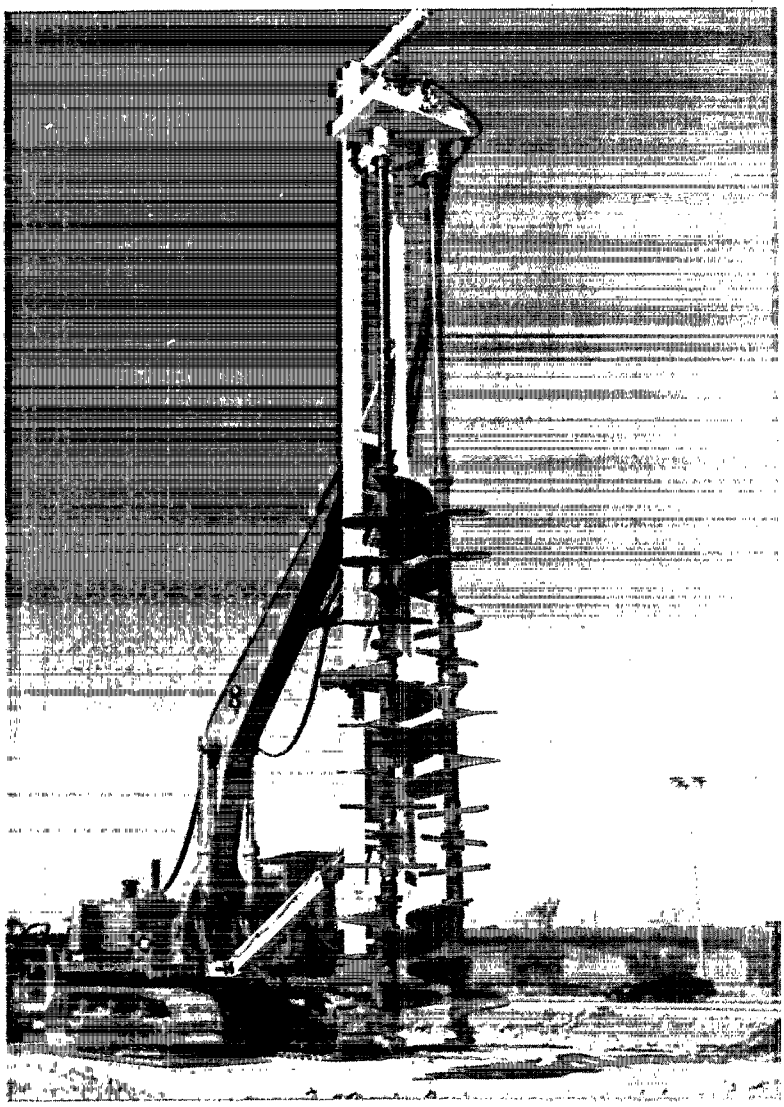
The SITE Program assesses but does not approve or endorse technologies.

IN-SITU FIXATION COMPANY
(Deep In Situ Bioremediation Process)

TECHNOLOGY DESCRIPTION:

This process increases the efficiency and rate of biodegradation in deep contaminated soils. The system injects site-specific microorganism mixture(s) and the required nutrients into contaminated soil. The microorganism mixture(s), nutrients, and soils are homogeneously mixed without requiring any excavation. The mixing process breaks down soil strata barriers and improves oxygen mass transfer through contaminated tight soil.

The process uses a twin, 5-foot-diameter, dual auger system (see photograph) powered and moved by a standard backhoe. The hollow shaft



Dual Auger System

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

auger drills into contaminated soil, allowing the microorganism and nutrient mixture(s) to be continually injected through a controlled nozzle system. Oxygen, water, nutrients, and natural bacteria, if necessary, are added to the contaminated area. A site-specific laboratory test program determines what needs to be injected into the soil to remediate it.

The distribution of the microorganisms and nutrients occurs during the initial auger action. The auger flights break the soil loose, allowing mixing blades to thoroughly blend the microorganism and nutrient mixture with the soil. Drilling occurs in an overlapping manner to ensure complete treatment of all contaminated soil. The mixing action is continued as the augers are withdrawn. Treatment depth is limited to 50 feet.

The development of site-specific microorganisms is an integral part of the process. Laboratory bench-scale tests are performed on contaminated soil to determine the water, nutrients, and, if necessary, bacteria required for successful biodegradation. Although some contaminants may volatilize during remediation, volatilization can be minimized by adding a hood around the auger assembly and treating the captured vapors in a filter system.

The dual auger system was also developed for the treatment of inorganic contaminated soils by injecting reagent slurry into the soil to solidify and stabilize contaminated waste.

Many sites require that an impermeable barrier or containment wall be constructed to prevent the continued migration of pollutants through soil and water. This wall allows for greater protection of the groundwater and surrounding area.

WASTE APPLICABILITY:

The deep in situ bioremediation process may be applied to all organic-contaminated soils. Varying degrees of success may occur with different contaminants. High concentrations of heavy metals or nonbiodegradable toxic organics, and alkaline or acidic conditions could interfere with the degradation process.

No residuals or wastes are generated in this process because all treatment is performed beneath the ground surface.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1990. The demonstration is on hold until a support mechanism can be established.

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

INTERNATIONAL ENVIRONMENTAL TECHNOLOGY
(Geolock and Bio-Drain Treatment Platform)

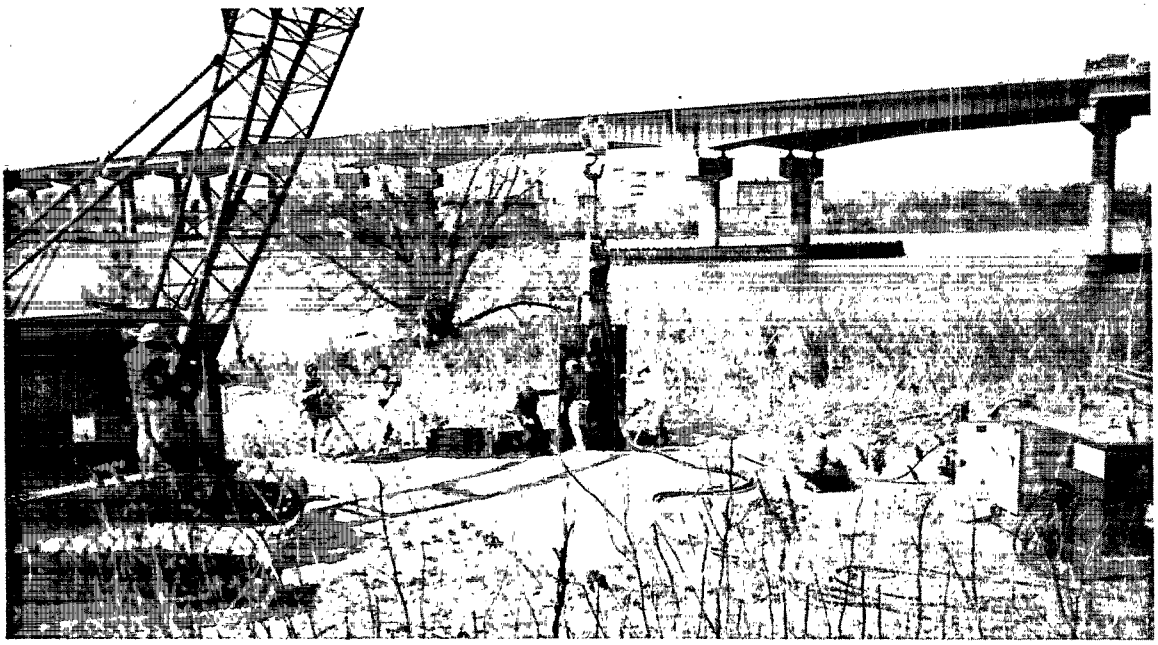
TECHNOLOGY DESCRIPTION:

The Geolock and Bio-Drain treatment platform (see photograph below) is a bioremediation system that treats soils in situ. The technology can be adapted to soil characteristics, contaminant concentrations, and area geologic formations. The system consists of an in situ tank, an application system, and a bottom water recovery system.

The Geolock tank, an in situ structure, consists of high density polyethylene (HDPE), sometimes in conjunction with a slurry wall. An underlying permeable water-bearing zone helps create inward gradient water flow conditions. The tank defines the treatment area, minimizes intrusion of off-site clean water, minimizes release of bacterial cultures to the aquifer, and maintains contaminant concentration levels that facilitate treatment. The inward gradient conditions also facilitate reverse leaching or soil washing.

The application system, called Bio-Drain, is installed within the treatment area. Bio-Drain aerates the soil column and any standing water. This creates an aerobic environment in the air pores of the soil. Other gas mixtures can also be introduced to the soil column, such as air/methane mixtures used to biodegrade chlorinated organics. Installation costs are low, and the treatment platforms can be placed in very dense configurations at competitive costs.

Existing or new wells make up the water recovery system, which removes water used to wash contaminated soil. The system causes reverse leaching or soil washing by controlling the water levels within the tank. The design of the in situ tank also controls the volume of clean off-site



Geolock and Bio-Drain Treatment Platform

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

water entering the treatment system. Inward gradient conditions direct existing contaminants and bacterial degradation products to migrate toward the surface instead of off site.

Until equilibrium conditions are established, the only residual is the quantity of water withdrawn from the system to create inwardgradient conditions. After equilibrium conditions are established, the water would be treated in situ to meet National Pollutant Discharge Elimination System (NPDES) or pretreatment limits.

The same Geolock/Bio-Drain platform can be used to remove floating or sinking contaminants prior to biological or physical/chemical treatment. The platform can perform air stripping using both pressure and vacuum systems to remove excess volatile organics from saturated waste or soil.

Conventional biological treatment is limited by the depth of soil aeration, the need for physical stripping, and the need to relocate the contaminated media to an aboveground treatment system. The Geolock/Bio-Drain treatment platform surpasses these limitations, reducing the health risks associated with excavation and air releases from other treatment technologies.

WASTE APPLICABILITY:

This system can treat all types and concentrations of biodegradable contaminants. Through direct degradation or co-metabolism, microorganisms can degrade most organic substances including some polychlorinated biphenyls. Only a few compounds, such as 1,4-dioxane, resist biodegradation. In these cases, the material may be washed from the soil using surfactants.

Extremely dense clays may be difficult to treat with this technology. Rock shelves or boulders may prevent installation.

STATUS:

The technology was accepted into the SITE Demonstration Program in August 1990. Two patents on the system were awarded in July and October 1991. A demonstration site is being selected.

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

IT CORPORATION
(In Situ Groundwater Treatment System)

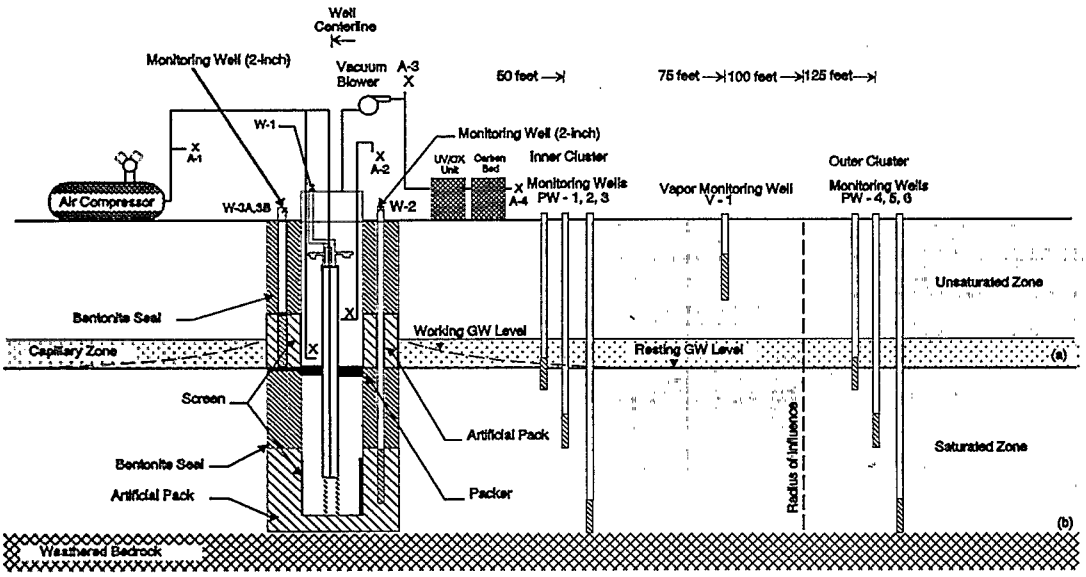
TECHNOLOGY DESCRIPTION:

The 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, possibly followed by treatment with granular activated carbon. The organic compounds may be halogenated or non-halogenated.

The process consists of three stages: (1) an air lift pumping technique, (2) an in situ vapor stripping method, and (3) air sparging. 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 causes displacement of groundwater from the lower section of the well, which is replaced by 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, partial transfer of chlorinated VOCs from the water phase to the vapor phase occurs. The vapor phase of the contaminants is then drawn off by the vacuum system.

In the second stage, water that has been lifted to the top of the well is sprayed as fine droplets



(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 screeond 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.

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 at the water table, in the upper well. A packer separates the upper well from the lower, forcing water to recharge at the water table. Fine bubble aerators transfer high volumes of air through the water, aerating and stripping off remaining VOCs. This air sparging step is the third and final treatment step prior to recharge into the upper aquifer. Throughout this process, a slight vacuum is maintained on the upper well, which 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 on March Air Force Base, California.

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

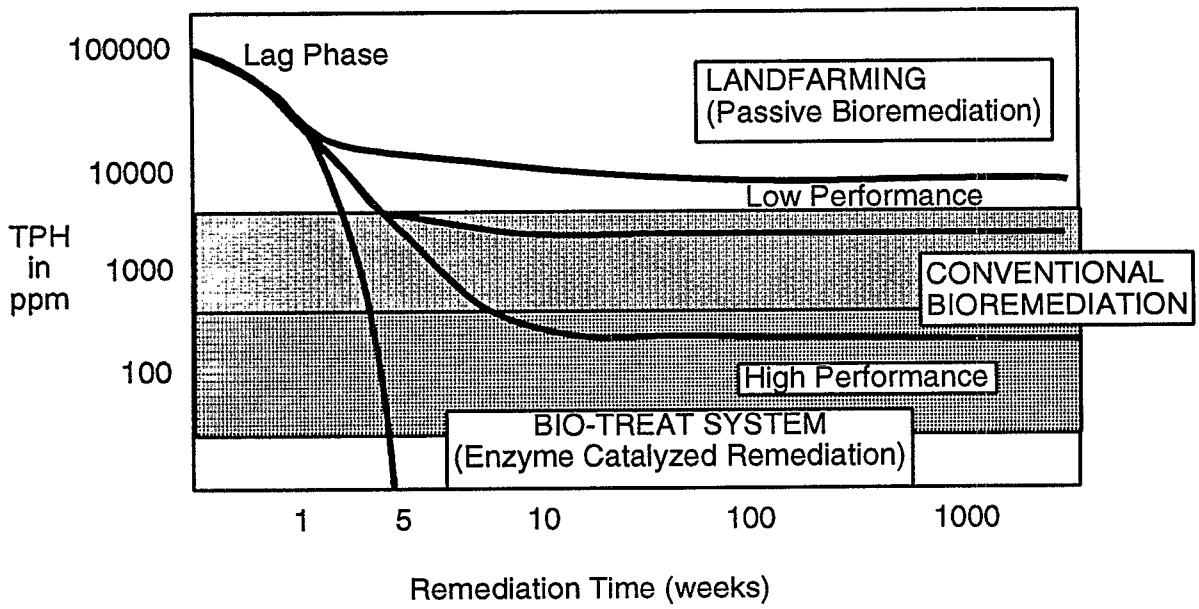
NORTH AMERICAN TECHNOLOGIES GROUP, INC.
(BioTreat™ System)

TECHNOLOGY DESCRIPTION:

The 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 process overcomes traditional bioremedial limitations by using indigenous bacteria with specially selected enzymes. The enzymes first break down the physicochemical bonds between clay lenses by neutralizing inherent electrical charges, thus drastically improving permeability and releasing trapped contaminants. Second, the enzymes chemically bind to the hydrocarbons, resulting in enzyme-catalyzed metabolic remediation which 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 as compared to landforming and conventional bioremediation techniques.

This process is designed to destroy contaminants on site through biological oxidation. Four proprietary bioremedial agents are used to assist biotreatment, each of which is specific to individual soil and contaminant characteristics such as size, depth, density, and concentration. In each case, indigenous bacteria are cultivated to effect remediation.

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



BioTreat™ System Remediation Times

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

ecosystem. Treatment bacteria are dispersed in a custom-blended nutrient mixture which is delivered by an enhanced polyphasic colloidal emulsifier when conditions require.

WASTE APPLICABILITY:

This process can treat most organic contaminants in a variety of media such as sludges, soils and mixed media. High clay soils traditionally represent the most difficult matrix for treatment; 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 days or more.

STATUS:

This technology was accepted into the SITE Demonstration Program in early 1993. EPA is seeking a suitable site for the demonstration.

FOR FURTHER INFORMATION:

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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 amine-coated ceramic chip that allows separation of suspended and dissolved hydrocarbons, and of 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 makes each granule more electrochemically attractive to the hydrocarbons in a non-stable emulsion.

Figure 1 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 (see Figure 2).

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

- Contaminated groundwater pump-and-treat
- In-process oil and water separation
- Filtration systems
- Combined oil and water separator-filter-coalescer system for on-site waste reduction and 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

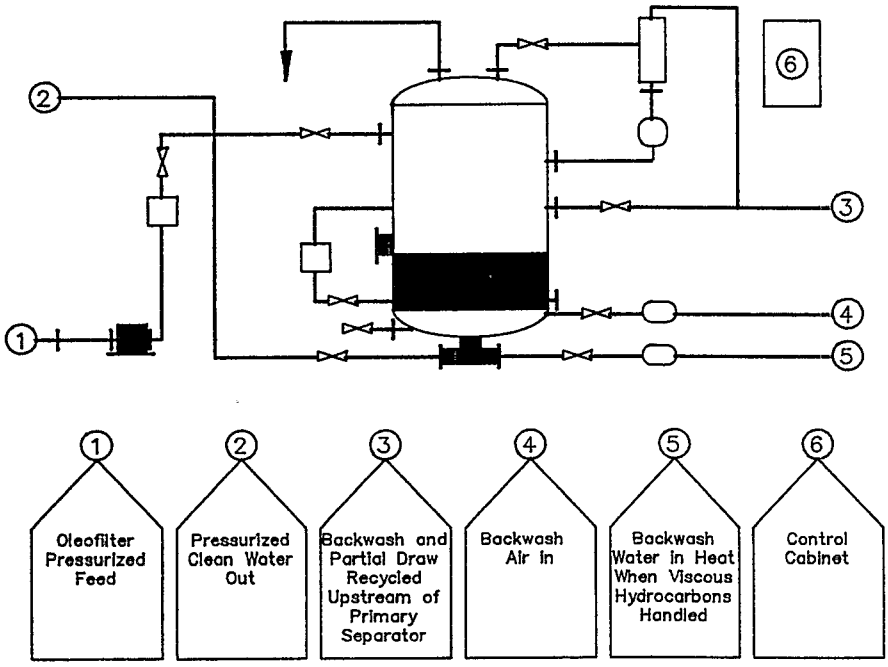

Figure 1: Schematic Diagram of the Oleofilter Technology

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

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.

WASTE APPLICABILITY:

The amine-coated granules have proven effective on a wide variety of hydrocarbons including gasoline; crude oil; diesel fuel; benzene, toluene, ehtylbenzene 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. A SITE demonstration is scheduled for winter 1993-1994 at the Petroleum Products Corporation site in Ft. Lauderdale, Florida.

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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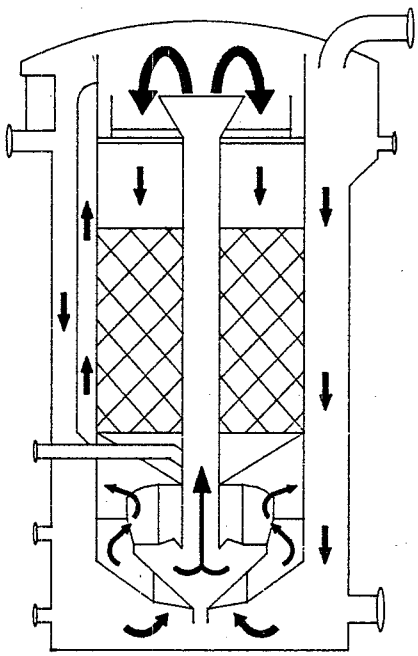


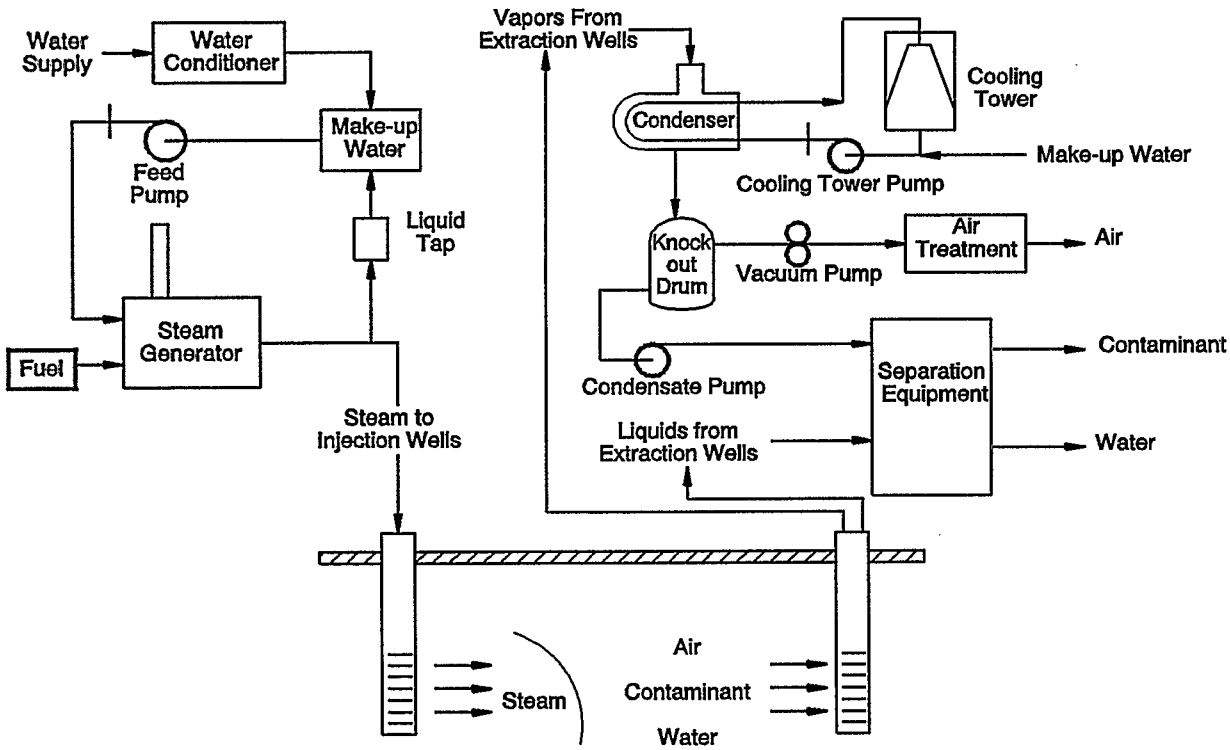
Figure 2: Separator, Filter, and Coalescer

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

PRAXIS ENVIRONMENTAL TECHNOLOGIES, INC.
(In Situ Steam Enhanced Extraction Process)

TECHNOLOGY DESCRIPTION:

The in situ steam enhanced extraction (ISEE) process (see figure below) removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils both above and below the water table. Steam is forced through the soil by injection wells to thermally enhance the vapor and liquid extraction processes. The extraction wells have two purposes: to pump and treat groundwater and to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are either condensed and processed with the contaminated groundwater or trapped by gas-phase activated carbon filters. The technology uses readily available components such as injection, extraction and monitoring wells; manifold piping; vapor and liquid separators; vacuum pumps; and gas emission control equipment.



In Situ Steam Enhanced Extraction Process

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

WASTE APPLICABILITY:

The ISEE process is used to extract VOCs and SVOCs from contaminated soils and groundwater. The primary compounds suitable for treatment are 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 below the water table. After application of this process, 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. Denser-than-water compounds may be treated only in low concentrations unless a barrier exists or can be created to prevent downward percolation of a separate phase.

STATUS:

This technology was accepted into the SITE Demonstration Program in August 1993. Through a cooperative effort within Armstrong Laboratory at Tyndall Air Force Base, Florida, the demonstration will occur at Hill Air Force Base in 1994.

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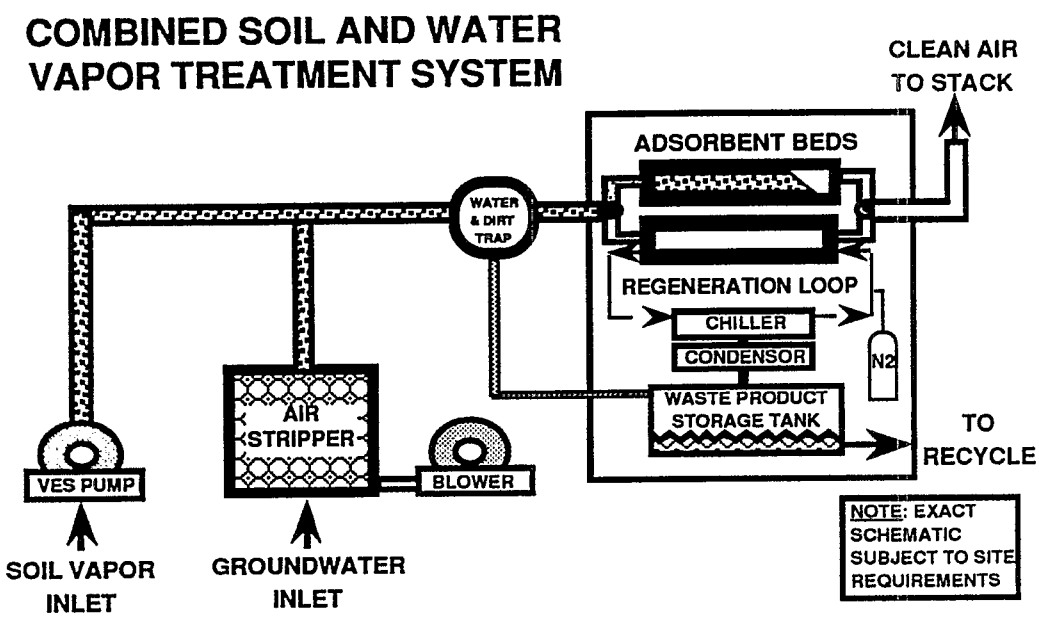
The SITE Program assesses but does not approve or endorse technologies.

PURUS, INC.
(Vapor Treatment Process)

TECHNOLOGY DESCRIPTION:

The Purus, Inc. (Purus), PurCycle™ vapor treatment process purifies air streams, contaminated with volatile organic compounds (VOC), directly from soil extraction wells or from groundwater (or wastewater) air strippers. The 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 of 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 humid contaminated air dramatically reduces the carbon's ability to adsorb organic contaminants; treatment



PurCycle™ Vapor Treatment Process

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

efficiency declines up to three times 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 Purus 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:

PurCycle™ units control VOC emissions at site remediation projects, industrial wastewater facilities, and industrial air processes. Site remediation usually involves vacuum extraction of solvents or fuels from soils, as well as the pumping and treatment of groundwater by air stripping. PurCycle™ units have 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 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.

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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:

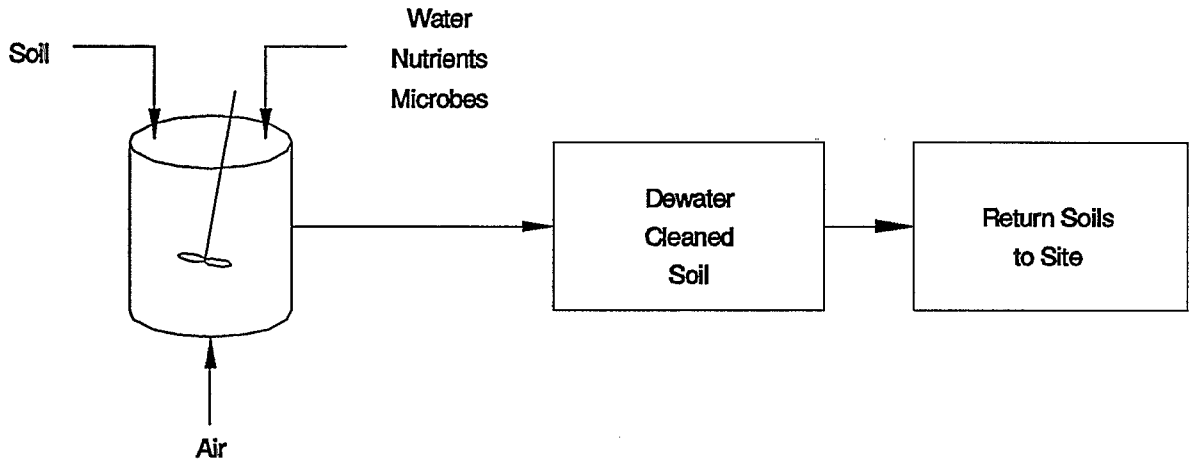
Liquid and solids biological treatment (LST) is a process that remediates soils and sludges contaminated with biodegradable organics (see figure below). The process is similar to activated sludge treatment of municipal and industrial wastewaters, but it occurs at substantially higher suspended solids concentrations (greater than 20 percent). First, an aqueous slurry of the waste material is prepared, and environmental conditions (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. Batch or continuous treatment can be conducted in impoundment-based reactors. This 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 are often a concern 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 be used to control emissions.

LST may require pre- and posttreatment operations. However, in situ applications in which treated sludge residues are to remain in place 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.



Liquid and Solids Biological Treatment

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

Remediation Technologies, Inc., (ReTeC) has constructed a mobile LST pilot system for field 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 be operated separately or as batch or continuous systems. Oxygen and pH are continuously monitored and recorded. Additional features include antifoaming and temperature control systems. Pre- and posttreatment equipment depends on site-specific circumstances and project requirements.

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). Polynuclear aromatic hydrocarbons (PAH), PCP, and a broad range of petroleum hydrocarbons (such as fuels and oils) have been successfully treated with LST in the laboratory and the field.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1987. A slurry bioreactor system will be constructed next spring in a walled off area of the barge harbor at Utica, New York. The system will treat harbor sediments contaminated with PAHs from municipal town gas wastes.

ReTeC has applied the technology in the field over a dozen times to treat wood preservative sludges in impoundment-type LST systems. In addition, the technology 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)

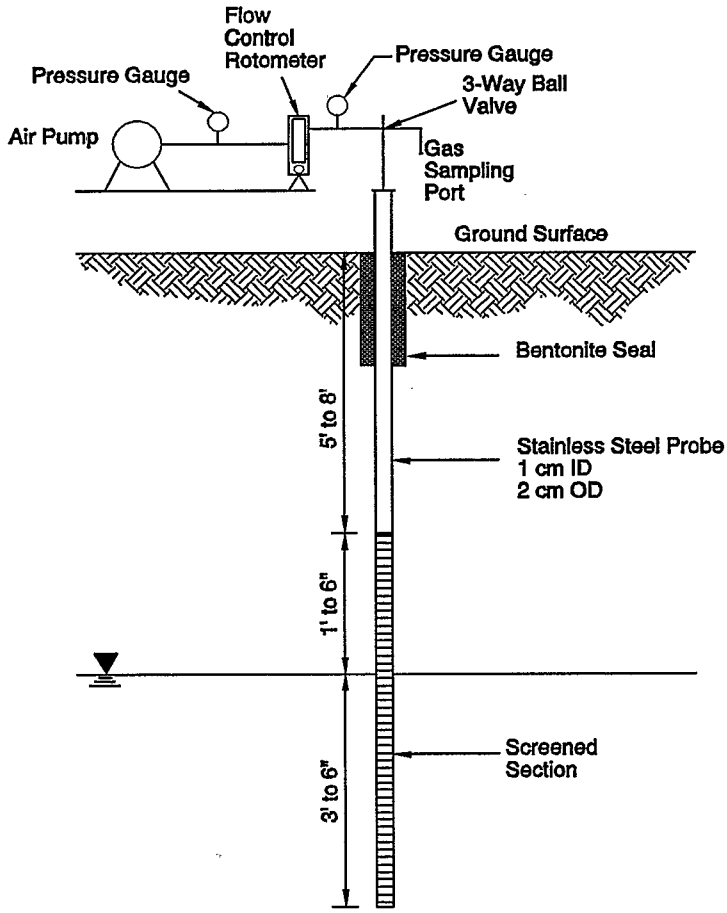
TECHNOLOGY DESCRIPTION:

Lack of oxygen in contaminated soil often limits aerobic microbial growth. This biological treatment 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, also may be required to stimulate microbial growth.

This 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, allowing inflow of oxygen without significant volatilization of contaminants in the soil. 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:

This technology is typically used to treat soil contaminated by industrial processes and can treat any contamination subject to aerobic microbial degradation. Different contaminants and



Bioventing System

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

combinations of contaminants may result in varied degrees of success. The SITE Demonstration Program plans to test the effectiveness of bioventing in degrading polynuclear aromatic hydrocarbons.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration of this process began during November 1992 at the Reilly Tar site in St. Louis Park, Minnesota. Preliminary findings after 9 months of bioventing indicate apparent increase in microbial respiration. The project will be completed in November 1995.

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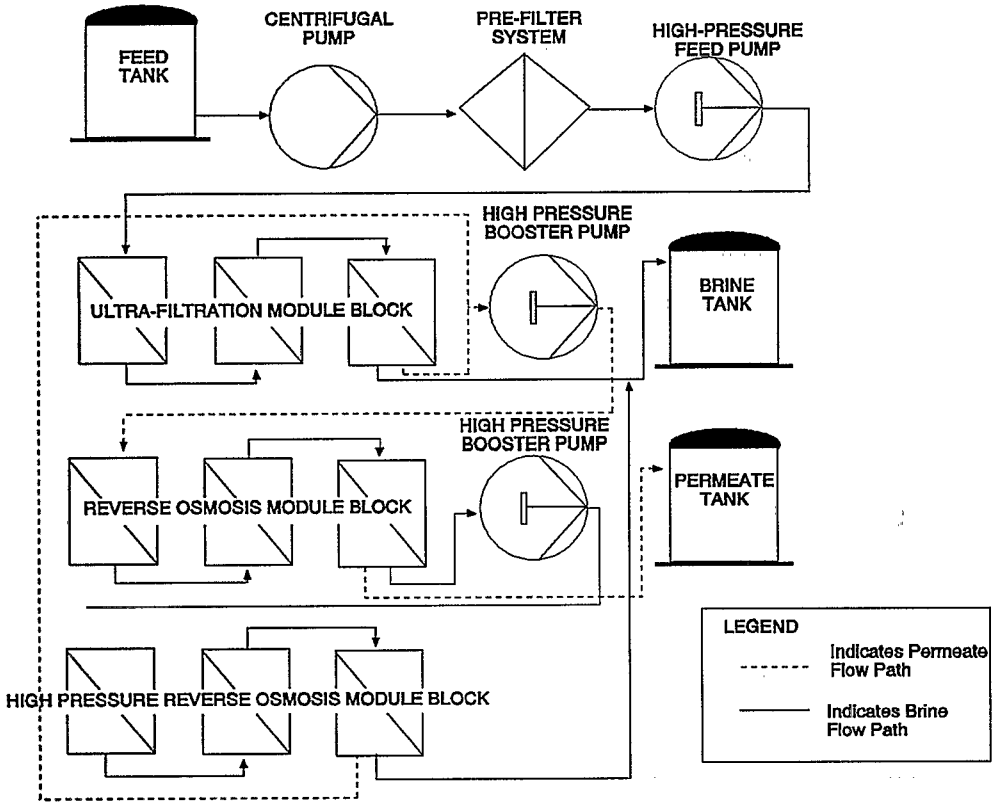
The SITE Program assesses but does not approve or endorse technologies.

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

TECHNOLOGY DESCRIPTION:

This technology uses membrane separation systems to treat a range of aqueous solutions, from seawater to leachates containing organic solvents. The system uses osmosis through a semipermeable membrane to separate pure water from contaminated liquids (see figure below). Osmotic theory implies that when a saline solution is separated from pure water by a semipermeable membrane, the higher osmotic pressure of the salt solution (because of its higher salt concentration) will cause 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. 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 be employed to separate pure water from contaminated matrices, such as the treatment of hazardous wastes through concentration of hazardous chemical constituents in an aqueous brine, while pure water can be recovered on the other side of the membrane.



Three Stage Ultra-Filtration and Reverse Osmosis Flow Path Diagram

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

Ultrafiltration (UF) is a pressure-driven, membrane filtration process that can be used to separate and concentrate macromolecules and colloids from process streams, water, and wastewaters. UF can be used in conjunction with RO in the Rochem Disc Tube Module System. The size of the particle rejected by UF depends on the inherent properties of the specific membrane selected for separation and can range from small particulate matter to large molecules. In general, a fluid is placed under pressure on one side of a perforated membrane having a measured pore size. All materials smaller than the pore pass through the membrane, leaving larger contaminants concentrated on the feed side of the process. Control of pass-through constituents can be achieved by using a membrane with a limiting pore size, or by installing a series of membranes with successively smaller pores. Although similar to RO, the UF process typically cannot separate constituents from water to the level of purity that RO can achieve. However, the two technologies can be used in tandem, with UF removing most of the relatively large constituents of a process stream before RO application selectively removes the water from the remaining mixture.

The fluid dynamics and construction of the system result in an open-channel, fully turbulent feed and water-flow system. This configuration prevents the accumulation of suspended solids on the separation membranes, thereby ensuring high efficiency filtration of 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 membrane components of the system.

Waste feed, process permeate, and rinse water are potential feed materials to the RO-UF modules, which are skid-mounted and consist of a tank and a highpressure 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-UF modules. The processing units themselves are self-contained and need only electrical and interconnection process piping to be installed prior to operation.

WASTE APPLICABILITY:

Numerous wastes can be treated using this system, including sanitary landfill leachate containing both organic and inorganic chemical species, water-soluble oil wastes used in metal fabricating and manufacturing industries, solvent-water mixtures, and oil-water mixtures generated during washing operations at metal fabricating facilities.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The BFI CECOS landfill in Williamsburg, Ohio has been selected as the demonstration site. The demonstration plan and QAPP are being finalized for a late 1993 or early 1994 demonstration.

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

S.M.W. SEIKO, INC.
(In Situ Solidification and Stabilization)

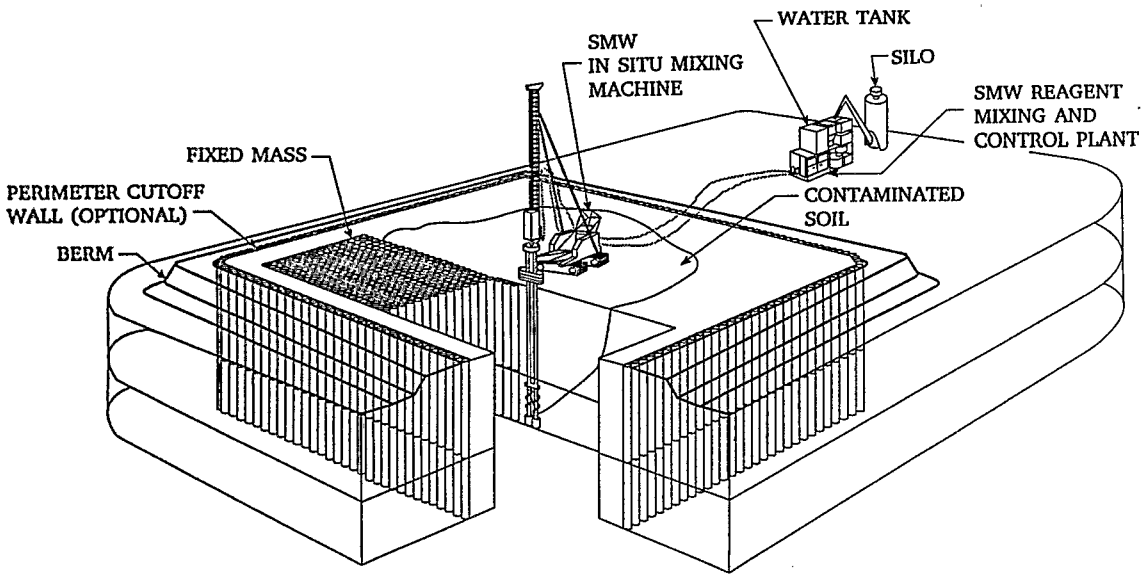
TECHNOLOGY DESCRIPTION:

The soil-cement mixing wall (SMW) technology developed by S.M.W. Seiko, Inc. (Seiko), involves the in situ fixation, solidification, and stabilization of contaminated soils. The technology has been used for more than 18 years to mix soil, cement, and chemical grout for various construction applications including cutoff walls and soil stabilization. Multi-axis overlapping hollow-stem augers (see figure below) are used to inject solidification and stabilization (S/S) agents into contaminated soils in situ. The S/S agents are then blended into the soils. The augers are mounted on a crawler-type base machine. A batch mixing plant and raw materials storage tanks are also used. This system can treat 90 to 140 cubic yards of soil in 8 hours at depths of up to 100 feet below ground surface.

The SMW technology produces a monolithic block that extends down to the treatment depth. The volume increase ranges from 10 to 30 percent, depending on the nature of the soil matrix and the amount of S/S reagents and water required for treatment.

WASTE APPLICABILITY:

This technology can be applied to soils contaminated with metals and semivolatile organic compounds such as pesticides, polychlorinated biphenyls, phenols, and polynuclear aromatic hydrocarbons.



Soil-Cement Mixing Wall Technology for
In Situ Fixation of Contaminated Soil

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

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1989. The demonstration site is being selected.

In October 1992, this technology was used to complete an in situ solidification and stabilization project at a pesticide manufacturing facility in the San Francisco Bay area. Soil contaminants included arsenic at 500 to 5,000 milligrams per kilogram (mg/kg), along with other heavy metals. Soils at the site were primarily Bay margin deposits and Bay Mud with fine sand and silt. The water table at this site was 3 to 6 feet below ground surface.

In situ treatment was carried out using SMW triple-axis auger equipment to mix two reagents with the contaminated soil to a maximum depth of 26 feet. A total of 4,000 cubic yards of soil was treated. Posttreatment samples were collected and tested. Eighty-three samples were tested for arsenic leachability; none exceeded the toxicity characteristic leaching procedure limit for arsenic of 5 milligrams per liter (mg/L). Only three samples exceeded 1 mg/L, and none exceeded 2 mg/L.

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

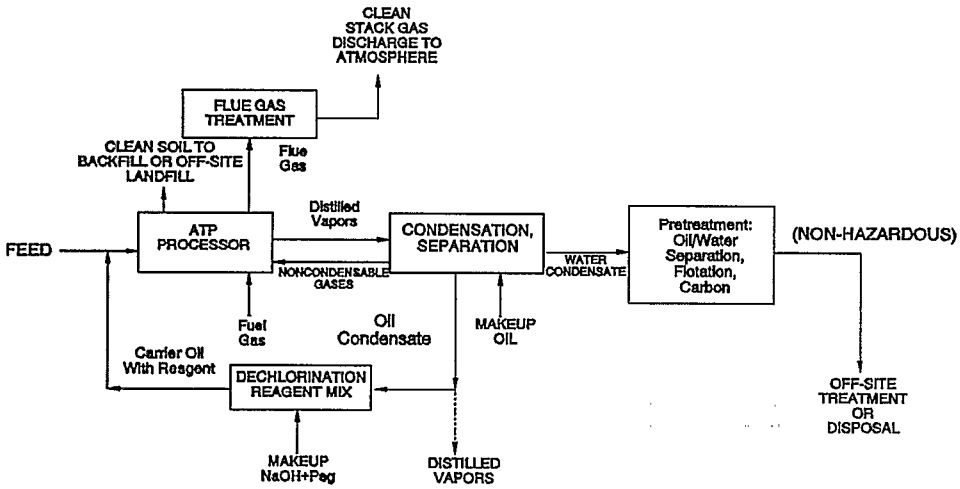
SEPARATION AND RECOVERY SYSTEMS, INC.
(SAREX Chemical Fixation Process)

TECHNOLOGY DESCRIPTION:

The SAREX chemical fixation process (CFP) (see figure below) 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. 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. It 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, it 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 placed on 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 it is thoroughly blended to a uniform consistency. The reagent blend reacts exothermally with the hazardous constituents to initiate the removal of 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 SAREX vapor recovery system. Dust particles can be removed in a baghouse, and the vapors



SAREX Chemical Fixation Process

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

are routed through a series of water scrubbers, which cool the vapors (below 120 °F) and remove any condensates. The vapors then pass through two demisters and a positive displacement blower to remove additional condensates. If needed, a freon chilling unit (37 °F or 0 °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 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 plating sludges or soils

In addition, metals are captured within the treated matrix and will 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 was 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 sometime in late 1993 or early spring 1994 at a CERCLA 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 recently completed bench-scale testing on samples collected from three lagoons. The test results were favorable.

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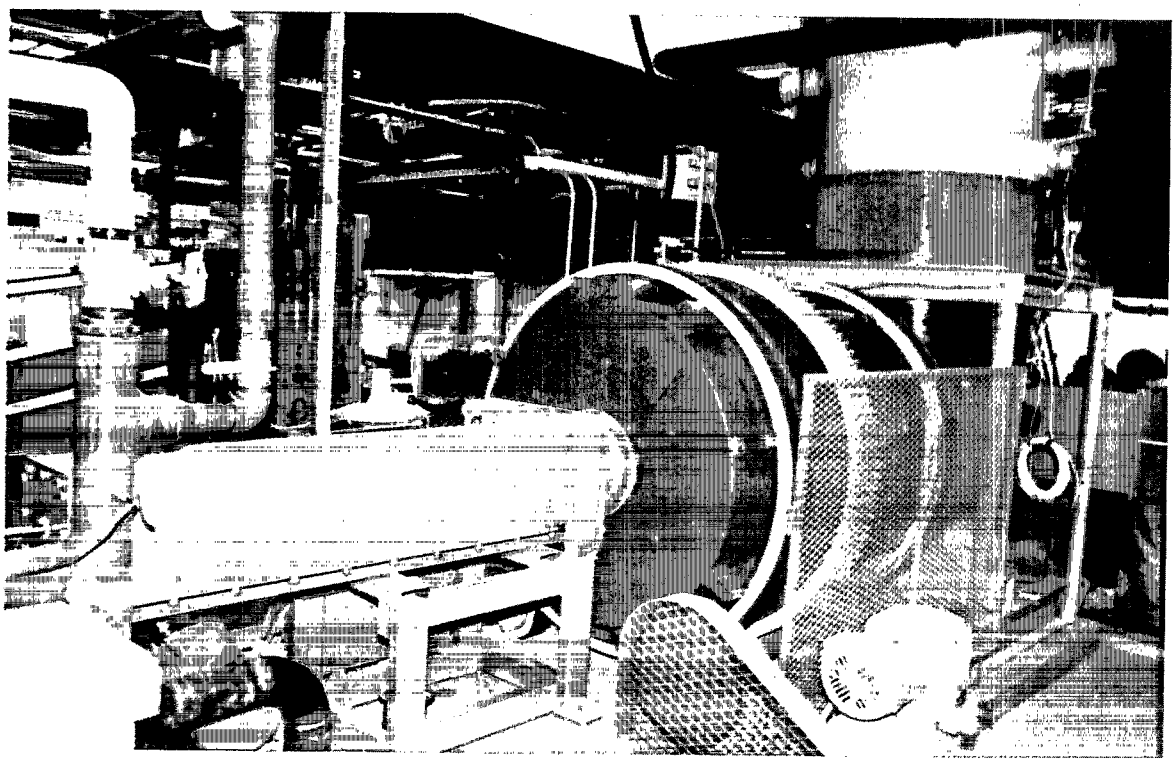
The SITE Program assesses but does not approve or endorse technologies.

SONOTECH, INC.
(Frequency Tunable Pulse Combustion System)

TECHNOLOGY DESCRIPTION:

Pulse combustion has the potential to improve the performance of various incineration and energy intensive processes. The 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. The FTPC improves an incinerator's performance by increasing mixing rates between the fuel and air and between reactive gas pockets and ignition sources (for example, flamelets or hot gases) and by increased rates of heat and mass transfer between the gas and the burning waste. These effects should reduce the amount of excess air required to completely burn the waste, increase destruction and removal efficiencies of principal organic hazardous constituents, minimize the formation of products of incomplete combustion, and eliminate or minimize detrimental emissions or "puffs."



Frequency Tunable Pulse Combustion System Installed at EPA RTP

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

In an industrial enclosure, the FTPC can excite axial, transverse, or three-dimensional acoustic mode oscillations within the enclosure. Amplitudes as high as 170 decibels and frequencies of 50 to 500 Hertz have been achieved. The high frequencies and velocities of these gas oscillations promote mixing of 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. The developer believes that it is ready for use in the incineration of contaminated soils and medical waste.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. The demonstration will test whether the technology can improve the performance of larger scale, continuously fed, incineration systems. To meet this goal, a pulse combustor retrofit system for EPA's Incinerator Research Facility (IRF) in Jefferson, Arkansas is being developed and will be tested in winter 1993. The IRF pilot-scale rotary kiln incinerator is approximately 4 times the size of the small-scale EPA unit that was previously tested. The retrofitted incinerator will then be used to treat a waste such as contaminated soil traditionally incinerated with conventional, nonpulse technology using air or oxygen enrichment.

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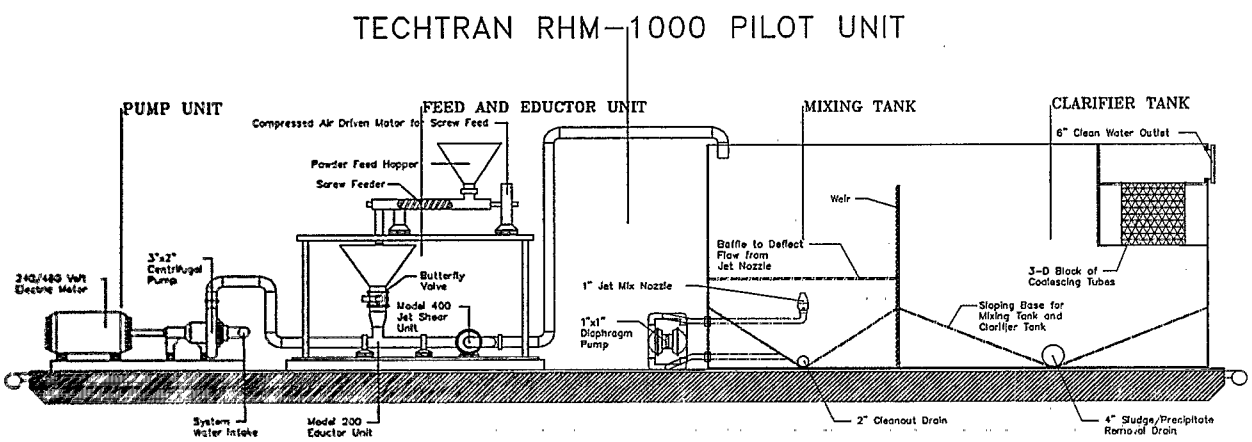
The SITE Program assesses but does not approve or endorse technologies.

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. 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



TechTran RHM-1000 Pilot Plant

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

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 on hold.

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

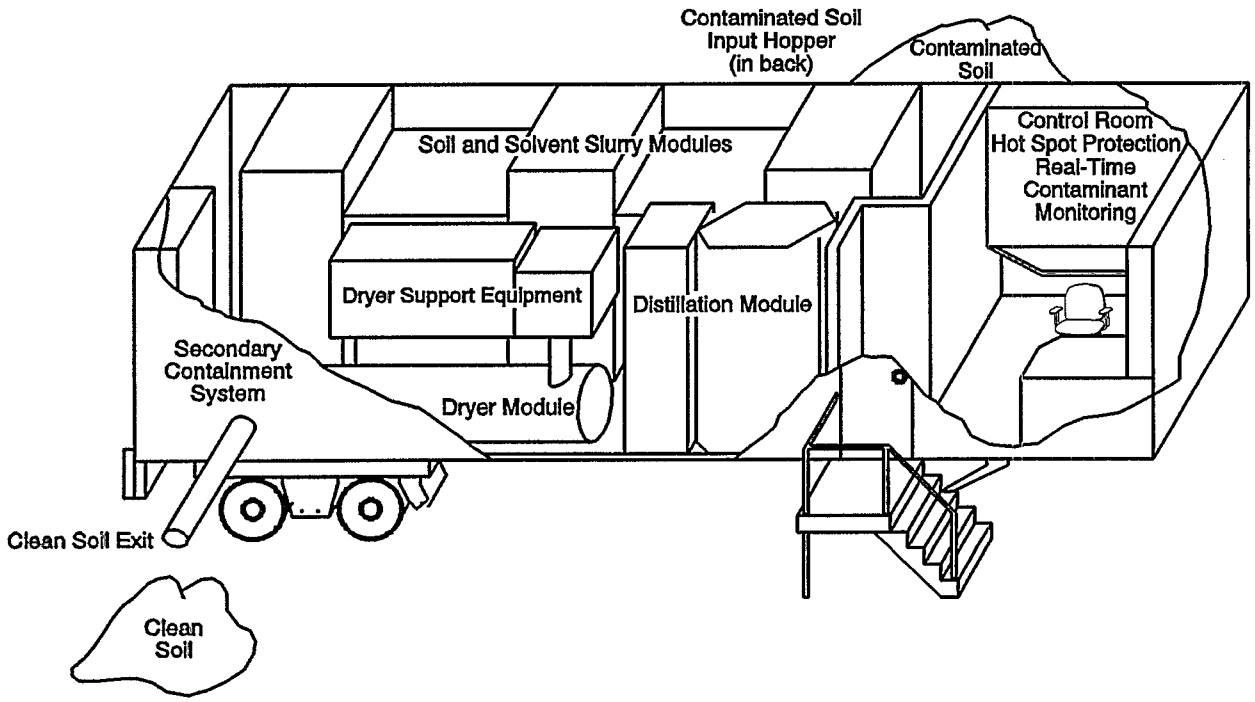
TERRA-KLEEN CORPORATION
(Soil Restoration Unit)

TECHNOLOGY DESCRIPTION:

The soil restoration unit is a mobile solvent extraction device designed to remove organic contaminants from soil. Extraction of soil contaminants is performed with a mixture of organic solvents in a closed loop, counter-current process that recycles all solvents. A combination of up to 14 solvents is used in the process, each of which dissolves specific contaminants in the soil and mixes freely with water. None of the solvents is a listed hazardous waste, and the most commonly used solvents are approved by the Food and Drug Administration as food additives for human consumption. The solvents are typically heated to efficiently strip contaminants from soil.

Contaminated soil is first fed into a hopper, then mixed with solvent to form a slurry. Soil in the slurry is continually cleaned by new solvent. The return solvent from the modules is monitored for contaminants so that the soil may be retained within the system until residual contaminants within the soil are reduced to targeted levels. The soil restoration unit offers "hot spot protection," in which real-time monitoring of contaminant levels alleviates problems associated with treating localized areas of higher contamination.

Used solvent from slurry modules is stripped of contaminants by fractional distillation. Materials extracted from the soil remain in distillation residuals and are periodically flushed from the



Soil Restoration Unit

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

system into 55-gallon drums for off-site disposal. Distillate from the columns is fractionally separated to remove the lower boiling point contaminants from the solvent. Clean solvent is then reused in the system, completing the closed solvent loop.

Treated soil and solvent slurry is then sent to a closed-loop dryer system that removes the solvent from the soil. Solvent vapors in the dryer are monitored with an organic vapor monitor that indicates when treatment is complete.

WASTE APPLICABILITY:

The technology can remove polychlorinated biphenyls (PCB), pentachlorophenol, creosote, chlorinated solvents, naphthalene, diesel oil, used motor oil, jet fuel, grease, organic pesticides, and other organic contaminants in soil. It has not been tested on contaminated sediments and sludges.

STATUS:

The soil restoration unit has been used for full-scale remediation of the Treband Superfund site. It also reduced levels of PCBs in soil to below 5 parts per million at the Pinette's Salvage Yard Superfund site.

Demonstration of this solvent extraction process under the SITE Demonstration Program is scheduled for late 1993.

FOR FURTHER INFORMATION:

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

TEXACO SYNGAS INC.
(Entrained-Bed Gasification)

TECHNOLOGY DESCRIPTION:

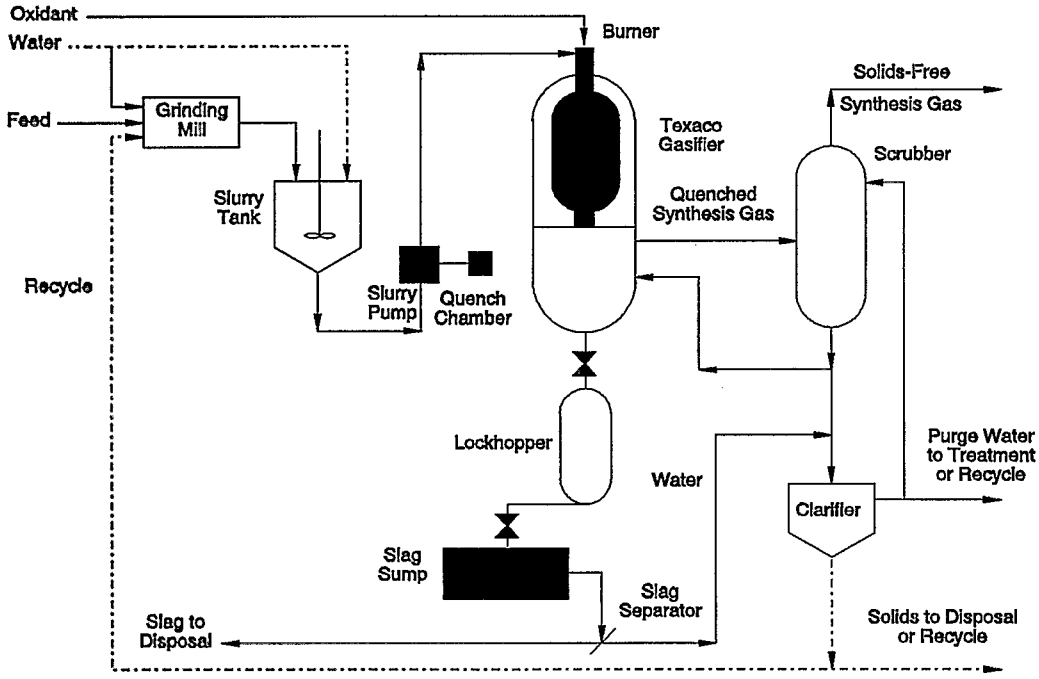
The Texaco entrained-bed gasification process (see figure below) is a noncatalytic, partial oxidation process in which carbonaceous substances react at elevated temperatures and pressures, producing a gas containing mainly carbon monoxide and hydrogen. This product, called synthesis gas, can be used to produce other chemicals or be burned as fuel. Ash in the feed melts and is removed as a glass-like slag. This technology is an extension of Texaco's conventional gasification technology, which has been operated commercially for over 30 years using feedstocks such as natural gas, heavy oil, coal, and petroleum coke.

The process treats waste material at pressures above 20 atmospheres and temperatures between 2,200 and 2,800 °F.

Wastes are pumped in slurry form to a specially designed burner mounted at the top of a refractory-lined pressure vessel. The waste feed, along with oxygen and an auxiliary fuel such as coal, react and flow downward through the gasifier to a quench chamber that collects the slag for removal through a lock hopper. A scrubber further cools the synthesis gas. Fine particulate matter removed by the scrubber may be recycled to the gasifier; a sulfur recovery system may also be added.

The cooled, water-scrubbed product gas, mainly consisting of hydrogen and carbon monoxide, should contain no hydrocarbons heavier than methane. Metals and other ash constituents become part of the inert slag.

The system can treat about 12 to 24 tons per day of hazardous waste, based on a wet synthesis gas



Entrained-Bed Gasification Process

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

production rate of 3 million standard cubic feet per day, depending on the heat content and proximate analysis.

WASTE APPLICABILITY:

This process can treat contaminated soils, sludges, and sediments containing both organic and inorganic constituents, such as used motor oils and lubricants, chemical wastes, and 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.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. A demonstration with Superfund waste is planned for 1993 at Texaco's Montebello Research Laboratory.

In December 1988, under a grant from the California Department of Health Services, Texaco demonstrated a coal-fired gasifier during a 40-hour pilot run. Low-heating-value petroleum tank bottoms were used as a supplemental feed to a coal-fired gasifier. Carbon conversion in the waste stream was over 99 percent, and solid residues from the process were nonhazardous based on California Assessment Manual limits for total and leachable materials. Both wastewater and solid residue were free of trace organics and EPA priority pollutants.

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

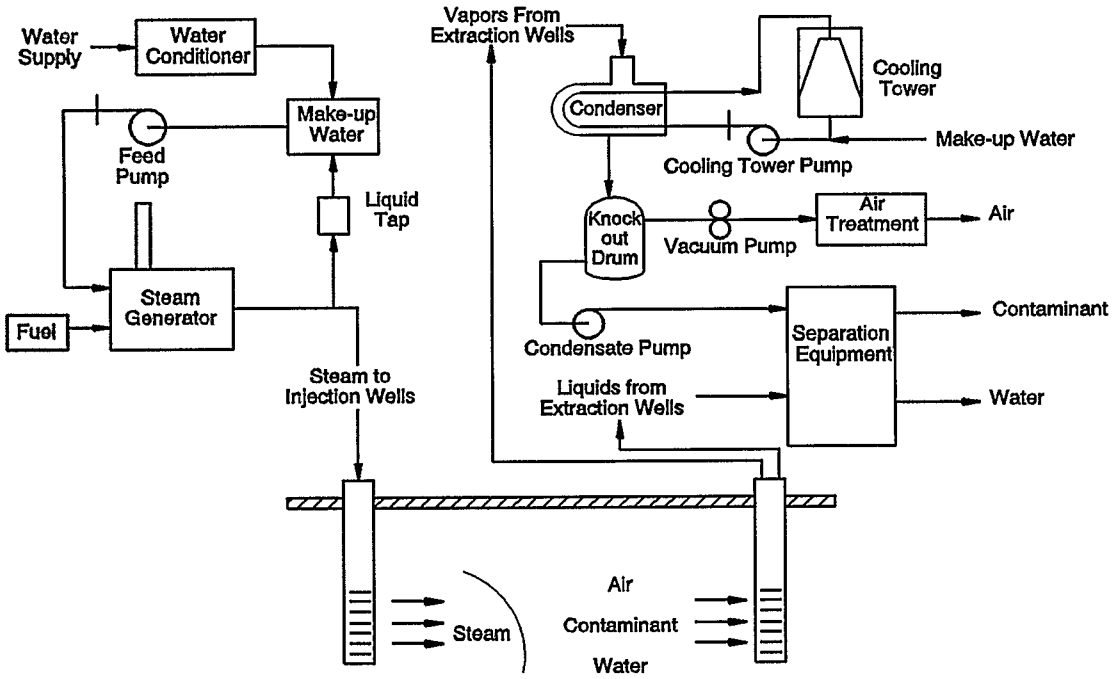
UDELL TECHNOLOGIES, INC.
(In Situ Steam Enhanced Extraction Process)

TECHNOLOGY DESCRIPTION:

The in situ steam enhanced extraction (ISEE) process (see figure below), developed by Udell Technologies, Inc., removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils both above and below the water table. Steam is forced through the soil by injection wells to thermally enhance the vapor and liquid extraction processes. The extraction wells have two purposes: to pump and treat groundwater and to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are either condensed and processed with the contaminated groundwater or trapped by gas-phase activated carbon filters. The technology 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 is used to extract VOCs and SVOCs from contaminated soils and groundwater. The primary compounds suitable for treatment are 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 below the water table. After application of this process, 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. Denser-than-water compounds may be treated only in low concentrations unless a barrier exists or



In Situ Steam Enhanced Extraction Process

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

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 of ISEE is nearing completion at Lawrence Livermore National Laboratory. Due to large groundwater fluctuations, separate phase gasoline was found dispersed both above and 25 feet below the water table. The lateral distribution of second liquid phase gasoline was about 150 feet in diameter. In the first 78 days of operation, free product gasoline was recovered both above and below the water table. Recovery rates have been up to 50 times greater than those that could have been achieved by vacuum extraction alone. About 7,000 gallons of gasoline has been recovered, mostly from the condenser either as a separate phase liquid or in the effluent air stream. Post-process soil borings indicate acceptable cleanup in all regions except cool, low permeability zones. Gasoline recovery rates remained high during intermittent vacuum extraction, however.

A pilot-scale test of ISEE is to be conducted at Naval Air Station Lemoore. This test will involve recovering liquid JP-5 from a partially-saturated region of medium permeability sand. The cleanup of a shallow aviation gasoline spill at NAS Alameda, California is planned for early 1994.

For more information regarding this technology, see the Hughes Environmental Systems, Inc., profile in the Demonstration Program (Completed Projects) section.

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

WESTERN RESEARCH INSTITUTE
[Contained Recovery of Oily Wastes (CROW™)]

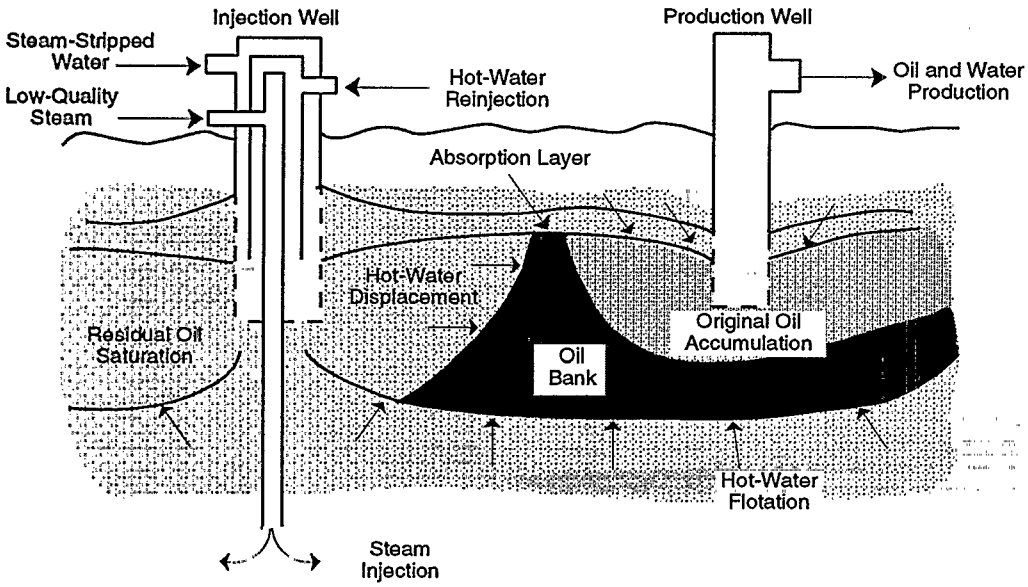
TECHNOLOGY DESCRIPTION:

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 for primary production of heavy oil and tar sand bitumen. Steam or hot water displacement is used to 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). If contamination has penetrated into or below the aquitard, 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, the 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 contaminant and water produced are treated for reuse or discharge.

In situ biological treatment may follow the displacement and is continued 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 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:

This technology can be applied to manufactured gas plant sites, wood treating sites, petroleum-refining facilities, and other areas with soils containing light to dense organic liquids such as coal tars, pentachlorophenol (PCP) solutions, creosote, and petroleum by-products.

STATUS:

This technology was tested both in the laboratory and at pilot scale under the SITE Emerging Technology Program. The program showed the effectiveness of hot water displacement and displayed the benefits of including chemicals with the hot water. Based on these results, the technology was invited to participate in the SITE Demonstration Program. The technology will be 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 full-scale remediation demonstration is scheduled for late 1993.

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 the biological treatment of the produced fluids.

A pilot-scale demonstration of the technology 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. However, PCP concentration 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.

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

WHEELABRATOR TECHNOLOGIES INC.
(WES-PHix Stabilization Process)

TECHNOLOGY DESCRIPTION:

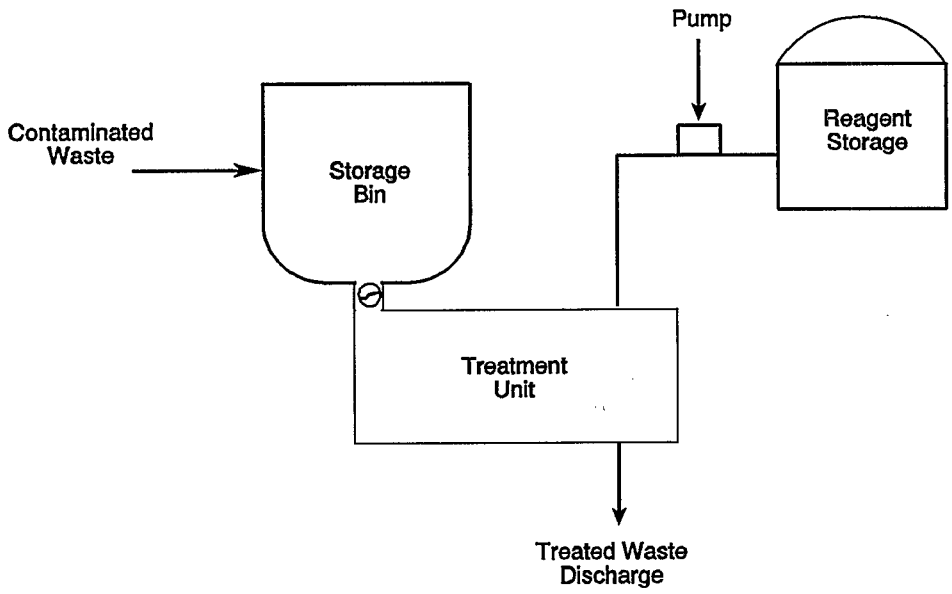
WES-PHix is a patented stabilization process that significantly reduces the solubility of certain heavy metals in solid waste streams by altering the chemical composition of the waste material. The process does not produce a solidified mass, unlike most other stabilization technologies. The first step in the process involves feeding the waste at a controlled rate to 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 from the end of the mixer by a conveyor. 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 characteristics leaching procedure (TCLP) requirements for the targeted metals. In addition, the use of small quantities of liquid phosphate reagent does not increase the volume of the stabilized waste.

Equipment requirements include a metering device for measuring waste stream delivery rates, a mixer, and storage tank for the liquid reagent. Oversized items such as boulders or wood debris require crushing or screening prior to treatment. There are no posttreatment needs associated with this process other than transporting the treated material from the mixer to a staging area. Treated residuals can be transported to final disposal using 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 almost 3 million tons of ash. However, data indicate that the technology can



WES-PHix Stabilization Process

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

also treat contaminated soils, sludges, and baghouse dusts. Recent research has shown that the process is particularly effective at stabilizing lead, cadmium, copper, and zinc in a variety of media as measured by TCLP.

STATUS:

The WES-PHix process was accepted into the SITE Demonstration Program in spring 1993. A demonstration site is being selected.

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

ZENON ENVIRONMENTAL SYSTEMS, INC.
(Cross-Flow Pervaporation System)

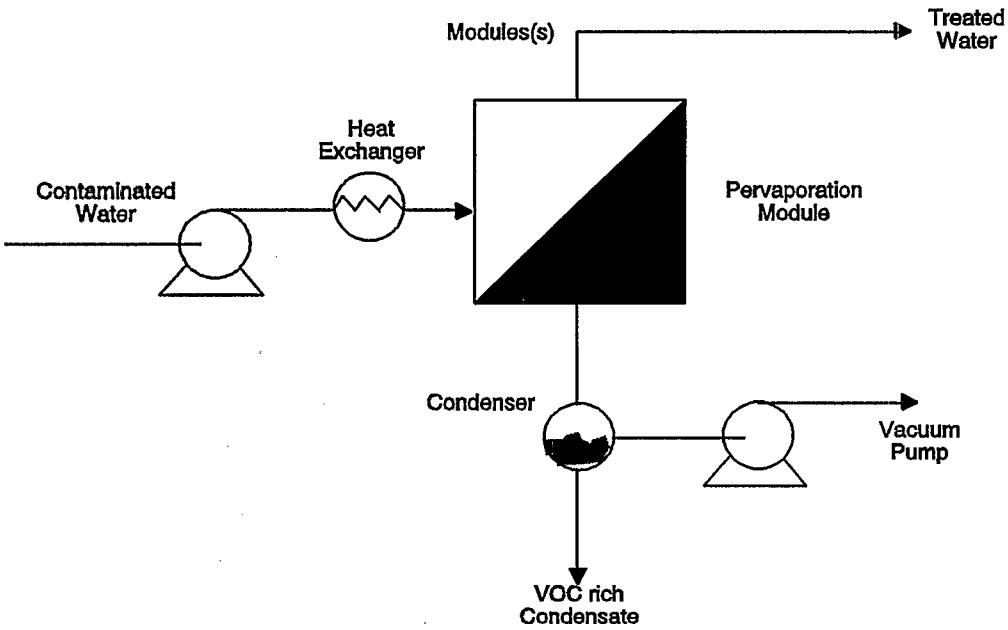
TECHNOLOGY DESCRIPTION:

Pervaporation is a membrane process for removing volatile organic compounds (VOC) from contaminated water. Permeable membranes that preferentially absorb VOCs are used to partition VOCs from the contaminated water. The VOCs diffuse from the membrane-water interface through the membrane and are drawn off under vacuum. Upstream of the vacuum pump, a condenser traps and contains the permeating vapors, condensing all the vapor to avoid fugitive emissions. The condensed organic vapors represent only a very small 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 organics may be recovered for reuse.

Zenon Environmental Systems, Inc., has developed a pilot-scale pervaporation system that is skid-mounted and compact. The membrane modules in this system consist of hollow fibers which are configured for maximum mass transfer efficiency. Removal to less than one part per billion (ppb) has been demonstrated. For flow rates of less than 1 gallon per minute this unit can remove 99.999 percent of VOCs. This high removal capacity plus containment of fugitive emissions and minimal pretreatment requirements are the primary advantages of this technology as compared with air stripping followed by gas-phase carbon adsorption.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams (in groundwater, lagoons, leachate, and rinse water) contaminated with VOCs such as solvents, degreasers, and gasoline. The technology is applicable to the types of aqueous wastes currently treated by carbon adsorption, air stripping, and steam stripping.



Cross-Flow Pervaporation System

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

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. A cost comparison, performed by Wastewater Technology Centre in 1992 under the SITE Emerging Technology Program, showed that pervaporation can be competitive with air stripping and activated carbon to treat low concentrations of VOCs. In addition, the cost competitiveness of pervaporation increases with VOC concentration.

A pilot plant with a removal efficiency of 99 percent was evaluated in-house and field tested in late 1992. Based on results from the Emerging Technology Program, this process was invited to participate in the Demonstration Program.

A pilot-scale demonstration will be conducted at a site near Toronto, Canada in fall of 1993. Groundwater at the site is contaminated with petroleum hydrocarbons. A full-scale demonstration is scheduled for summer 1994 at a site in the United States.

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

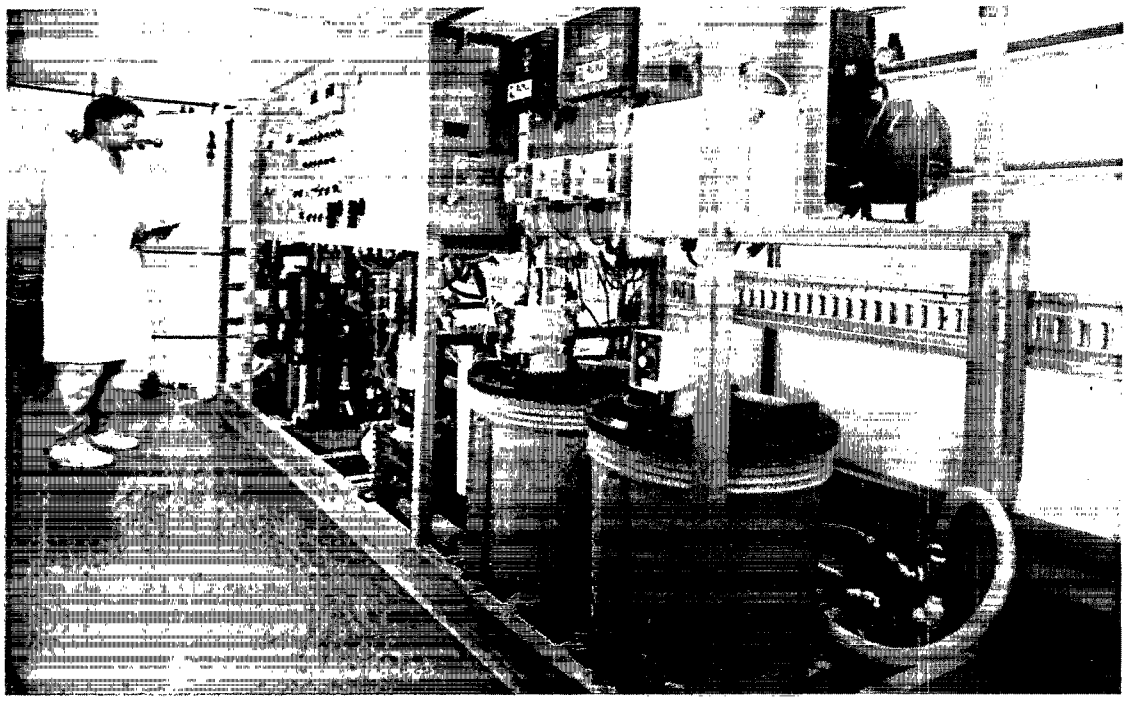
ZENON ENVIRONMENTAL SYSTEMS, INC.
(ZenoGem™ Process)

TECHNOLOGY DESCRIPTION:

The ZenoGem™ Process, developed by Zenon Environmental Systems, Inc. (Zenon), consists of a bioreactor combined with an ultrafiltration membrane system (see below). Combining these technologies results in a system that can treat wastes with high concentrations of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) at long sludge retention time but very short hydraulic residence time. Therefore, the size of the bioreactor is significantly reduced. Membrane filtration reduces the turbidity of the treated waste to less than 1 nephelometric turbidity unit (NTU).

In the ZenoGem™ Process, wastewater contaminated with organic compounds enters the bioreactor, from which 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, which are recycled to the bioreactor. This system captures higher molecular weight materials that would otherwise pass through conventional clarifiers and filters and be lost in the effluent.

The mobile version of the ZenoGem™ Process unit is mounted on a 48-foot trailer and consists of seven major components. The first component, the pretreatment system, reduces contaminants to the limits required for optimum performance of the ultrafilters. The second component, the polyethylene equalization tank,



ZenoGem™ Process

reduces the normal fluctuations of flow and waste concentrations in the system. The third component, the polyethylene bioreactor tank, contains the bacterial culture used to break down organic contaminants in the waste. A unique in-line aerator feeds oxygen into the bioreactor, to support bacterial growth. The fourth component, the process pump, is sized to ensure proper flow and pressure for optimum system performance. The ultrafiltration system, the fifth component, contains rugged, clog-free, tubular membrane modules. The sixth component, the clean-in-place tank, includes all the necessary valves, instrumentation, and controls to clean the membrane filters. Finally, the system has a control panel and a computer for remote and local data and alarm monitoring and reporting.

The system's capacity is about 500 to 1,000 gallons of wastewater per day. Volume is dependent on the flux rate of the ultrafilters and the required hydraulic retention time for the bioreactor.

WASTE APPLICABILITY:

The ZenoGem™ Process is designed to remove biodegradable materials, including most organic contaminants, to produce a high quality effluent. Consistent nitrification can be readily achieved. The system is limited to aqueous media and may be used to treat leachates and contaminated groundwater. Soils can be treated indirectly by treating liquid effluents from soil washing operations.

STATUS:

Zenon's technology was accepted into the SITE Demonstration Program in summer 1992. Potential demonstration sites are being evaluated.

FOR FURTHER INFORMATION:

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The SITE program assesses but does not approve, endorse, or recommend any technologies.

ZIMPRO PASSAVANT ENVIRONMENTAL SYSTEMS, INC.
(PACT® Wastewater Treatment System)

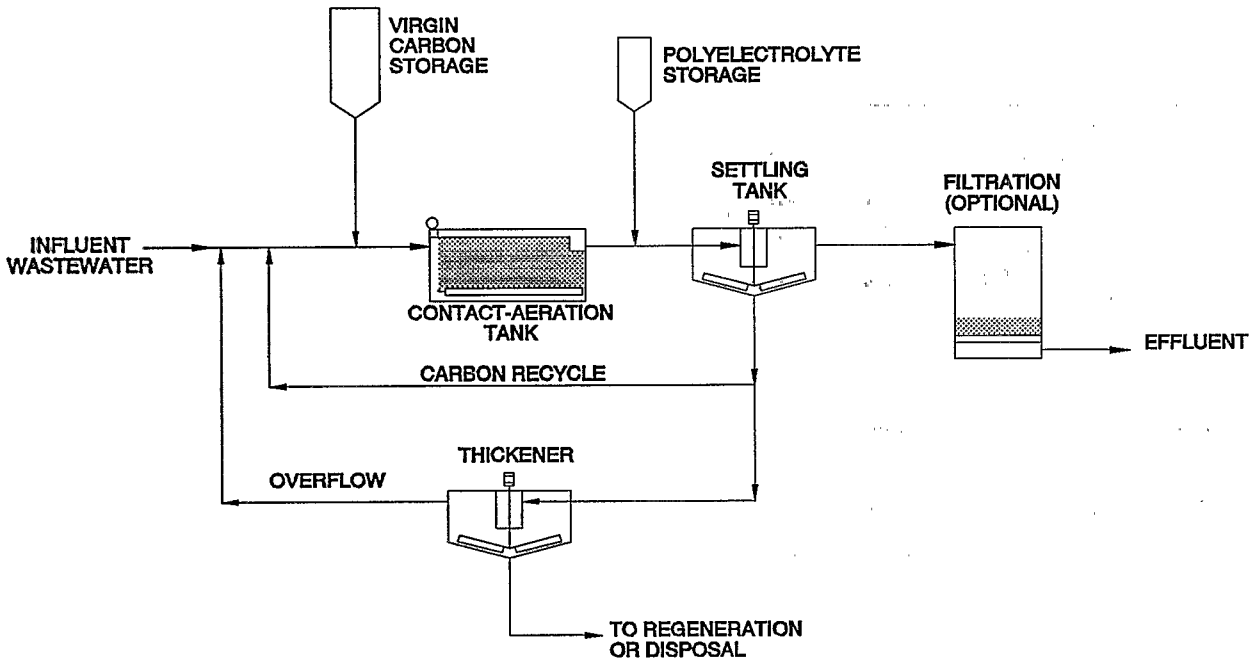
TECHNOLOGY DESCRIPTION:

Zimpro Passavant Environmental Systems, Inc., (Zimpro) has adapted the PACT® wastewater treatment system to contaminated groundwaters that are encountered at many Superfund sites. The system combines biological treatment and powdered activated carbon (PAC) adsorption to achieve treatment standards that are not readily attainable using conventional technologies. The system can be mounted on a trailer and function as a mobile unit, having a treatment capacity range of 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. This technology removes organic contaminants from the wastewater through biodegradation and adsorption on the PAC.

Living microorganisms (biomass) and PAC contact the wastewater in the aeration basin. The biomass removes biodegradable organic contaminants. PAC enhances the adsorption of toxic organic compounds. A flow diagram of a single-stage PACT® wastewater treatment system is shown in the figure below.

The degree of removal achieved by the system 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 is adjusted to the specific waste stream by controlling the flow rate of the influent waste, recycle streams, and air. This is



PACT® Wastewater Treatment System

The SITE program assesses but does not approve, endorse, or recommend any technologies.

done by varying the concentration of PAC in the system, adjusting the retention time of the mixed liquid, and adjusting the waste to biomass ratio. If necessary, the temperature and pH of incoming waste can be adjusted and nutrients can be added.

After completion of the aeration cycle, solids (PAC with adsorbed organics, biomass, and inert solids) are removed in the settling tank. The removed solids are partially returned to the aeration tank with the excess quantity diverted to the thickener where the solids are concentrated. Overflow from the thickener is returned to the aeration tank, and the concentrated solids are removed. Dewatered solids may be regenerated to recover PAC.

A two-stage PACT® system can be applied where environmental regulations require the virtual elimination of organic priority pollutants or toxicity in the treated effluent. In the first stage aeration basin, a high concentration of biomass and PAC is used to achieve the removal of most of the contaminants. The second-stage aeration basin is used to polish the first-stage effluent. The virgin PAC added just ahead of the second stage and the counter flow of solids to the first stage increases process efficiency. The excess solids from the first stage are removed and treated as described in the single-stage PACT® system.

Zimpro has also developed anaerobic and multi-staged anaerobic-aerobic PACT® systems.

WASTE APPLICABILITY:

This technology can be applied to municipal and industrial wastewaters, as well as groundwater and leachates containing hazardous organic pollutants. It has successfully treated various industrial wastewaters, including chemical plant wastewaters, dye production wastewaters, pharmaceutical wastewaters, refinery wastewaters, 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. The developer's treatability studies have shown that the system can reduce the organics in contaminated groundwater from several hundred ppm to below detection limits (parts per billion range).

STATUS:

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; however, additional sites are now being evaluated for a full-scale demonstration of the PACT® system.

FOR FURTHER INFORMATION:

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The SITE program assesses but does not approve, endorse, or recommend any technologies.

EMERGING TECHNOLOGY PROGRAM

The Emerging Technology Program provides a framework to encourage bench-and pilot-scale testing and evaluation of technologies that are at a minimum proven on the conceptual and bench-scale stage. The goal is to promote the development of alternative technologies for 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 Department of Energy (DOE) and the United States Air Force (USAF). DOE has helped fund 22 projects, and USAF has helped fund eight projects.

Seven 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).

Twenty-nine Emerging Technology projects have been completed, and several more will be completed in 1994. Three technologies, Babcock & Wilcox Co.'s Cyclone Furnace and J.R. Simplot's Biodegradation of Dinoseb and Biodegradation of Trinitrotoluene, have been demonstrated under the SITE Demonstration Program. Five more Emerging Technology projects are participating in the Demonstration Program.

Completed Emerging Technology Program projects are presented in alphabetical order in Table 3 and in the technology profiles that follow; ongoing projects are presented in alphabetical order in Table 4 and in the profiles that follow. One developer, Williams Environmental Services, Inc. (formerly Harmon Environmental Services, Inc.), has exited the program and is not profiled in this document.

TABLE 3

Completed SITE Emerging Technology Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Aluminum Company of America (formerly ALCOA Separation Technology, Inc.), Pittsburgh, PA (E03)*	Bioscrubber	Paul Liu 412-826-3711	Naomi Barkley 513-569-7854	Airstreams from Soil, Water, and Air Decontamination Processes	Not Applicable	Most Volatile Organics
Atomic Energy of Canada, Limited, Chalk River, Ontario, Canada (E01)	Chemical Treatment and Ultrafiltration	Leo Buckley 613-584-3311	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Heavy Metals, Uranium	Not Applicable
Babcock & Wilcox Co., Alliance, OH (E02)	Cyclone Furnace	Lawrence King 216-829-7576	Laurel Staley 513-569-7863	Solids, Soil	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, Low-level Radionuclides	Nonspecific Organics
Bio-Recovery Systems, Inc., Las Cruces, NM (E01)	Biological Soprtion	Mike Hosea 505-523-0405	Naomi Barkley 513-569-7854	Groundwater, Leachate, Wastewater	Heavy Metals, Uranium	Not Applicable
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 412-826-5320	Kim Lisa Kreiton 513-569-7328	Soil	Heavy Metals	Not Applicable
Colorado School of Mines, Golden, CO (E01)	Wetlands-Based Treatment	Thomas Wildeman 303-273-3642	Edward Bates 513-569-7774	Acid Mine Drainage	Metals	Not Applicable
Electro-Pure Systems, Inc., Amherst, NY (E02)	Alternating Current Electrocoagulation Technology	James LaDue 716-691-2610	Naomi Barkley 513-569-7854	Groundwater, Wastewater, Leachate	Heavy Metals	Petroleum By-products, Coal-Tar Derivatives
Electrokinetics, Inc., Baton Rouge, LA (E03)	Electrokinetic Remediation	Yalcin Acar 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	Franklin Alvarez 513-569-7631	Water Streams and Sludges	Not Applicable	Most Organics

* Solicitation Number

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Energy and Environmental Engineering, Inc., East Cambridge, MA (E01)	Laser-Induced Photochemical Oxidative Destruction	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, Sludges	Volatile Inorganics	Nonspecific Organics
Ferro Corporation, Independence, OH (E03)	Waste Vitrification Through Electric Melting	Emilio Spinosa 216-641-8580	Randy Parker 513-569-7271	Soils, Sediments, Sludges	Nonspecific Inorganics	Nonspecific Organics
Institute of Gas Technology, Chicago, IL (E04)	Chemical and Biological Treatment	Robert Kelley 312-567-3809	Naomi Barkley 513-569-7854	Soil, Sludge, Groundwater, Surface Water	Not Applicable	Most Organics
Institute of Gas Technology, Chicago, IL (E03)	Fluid Extraction - Biological Degradation Process	J. Robert Paterek 312-949-3947	Annette Gatchett 513-569-7697	Soil	Not Applicable	Nonspecific Organics
IT Corporation, Knoxville, TN (E02)	Batch Steam Distillation and Metal Extraction	Robert Fox 615-690-3211	Ronald Lewis 513-569-7856	Soil	Heavy Metals, Nonspecific Organics	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	Brian Butters 519-457-2963	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
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
PSI Technology Company, Andover, MA (E04)	Metals Immobilization and Decontamination of Aggregate Solids	Srivats Srinivasachar 508-689-0003	Mark Meckes 513-569-7348	Soils, Sediments, Sludges	Heavy Metals, Volatile Metals	Low Volatile Organics, Organometallics

TABLE 3 (continued)

Completed SITE Emerging Technology Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
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 Company, Pocatello, ID (E03)	Anaerobic Biological Process	Dane Higdem 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	Kim Lisa Kreiton 513-569-7328	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 215-489-2255	Teri Richardson 513-569-7949	Soil, Sediments, Sludges, Mill Tailings	Metals, Other Nonspecific Inorganics	Nonspecific Organics
Wastewater Technology Centre, Burlington, Ontario, Canada (E02)	Cross-Flow Pervaporation System	Rob Booth 416-336-4689 Phil Canning 416-639-6320	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Not Applicable	VOCs, Solvents, Petroleum Hydrocarbons
Western Research Institute, Laramie, WY (E01)	Contained Recovery of Oily Wastes (CROW™)	Lyle Johnson 307-721-2281	Eugene Harris 513-569-7862	Soil	Not Applicable	Coal Tar Derivatives, Petroleum By-products

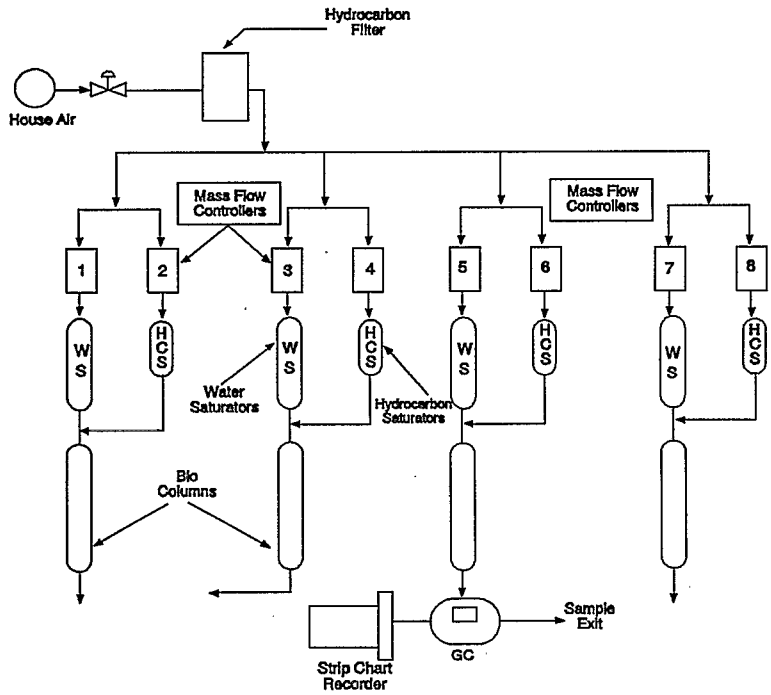
ALUMINUM COMPANY OF AMERICA
(formerly ALCOA SEPARATION TECHNOLOGY, INC.)
(Bioscrubber)

TECHNOLOGY DESCRIPTION:

This bioscrubber technology digests hazardous organic emissions from 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 provides biomass removal, nutrient supplement, and moisture addition. A pilot-scale unit with 4-cubic-foot-per-minute capacity is being field tested (see photograph 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 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 available constantly; 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 methylene chloride, or adsorbates competing with moisture in the stream. Finally the chromatographic effect (premature desorption) com-



Bioscrubber Pilot-Scale Unit

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

mon 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 (about 10 to 20 ppm). The bioscrubbers accomplished greater than 95 percent removal efficiency. The filter had a biodegradation efficiency 40 to 80 times greater than existing filters. The project was completed in June 1993. Results have been published in the report "Bioscrubber for Removing Hazardous Organic Emissions from Soil, Water and Air Decontamination Processes" (EPA 540/R-93/521). This report is available from the National Technical Information Service (NTIS). Other reports available are the Technology Bulletin (EPA/540/F-93/507) and the Technology Summary (EPA/540/SR-93/521).

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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412-826-3711

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

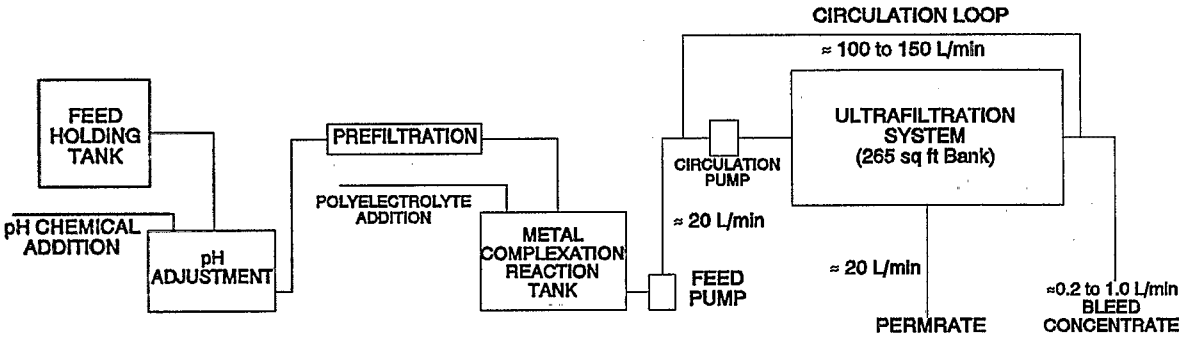
ATOMIC ENERGY OF CANADA, LIMITED
(Chemical Treatment and Ultrafiltration)

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. The two banks of filters provide a total membrane surface area of 390 square feet and a permeate rate of about 8 gallons per minute (gpm). The wastewater enters the prefilter through the feed tank, where suspended particles from the feed are removed. The filtered wastewater is then routed to conditioning tanks where the solution pH is adjusted and water-soluble macromolecular compounds are 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 polyelectrolyte quantities needed to enlarge the metal complex to the desired size depend on the concentration of metal ions. Therefore, separated metal ions should generally be in the parts per million (ppm) range.

The treated wastewater then passes through a cross-flow ultrafiltration membrane system through a recirculation loop. The membranes retain the metal complexes (concentrate), while allowing uncomplexed ions to pass through the membrane with the filtered water. The filtered water, which can be discharged, is continuously withdrawn, while the concentrate stream, consisting of most of the contaminants, is recycled through the recirculation loop until it meets the



Single-Stage Chemical Treatment and Ultrafiltration Process

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

target concentration. After reaching the target concentration, the concentrate stream is withdrawn for further treatment, such as solidification. It can then be safely disposed of.

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:

During initial bench-scale and pilot-scale tests, the system successfully removed cadmium, lead, and mercury. These results were used to design and construct the mobile unit.

The mobile unit has undergone initial testing at the Chalk River Laboratories and at a uranium mine tailings site in Ontario. 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.

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

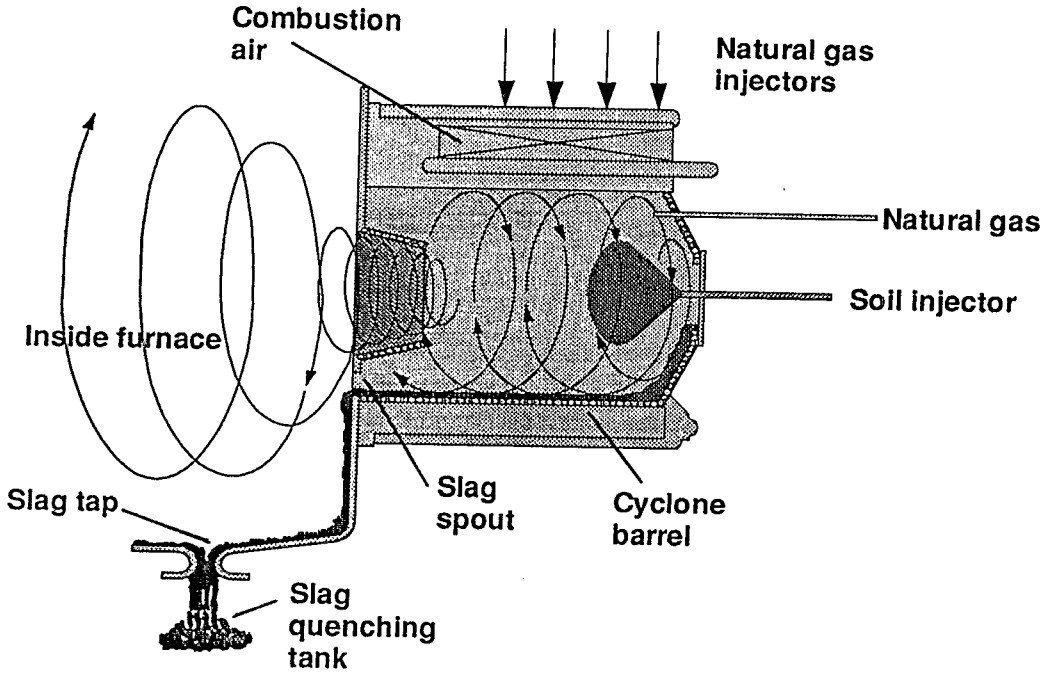
BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed for the combustion of high inorganic content (high-ash) coal. The combination of high heat-release rates (45,000 British thermal units per cubic foot [Btu/ft^3]) of coal] and high turbulence in cyclones assures achievement of 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 cyclone furnace, shown 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 °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 is captured and melted, and organics are destroyed in the gas phase or in the molten slag layer 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 is dropped 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 proportionally lower energy requirements. The cyclone furnace can be operated with gas, oil, or



Cyclone Furnace

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

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 in the form of solids, 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 of the technology's ability to capture heavy metals in the slag and render these nonleachable, an important application of the technology is to treat contaminated 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. An advantage of vitrification over other thermal treatment technologies is that in addition to destruction of organic wastes, the resulting vitrified product captures and does not leach heavy metals. When operated at 50 to 150 pounds per hour (lb/hr) of dry SSM feed, and at 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 the hazardous soil.

From 95 to 97 percent of the dry SSM was incorporated within the slag. Stable cyclone operation was achieved during the two projects, which 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. The percentages of each metal retained in the vitrified slag for wet soil fed at 200 lb/hr were 12 to 23 percent for cadmium, 38 to 54 percent for lead, and 78 to 95 percent for chromium. The capture of heavy metals in the slag was found to increase with feed rate and to decrease 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 treatment of the SSM resulted in a volume reduction of 25 to 35 percent on a dry basis. Vitrification results in an easily-crushed, glassy product.

FOR FURTHER INFORMATION:

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Babcock & Wilcox Co.
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Alliance, OH 44601
216-829-7576

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

BATTELLE MEMORIAL INSTITUTE
(In Situ Electroacoustic Soil Decontamination)

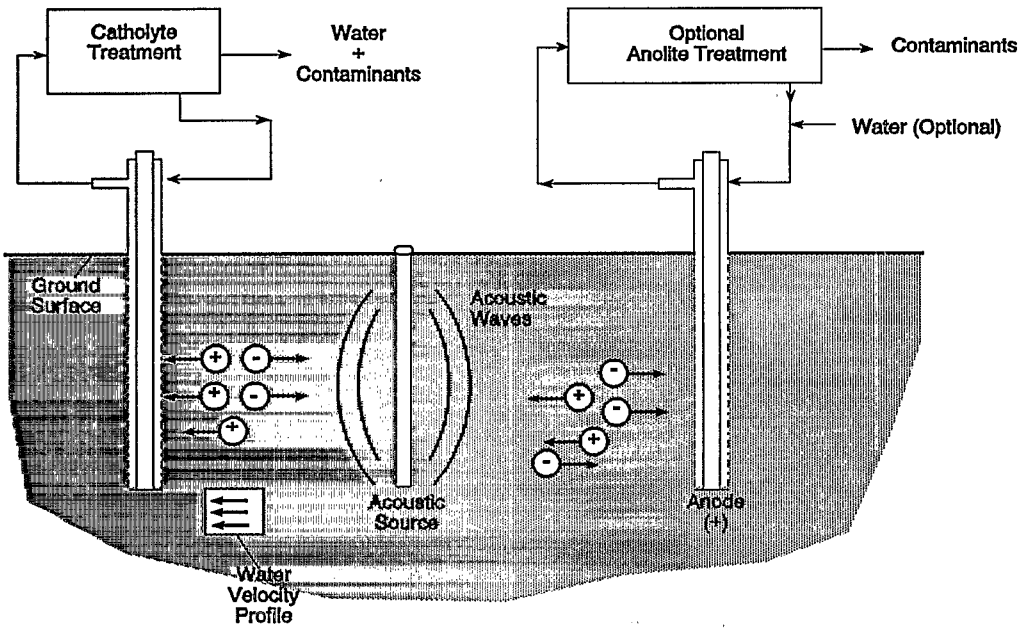
TECHNOLOGY DESCRIPTION:

This patented technology is used for in situ decontamination of soils containing hazardous organics by applying electrical (direct current) and acoustic fields. The direct current facilitates the transport of liquids through soils. The process 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 drag water along with them as they move toward the cathode.

Besides the transport of water through wet soils, the direct current produces other effects, such as ion transfer; development of pH gradients; electrolysis; oxidation and reduction; and heat generation. The heavy metals present in contaminated soils can be leached or precipitated out of solution by electrolysis, oxidation and reduction reactions, or ionic migration. The contaminants in the soil may be (1) cations, such as cadmium, chromium, and lead; and (2) anions, such as cyanide, chromate, and dichromate. The existence of these ions in their respective oxidation states depends on the pH and concentration gradients in the soil. The electric field 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 the dewatering or leaching of wastes such as sludges. This phenomenon is not fully understood. Another possible application involves unclogging of recovery wells. Since contaminated particles are driven to the recovery



In Situ Electroacoustic Soil Decontamination (ESD) Process

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

well, the pores and interstitial spaces in the soil can become plugged. This technology could be used to clear these clogged spaces.

WASTE APPLICABILITY:

Fine-grained clay soils are ideal. The technology's potential for improving nonaqueous 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 electroacoustic soil decontamination (ESD) is technically feasible for removal of 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 (NTIS) (703-487-4650). The NTIS order number is PB 90-204 728/AS.

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

BIO-RECOVERY SYSTEMS, INC.
(Biological Sorption)

TECHNOLOGY DESCRIPTION:

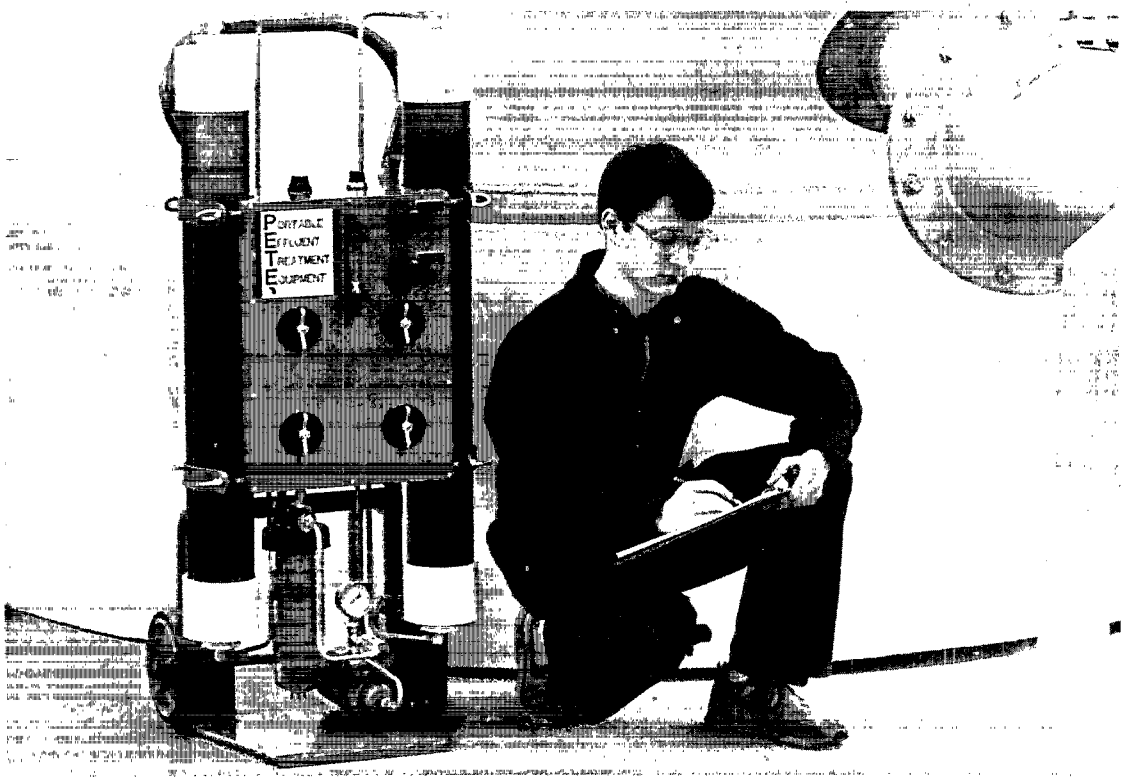
The AlgaSORB™ sorption process uses algae to remove heavy metal ions from aqueous solutions. The process takes advantage of the algae's natural affinity for heavy metal ions.

The photograph below shows a prototype portable effluent treatment equipment (PETE) unit, consisting of two columns operating in series. 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 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})



Portable Effluent Treatment Equipment (PETE) Unit

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

and magnesium (Mg^{+2}), or monovalent cations, 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 are 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 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) is available. Based on results from the Emerging Technology Program, Bio-Recovery Systems, Inc., was invited to participate in the SITE Demonstration Program.

The process is being commercialized for groundwater treatment and industrial point source treatment.

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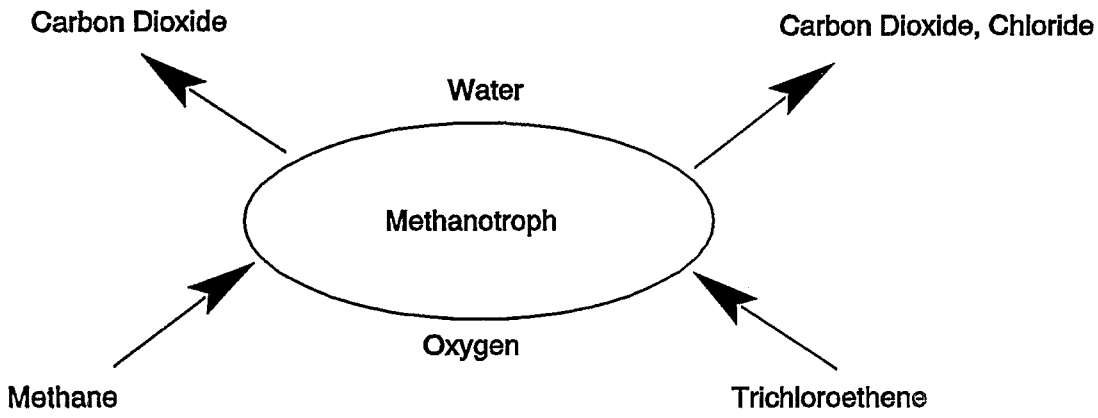
The SITE Program assesses but does not approve or endorse technologies.

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 be used as a primary substrate for growth by bacteria. Degradation depends on the process of cometabolism (see figure below), which is attributed to the broad substrate specificity of certain bacterial enzyme systems. Although many aerobic enzyme systems are reported to 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 it has been known that certain methanotrophs can express MMO in either a soluble or particulate (membrane-bound) form, BioTrol-sponsored research has led to the discovery that the soluble form induces extremely rapid rates of TCE degradation. One patent has been obtained and two additional patents are pending on the process. BioTrol has also developed a colorimetric assay which verifies the presence of the desired enzyme 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 rates of TCE degradation by nonmethanotrophs. This



Cometabolism of TCE

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

species of methanotrophic bacteria is reported to remove various chlorinated aliphatic compounds by more than 99.9 percent.

WASTE APPLICABILITY:

The technology is applicable to 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 (1) reinjected or (2) discharged to a sanitary sewer or a National Pollutant Discharge Elimination System receiving water.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Both bench-scale and pilot-scale tests were conducted using a continuous-flow dispersed-growth system. As shown in the figure below, first-order TCE degradation kinetics were observed in the pilot-scale reactor. The final report on the pilot-scale demonstration is expected to appear in the *Journal of the Air and Waste Management Association* in late 1993. 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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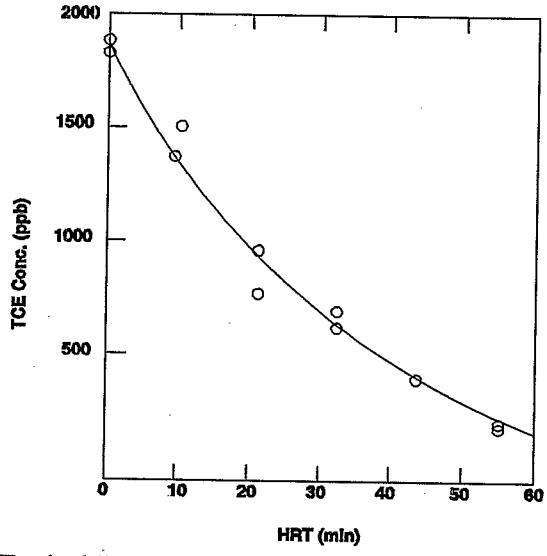


Typical Laboratory Continuous-Flow Results

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, requiring 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. Then it is contacted with hydrochloric acid 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.

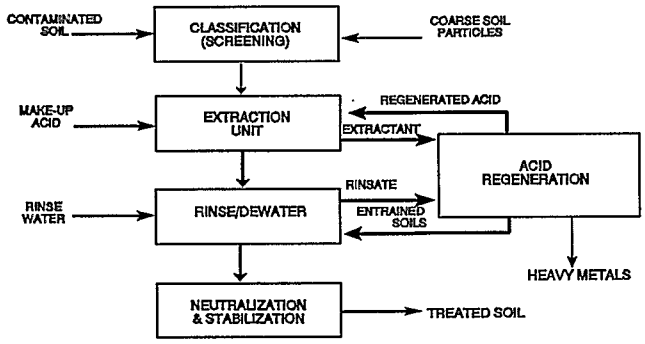
When extraction is complete, the solids are transferred to the rinse system. The soils are rinsed with water to remove entrained acid and metals. The extraction solution and rinsewaters are regenerated using a proprietary technology that removes the metals and reforms the acid. The heavy metals are concentrated in a form potentially suitable for recovery. During the final step, the soils are mixed with lime and fertilizer to neutralize any residual acid.

WASTE APPLICABILITY:

The main application of AETS is removal 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 fractions of the soils, including fines. The major residuals anticipated from treatment using AETS 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 (NL Industries in Pedricktown, New Jersey; King of Prussia site in Winslow Township, New Jersey; 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 the soil treatability across the soils and metals tested, 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.

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 and to 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 limits. The only exception to this among the soils tested 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 other metals in this soil including arsenic, cadmium, chromium, copper, nickel, and zinc.
- Costs for treatment, under expected process conditions, range between $100 and $180 per cubic yard of soil, depending on the site size, soil types and contaminant concentrations. Operating costs ranged between $50 and $80 per cubic yard. These costs are competitive with alternative technologies.

The developers are looking for additional partners interested in finding a suitable site to demonstrate the technology. SITE Program final reports for this project will be available after December 1, 1993.

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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.

COLORADO SCHOOL OF MINES
(Wetlands-Based Treatment)

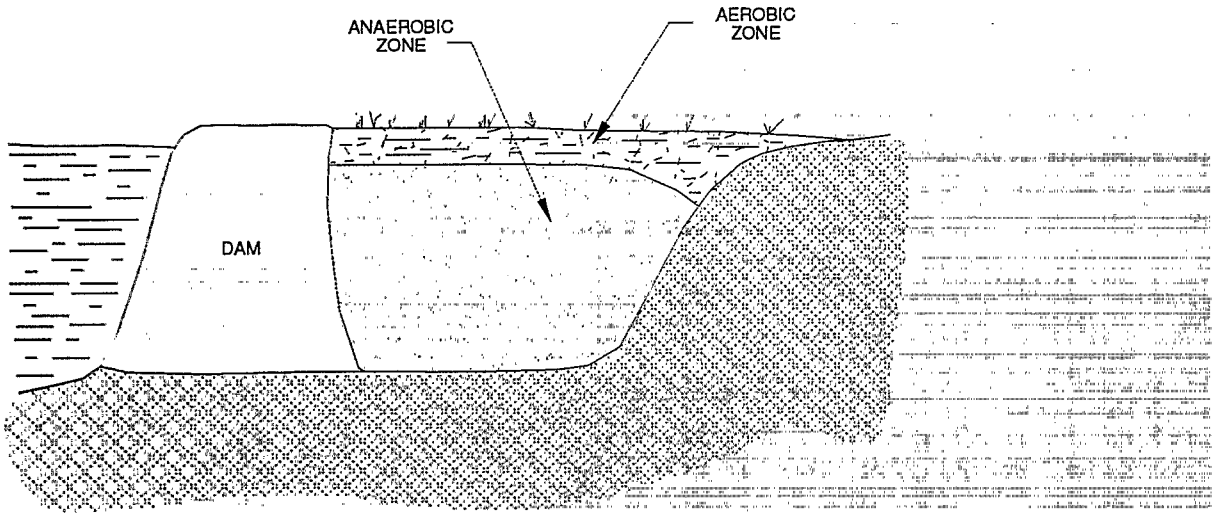
TECHNOLOGY DESCRIPTION:

The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in a manmade wetland ecosystem (see figure below) to accumulate and remove metals and other contaminants from influent waters. Although 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 by filtration, ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. In filtration, metal flocculates and metals that are adsorbed onto fine sediment particles settle in quiescent ponds or are filtered out as the water percolates through the soil or the plant canopy. 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 removing metals as hydroxides and sulfides.

WASTE APPLICABILITY:

The wetlands-based treatment process has been developed for acid mine drainage from 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:

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 near Idaho Springs, Colorado. Study results have shown that removal efficiency of heavy metals can approach the removal efficiency of chemical precipitation treatment plants. Some of the optimum results from the 3 years of operation are given 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 by 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.

One final goal of this project 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 will be available from the National Technical Information Service in 1993. Currently, a copy of the manual can be purchased from BiTech Publishing (604-277-4250).

As a result of this technology's success in the SITE Emerging Technology Program, it has been selected for the Demonstration Program.

The SITE demonstration will evaluate the effectiveness of a full-scale wetland. The proposed remediation site is the Burleigh Tunnel near Silver Plume, Colorado. The Burleigh Tunnel is part of the Clear Creek/Central City Superfund site in Colorado.

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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:

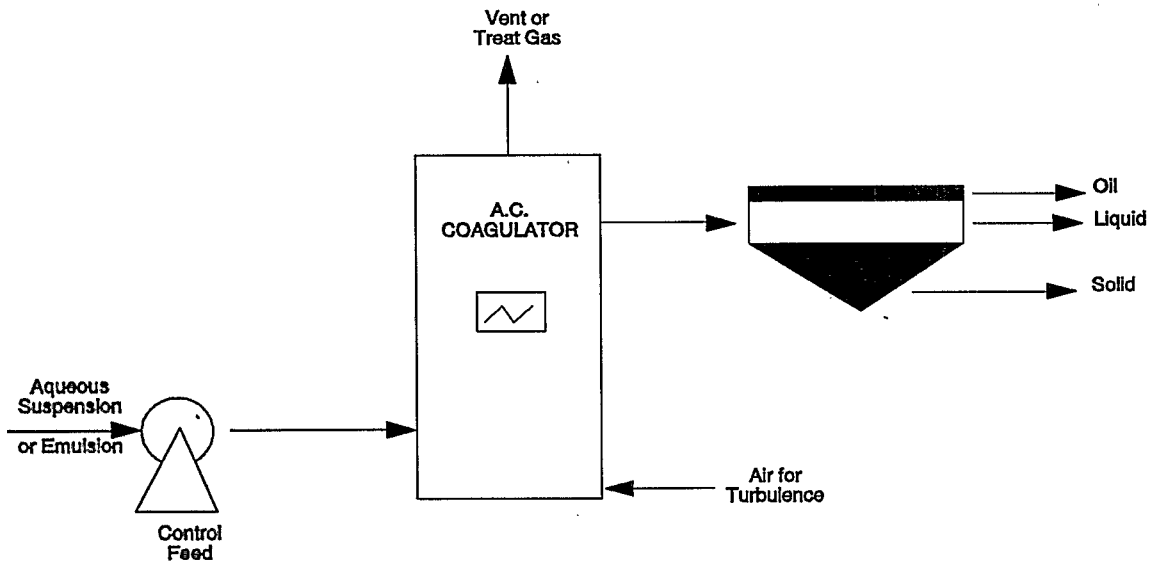
The alternating current electrocoagulation (ACE) technology offers an alternative to metal salts or polymer and polyelectrolyte addition for breaking stable emulsions and suspensions. The technology also removes certain metals and other soluble pollutants in the polishing step of effluent treatment.

Electrocoagulation introduces highly charged polyhydroxide aluminum species that prompt the flocculation of colloidal particles and destabilization of 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 can be easily integrated into a process treatment train for effluent, pretreatment, or polishing.

Coagulation and flocculation occur simultaneously within the ACE Separator™ as a result of exposure of the effluent to the electric field and dissolution of aluminum from the electrodes. This activity usually occurs within 30 seconds for most aqueous suspensions. After charge neutralization and the onset of coagulation, the suspension and emulsion may be transferred by gravity flow to the product separation step.

Product separation occurs in conventional gravity-separation, decant vessels or through pressure or vacuum filtration. Coagulation and floc-



Alternating Current Electrocoagulation (ACE)

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

culation continue until complete phase separation is achieved. Each phase (oil, water, and solid) is removed for reuse, recycling, further treatment, or disposal. Waste is removed by using surface skimming, bottom scraping, and decanting.

The 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.

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 has reduced the loadings of aqueous clay, latex, and titanium dioxide suspensions over 90 percent. Reductions exceeding 80 percent in the chemical oxygen demand and total organic carbon contents of diesel fuel-spiked slurries have been achieved. 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 been used to recover fine-grained products (latex, titanium dioxide, and edible oil solids) from industrial process streams that would otherwise have been discharged to the sewer system.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1988. The second year of laboratory-scale testing and development is complete. The final report (EPA/540/S-93/504) has 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.

ELECTROKINETICS, INC.
(Electrokinetic Remediation)

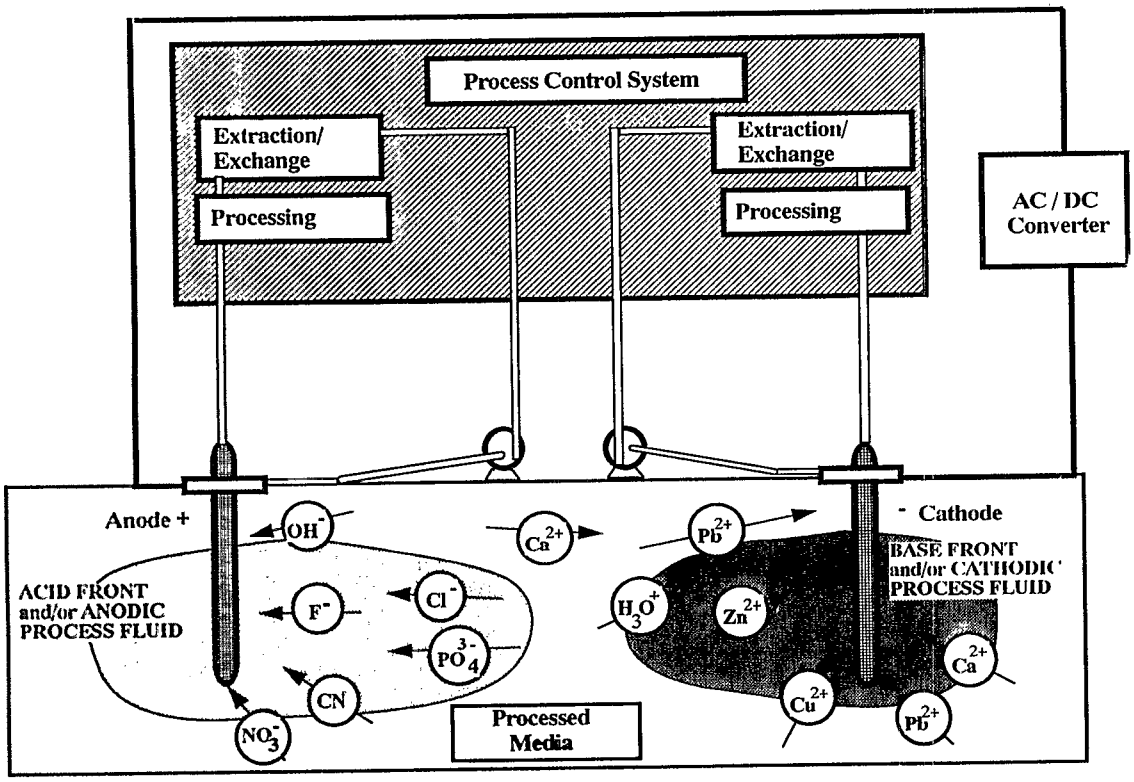
TECHNOLOGY DESCRIPTION:

Electrokinetic remediation is an in situ separation and removal technique used to extract heavy metals and organic contaminants from soils. The technology uses direct currents across electrodes and conditioning pore fluids circulating at the electrodes to remove the contaminants.

The figure below illustrates the field processing scheme, as well as the flow of ions to respective boreholes (or trenches). A conditioning pore fluid may be circulated at the electrodes. This pore fluid conditions the reactions at the electrodes based on remediation goals and specific contaminants. The contaminants are either deposited at the electrode or removed from the conditioning fluid by a purification process.

Studies indicate that an acid front is generated at the anode. This acid front eventually migrates from the anode to the cathode. The phenomena responsible for desorption of contaminants from the soil are advance of the acid front and advection due to electro-osmosis coupled with migration due to electrical gradients. The concurrent mobility of the ions and pore fluid decontaminates the soil mass. These phenomena provide an added advantage over conventional pumping techniques.

Bench-scale data indicate that the process may treat both saturated and partially saturated soils. The pore fluid supplied at the anode flushes across the soil and saturates the deposit under electrical currents, leading to temporary acidification of the treated soil. However, equilibrium conditions will be rapidly reestablished by



Electrokinetic Remediation Process

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

diffusion when the electrical potential is removed. Metallic electrodes may dissolve as a result of electrolysis, introducing corrosion products into the soil mass. However, carbon or graphite electrodes will not introduce residue into the treated soil.

WASTE APPLICABILITY:

This technique extracts heavy metals, radionuclides, and other inorganic contaminants below their solubility limit. The technique may also be used ex situ. Bench-scale tests have shown removal of 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 both 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 (ppm). 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 the removal of heavy metals, radionuclides, and organic contaminants 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 1 inch apart in a 2-ton kaolinite specimen for 4 months, at an energy cost of about $15 per ton. A second pilot-scale laboratory study treating wastes containing 5,000 μg/g of lead will be completed by October 1993. A field study is also in progress at a site with lead concentrations in soil up to 75,000 μg/g. Bench-scale treatability studies and process enhancement schemes using conditioning fluids are continuing. The technology is expected to be available for full-scale implementation in 1994 or 1995.

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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

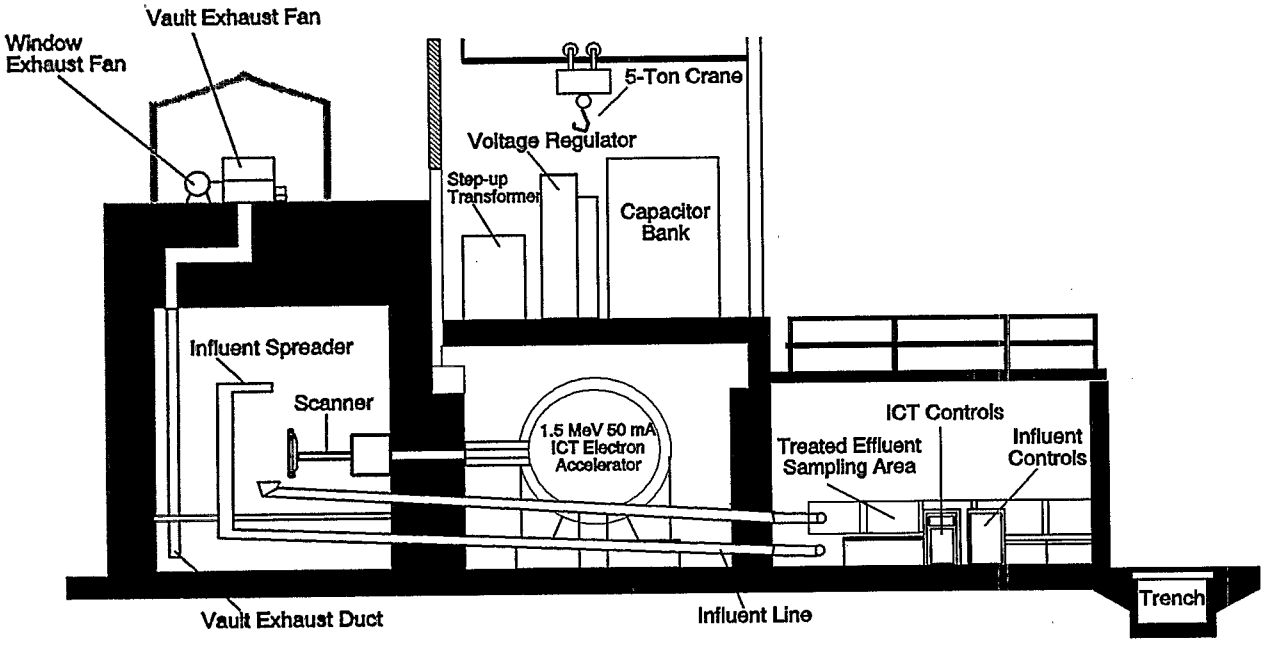
(High-Energy Electron Irradiation)

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 byproducts. The principal reaction that e^-_{aq} undergoes is electron transfer to halogen-containing compounds, which breaks the halogen-carbon bond and liberates the halogen anion (for example, 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 are formed at very low concentrations in some cases. These compounds are biodegradable end products.

In the electron beam treatment process, electricity is used to generate a high voltage (1.5 megavolts [MeV]) and 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 as it falls through the beam. 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. The facility is equipped to handle tank trucks carrying up to



Electron Beam Research Facility

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

6,000 gallons of waste. The figure on the previous page is a schematic of the Electron Beam Research Facility in Miami, Florida.

WASTE APPLICABILITY:

This system has been found to effectively treat a large number of common organic chemicals. These include (1) trihalomethanes (such as chloroform), which are found in chlorinated drinking water; (2) chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromochloropropane, hexachlorobutadiene, and hexachloroethane; (3) aromatics found in gasoline, including benzene, toluene, ethylbenzene and xylene; (4) chlorobenzene and dichlorobenzenes; (5) phenol; and (6) dieldrin, a persistent pesticide; (7) pentachlorophenol; and (8) polychlorinated biphenyls (PCB) and other organic compounds.

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

STATUS:

This technology 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. The reaction by-products have been determined for all six compounds. It appears, for the most part, that these compounds are converted. Trace quantities (several micrograms per liter) of formaldehyde and other low molecular weight aldehydes have been detected. Formic acid has also been detected at low concentrations; however, these compounds are not toxic at these concentrations. A final report titled "Removal of Phenol from Aqueous Solutions Using High Energy Electron Beam Irradiation" (EPA/540/F-93/509) is 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 of High Voltage Environmental Applications, Inc.

Potential demonstration sites are being sought. The demonstration is anticipated for late 1994.

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

ENERGY AND ENVIRONMENTAL ENGINEERING, INC.
(Laser-Induced Photochemical Oxidative Destruction)

TECHNOLOGY DESCRIPTION:

This technology photochemically oxidizes organic compounds in wastewater using a chemical oxidant and ultraviolet (UV) radiation from an Excimer laser. The photochemical reaction can reduce saturated concentrations of organics in water to nondetectable levels. The beam 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 groundwater and industrial wastewaters to acceptable discharge limits.

The existing system can treat a solution containing 32 parts per million of total organic carbon at a rate of 1 gallon per minute. The system consists of a photochemical reactor, where oxidation occurs, and an effluent storage tank to contain reaction products. The design of the portable, skid-mounted system depends on the chemical composition of the groundwater or wastewater being treated.

Typically, contaminated groundwater is pumped through a filter unit to remove suspended particles. Next, the filtrate is fed to the photochemical reactor and irradiated. Hydrogen peroxide (H_2O_2) is then added to provide hydroxyl radicals required for oxidation. The overall reaction is as follows:

$$C_aH_bX + [2a + 0.5(b - 1)]H_2O_2 \xrightarrow{hv} aCO_2 + [2a+(b-1)]H_2O + HX$$

where C_aH_bX represents a halogenated contaminant in the aqueous phase. Reaction products are carbon dioxide, water, and the appropriate halogen acid.

The reactor effluent is directed to a vented storage tank, where the carbon dioxide (CO_2) oxidation product is vented. An appropriate base (such as calcium carbonate [$CaCO_3$]) may be added to the storage tank to neutralize any halogenated acids.

The reaction kinetics depend on (1) contaminant concentration, (2) peroxide concentration, (3) irradiation dose, and (4) irradiation frequency.

The table below presents typical reaction times for specific levels of destruction for several toxicants.

DESTRUCTION OF TOXIC ORGANICS BY LASER-INDUCED PHOTOCHEMICAL OXIDATION

Compound	Reaction Time (hrs)	Destruction Removal Efficiency Achieved (percent)
Benzene	96	91
Benzidine	288	88
Chlorobenzene	114	98
Chlorophenol	72	100
Dichloroethene	624	88
Phenol	72	100

WASTE APPLICABILITY:

This technology treats groundwater and industrial wastewater containing organics. Destruction removal efficiencies greater than 95 percent have been obtained for chlorobenzene, chlorophenol, and phenol.

The table on the next page lists compounds destroyed by UV ozonation processes that can

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

also be treated by laser-induced photochemical oxidative destruction.

COMPOUNDS TREATED WITH UV/OXIDATION	
Ethers	Pesticides
Aromatic Amines	Benzene
Toluene	Ethylbenzene
Xylene	Citric Acid
Complexed Cyanides	Phenol
Trichloroethane	Trinitrotoluene
Polycyclic Aromatics	Trichloroethene
Dichloroethane	Dioxins
Tetrachloroethene	Methylene Chloride
Hydrazine	Dichloroethene
Cresols	Cyclonite
Polynitrophenols	Polychlorinated Biphenyls
1,4-dioxane	Ketones
Pentachlorophenol	Vinyl Chloride
Ethylenediaminetetraacetic Acid	

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1987 and has been invited to participate in the SITE Demonstration Program. A final report (EPA/540/SR-92/080) summarizing results found under the Emerging Technology Program is available from EPA.

The developer has made significant improvements on the technology. By replacing the laser with specially designed UV lamps, flows can be increased to 100 gallons per minute at a cost of about $3 per 1,000 gallons for wastewaters containing 100 ppm organics. The developer will conduct treatability studies for prospective clients and is seeking funding for a full-scale pilot system. The technology is cost-competitive with other UV-oxidation processes and carbon adsorption.

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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 (1) incinerating organic compounds and (2) 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 extract volatile organic and inorganic compounds. The 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 very 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 (ft/sec). This 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 °F, 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. This stage 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, this stage contains bed materials that absorb metal vapors, capture fine particles, and promote the 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, clean processed soil is removed from the effluent gas stream with one or two hot cyclones. The clean soil is extracted hot to prevent unreacted volatile metal species from forming. 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 (rpm) feeding-grinding device. Standard augers are simple and reliable, but they are susceptible to clogging due to compression of the feed in the auger. In this design, the auger shredder is close-coupled to the spouted bed to reduce compression and clump formation

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

during feeding. The close couple arrangement locates the tip of the auger screw several inches from the internal surface of the spouted bed, preventing the formation of soil plugs.

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 is complete. Limited shakedown testing has been performed. A 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.

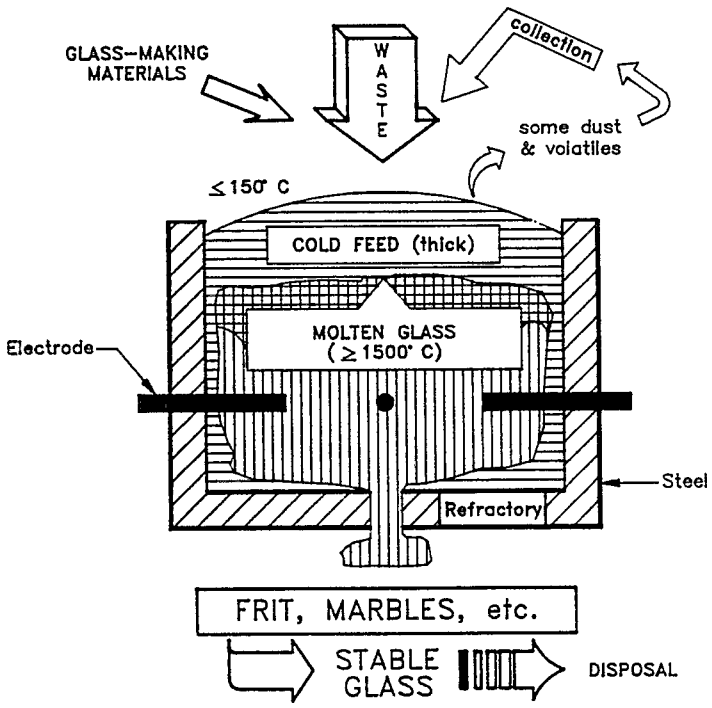
FERRO CORPORATION
(Waste Vitrification Through Electric Melting)

TECHNOLOGY DESCRIPTION:

Vitrification technology converts contaminated soils, sediments, and sludges into oxide glasses, rendering them nontoxic and suitable for landfilling as a nonhazardous material. The technology chemically bonds inorganic and toxic species into an oxide glass, changing them chemically to a nontoxic form.

Successful vitrification of soils, sediments, and sludges requires (1) the development of glass compositions tailored to the waste being treated, and (2) a 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 — can be kept molten through 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



Electric Furnace Vitrification

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

melting is a promising technology for incorporating waste into a stable glass.

WASTE APPLICABILITY:

Vitrification stabilizes inorganic components found in hazardous waste. In addition, the high temperature involved in glass production (about 1,500 °C) decomposes organic material in the waste to relatively harmless components, which can be removed easily 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 the toxicity characteristic leaching procedure testing. Ten independent replicates of the preferred composition produced the following results:

	TCLP analyte concentration, ppm	
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 it 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'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.

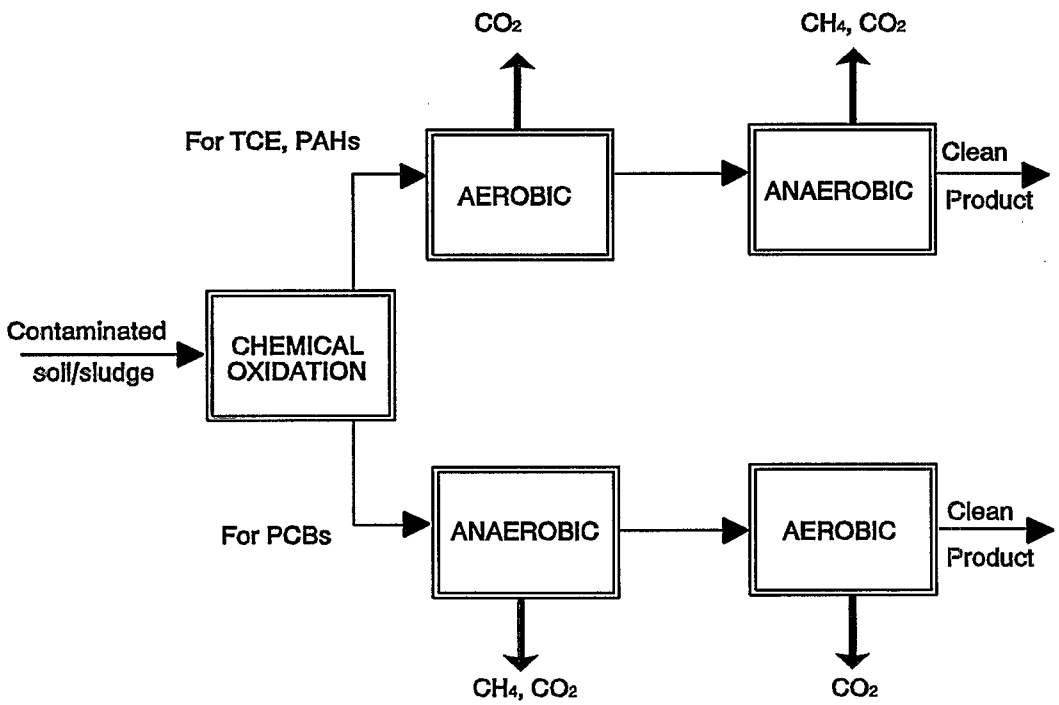
INSTITUTE OF GAS TECHNOLOGY
(Chemical and Biological Treatment)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology's (IGT) Chemical and Biological Treatment (CBT) process remediates sludges and soils contaminated with organic compounds. The treatment system combines two remedial techniques: (1) chemical oxidation as pretreatment, and (2) biological treatment using aerobic and anaerobic biosystems either in sequence or alone, depending on the waste. The CBT process uses mild chemical treatment to produce intermediates that are biologically degraded, reducing both the cost and risk associated with a more severe chemical treatment process.

In chemical treatment and oxidation, metal salts and hydrogen peroxide are used to produce the hydroxyl radical, a powerful oxidizer. The reaction of the hydroxyl radical with organic contaminants causes chain reactions, resulting in modification and degradation of organics to biodegradable and environmentally benign products. These products are later destroyed in the biological treatment step.

Wet oxidation and ozone (O_3) are other commonly used chemical oxidation techniques that will be evaluated and compared with Fenton's reagent. Wet oxidation is a thermal treatment process in which slurry consisting of water and carbonaceous material is heated to temperatures ranging from 250 to 650 °F under air or oxygen pressure. Depending on the temperature, residence time, and the type of compounds being oxidized, carbonaceous material is either oxidized to carbon dioxide and water, or modified for subsequent biodegradation. The CBT process will be compared with wet oxidation or ozonation with and without chemical treatment.



Chemical and Biological Treatment (CBT) Process

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

Special pressure vessels, which can withstand high temperatures and pressures, are used in these studies.

The figure on the previous page shows some of the options available for application. The contaminated material is treated with a chemical reagent that degrades the organopollutants to carbon dioxide, water, and more biodegradable, partially-oxidized intermediates. Additional treatment with O_3 and mild wet oxidation may increase the efficiency of the pretreatment oxidation process. In the second stage of the CBT process, biological systems are used to 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.

WASTE APPLICABILITY:

The CBT process can be applied to soils containing high and low waste concentrations that would typically inhibit bioremediation. 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 aromatics. Applicable matrices include soil, sludge, groundwater, and surface water.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1991. This testing included laboratory-scale evaluation of important operational parameters for applying the technology to soils contaminated with polychlorinated biphenyls (PCB). Results indicate that this technology can treat PCBs, with some modifications to the original treatment protocol.

IGT's CBT technology continues to be successfully applied to polynuclear aromatic hydrocarbon (PAH)-contaminated soils. Two field tests are planned under other non-EPA supported programs. Both land-treatment-based and bioslurry field tests have been planned. The CBT process consistently outperforms conventional bioremediation, especially with multi-ring (4 to 6) PAH compounds. The CBT process increases both the rate and extent of removal of contamination from various types of soils. The project was completed in June 1993; the final report is due in early 1994.

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

INSTITUTE OF GAS TECHNOLOGY
(Fluid Extraction-Biological Degradation Process)

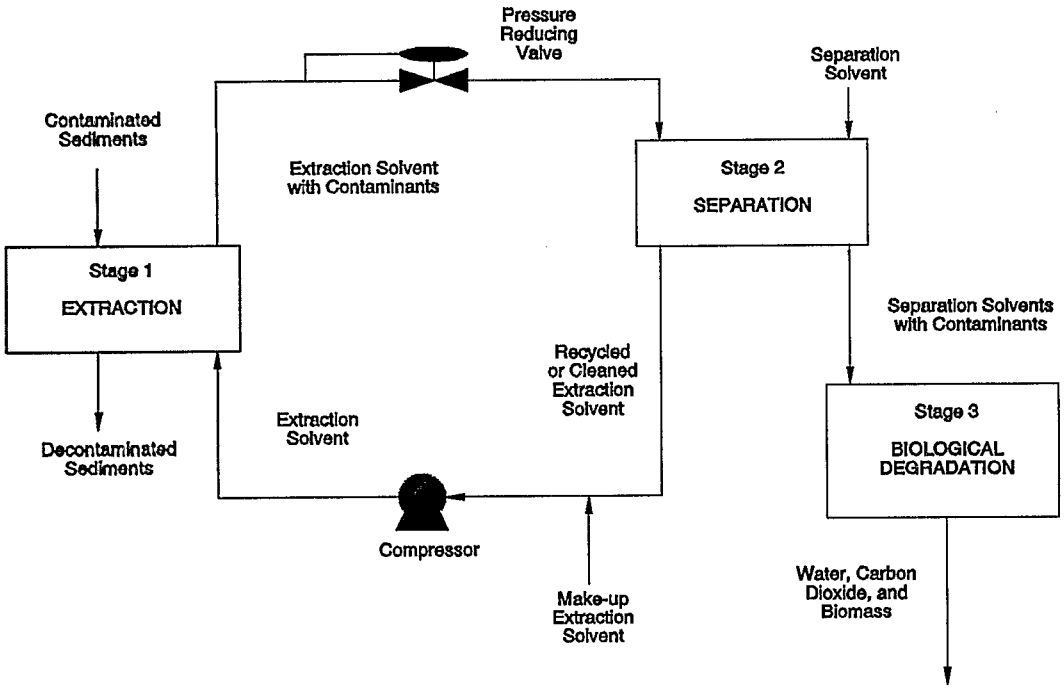
TECHNOLOGY DESCRIPTION:

The fluid extraction-biological degradation (FEBD) process is a three-step process that remediates organic contaminants in soil (see figure below). It 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 degrades the pollutants to 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.

Following extraction, organic contaminants are transferred to a biologically-compatible separation solvent such as water or a water-methanol mixture. The separation solvent is sent to the final stage of the process, where bacteria degrade the waste to carbon dioxide and water. Clean extraction solvent is recycled to the extraction stage.

Biological degradation occurs in aboveground 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. Various bioreactor configurations or types may be applied 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 is continuing on the use of bound activated carbon in a carrier system to execute the separation step. This should allow high pressure conditions to be maintained in the fluid extraction step, enhancing the extraction efficiency and decreasing extraction time. This 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 steps 1 and 2.

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 developer 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 2- to 6-ring compounds, were removed from the soils.

Biological conversion of the measurable PAHs was obtained in both batch-fed and continuously-fed constantly stirred tank reactor. 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 4- to 6-ring compounds, were susceptible to biological removal.

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. A final report will be available in late 1993.

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

IT CORPORATION
(Batch Steam Distillation and Metal Extraction)

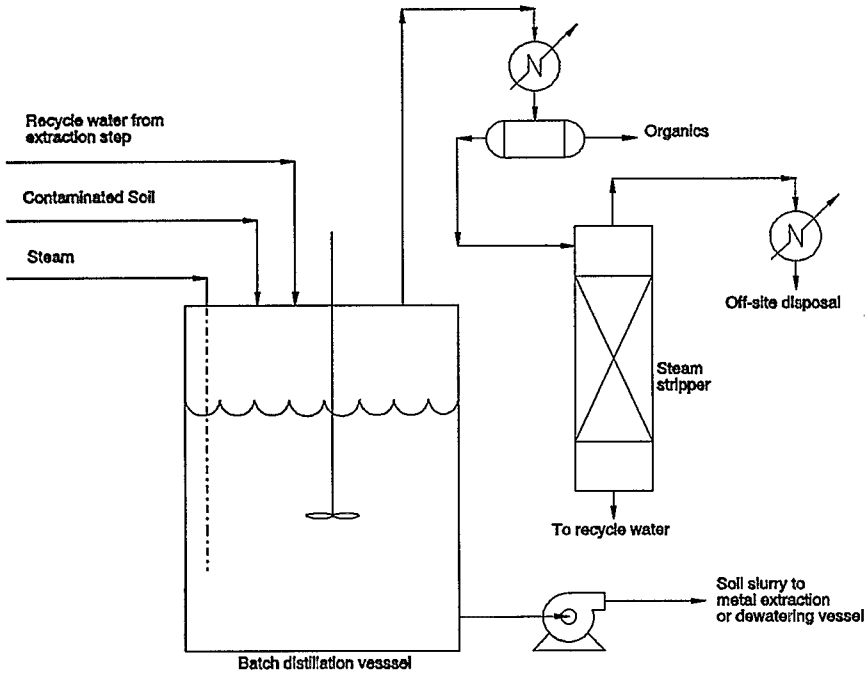
TECHNOLOGY DESCRIPTION:

The batch steam distillation and metal extraction treatment process is a two-stage system that treats soils contaminated with organics and inorganics. This technology 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 °C. This vaporizes volatile organic compounds (VOC) and an amount of steam equal to 5 to 10 percent of the slurry volume is produced (see figure below). Resulting vapors are condensed and decanted to separate organic contaminants from the aqueous phase. Condensed water from the 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. 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 depends on the size of equipment used and batch cycle times.



Batch Steam Distillation Step

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

Estimated treatment costs per ton, including capital recovery, for the two steps of this treatment 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 contaminated with organics, inorganics, and heavy metals.

STATUS:

This technology 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. Removal of benzene, toluene, ethylbenzene, and xylene was greater than 99 percent. 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 (TCLP) 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)

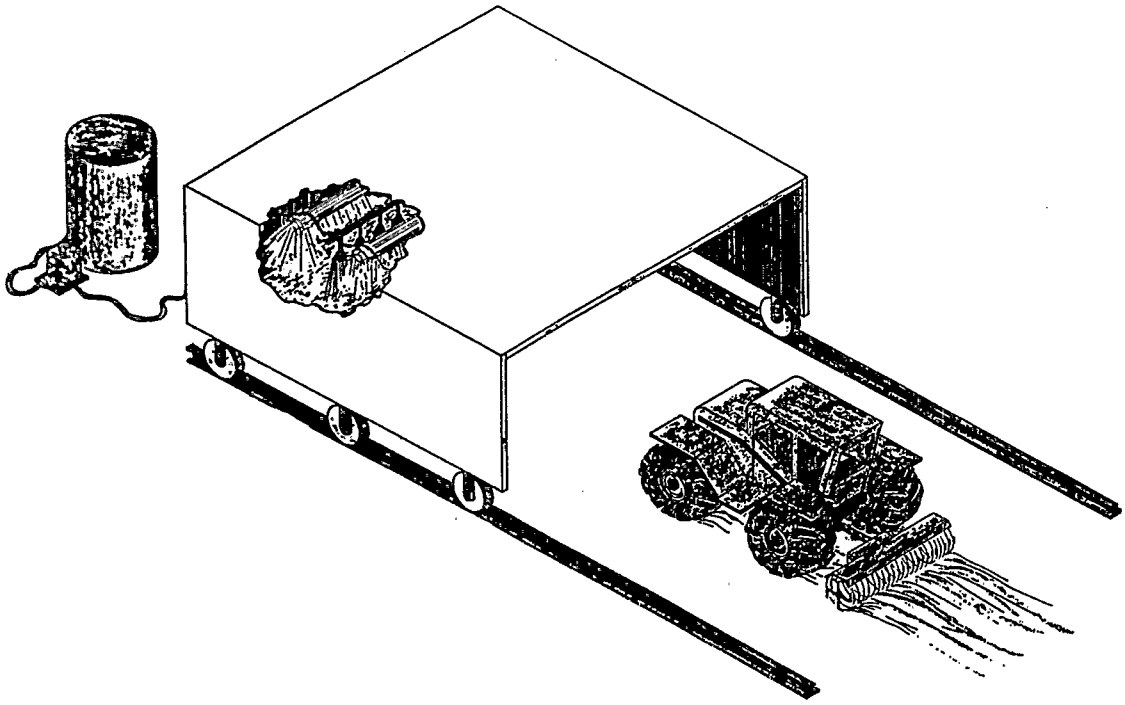
TECHNOLOGY DESCRIPTION:

This technology is a two-stage, in situ photolytic and biological detoxification process for shallow soil contamination. The first step in the process is to degrade the organic contaminants using ultraviolet (UV) radiation. The rate of photolytic degradation 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. Biodegradation, the second step, is then used to further destroy organic contaminants and detoxify the soil.

When sunlight is used for 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 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 by further tilling of the soil.

When these techniques are applied to soils with deep contamination, excavated soil is treated in a specially constructed shallow treatment basin that meets the requirements of the Resource Conservation and Recovery Act (RCRA).

The only treatment residuals are soil contaminated with surfactants and the end metabolites of the biodegradation processes. The end



Photolytic Degradation Process Using UV Lights

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

metabolites depend on the original contaminants. The surfactants are common materials used in agricultural formulations.

WASTE APPLICABILITY:

This technology 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 soils contaminated with either PCBs or dioxin have shown that the effectiveness of surface irradiation to destroy TCDDs or PCBs is strongly influenced by the type of soil. Early tests on sandy soils had shown 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.

Additional testing was conducted using 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 the biodegradability of PCBs 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.
- Biphenyl was a more efficient inducer of PCB degradation than 4-bromobiphenyl in the untreated soil.
- Surfactant treatment may have inhibited microbial activity as evidenced by the high total organic carbon and low pH of the treated soil.

Isolation and enrichment techniques have made it possible to isolate microorganisms capable of biodegrading PCBs in contaminated soil.

The PCB pilot-scale test has received a Toxic Substances Control Act permit for soil brought to IT Corporation's Environmental Technology Development Center in Oak Ridge, Tennessee. IT Corporation has applied for a RCRA research, development and demonstration permit to conduct a pilot test on soil contaminated with TCDD.

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

MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(Photocatalytic Water Treatment)

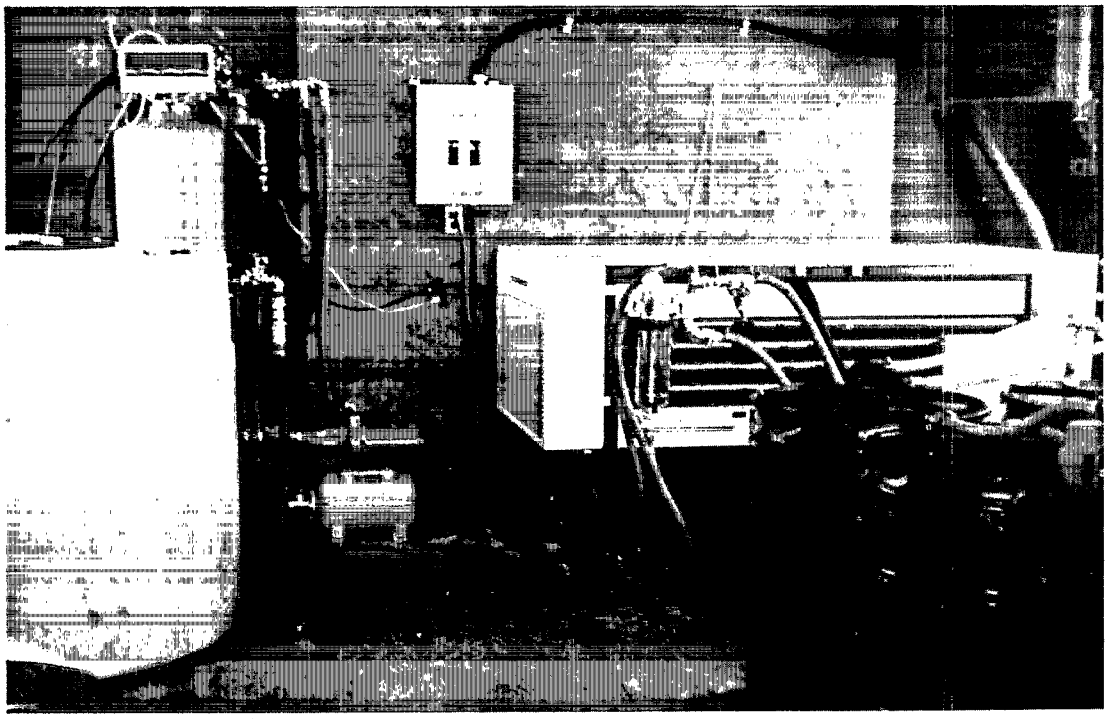
TECHNOLOGY DESCRIPTION:

The Matrix Photocatalytic Inc. (Matrix) (formerly Nutech Environmental) photocatalytic oxidation system, shown below, efficiently removes and destroys dissolved organic contaminants from water in a solid state, continuous flow process at ambient temperatures. The titanium dioxide (TiO_2) semiconductor catalyst, when excited by light, generates hydroxyl radicals which break the carbon bonds of hazardous organic compounds.

The system, when given sufficient time, converts most 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. Total organic carbon removal takes somewhat longer, as it depends on the other organic molecules present and their molecular weights.

WASTE APPLICABILITY:

Matrix's technology was initially designed to destroy organic pollutants or to remove total organic carbon in drinking water, groundwater, and plant process water. Organic pollutants such as PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones, aldehydes, and amines can be destroyed by this technology. Inorganic



10-gpm TiO_2 Photocatalytic System Treating BTEX in Water

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

pollutants such as, but not limited to, cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion, sulphate ion, and nitrate ions, respectively.

The technology can treat a wide range of concentrations of organic pollutants in industrial wastewater. It can be applied to the ultrapure water industry and the drinking water industry. It can also be used for groundwater remediation.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in May 1991. Technology advances since that time include the following:

- The technology has treated effluents with contaminants as high as 1,000 parts per million (ppm), and has achieved effluent qualities as low as 5 parts per trillion.
- Performance has doubled over 1992 standards and is expected to be doubled again by 1994.
- Several 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}).
- Modular systems have been developed for high flow rates with capacity increments of 5 gallons per minute. Capital costs, operating costs, and maintenance requirements are being developed.
- Matrix has successfully designed and field tested support systems for unattended operation, with chemical-free pretreatment.
- The technology has treated highly turbid effluents and dyes in plant operations.

The research was completed in September 1993; the final report is due in 1994.

FOR FURTHER INFORMATION:

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

MEMBRANE TECHNOLOGY AND RESEARCH, INC.
(VaporSep™ Membrane Process)

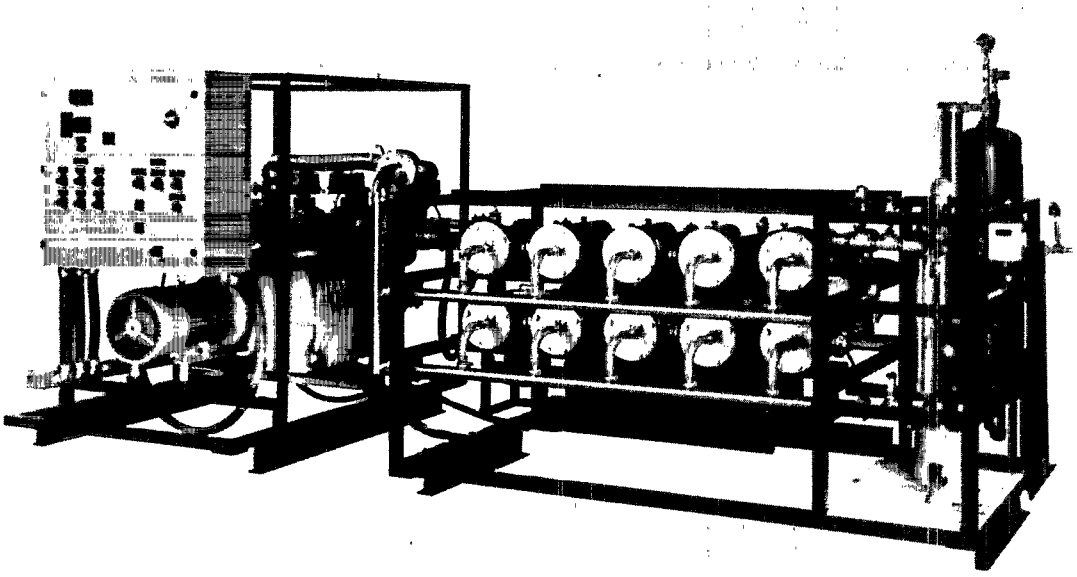
TECHNOLOGY DESCRIPTION:

VaporSep™ systems, developed by Membrane Technology and Research, Inc. (MTR), use synthetic polymer membranes to remove organic vapors from contaminated air streams. 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 the 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.

To provide the driving force for permeation, a lower vapor pressure is maintained on the permeate side of the membrane than on the feed side. This pressure difference can be obtained by compressing the feed stream, by using a vacuum pump on the permeate stream, or both.

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 technology 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 are (1) reduction of process vent emissions, such as those regulated by EPA's source performance standards for the synthetic organic chemical manufacturing industry; (2) treatment of air stripper exhaust before discharge to the atmosphere; and (3) recovery of CFCs and hydrochlorofluorocarbons. Between 90 and 99 percent of the organic vapor is removed depending on the class of organic compound and the system design.

No secondary wastes are produced, and the volume of organic condensate is small. 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 scale, achieved removal efficiencies of over 99.5 percent for selected organic compounds. Eighteen systems have been successfully installed in numerous industrial processes including CFC and halocarbon recovery from process vents and transfer operations, CFC recovery from refrigeration systems, vinyl chloride monomer recovery from polyvinyl chloride manufacturing operations, and CFC-12/ethylene oxide recovery from sterilizer emissions. A VaporSep™ system to treat an air stream from a soil vacuum extraction operation is being evaluated.

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

NEW JERSEY INSTITUTE OF TECHNOLOGY
(GHEA Associates Process)

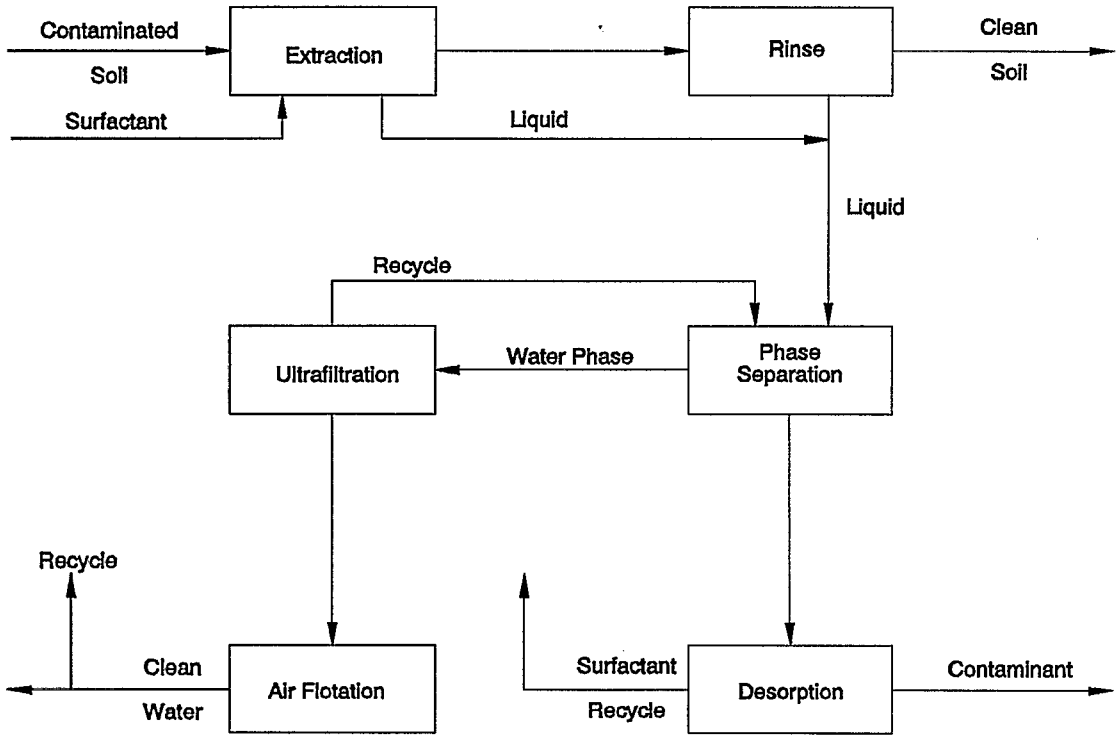
TECHNOLOGY DESCRIPTION:

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 excavated, washed, and rinsed to produce clean soil. Wash and rinse liquids are combined and treated to separate surfactants and contaminants from the water. Contaminants are separated from the surfactants by desorption and are 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 to be (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 process results in 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



GHEA Process for Soil Washing

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

include both organics and heavy metals, non-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 been conducted. The final report will be available in late 1993.

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SUMMARY OF TREATABILITY TEST RESULTS			
MATRIX	UNTREATED SAMPLE	TREATED SAMPLE	PERCENT REMOVAL
Volatile Organic Compounds (VOC): TCE; 1,2 DCE; Benzene; Toluene			
Soil, ppm	20.13	0.05	99.7%
Water, 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 TECHNOLOGY COMPANY
(Metals Immobilization and Decontamination of Aggregate Solids)

TECHNOLOGY DESCRIPTION:

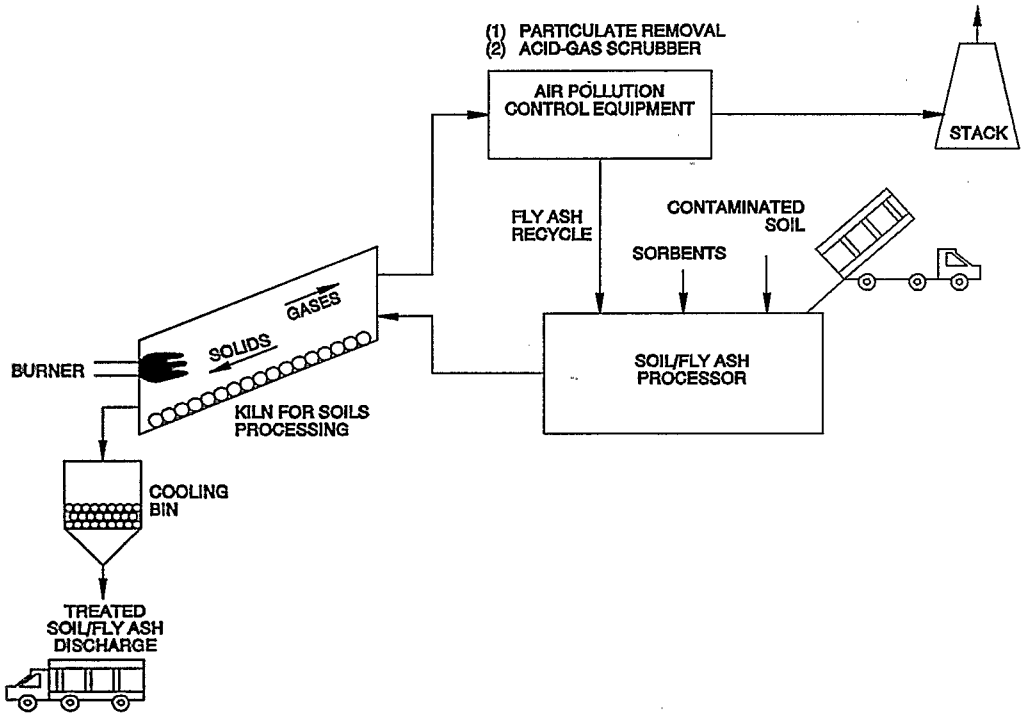
PSI Technology Company has developed a metals immobilization and decontamination of aggregate solids (MeIDAS) treatment process (see figure below). The technology involves a modified incineration process in which high temperatures destroy organic contaminants and concentrate metals into fly ash. The 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). A sorbent fraction of less than 5 percent by weight of the soil is needed for the MeIDAS process.

Standard air pollution control devices are used to 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.

This technology is particularly applicable to wastes contaminated with volatile metals in combination with a complex mixture of organics of low volatility. Possible applications of the



MeIDAS Process

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

MeIDAS process include battery waste sites and urban sites containing lead paint or leaded gasoline, or a site 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. The final report is being prepared.

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

PURUS, INC.
(Photolytic Oxidation Process)

TECHNOLOGY DESCRIPTION:

This process uses photolytic oxidation to destroy volatile organic compounds (VOC) in soil and groundwater. The system 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, where the UV treatment converts the VOCs into less hazardous compounds.

Direct photolysis occurs when the contaminants absorb sufficient UV light energy, transforming electrons to higher energy states and breaking molecular bonds (see figure below). Hydroxyl radicals 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 the ability to shift the UV spectral output to optimize the photolysis.

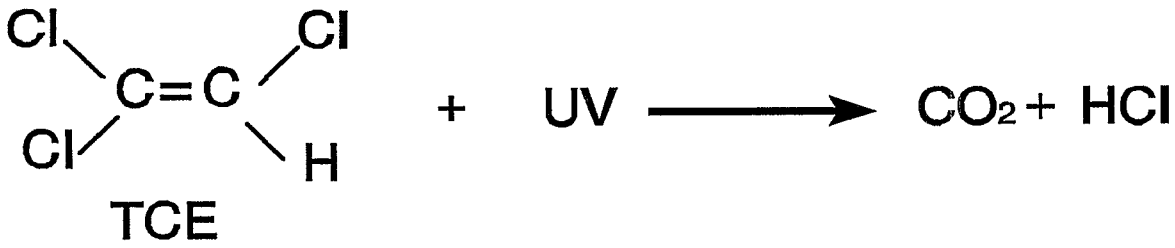
The process uses vacuum extraction or air stripping to volatilize VOCs from soils or groundwater, respectively. VOCs then enter the photolysis reactor, where a xenon flashlamp generates UV light. The plasma is produced by pulse discharge of electrical energy across two electrodes in the lamp. Ninety-nine 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, Inc. (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 being investigated.

STATUS:

This technology 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 (EPA Region 9). The site contains soil zones highly contaminated with TCE. A vacuum extraction system delivered contaminated air to the Purus unit at air flows of up to 500 cubic feet per minute (cfm). Initial concentrations of TCE in the air were approximately 250 parts per million



Purus Advanced UV Photolysis

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

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 are shown in the table below. The Project Report (EPA/540/R-93/516) and the Project Summary (EPA/540/SR-93/516) 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. Very rapid and efficient destruction was observed for TCE, PCE, and DCE. Nevertheless, some VOCs would require either photosensitization or an even lower-wavelength light source for rapid photolysis.

TCE removal resulted in undesirable intermediates. The main product (greater than 85 percent) from the chain photo-oxidation of TCE is dichloroacetyl chloride (DCAC). Further oxidation of DCAC is about 100 times slower than the photolysis of TCE and forms dichlorocarbonyl (DCC) in about 20 percent yield. At this level of treatment, the DCC concentration may be excessive, requiring additional treatment. Further studies should focus on the effectiveness of dry or wet scrubbers for removing acidic photo-oxidation products, developing thermal or other methods for posttreatment of products such as DCAC, and 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 Department of Energy Savannah River site.

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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

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

J.R. SIMPLOT COMPANY
(Anaerobic Biological Process)

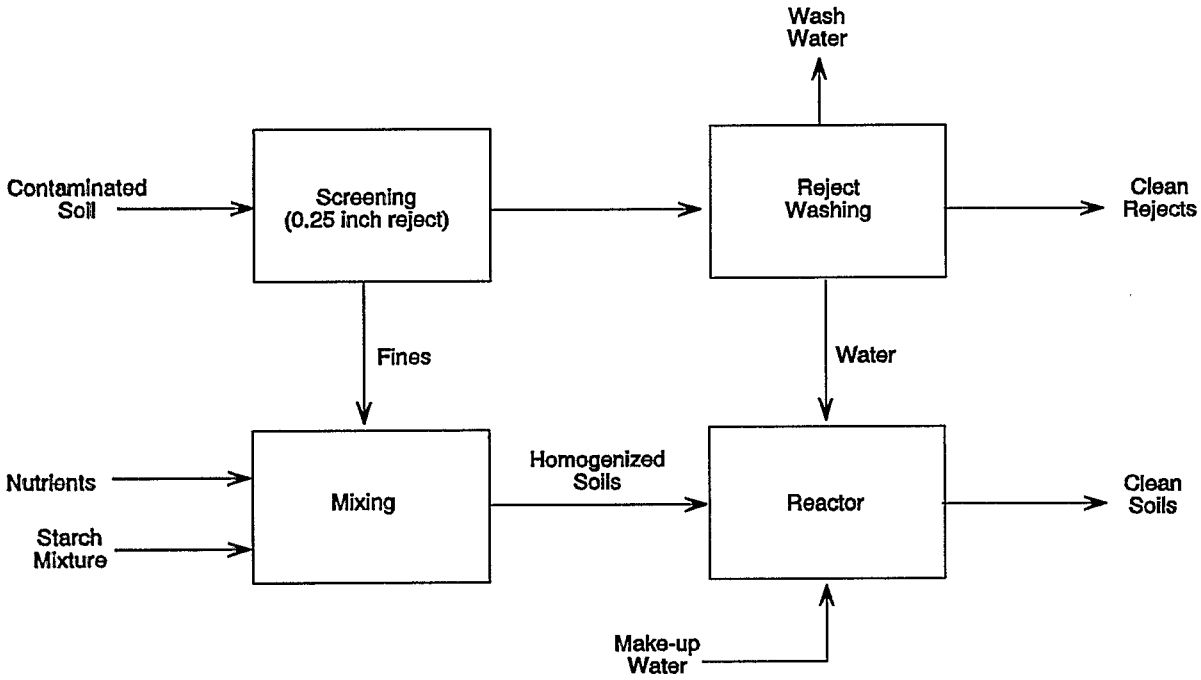
TECHNOLOGY DESCRIPTION:

This technology bioremediates soils and sludges contaminated with nitroaromatics. Nitroaromatics have become serious environmental contaminants at military locations nationwide. Examples of nitroaromatics include nitrotoluenes, used as explosives, and pesticides.

Pilot-scale treatment units (see figure) consist of simple plastic or fiberglass vessels that contain static soil slurries (50 percent soil and 50 percent water). The units are scaled in steps up to about 50 cubic meters of soil. The biodegradation process involves adding starch to flooded soils and sludges. Anaerobic, starch-degrading bacteria may also be introduced. After anaerobic conditions are established [at Eh equal to -200 millivolts (mV)], an anaerobic microbial consortium is injected to destroy the nitroaromatics. In some soils, inoculations are not necessary, because native consortia develop quickly.

Recently, it was discovered that anaerobic microbial mixtures can completely destroy many chemicals, such as chloroform, benzene, and chlorophenols, that had been considered nonbiodegradable under such conditions. Research indicates that these systems can completely mineralize nitroaromatic pollutants.

Anaerobic microbial mixtures have been developed for both the pesticide dinoseb (2-sec-butyl-4,6-dinitrophenol) and trinitrotoluene (TNT). These mixtures completely degrade their target molecules to simple nonaromatic products within a few days forming reduced intermediates (such



Pilot-Scale Treatment Unit

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

as aminonitrotoluenes) and hydroxylated intermediates (such as methylphlorglucinol and p-cresol). The microbial consortia function at Eh's of -200 mV or more.

WASTE APPLICABILITY:

This technology is designed to treat soils contaminated with nitroaromatic pollutants. Anaerobic microbial mixtures have been developed for the pesticide dinoseb and for TNT. These pollutants can be reduced to less than 1 part per million in most soils.

STATUS:

This technology 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 dinoseb-contaminated soils from a site in Idaho, with the largest reactors holding 4 cubic meters (m^3) of soil. With three replicates per treatment, up to 12 m^3 of soil were treated at one time. The procedure's efficacy was confirmed at a small scale (50 kilograms), using dinoseb-contaminated soil from a spill site in Washington state.

During bench-scale tests, soil contaminated with 2 percent TNT was treated to below detectable limits. Degradation intermediates were identified using gas chromatograph/mass spectrograph techniques.

Based on these results, this technology was accepted into the SITE Demonstration Program in winter 1992.

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

TRINITY ENVIRONMENTAL TECHNOLOGIES, INC.
(PCB- and Organochlorine-Contaminated Soil Detoxification)

TECHNOLOGY DESCRIPTION:

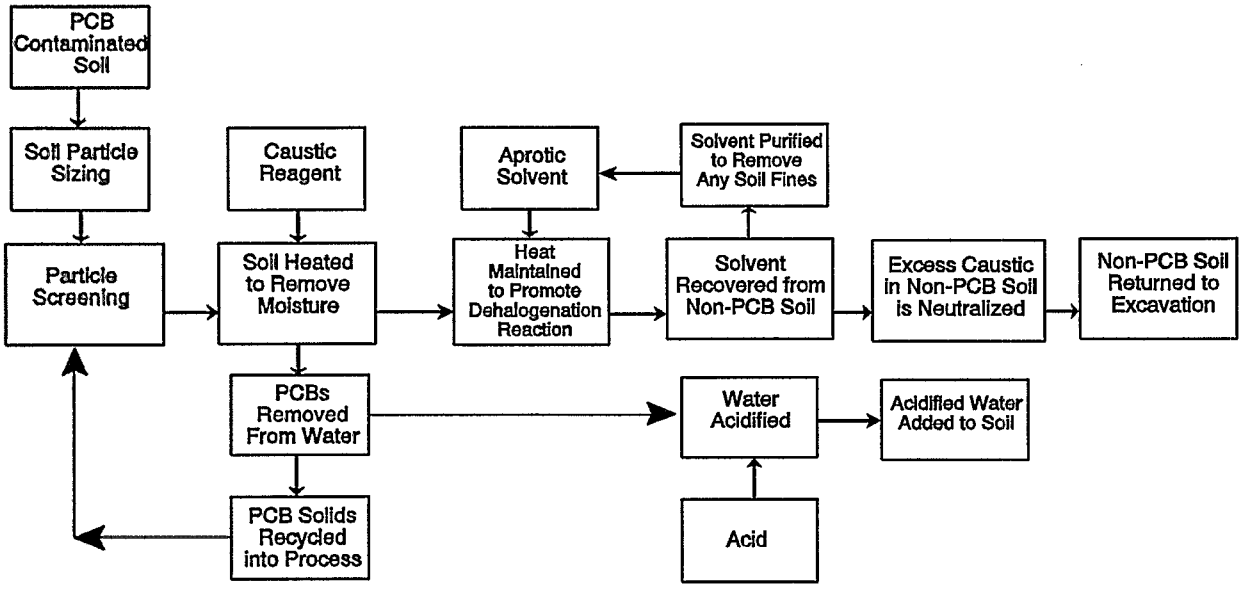
This technology uses an aprotic solvent, other reagents, and heat to dehalogenate polychlorinated biphenyls (PCB) to inert biphenyl and chloride salts. The process begins by sizing the solid material to allow better contact between the reagents and PCBs. In a continuous flow reactor, the soils are heated to drive off excess water. Then reagents are 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 assure that the physical structure of the soil is not appreciably changed.

Gas chromatography/mass spectroscopy analyses of processed PCB materials showed that the process produces no toxic or hazardous products. A chlorine balance confirmed that PCBs are completely dehalogenated. To further confirm chemical dehalogenation, inorganic and total chloride analyses were also used. The average total chloride recovery for treated soils was 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 been used to treat 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



PCB Soil Detoxification Process

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

by this technology. The process can treat many different solid and sludge-type materials, provided that they are compatible with the solvent.

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 in 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 being conducted 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 utilizes 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 is anticipated by December 1993.

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

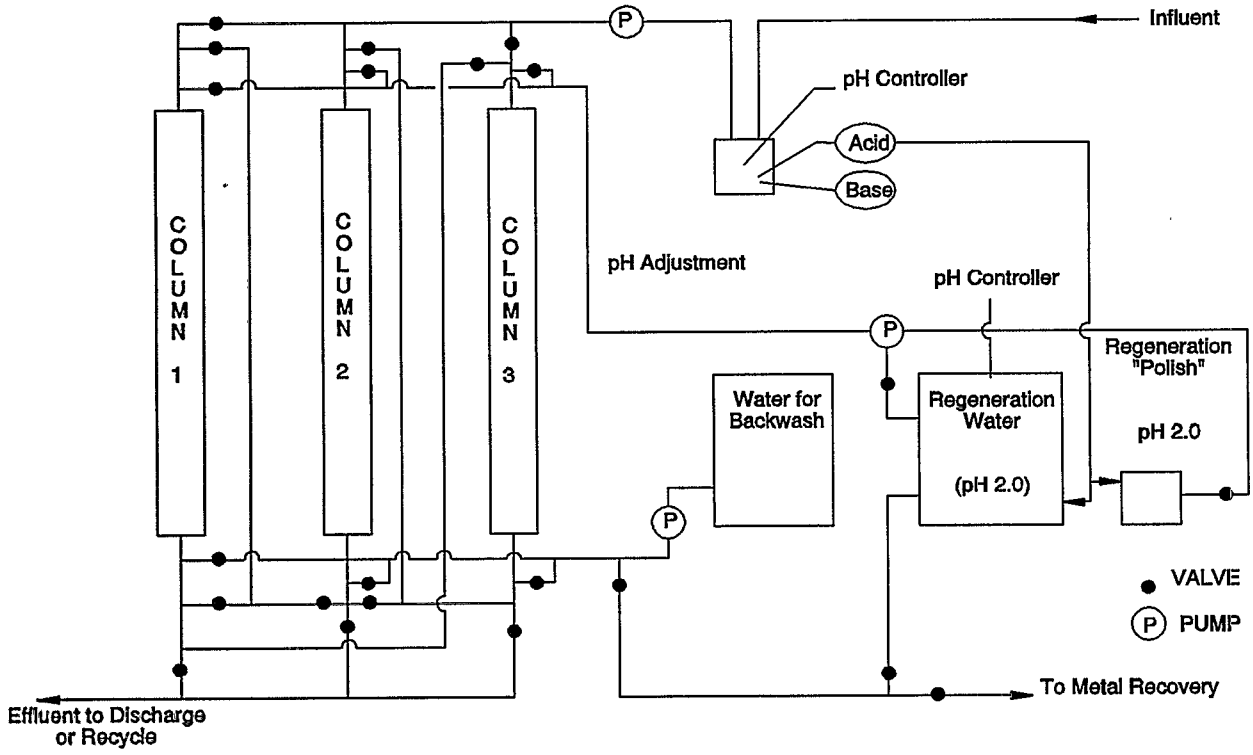
UNIVERSITY OF WASHINGTON
(Adsorptive Filtration)

TECHNOLOGY DESCRIPTION:

This technology uses adsorptive filtration to remove inorganic contaminants (metals) from the liquid phase. 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). A metal-containing solution is adjusted to a pH of 9 to 10 and passed through the column, where the iron-coated sand grains act simultaneously as a filter and adsorbent. When the filtration capacity is reached (indicated by particulate breakthrough or attainment of maximum allowable headloss), 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 using a pH-induced desorption process.

Sand can be coated using a few different procedures. All involve using an iron nitrate or iron chloride salt, (as the source of the iron), sand, heat, and, in some cases, base (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. There has been no apparent loss of 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 advantages this technology has over conventional treatment technologies are that it (1) acts as a filter to remove both dissolved and suspended contaminant from the waste stream, (2) removes a variety of complex metals, (3) works in



Adsorptive Filtration Treatment System

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

the presence of high concentrations of background ions, and (4) removes anions.

WASTE APPLICABILITY:

This process removes inorganic contaminants, mainly 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) have been 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, indicating 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 removal of copper have not been analyzed yet. At a flow rate yielding a 2-minute retention time, it 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 copper 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 and project summary have been accepted by EPA and will be available in the near future.

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TECHNOLOGY DEVELOPER CONTACT:
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Department of Civil Engineering
Seattle, WA 98195
206-543-7645

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

VORTEC CORPORATION
(Oxidation and Vitrification Process)

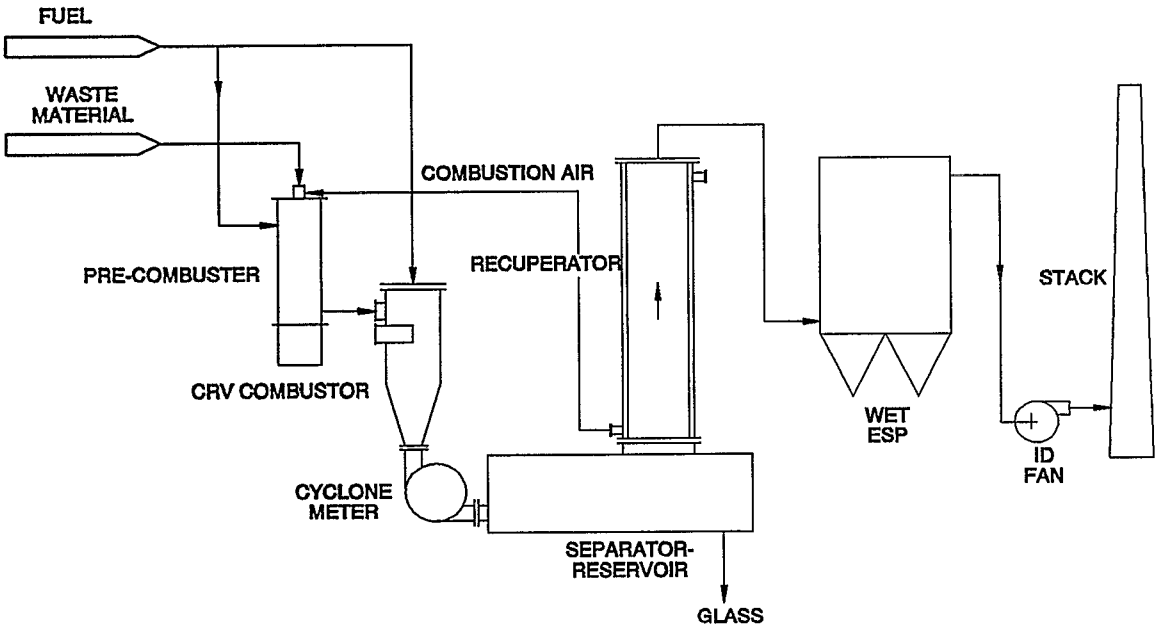
TECHNOLOGY DESCRIPTION:

Vortec Corporation (Vortec) has created an oxidation and vitrification process for remediation of soils, sediments, sludges, and mill tailings that have organic, inorganic, and heavy metal contamination. The system can oxidize and vitrify materials introduced as slurries, thus enabling waste oils to be mixed with hazardous soils.

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) an upstream material handling, processing, storage, and feed subsystem; (3) a vitrified product separation and reservoir assembly; (4) a waste heat recovery air preheater (recuperator); (5) a gas cleanup subsystem; and (6) a vitrified product handling system.

The Vortec CMS is the primary thermal processing system and consists of three major assemblies: (1) a precombustor, (2) an in-flight suspension preheater, and (3) a cyclone melter. As the first step in the process, contaminated soil (in slurry or dry form) is introduced into the precombustor where heating and oxidation of the waste material begin. The precombustor is a vertical vortex combustor that provides sufficient residence time to vaporize water and to initiate oxidation of organics before the materials melt. The suspension preheater, a counter rotating vortex (CRV) combustor, provides suspension preheating of the materials, secondary combustion of volatiles emitted from the precombustor, and combustion of auxiliary fuel introduced directly into the CRV combustor. The average temperature of materials leaving the CRV combustion chamber is between 2,200 and 2,700 °F.

The preheated solid materials exiting the CRV combustor enter the cyclone melter, where they are separated to the chamber walls to form a molten glass product. The vitrified, molten glass product and the exhaust gases exit the



Vortec Oxidation and Vitrification Process

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

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 a slag tap and is delivered to a water quench assembly for subsequent disposal.

Unique features of the Vortec oxidation and vitrification process include the following:

- Processes solid waste contaminated with both organic and heavy metal contaminants
- Uses various fuels, including gas, oil, coal and waste fuels
- Handles waste quantities ranging from 5 tons per day to more than 400 tons per day
- Recycles toxic materials collected in the air pollution control system
- 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 determine the amount and type of glass-forming additives required to produce a vitrified product. The 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. The technology has been under the development of U.S. Department of Energy 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 been designed. The pilot-scale facility was also used to process a surrogate soil spiked with compounds of arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Pilot testing using a dry, granulated feed stream was completed in June 1992, and the glass product successfully passed TCLP tests. A final report is due December 1993. Additional testing with a slurry feedstock was completed in 1993. Transporation systems are being designed for DOE mixed waste applications. Commercial demonstration of the CMS technology using contaminated soil is planned for 1994-1995. Vortec is offering commercial systems and licenses for the CMS technology.

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

WASTEWATER TECHNOLOGY CENTRE
(Cross-Flow Pervaporation System)

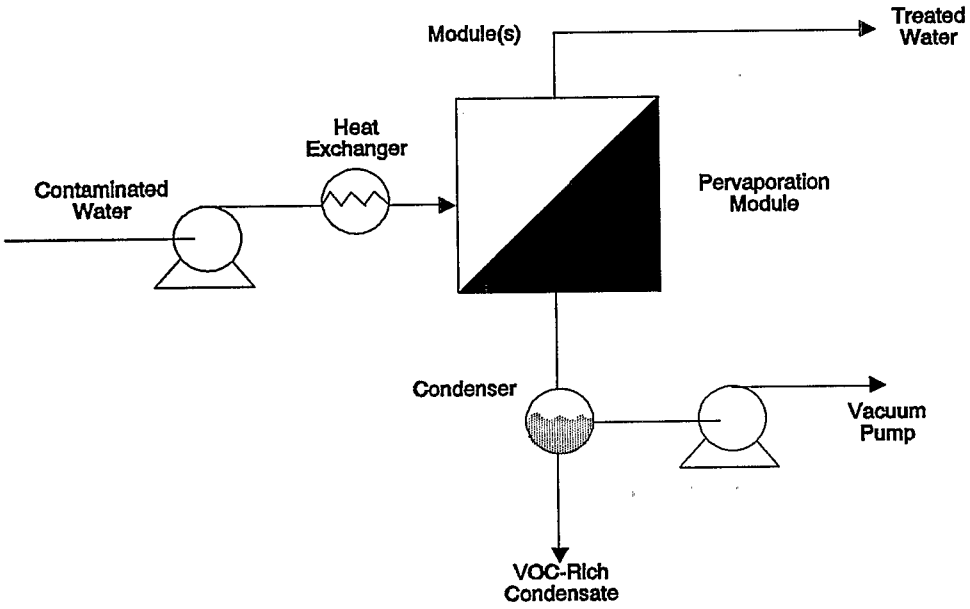
TECHNOLOGY DESCRIPTION:

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. The VOCs diffuse from the membrane-water interface through the membrane and are drawn under vacuum. Upstream of the vacuum pump, a condenser traps and contains the permeating vapors, condensing all the vapor to avoid fugitive emissions. The condensed organic vapors 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.

A pilot pervaporation system has been developed that is skid-mounted, compact, and rated for Class I, Division I, Group D environments. The membrane modules used in this system consist of beds of hollow fibers (much like a carbon bed) with well-defined alignment that results in minimal pressure drop and operating costs per 1,000 gallons of treated wastewater. The unit, shown below, can reduce VOCs by 99 percent. Removal has been demonstrated to less than 5 parts per billion (ppb). For flow rates of less than 1 gallon per minute this unit can achieve 99.999 percent removal of VOCs. This high removal capacity plus containment of fugitive emissions are the primary advantages of this technology as compared with air stripping followed by gas-phase carbon adsorption.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams (in groundwater, lagoons, leachate, and rinse water) 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.



Cross-Flow Pervaporation System

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

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. A cost comparison performed by Wastewater Technology Centre in 1992 showed that pervaporation can be competitive with air stripping and activated carbon to treat low concentrations of VOCs.

A pilot plant with a removal efficiency of 99 percent was evaluated in-house and field tested in late 1992. Based on results from the Emerging Technology Program, the cross-flow pervaporation system was invited to participate in the SITE Demonstration Program. This technology will be demonstrated under the SITE Program in late 1993 and 1994.

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

WESTERN RESEARCH INSTITUTE
[Contained Recovery of Oily Wastes (CROW™)]

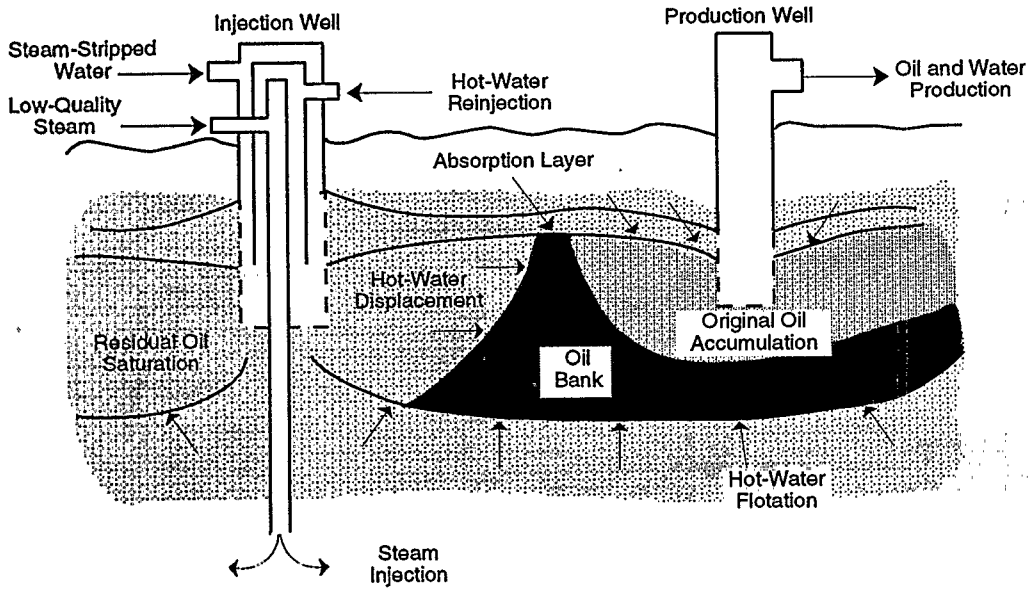
TECHNOLOGY DESCRIPTION:

The Contained Recovery of Oily Wastes (CROW™) process recovers oily wastes from the ground by adapting a technology 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 which 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



CROW™ Subsurface Development

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

liquid flotation. Excess water is treated in compliance with discharge regulations.

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 containing light to dense organic liquids, such as coal tars, pentachlorophenol solutions, creosote, and petroleum by-products.

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 will be demonstrated at the Pennsylvania Power and Light (PP&L) Brodhead Creek site in Stroudsburg, Pennsylvania. The project is now in the planning and negotiation stage.

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. 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.

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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 1993

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 Strategy	Alex Vira 617-245-6606	Ronald Lewis 513-569-7856	Groundwater, Wastewater	Not Applicable	Chlorinated and Nonchlorinated Solvents
Allis Mineral Systems (formerly Boliden Allis, Inc.), Oak Creek, WI (E03)	PYROKILN THERMAL ENCAPSULATION Process	John Lees 414-798-6211 Glenn Heian 414-762-1190	Marta Richards 513-569-7783	Soil, Sludge	Most Metallic Compounds	Nonspecific Organics
Arizona State University/ IT Corporation, Tempe, AZ (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
ART International, Inc., Denville, NJ (E03)	Low-Energy Solvent Extraction Process	Werner Steiner and Genya Mallach 201-627-7601	Jack Hubbard 513-569-7507	Soils, Sediments, Sludges	Not Applicable	PCBs, Petroleum Hydrocarbons, PAHs, Pesticides
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 P. 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	A. Bruce King 412-826-5320	Randy Parker 513-569-7271	Soil, Sediment	Heavy Metals	Nonspecific Organics
Center for Hazardous Materials Research, Pittsburgh, PA (E04)	Smelting Lead-Containing Waste	Stephen Paff 412-826-5320	Laurel Staley 513-569-7863	Solid, Lead-Containing Waste	Lead	Not Applicable
COGNIS, Inc., Santa Rosa, CA (E05)	Biological/Chemical Treatment	Dudley Eirich 707-576-6283	Naomi Barkley 513-569-7854	Soil	Heavy Metals	PAHs, Petroleum Hydrocarbons
COGNIS, Inc., Santa Rosa, CA (E05)	Chemical Treatment	Bill Fristad 707-576-6235	Michael Royer 908-321-6633	Soil, Sediment, Sludge	Heavy Metals	Not Applicable

* Solicitation Number

TABLE 4

SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Davy Research and Development, Limited, Cleveland, United Kingdom (E04)	Chemical Treatment	Graham Wightman 01-44-642-607108	Kim Lisa Kreiton 513-569-7328	Soils, Sediments	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
Energy and Environmental Research Corporation, Irvine, CA (E06)	Reactor/Filter System	Jerald Cole 714-859-8851	Dan Sullivan 908-321-6677	Gas Streams	Volatile Toxic Metals	Condensed-Phase Organics
Environmental Biotechnologies, Inc./Michigan Biotechnology Institute, Montara, CA (E06)	Microbial Composting Process	Dougles Munnecke 415-728-8609	Ronald Lewis 513-569-7856	Soil and 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
Groundwater Technology Government Services, Inc., Concord, CA (E04)	Below-Grade Bioremediation Cell	Ronald Hicks 510-671-2387	Ronald Lewis 513-569-7856	Soil, Sludge, Sediments	Not Applicable	Biodegradable Organic Compounds
Hazardous Substance Management Research Center at New Jersey Institute of Technology, Newark, NJ (E04)	Pneumatic Fracturing/ Bioremediation	John Schuring 201-596-5849	Uwe Frank 908-321-6626	Soil	Not Applicable	Petroleum Hydrocarbons, Benzene, Toluene, Xylene
High Voltage Environmental Applications, Inc., Miami, FL (E06)	High Energy Electron Beam Irradiation	William Cooper 305-593-5330	Franklin Alvarez 513-569-7631	Soil, Sediment, Groundwater, Sludge	Not Applicable	Pesticides, Insecticides, Petroleum Residues, PCBs
Institute of Gas Technology, Chicago, IL (E03)	Fluidized-Bed Cyclonic Agglomerating Combustor	Amir Rehmat 312-949-3900 Michael Mensinger 312-949-3730	Teri Richardson 513-569-7949	Solid, Liquid, Gas, Sludge	Nonvolatile Inorganics	Nonspecific Organics
IT Corporation, Knoxville, TN (E06)	Eimco Biolift™ Slurry Reactor	Kandi Brown 615-690-3211	Brunilda Davila 513-569-7849	Soil, Sludges	Not Applicable	PAHs

TABLE 4 (continued)

Ongoing SITE Emerging Technology Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
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
Lewis Environmental Services, Inc., Pittsburgh, PA (E06)	Chromated Copper Arsenate Soil Leaching Process	Tom Lewis III 408-322-8100	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	Brian Butters 519-457-2963	John Ireland 513-569-7413	Air	Not Applicable	VOCs
Montana College of Mineral Science & Technology, Butte, MT (E03)	Air-Sparged Hydrocyclone	Theodore Jordan 406-496-4112	Eugene Harris 513-569-7862	Aqueous Solutions	Low-Concentration Metals	Not Applicable
Montana College of Mineral Science & Technology, Butte, MT (E05)	Campbell Centrifugal Jig	Gordon Ziesing 406-496-4112	Jack Hubbard 513-569-7507	Soil, Mine Tailings	Heavy Metals	Not Applicable
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 (E04)	X-Ray Treatment of Aqueous Solutions	Vernon Bailey 510-632-5100	Esperanza Piano Renard 908-321-4355	Water	Not Applicable	VOCs and SVOCs
Pulse Sciences, Inc., San Leandro, CA (E06)	X-Ray Treatment of Organically Contaminated Soils	Vernon Bailey 510-632-5100	Esperanza Piano Renard 908-321-4355	Soil	Not Applicable	Benzene, TCA, TCE, Carbon Tetrachloride and PCBs
Remediation Technologies, Inc., Seattle, WA (E05)	Methanotrophic Biofilm Reactor	Hans Stroo 206-624-9349	Kim Lisa Kreiton 513-569-7328	Gas	Not Applicable	Chlorinated Volatile Hydrocarbons
State University of New York at Oswego, Oswego, NY (E06)	Photocatalytic Degradation of PCB-Contaminated Sediments and Wastes	Pengchu Zhang and Ronald Scrudato 315-341-3639	Hector Moreno 513-569-7882	Sediments and Water	Not Applicable	PCBs, Other Chlorinated Organics
University of Dayton Research Institute, Dayton, OH (E05)	Photothermal Detoxification Unit (PDU)	John Graham 513-229-2846	Chien Chen 908-906-6985	Soil, Sludge, Aqueous Streams	Not Applicable	PCBs, PCDDs, PCDFs, Aromatic and Aliphatic Ketones, Aromatic and Chlorinated Solvents

TABLE 4 (continued)

Ongoing SITE Emerging Technology Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
University of South Carolina, Columbia, SC (E03)	In Situ Mitigation of Acid Water	Frank Caruccio 803-777-4512	Roger Wilmoth 513-569-7509	Acid Drainage	Most Metals	Not Applicable
Warren Spring Laboratory, Hertsfordshire, United Kingdom (E04)	Physical and Chemical Treatment	Peter Wood 01-44-438-741122	Mary Stinson 908-321-6683	Soil	Metals	Petroleum Hydrocarbons, PAHs
Western Product Recovery, Group, Inc., Houston, TX (E04)	CCBA Physical and Chemical Treatment	Donald Kelly 713-493-9321	Mark Meckes 513-569-7348	Wastewater, Sludges, Sediments, Soil	Heavy Metals	Nonspecific Organics
Roy F. Weston, Inc., West Chester, PA (E06)	Ambersorb® 563 Adsorbent	Russ Turner 215-430-3097	Ronald Turner 513-569-7775	Water	Not Applicable	VOCs

ABB ENVIRONMENTAL SERVICES, INC.
(Two-Zone Plume Interception In Situ Treatment Strategy)

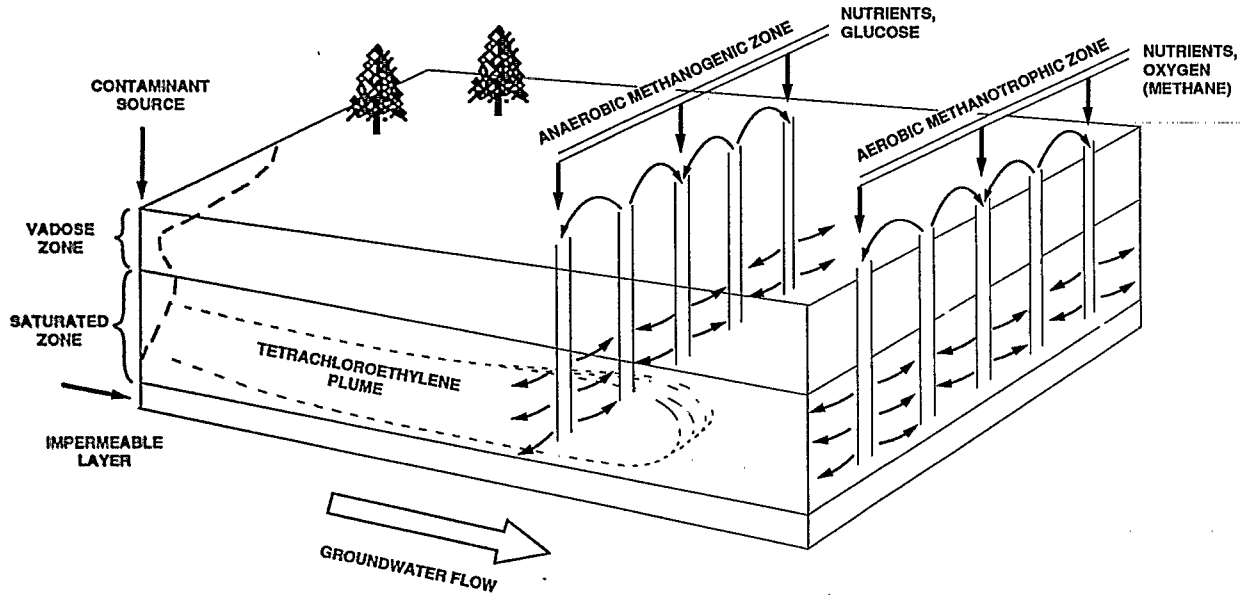
TECHNOLOGY DESCRIPTION:

The two-zone plume interception in situ treatment strategy treats a mixture of chlorinated and nonchlorinated organic solvents in saturated soils and groundwater. The first zone is anaerobic and partially dechlorinates highly chlorinated solvents, such as tetrachloroethene (PCE). Immediately downgradient is the second zone, where special aerobic conditions encourage the biological oxidation of the partially dechlorinated products from the first zone, as well as other compounds (see figure below). This technology uses dechlorinating bacteria that are specially adapted to high concentrations of chlorinated solvents, such as PCE.

The first step of the treatment strategy is to encourage growth of anaerobic, methanogenic bacteria in the saturated soil. This is accomplished by providing the bacteria with a primary carbon source, such as glucose, and with mineral nutrients, such as ammonia and phosphate.

If groundwater beneath the site contains chlorinated chemicals, any indigenous methanogenic bacteria present may exhibit dechlorinating activity. The presence of ethylene or elevated levels of vinyl chloride (VC) indicates that bacteria have dechlorinating capabilities. In this case, the number of bacteria can be increased by adding appropriate nutrients.

If the indigenous methanogenic bacteria do not dechlorinate organics, a specially adapted culture of methanogens can be introduced using trenches in which methanogens are sorbed to specific media. Essential nutrients would be added to the trench, as well as gas control equipment.



Two-Zone Plume Interception In Situ Treatment Strategy

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

Once methanogenic bacteria convert the more highly chlorinated ethenes and ethanes (trichloroethene and trichloroethane) to less chlorinated forms (dichloroethene [DCE], VC, and dichloroethane [DCA]), a second treatment step occurs. In the second step, oxygen is reintroduced into the groundwater at a point downgradient from the first zone. Methanotrophic bacteria, growing on methane and oxygen, oxidize the DCE, VC, and DCA, as well as nonhalogenated solvents, to carbon dioxide, biomass, and chloride ion.

WASTE APPLICABILITY:

This in situ treatment technology treats groundwater and industrial wastewater containing chlorinated and nonchlorinated solvents. Residuals include carbon dioxide, biomass, and inorganic chloride.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in July 1989. Optimal treatment parameters for field testing are being determined using bench-scale soil aquifer simulators. Objectives of the bench-scale tests are to (1) determine factors affecting the development of each zone, (2) adapt dechlorinating bacterial cultures, (3) demonstrate treatment of chlorinated and nonchlorinated solvent mixtures, and (4) develop a model for the design of field remediations. A final report on the bench-scale testing results is scheduled for release in fall 1993. The developer is preparing designs for implementing this technology at several sites.

FOR FURTHER INFORMATION:

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

ALLIS MINERAL SYSTEMS
(formerly BOLIDEN ALLIS, INC.)
(PYROKILN THERMAL ENCAPSULATION Process)

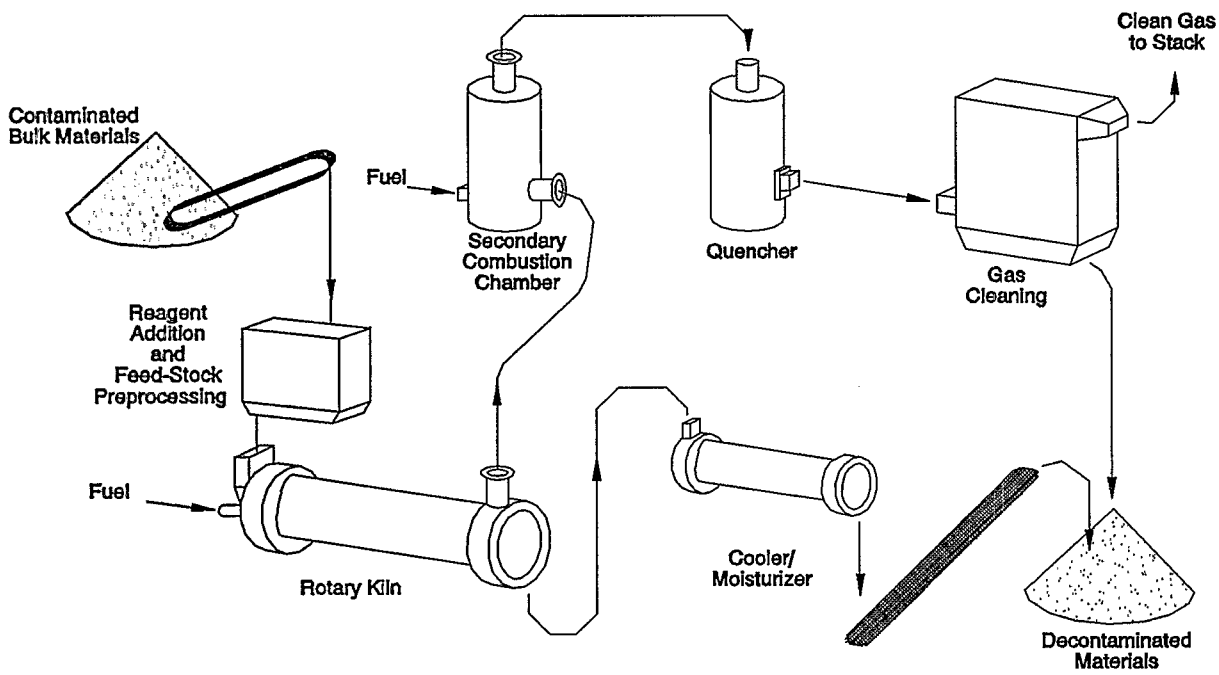
TECHNOLOGY DESCRIPTION:

This technology seeks 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. It traps metals in a controlled melting process operating in the temperature range between slagging and nonslagging modes, producing nodules of ash 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 expected to be trapped in the bottom ash from the kiln through the use of fluxing agents that promote agglomeration via "controlled nodulizing." This PYROKILN THERMAL ENCAPSULATION Process may reduce metals leaching to levels below EPA limits as proved by toxicity characteristic and toxicity characteristic leaching procedure tests. Metals with low melting and vaporization temperatures, such as arsenic, lead, and zinc, are expected to partition between the bottom ash and



PYROKILN THERMAL ENCAPSULATION Process

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

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.

This process may also reduce both the total dust load to the air pollution control system as well as the amount of particulate emissions from the stack.

The use of fluxing reagents is a key element in this technology. These are introduced into the kiln in the proper amount and type to lower the softening temperature of the ash. 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. The production of nodules, rather than a molten slag, is expected to prevent operating problems such as ash quenching, overheating, and premature failure of refractory. It 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 for stabilizing 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 non-halogenated 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. A batch kiln test program has been completed, and the final report is expected by the end of 1993.

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

ARIZONA STATE UNIVERSITY/IT CORPORATION
(Photocatalytic Oxidation with Air Stripping)

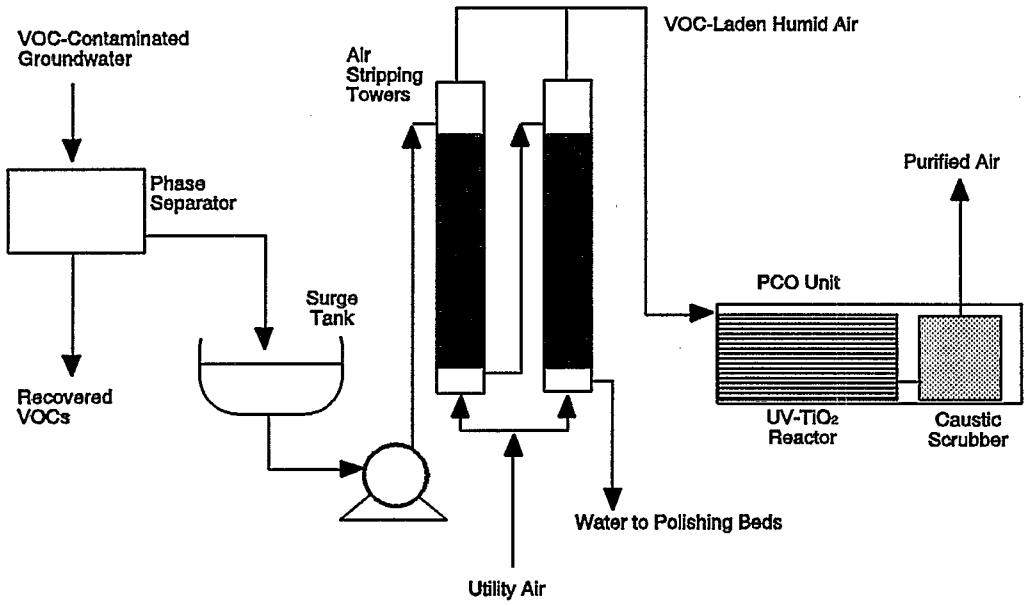
TECHNOLOGY DESCRIPTION:

No synthetic organic contaminants occur more frequently in groundwater or are detected at higher concentrations than chlorinated volatile organic compounds (VOC), such as trichloroethene (TCE) and trichloroethane (TCA). These contaminants are readily removed from groundwater using pump-and-treat methods that include air stripping. However, this solution produces a VOC-contaminated air stream; thus contaminants are not permanently removed from the environment.

In gas-solid photocatalytic oxidation (PCO) of volatile organics, a contaminated air stream is simultaneously contacted with a titania catalyst and near ultraviolet (UV) light in a continuous flow, resulting in complete destruction of the volatile organics. Arizona State University (ASU) is investigating an integrated pilot-scale pump-and-treat system in which chlorinated VOCs are transferred to a gas carrier stream using air stripping, with PCO reactors installed downstream of the air stripping unit to treat the contaminated air stream. The figure below illustrates this system. The skid-mounted PCO unit incorporates a flow-by photocatalytic reactor for VOC destruction and a closed-loop caustic scrubber for hydrochloric acid removal.

PCO offers the following advantages over conventional treatment technologies:

- Near UV photon excitation of the titania catalyst indirectly provides chemical activation of contaminants, allowing significant reaction rates at or near room temperature.
- The process is extremely energy-efficient, with reaction rates that are orders of magnitude higher than those for liquid-solid photocatalytic oxidation over titania.
- The titania catalyst is relatively inexpensive, is active in a variety of forms, and



Photocatalytic Oxidation with Air Stripping

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

does not require loading with expensive metal.
- An expendable oxidizing agent, such as hydrogen peroxide, is not required.
- A variety of halogenated and non-halogenated paraffinic, olefinic, and aromatic hydrocarbons can be completely oxidized to relatively innocuous or easily neutralized products, such as carbon dioxide or hydrochloric acid.

These advantages should result in a cost-effective solution to management of dilute air toxics produced by air stripping of contaminated groundwater.

WASTE APPLICABILITY:

This technology can be used to treat VOC-contaminated air streams produced by air stripping of contaminated groundwater. Research indicates that the PCO technology can also be adapted for use by any industrial facility that produces dilute air emissions, such as chemical process plants, dry cleaning and degreasing facilities, paint spray booths, and wastewater and hazardous waste treatment facilities. Air in closed environments could also be purified by combing PCO units with heating, ventilation, and air conditioning systems.

STATUS:

ASU was accepted into the SITE Emerging Technology Program in 1993. Under the program, ASU will evaluate the integration of gas-solid PCO downstream of an air stripper unit using bench-scale laboratory test. Results of the bench-scale testing will be used to develop a pilot-scale unit to be tested in the field at a Superfund site. ASU has tentatively identified two suitable Superfund sites in the Phoenix metropolitan area that are contaminated with chlorinated VOCs. Previous laboratory studies by ASU resulted in rapid, complete destruction of various concentrations of trichloroethene and trichloroethane in humid air streams using PCO.

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

ART INTERNATIONAL, INC.
(formerly ENVIRO-SCIENCES, INC. AND ART INTERNATIONAL, INC.)
(Low-Energy Solvent Extraction Process)

TECHNOLOGY DESCRIPTION:

The Low Energy Extraction Process (LEEP®), a patented process, uses common organic solvents to extract and concentrate organic pollutants from soil, sediments, and sludges. The process can treat contaminated solids to the stringent cleanup levels mandated by regulatory agencies.

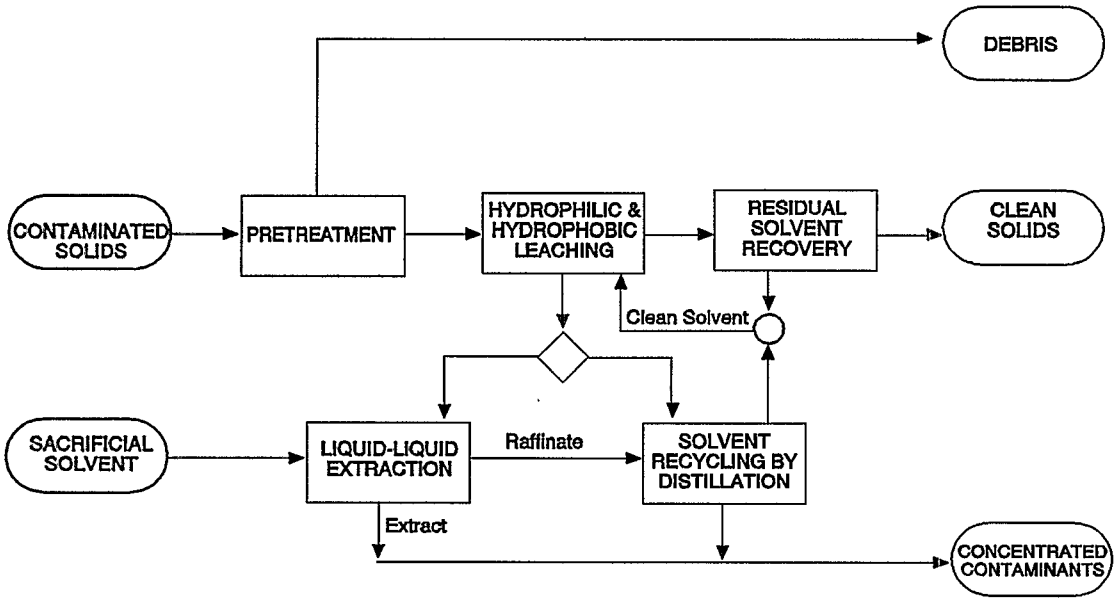
The solid matrix first undergoes pretreatment. The pretreatment step can accommodate particles up to 8 inches in diameter; it includes a metal detector and remover, a crusher, and a metering feeder. Floating material often found at remediation sites, such as wood chips, grass, or root material, is removed using a gravity settler-floater.

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 removal of the contaminants. The extracted pollutants are 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 self-contained, mobile unit consisting of proven heavy-duty equipment. The solvents used in the process are inexpensive and are applicable to almost every type of organic contaminant. Their physical properties enhance the settling of clay and silt particles. In addition, the solvents can be recycled using little energy.

WASTE APPLICABILITY:

The LEEP® technology can treat many classes of organic contaminants in soil, sediments, and sludges, including tar, creosote, chlorinated hydrocarbons, polynuclear aromatic hydrocarbons, pesticides, and wood preserving chloro-



LEEP® Technology Schematic

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

phenol formulations. Bench- and pilot-scale experiments have shown that the LEEP® technology 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:

The LEEP® technology 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:

- A 200-pound-per-hour pilot plant has been constructed.
- Pilot-plant tests have shown that the LEEP® technology can treat soil from manufactured gas plant sites containing up to 5 percent tar.
- Pilot-plant tests for scaling up to a commercial plant are complete.
- Preliminary engineering and design turnkey bid packages for a commercial plant have been completed.
- Commercialization activities for a full-scale unit are underway.

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

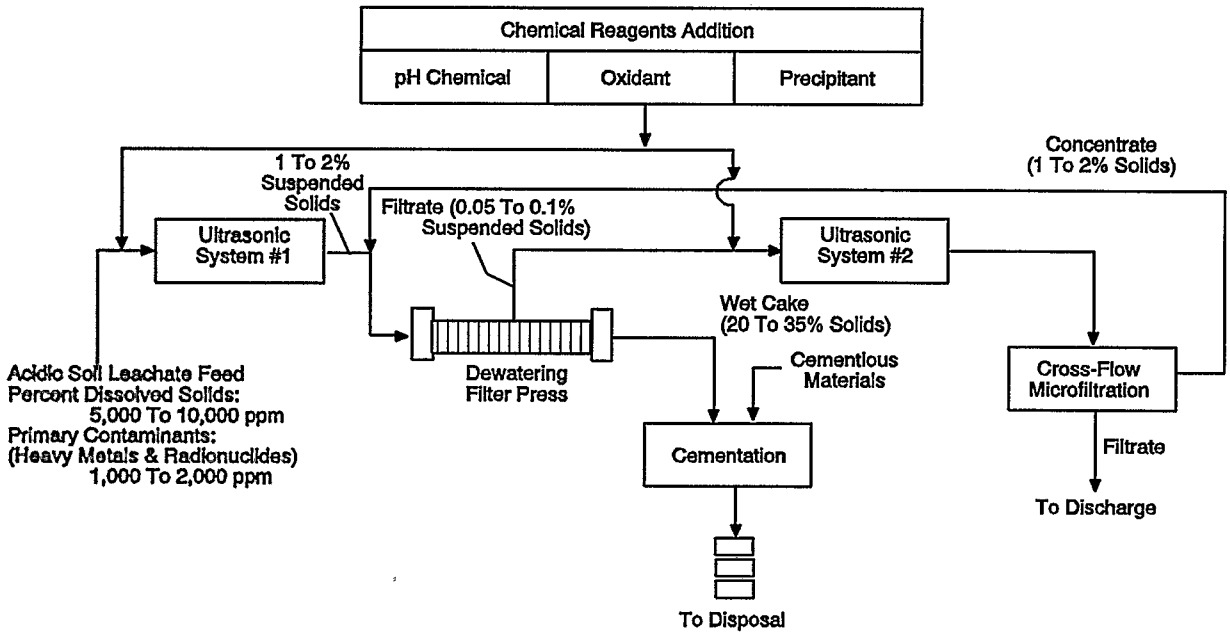
ATOMIC ENERGY OF CANADA, LIMITED
(Ultrasonic-Aided Leachate Treatment for Mixed Wastes)

TECHNOLOGY DESCRIPTION:

This technology 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, shown in the figure below, uses an ultrasonic field to improve the removal of contaminants by processes such as precipitation, coprecipitation, oxidation, ion scavenging, and sorption. 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 major difference between this technology and conventional processes is the use of ultrasonic mixing instead of mechanical agitation in large tanks. Research has shown 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 is compact, portable, and energy-efficient. Safety and process controls are built in as necessary for handling mixed radioactive solutions. This technology also generates minimal fugitive emissions and produces a treated effluent that meets applicable discharge limits. The technology may be able to treat waste containing small amounts of dissolved or suspended organics.

WASTE APPLICABILITY:

This technology treats acid mine drainage contaminated with heavy metals and radionuclides. It can also be integrated with soil and groundwater remediation technologies.

STATUS:

This technology 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 and the Berkeley Pit near Butte, Montana in its experiments.

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

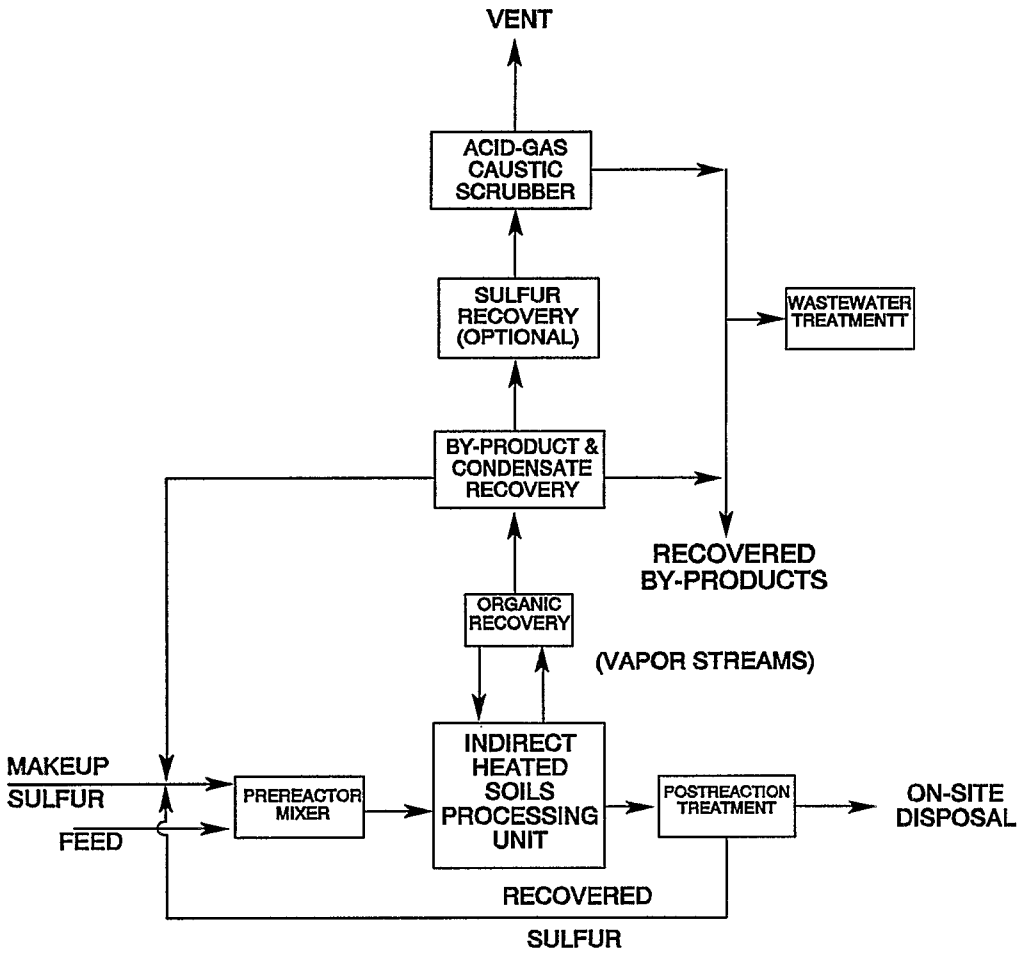
CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Organics Destruction and Metals Stabilization)

TECHNOLOGY DESCRIPTION:

The technology is designed to provide destruction of hazardous organics while simultaneously stabilizing metals and metal ions in contaminated soils. The technology uses elemental sulfur, which reacts with the carbon in organic materials at moderately elevated temperatures to form an insoluble, inert carbon-sulfur amorphous solid. The process occurs in an enclosed unit that traps condensable by-products and removes gaseous emissions with caustic scrubbing.

The technology's main process components include the following:

- A prereaction mixer where the solid and reagent are mixed
- A reactor to heat and cool the mixture
- The off-gas handling system, which collects and treats condensable by-products and scrubs acid gases from the effluent vapors
- A treated solids processing unit that recovers excess reagent and prepares the



Organics Destruction and Metals Stabilization

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

treated product to comply with on-site disposal requirements

Initial pilot-scale testing of the technology demonstrated that organic contaminants can be destroyed in the vapor phase by reaction with elemental sulfur. Among the organic compounds destroyed were tetrachlorethene, trichloroethene, and polychlorinated biphenyls (PCB).

Batch treatability tests of contaminated soil mixtures have demonstrated organics destruction and immobilization of various heavy metals including lead, cadmium, mercury, and zinc. In treatability tests with approximately 700 parts per million of Aroclor 1260, destruction levels of 99.0 to 99.95 percent were achieved.

Current experiments are providing more detailed definition of the process limits, metal concentrations, and soil type for stabilization of various heavy metals to pass the toxicity characteristic leaching procedure. 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 is currently underway. Larger scale batch tests are planned for summer 1994. Continuous pilot unit tests will be performed during 1994.

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

CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Smelting Lead-Containing Waste)

TECHNOLOGY DESCRIPTION:

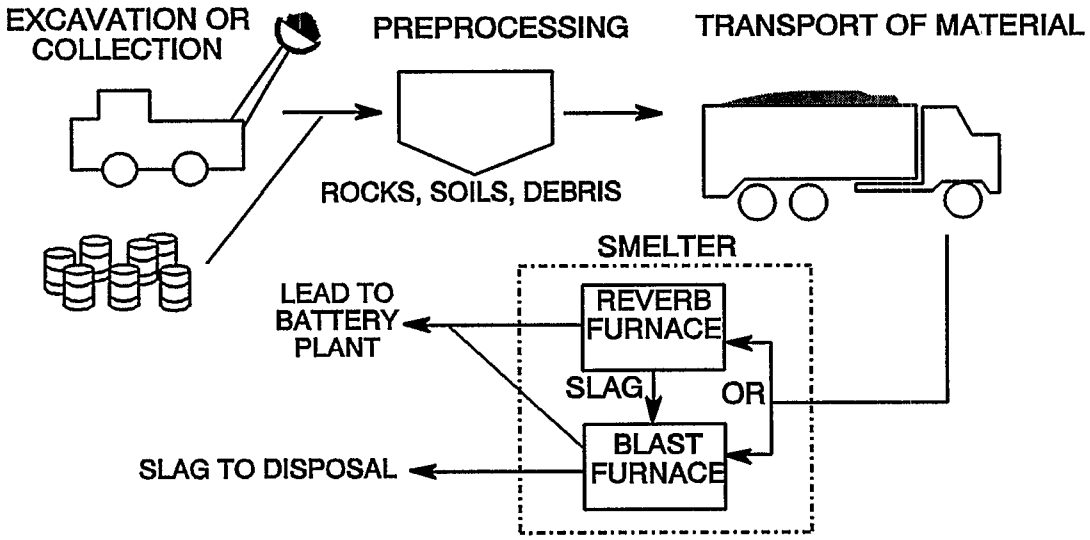
Secondary lead smelting is a proven technology used to reclaim lead from waste lead-acid batteries. The Center for Hazardous Material Research (CHMR) and Exide Corporation (Exide) are demonstrating the use of secondary lead smelting to reclaim usable lead from various types of waste materials.

The reclamation of lead from Superfund and other lead-containing materials is based on existing lead smelting procedures and basic pyrometallurgy. A general schematic for the technology is provided in the figure below. The materials are first excavated from Superfund sites or collected from other sources. They are next preprocessed to reduce particle size and to remove rocks, soil, and other debris. Then they are transported to the smelter.

At the smelter, the materials are fed either to the 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 the slag generated from the reverberatory furnaces as well as larger sized lead-containing waste. These furnaces are tapped continuously for lead and intermittently to remove the 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, and slag 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 also cannot be processed in the furnace. This technology as tested 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 several papers and presentations concerning the technology.

The process was demonstrated at three Superfund sites. Materials obtained from two additional sites were also used for these demonstrations.

The results from the demonstrations, 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. The estimated costs ranged between $100 and $150 per cubic yard for battery case material, and $90 and $160 for lead debris and other materials.

Specific technical problems encountered included loss of furnace production due to material build-up within the furnaces, breakdowns in the feed system due to mechanical overloads and increased oxygen demands inside the furnaces. All of these problems were solved by adjusting material feed rates or furnace parameters.

Based on these demonstrations, CHMR has concluded that secondary lead smelting is an economical method of reclaiming lead from waste material collected at Superfund sites and other sources.

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Source of Material Type of Material Tested	% Lead	Economical?*	Results of Test
Tonolli Superfund site (PA) Battery Cases	3 to 7	Yes < $150/yd^3	Lead can be reclaimed in secondary lead smelter. Incorporate into regular blast furnace feed stock.
Hebalka Superfund Site (PA) Battery Cases	10	Yes < $150/yd^3	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 < $160/ton	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 Approx. $250/ton	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	Results pending	Lead can be reclaimed in secondary lead smelter. Incorporate into regular blast furnace feed stock.

* Economical compared to stabilization or landfilling.

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

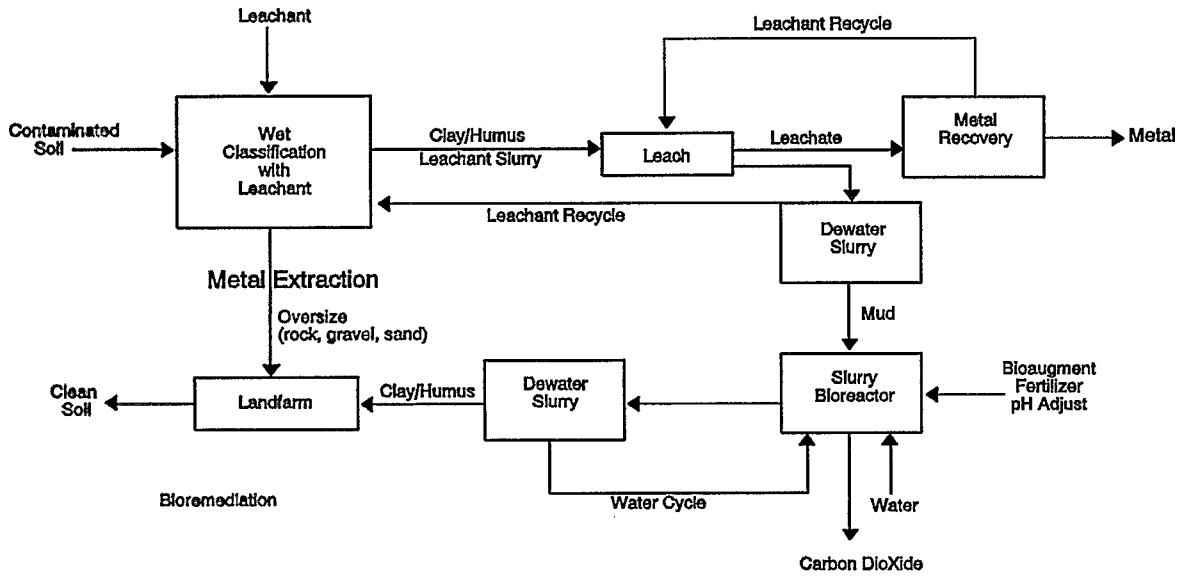
COGNIS, INC.
(Biological/Chemical Treatment)

TECHNOLOGY DESCRIPTION:

The COGNIS, Inc. (COGNIS), technology is a two-stage process to treat 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 high. 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 incoming soil is first exposed to a leachant solution and classified by particle size (see figure below). This 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 to remove the metals bound tightly to these substrates. Organic pollutants also typically reside in these fines. After dissolution of the metal compounds, the metal ions (for example, Zn^{+2}, Pb^{+2}, Cd^{+2}) are removed from the aqueous leachate by one of several metals recovery systems such as liquid ion exchange, resin ion exchange, or reduction. The aqueous leaching solution is thereby 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.

After metals extraction is complete, the "mud" slurry is allowed to settle and is neutralized. Liquids are returned to the classifier, and the soil is transferred to a slurry bioreactor, a slurry-phase treatment lagoon, or a closed land treatment cell for bioremediation. The metal-extracted matrix (for example, soil) and residual leachate solution are treated to maximize bio-



Metal Leaching and Bioremediation Process

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

degradation of the contaminants. With the addition of micronutrients to support microbial growth, the residual leaching solution components and most readily biodegradable organic compounds are aerobically degraded. The residual leachant from the metals extraction process can be the primary source of nutrients for aerobic or anaerobic microbial growth.

Bench-scale tests show that a variety of heavy metals and organic pollutants can be remediated by this process. 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. Specific contaminants include 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 other metals such as mercury, from soils and to degrade more recalcitrant halogenated hydrocarbons.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in August 1992. Bench- and pilot-scale testing of the metals extraction and bioremediation process is being conducted. Experiments with the combined pilot-scale process are scheduled to begin in early 1994.

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

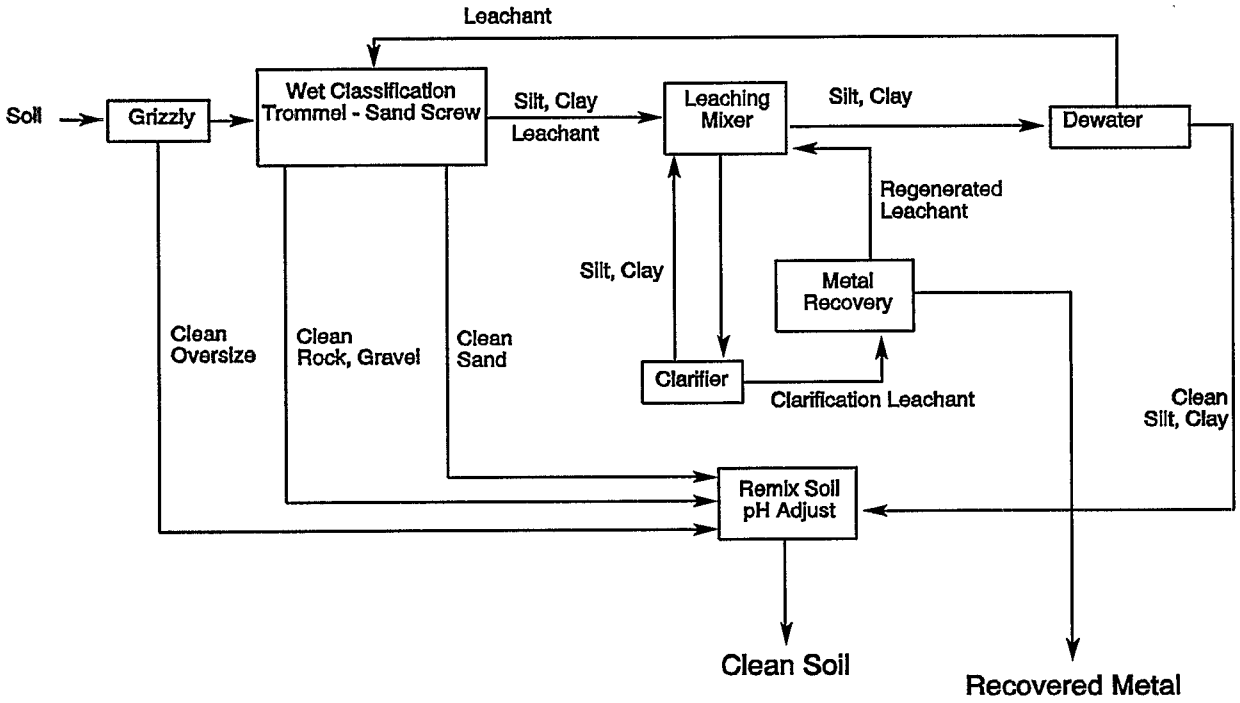
COGNIS, INC.
(Chemical Treatment)

TECHNOLOGY DESCRIPTION:

The COGNIS, Inc. (COGNIS), TerraMet™ soil remediation system leaches and recovers metals, specifically lead, from contaminated soil, dust, sludge, or sediment. The process uses a proprietary aqueous leachant which is optimized through treatability tests for the soil and the contaminant present. The TerraMet™ system can treat most types of lead contamination, including metallic lead, soluble ions, and insoluble lead oxides and salts. These are often tightly bound by fine soil constituents such as clay, manganese and iron oxides, and humus.

The first processing stage involves dry screening to remove oversized material. Leaching typically begins after the second stage, 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. When the contamination is distributed throughout the soil fractions, the whole soil can be leached.

After dissolution of the lead contaminants, the lead ions are recovered from the aqueous leachate by a metals recovery process such as 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

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

Residual leachant in the treated soil is nontoxic and biodegradable by both aerobic and anaerobic organisms.

Important characteristics of the leachant and extractant combination are as follows:

- The leachant is tailored to the substrate and the contaminant.
- The leachant and extractant are fully reusable.
- Leachant materials are readily available.
- The process uses commercially proven metals recovery techniques.

WASTE APPLICABILITY:

The COGNIS TerraMet™ metals leaching process can treat soil, sediment, and sludge contaminated by heavy metals or metal mixtures in addition to lead. Appropriate sites include contaminated battery recycling centers, scrapyards, metal plating shops, and chemical manufacturing facilities. The technology 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, from soils. End products include clean soil and recycled metal or metal salts. No wastewater streams are generated.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in August 1992. COGNIS conducted bench-scale testing to enter the SITE Program, and pilot-scale equipment (250 kilograms of soil per batch) is being assembled. To date, lead-contaminated soil samples, with 17,000 parts per million (ppm) lead, have been treated to less than 300 ppm residual lead. Metals removal to below background concentrations has also been achieved (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. Field testing will begin in September 1993.

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

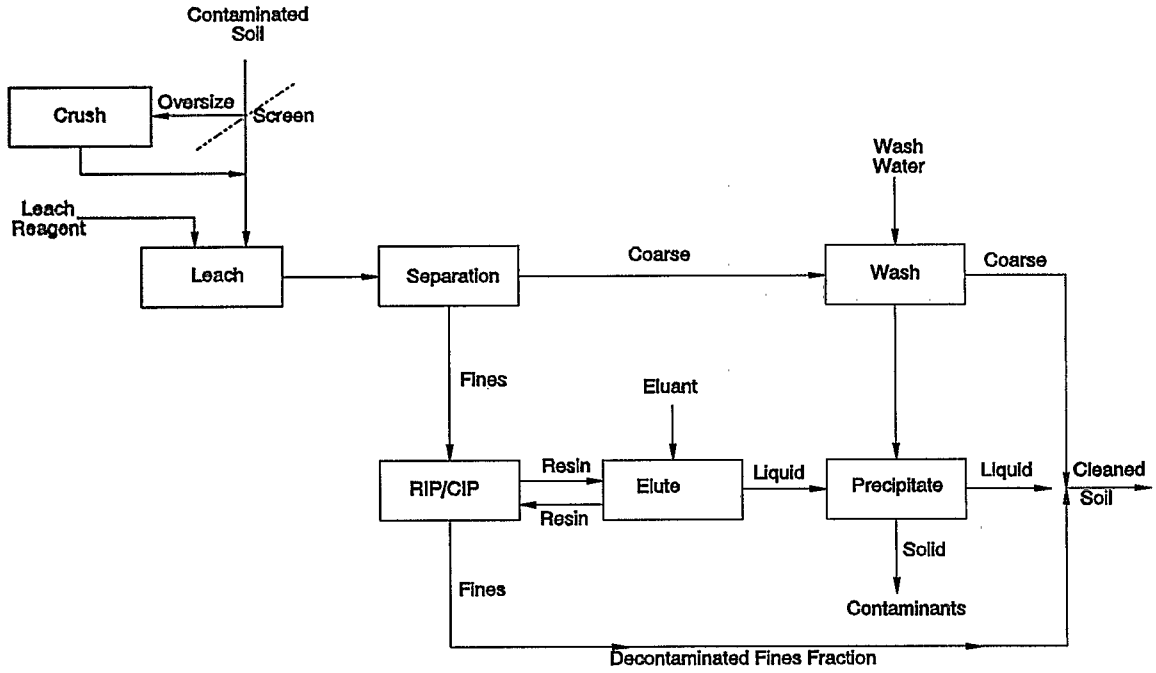
DAVY RESEARCH AND DEVELOPMENT, LIMITED
(Chemical Treatment)

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 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 is used to recover contaminants from the wash and elute solutions. A concentrated solid material is produced from the precipitate and can be disposed of or treated to recover metals or other materials. The liquid effluent from the recovery section can be recycled to the process.



Chemical Treatment Process

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

For organically contaminated feeds, the in-pulp or slurry process is used to treat 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 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 has developed proprietary RIP and CIP processes which 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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The SITE Program assesses but does not approve or endorse technologies.

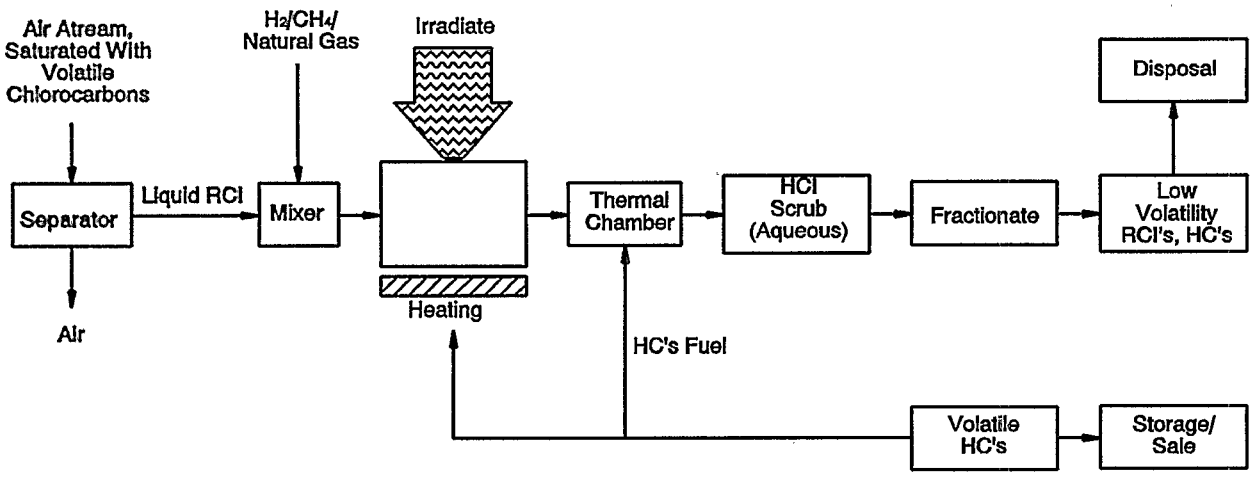
M. L. ENERGIA, INC.
(Reductive Photo-Dechlorination Treatment)

TECHNOLOGY DESCRIPTION:

The Reductive Photo-Dechlorination (RPD) treatment uses ultraviolet (UV) light in a reducing atmosphere to remove chlorine atoms from organochlorine-contaminated wastes at temperatures below 500 °C. Because chlorinated organics are destroyed in a reducing environment, process by-products include hydrocarbons and hydrogen chloride (HCl).

All reactions central to the process occur in the thermal treatment chamber (see figure below). 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 either hold their original structure, rearrange, cleave, couple, or go through additional hydrogenation. Hydrocarbons produced from the dechlorination of wastes include ethane, acetylene, ethylene, and methane. These hydrocarbons can be recycled as industrial intermediates, or as fuel.

Chlorinated wastes may be introduced into the process in one of three ways: (1) as a liquid, (2) as a vapor, or (3) bound with an adsorbent, such as carbon. Liquids are fed into a vaporizer, mixed with a reducing gas, and passed into the photothermal chamber. If treating a contaminated vapor, the stream first passes through a separator, which removes chlorinated materials as a liquid. If the wastes are adsorbed onto carbon, they are mildly heated and purged with reducing gas to induce volatilization. The chlorinated vapors are then fed to the treatment chamber and mixed with the reducing gases. In the treatment chamber, the mixture is heated to a temperature that will sustain radical chain reactions. Radicals are created using UV light that breaks carbon-chlorine bonds. After a suitable residence time, HCl is scrubbed from



Reductive Photo-Dechlorination (RPD) Treatment

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

the mixture. Hydrocarbons can be recycled as an energy source to heat the thermal chamber.

WASTE APPLICABILITY:

The RPD process is designed specifically to treat volatile chlorinated wastes in the liquid or gaseous state. Field applications include treatment of organic wastes produced from soil venting operations and those adsorbed on activated carbon. The process can also be used to pretreat gas streams entering catalytic oxidation systems, reducing chlorine content and thereby protecting the catalyst against poisoning.

STATUS:

The RPD technology, developed under the EPA Small Business Innovation Research program, was accepted into the SITE Emerging Technology Program in summer 1992. The principal objective under the SITE Program is to design, construct, and test the effectiveness of a pilot-scale RPD apparatus in treating waste streams containing chlorocarbons such as 1,1,1-trichloroethane, dichloroethene, trichloroethene, or dichloromethane.

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

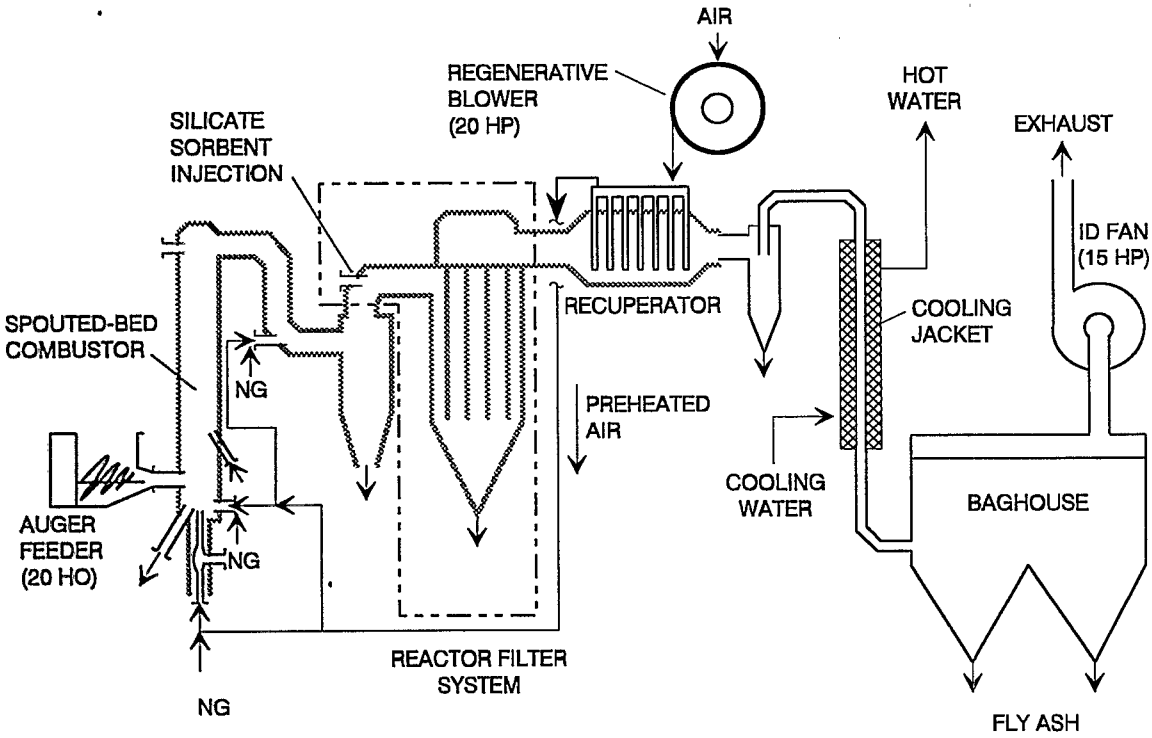
ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION
(Reactor/Filter System)

TECHNOLOGY DESCRIPTION:

The Reactor Filter System (RFS) is designed to treat gaseous and entrained particulate matter emissions from the primary thermal treatment of sludges, soils and sediments. The process equipment is relatively compact and transportable. It is designed to overcome many shortcomings of conventional treatment/emissions control technologies when applied at remote sites. For example, treatment of contaminated solids by thermal means, such as desorption or incineration, may release metal emissions and products of incomplete combustion (PIC). Also, the large air pollution control devices which are often required to control PICs and metals are generally not suitable for transport to sites.

RFS technology combines sorbent injection with a high temperature fabric filter immediately downstream of a thermal process. The process involves three steps:

- Solids are thermally treated in a primary process, such as a rotary kiln, fluidized bed, or other system designed for thermal treatment.
- A low-cost, silicate-containing sorbent, such as kaolinite, is injected into the flue gases at temperatures near 1,300 °C (2,370 °F). The sorbent reacts with volatile metal species such as lead, cadmium, selenium, and arsenic in the gas stream and chemically adsorbs onto the surface of sorbent particles. This



Example Application of RFS Equipment

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forms insoluble, nonleachable silicate complexes similar to cementitious species.

- High temperature (up to 1,000 °C) filtration using a fabric filter provides additional residence time for the sorbent particles to react with the metals. This step also provides additional time for the destruction of organic compounds associated with particulate matter, virtually eliminating the formation of chlorinated dioxins and furans.

The RFS has the potential to dramatically improve the performance of existing thermal treatment systems for Superfund wastes containing 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 temperature to destroy such organics. Also, by increasing gas-solid contact parameters, the system can decrease metal emissions by preventing the release of metals as vapors or on entrained particles.

The RFS is installed in a conventional thermal treatment system immediately downstream from the primary thermal treatment unit, before the recuperator or air heater. The figure on the previous page shows an example of the RFS installed in Energy and Environmental Research Corporation's Spouted Bed Combustion Facility. Because the spouted bed generates a highly particulate-laden gas stream, a high temperature cyclone is used to remove coarse particulate matter before the RFS. Sorbent is injected at the cyclone exit. A conventional baghouse was used to quantify particulate capture efficiency during the pilot-scale demonstration. The baghouse is not needed during actual application of the RFS since the high temperature filtration medium performs as well as or better than conventional fabric filtration media.

WASTE APPLICABILITY:

This technology is designed to remove entrained particulates, volatile toxic metals, and condensed-phase organics present in high temperature (800 to 1,000 °C) gas streams generated from the thermal treatment of contaminated soils, sludges, and sediments. Many conventional means of treating such materials, such as rotary kiln incineration, fluidized bed incineration, or thermal desorption, can be combined with the RFS technology. Residuals from the process consist of nonleachable particulate that is essentially free of organic compounds, thus reducing the toxicity and risks of handling and landfill disposal.

STATUS:

This technology was accepted into the Emerging Technology Program in 1993. Pilot-scale evaluation of the RFS is scheduled to begin in 1994.

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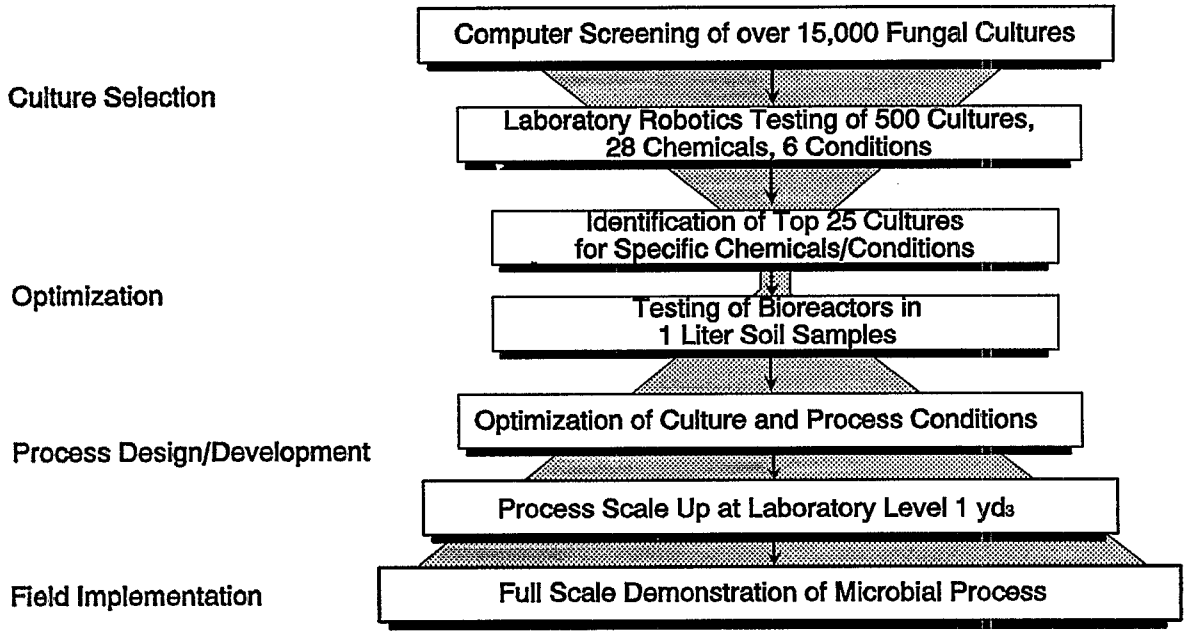
The SITE Program assesses but does not approve or endorse technologies.

ENVIRONMENTAL BIOTECHNOLOGIES, INC./ MICHIGAN BIOTECHNOLOGY INSTITUTE
(Microbial Composting Process)

TECHNOLOGY DESCRIPTION:

Environmental BioTechnologies, Inc. (EBT), and Michigan Biotechnology Institute (MBI) investigated the bioremediation of coal tar wastes derived from former manufactured gas plant (MGP) sites in programs sponsored by the Electric Power Research Institute. In EBT's program, initial screening of over 15,000 brown rot and white rot fungi led to 500 cultures that were selected for a laboratory robotics screening program. This program tested these diverse fungi for metabolic activity against a wide range of organic pollutants associated with coal tars. Standard cultures such as *Phanaerochaete* and *Coriolus sp.* were used to determine which fungal cultures displayed potential for environmental applications. MBI developed a method to treat soils contaminated with polynuclear aromatic wastes associated with MGP sites. This method involves providing the proper environmental conditions to allow proliferation of white rot and brown rot fungi, which were selected based on their ability to degrade coal tar components. Selected cultures from the EBT screening program performed well in the MBI soil treatment bioreactors. This process may eventually be applied in situ; however, current work is focused on treatment in prepared bed systems.

Due to the wide variability in environmental conditions and in the structure and partitioning of organic contaminants, an organism applicable to every site is unlikely to exist. Therefore, EBT and MBI have developed a relatively rapid method that screens for a group of organisms with the desired traits and degradation capabilities so that one or several appropriate organisms can then be selected for a development program. The overall strategy involves culture screening and development along with process optimization



Pathway of Fungal Technology Development Program

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and design as shown below. As process development proceeds, fungal and bacterial consortia are evaluated and process conditions optimized to support the desired degradative function.

WASTE APPLICABILITY:

This technology is being developed for treatment of soil and sediment contaminated with coal tar wastes (polynuclear aromatic hydrocarbons) from former MGP sites. EBT and MBI plan to adapt this technology to aqueous systems.

STATUS:

EBT was accepted into the SITE Emerging Technology Program in 1993. The overall objectives of testing under this program are to (1) identify microbial cultures with the metabolic functions required for remediation of coal tar organic wastes, and (2) develop and demonstrate a pilot-scale process, based on the cultures and conditions identified under the first objective, that can be commercialized for utility industry applications.

EBT and MBI will work with soils from several MGP sites but will focus on one site, in collaboration with an electric utility company sponsor, during the later development stages.

EBT and MBI will use a bench-scale composter system for determining optimal moisture content, soil amendment requirements, and inoculation procedures for accelerating degradation of polynuclear aromatic hydrocarbons (PAH) in these coal tar-contaminated soils. Subsequently, small (less than a cubic yard) plots of soil will be used to test the optimized process in laboratory studies before a field demonstration is conducted.

During the screening program, EBT identified top fungal cultures for PAH degradation. Selected cultures tested in bench-scale bioreactors at MBI indicated that fungi selected based on screening assays performed better than other fungi. PAH degradation significantly improved when three fungi were added to contaminated soil along with lignocellulosic cosubstrates and humic-based fertilizer. However, more information is needed on factors such as optimal cultures for specific applications, aeration and mixing requirements, timing of microbial and nutrient augmentation, and bioavailability of hazardous compounds in order for fungal composting to be a reliable method of degrading PAHs.

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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:

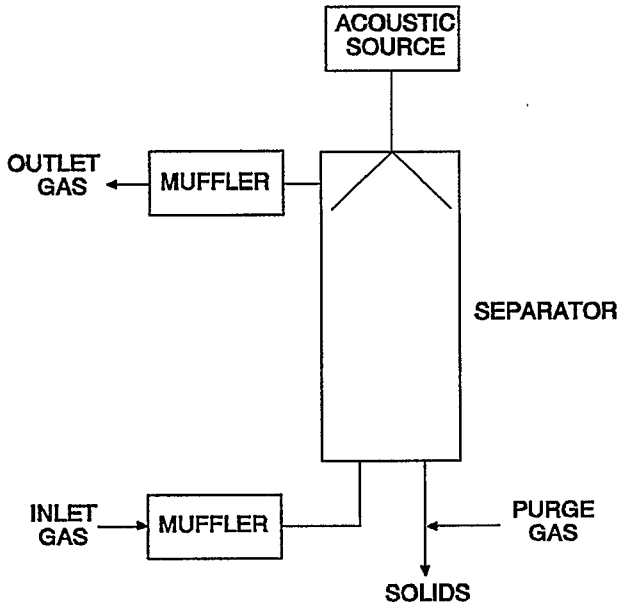
The acoustic barrier particulate separator separates particulates in a high temperature gas flow. The separator produces an acoustic waveform directed against the gas flow, causing particulates to move opposite the flow. Eventually, the particulates drift to the wall of the separator, where they aggregate with other particulates and precipitate into a collection hopper. The acoustic barrier separator differs from other separators in that it combines both high efficiency and high temperature capability.

The figure below presents a conceptual design. High temperature gas flows through a muffler chamber and then into 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 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 can assist solids transport if necessary.

The gas flows past the acoustic horn and leaves the chamber through an exit port. It 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.

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. It 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 ther-



Schematic Diagram of the Acoustic Barrier Particulate Separator

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

mal 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:

General Atomics, Nuclear Remediation Technologies Division 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.

GROUNDWATER TECHNOLOGY GOVERNMENT SERVICES, INC.
(Below-Grade Bioremediation Cell)

TECHNOLOGY DESCRIPTION:

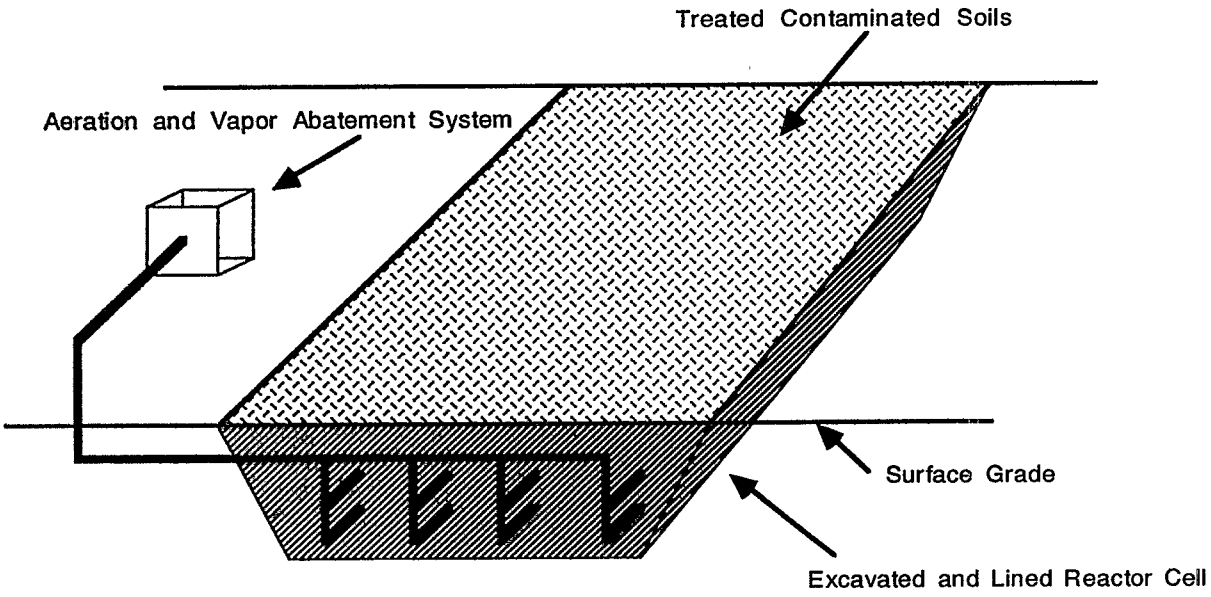
This technology utilizes bioremediation to treat soils contaminated with cyclodiene insecticides, such as chlordane and heptachlor.

Bioremediation is a proven technique for the remediation of soils containing a variety of organic compounds. The process involves stimulating the indigenous microbial population to degrade organic wastes into biomass and harmless by-products of microbial metabolism such as carbon dioxide, water, and inorganic salts. The process relies on aerobic metabolism of microorganisms present at the site.

In this process, contaminated soils are excavated, and the site is lined with an impermeable layer. The liner is used to protect against possible groundwater contamination during operation of the bioremediation system. A leachate collection system is installed to avoid saturated conditions at the site. The excavated soil is conditioned using shredding and sieving equipment, and bulking agents are added to assist in increasing air permeability. Soil amendments such as inorganic nutrients and micronutrients are added. The soil is placed in the excavated and lined pit, and a negative-pressure vacuum extraction system is installed. The vacuum system controls and captures any volatile organic compounds released during operation and provides oxygen for aerobic degradation of the contaminant. Upon completion of the project, soils may be left in place or disposed of. The figure below illustrates the technology.

WASTE APPLICABILITY:

Applicable waste media include soil, sludge, and sediment. This technology is being developed specifically for cyclodiene insecticides; however, the process is applicable to all biodegradable



Below-Grade Bioremediation Cell

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

organic compounds. Residuals expected after treatment include carbon dioxide, water, and inorganic chloride salts.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in summer 1991. Initial treatability studies were concluded in spring 1992. The results of these studies indicate that degradation of chlordane and heptachlor can be accelerated by the process, and that treatment times vary between 3 months and 2 years, depending on the initial contaminant concentration.

Additional laboratory testing is being conducted to quantify additional treatment options, such as use of white rot fungi or chemical oxidation during the soil conditioning phase of the project.

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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.

The pneumatic fracturing process consists of injecting high pressure air or other gas into soil formations at controlled flow rates and pressures. In low permeability soils, the process creates conductive channels in the formation. These channels increase the permeability and exposed surface area of the soil, accelerating removal and treatment of the contaminants. In high permeability soils, the process provides a means for rapidly aerating the soil formation.

The technology uses pneumatic fracturing to enhance microbial processes, in staggered spatial distribution for maximum effectiveness (see Figure 1). Aerobic processes dominate at the fracture interfaces and, to a limited distance, into the soil away from the fracture. Depletion of oxygen 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, shown in

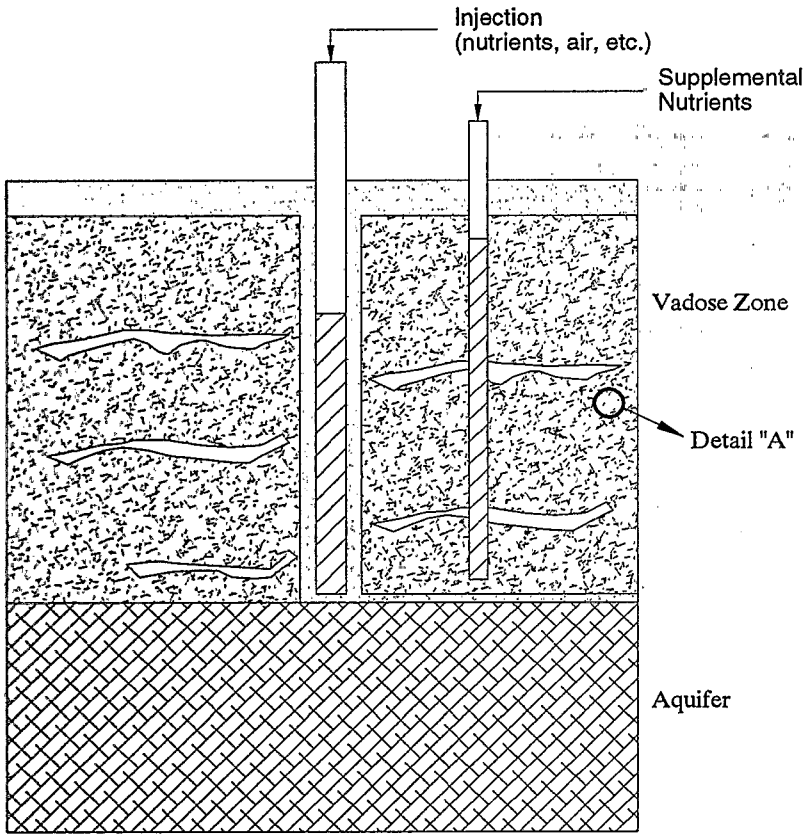

Figure 1: Vadose Zone Biodegradation With Fracturing and Vapor Stripping

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

Figure 2, enhances the growth of aerobic microbial populations by reducing substrate concentrations in the denitrifying and methanogenic zones.

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. A site at Marcus Hook, Pennsylvania has been selected to demonstrate this technology. Site characterization is complete. Field pilot-scale testing is underway and is scheduled for completion in July 1994.

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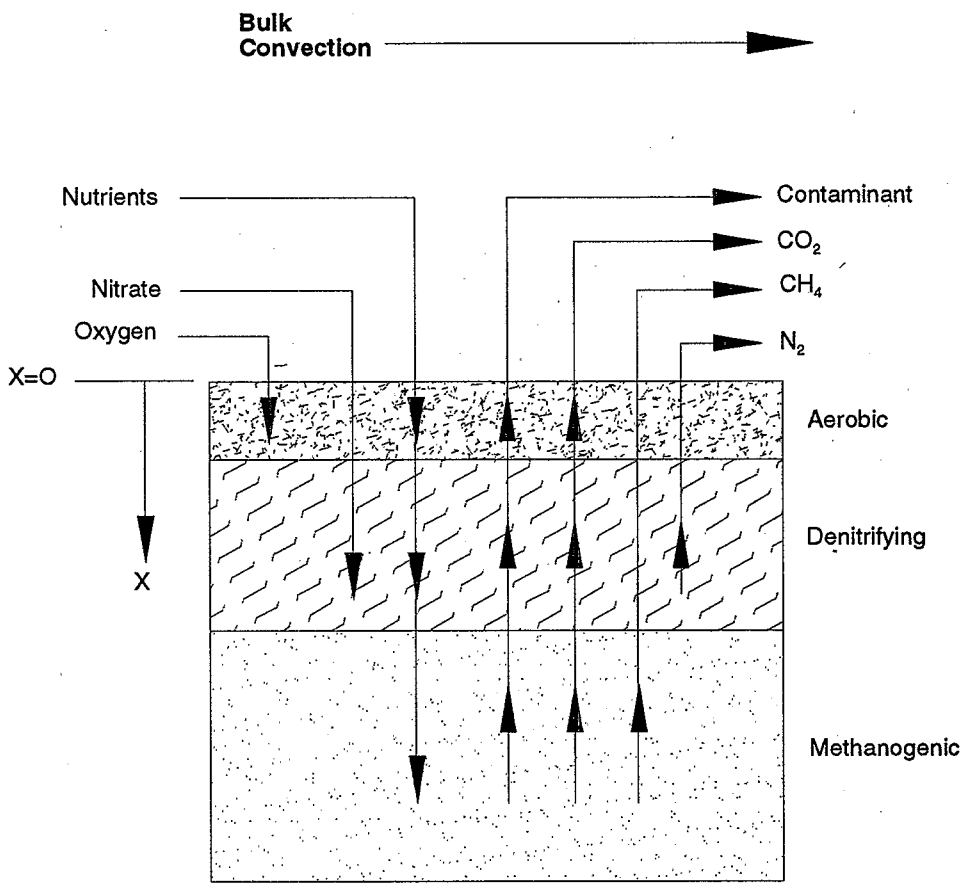


Figure 2: Contaminant, Oxygen, Nutrient, and Reaction Product Fluxes

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

HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.
(High Energy Electron Beam Irradiation)

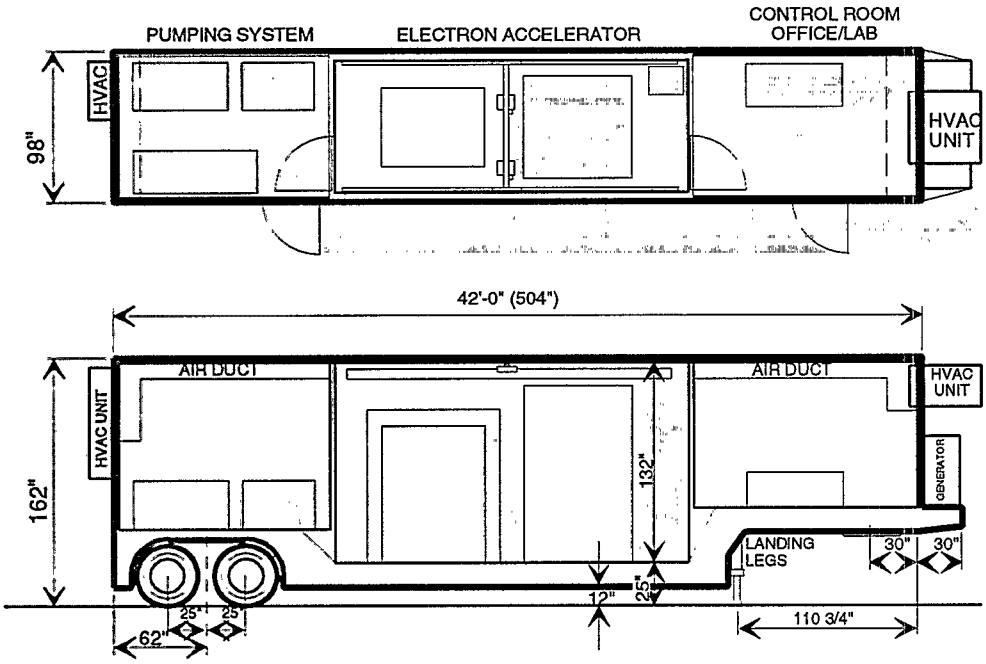
TECHNOLOGY DESCRIPTION:

The high energy electron beam irradiation technology is a low temperature method for destroying complex mixtures of hazardous organic chemicals from solutions containing solids, such as slurried soils, river or harbor sediments, and sludges. The technology can also treat soils and groundwater containing these chemicals.

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 for use with aqueous streams, slurried soils, sediments and sludges. The 500-kilovolt electron accelerator produces a continuously variable beam current from 0 to 50 milliamperes. At full power, the system is rated at 25 kilowatts. The flow rate is also continuously variable, 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. It requires only an external source of power and a mixing tank to slurry the solids to be treated. 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 using 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 equipped with monitoring devices that measure the waste stream



Mobile Electron Beam Hazardous Waste Treatment System

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

temperature before and after irradiation. Both the accelerating potential and the beam current are obtained directly from the transformer.

This technology does not require pretreatment of wastes, except for slurrying. It does not produce hazardous by-products, sludge, or air emissions; the resulting effluent can be discharged directly to the environment.

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. It may also be applied to mixed, low-level radioactive wastes in soils and groundwater.

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 study, a multisource hazardous waste leachate containing 1 percent dense nonaqueous phase liquid was successfully treated at bench scale. Another leachate containing PCBs in a light nonaqueous phase liquid was also treated to F039 standards in bench-scale studies.

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

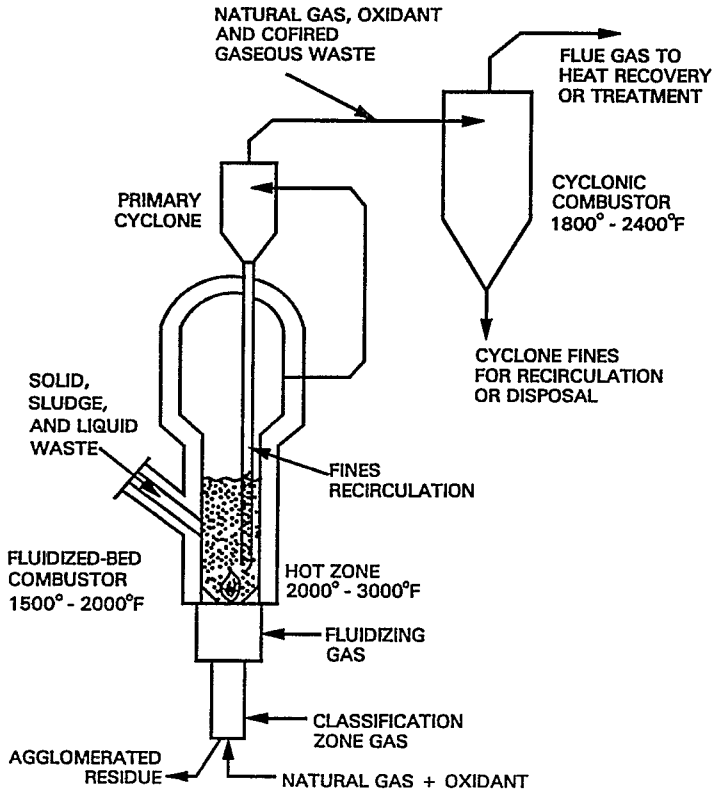
INSTITUTE OF GAS TECHNOLOGY
(Fluidized-Bed Cyclonic Agglomerating Combustor)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology (IGT) has developed a two-stage, fluidized-bed cyclonic agglomerating combustor (see figure below) based on a combination of technologies developed at IGT over many years. In the combined system, solid, liquid, and gaseous organic wastes can be efficiently destroyed, while 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 either under substoichiometric conditions or with excess air. The system can operate from low temperature (desorption) to high temperature (agglomeration). The gasification of materials with high calorific values (for example, municipal solid wastes) is also possible. With a unique distribution of fuel and air, the bulk of the fluidized bed is maintained at 1,500 to 2,000 °F, while the central spout temperature can be varied between 2,000 and 3,000 °F.

When the contaminated soils and sludges are fed into the fluidized bed, the combustible fraction of the waste undergoes rapid gasification and combustion. The solid fraction, containing inorganic and metallic contaminants, undergoes a chemical transformation in the hot zone and is agglomerated into glassy pellets that 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,



Two-Stage Fluidized-Bed/Cyclonic Agglomerating Combustor

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dioxins, and carbon monoxide as well as the products of complete combustion: carbon dioxide and water.

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 (2.5 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.

IGT's two-stage fluidized-bed cyclonic agglomerating combustor is based on experience with other fluidized-bed 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 stage. The particle size of the solids must be suitable (less than 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 their fusion temperature during the agglomeration process, metals and other inorganic materials, such as arsenic, 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 to date 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. Shakedown and testing of the pilot plant are in progress. Initial pilot plant tests have produced samples of agglomerated soil.

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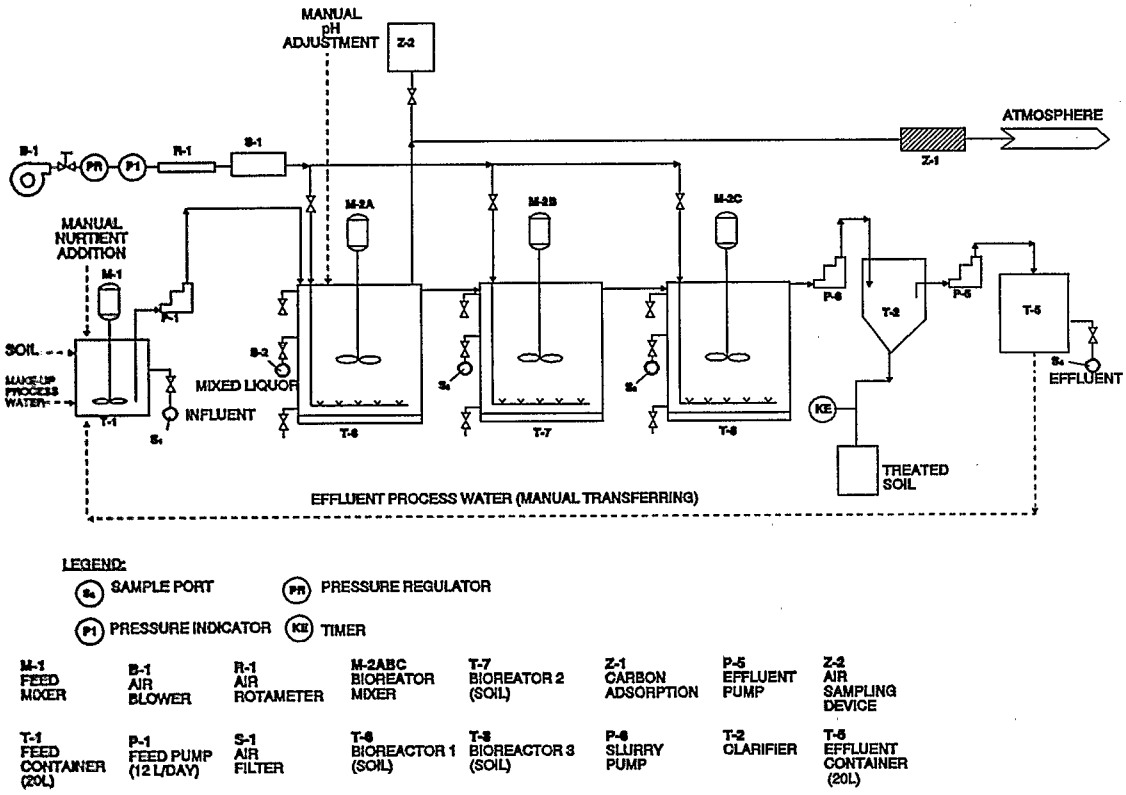
IT CORPORATION
(Eimco Biolift™ Slurry Reactor)

TECHNOLOGY DESCRIPTION:

IT Corporation (IT) has used the Eimco Biolift™ Slurry Reactor (developed by Eimco Process Equipment Company, Salt Lake City Utah) to biodegrade 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.

The system to be demonstrated consists of three 60-liter (L), stainless-steel reactors operating in series in a semicontinuous, plug-flow mode (see figure below). Specific organic (succinate and salicylate) and inorganic (ammonia and phosphate) nutrient supplements are used in combination with a specific water-miscible, degradable cosolvent (ethanol or acetone). The cosolvent enhances desorption of PAHs into the aqueous phase.

First, the influent waste stream is continuously stirred and fluidized in a closed container. It is then placed in the first reactor at an average flow rate of 2 L per day and overflows to the remaining two reactors. Following aeration in the reactors, the treated slurry is pumped to the system clarifier. The clarifier is covered to reduce emissions of volatile compounds and is maintained under quiescent conditions to allow gravitational settling. The clarified water is then



Eimco Biolift™ Slurry Reactor System

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

transferred to the effluent container and manually mixed with the influent feed. Treated solids are removed from the final slurry reactor.

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 60-L Eimco Biolift™ Slurry Reactors operated in series. A suitable soil will be obtained from a manufactured gas plant or creosote site and will be prescreened on site. The primary objective of the investigation is to achieve a treatment target risk level of 10^{-4}.

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

IT CORPORATION
(Mixed Waste Treatment Process)

TECHNOLOGY DESCRIPTION:

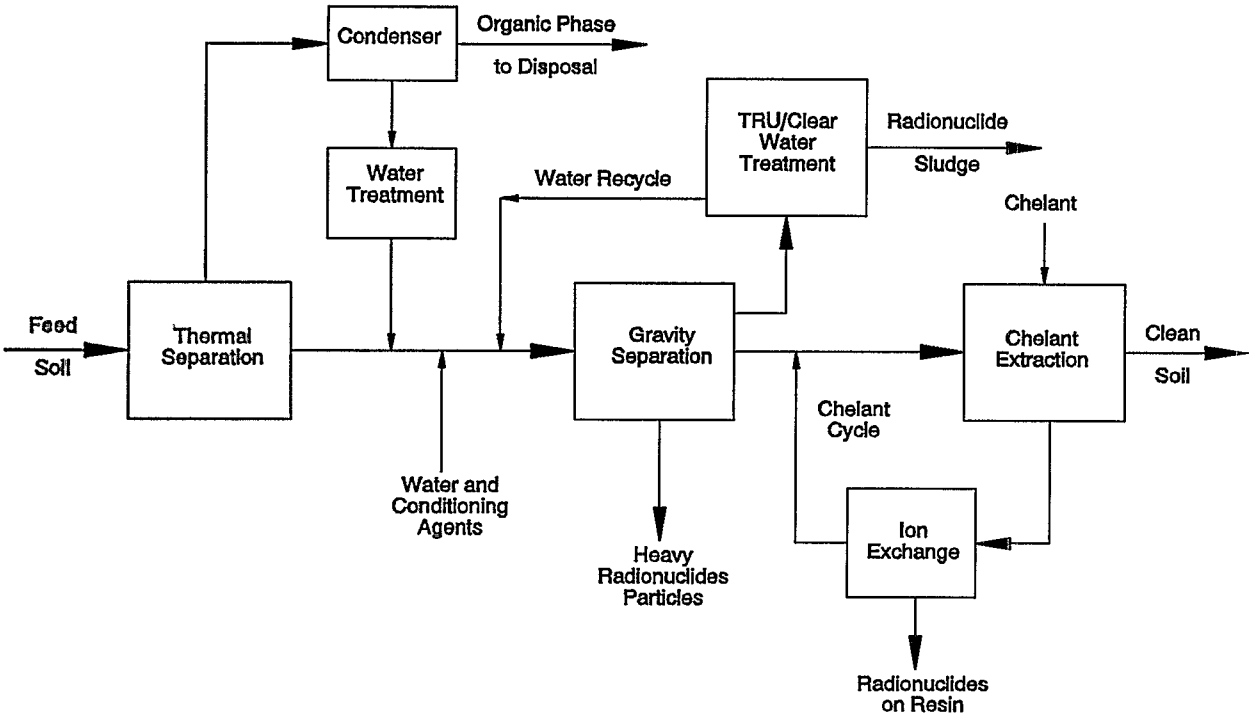
The mixed waste treatment process treats soils contaminated with both hazardous and radioactive constituents. The process separates these contaminants into distinct organic and inorganic phases. The separated streams can then be further minimized, recycled, or destroyed at commercial disposal facilities, and the decontaminated soil can be returned to the site.

This process combines thermal desorption, gravity separation, water treatment, and chelant extraction. 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 address the problems of treating mixed waste streams.

The initial treatment step prepares the bulk contaminated soil for processing by crushing and grinding oversized material.

Volatile and semivolatile organics are removed from the soil by thermal treatment. Indirect heating of the soil in a rotating chamber volatilizes organic contaminants along with 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, removing soluble organics before combining with the thermally treated soil.

Inorganic contaminants are removed by three physical and chemical separation techniques:



Mixed Waste Treatment Process

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(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 fraction. Selection of the gravity separation device (shaker table, jig, cone, or spiral) depends on the distribution of contaminants and physical properties of the thermally treated soil.

Many radionuclides and other heavy metals are in a form that makes them soluble or suspended in the aqueous media used for separation. These contaminants are separated from the soils and are precipitated. A potassium ferrate formulation is used to precipitate radionuclides. The resulting microcrystalline precipitant is removed, allowing recycling of the aqueous stream.

Some insoluble radionuclides remain with the soil through the gravity separation process. These radionuclides are removed via 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 under the program is planned for late 1993. Individual components of the treatment process have been demonstrated on various wastes from U.S. Department of Energy (DOE), U.S. Department of Defense (DOD), and commercial sites. Thermal separation has been used to remove and recover 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 at Johnston Atoll in the South Pacific. 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)

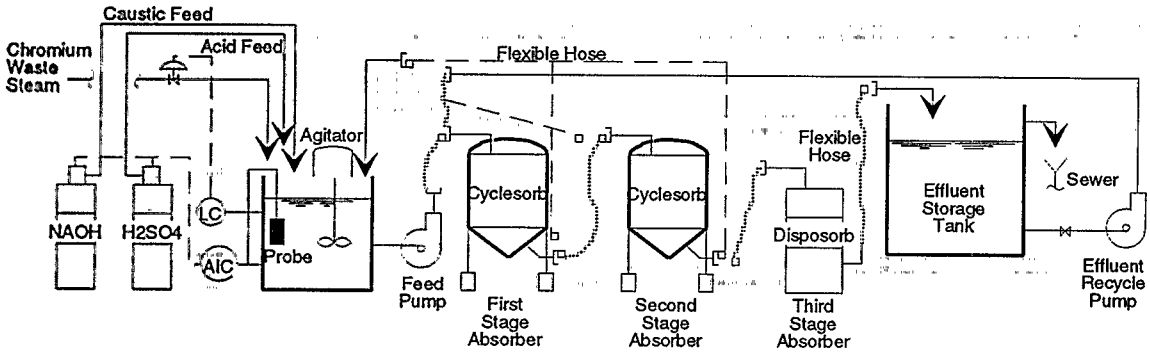
TECHNOLOGY DESCRIPTION:

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 as well as with some organics, heavy metal hydroxide sludges, and sediments.

The Soil Leaching Process consists of leaching contaminated soil in a countercurrent stirred reactor system. The soil is placed into the reactor by a screw feeder system and leached with sulfuric acid for 30 to 60 minutes, which solubilizes the inorganics and heavy metals into the leaching solution. The processed soil is then separated and washed with water and allowed to air-dry. Any organic contaminants are separated and decanted from the leaching acid. 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 for reuse by industry 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 processed by the ENVIRO-CLEAN process or can be returned directly to the stirred reactor system, depending on its metals concentration. The figure below illustrates the Soil Leaching Process.

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 prior to treatment. Standard screening and classification equipment, such as that used in municipal waste treatment plants, is suitable for this purpose.

The Soil Leaching Process does not generate appreciable quantities of treatment by-products



Chromated Copper Arsenate Soil Leaching Process

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

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 used in the ENVIRO-CLEAN process 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.
- The need for 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 Soil Leaching Process successfully treats CCA-contaminated soil. 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 and 41.4 mg/L of chromium, 94.8 mg/L of copper, and 3.0 mg/L of arsenic in the wash water. The wash water after being treated by the ENVIRO-CLEAN process had 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 Conley, Georgia facility.

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MATRIX PHOTOCATALYTIC INC.
(formerly NUTECH ENVIRONMENTAL)
(TiO_2 Photocatalytic Air Treatment)

TECHNOLOGY DESCRIPTION:

Matrix Photocatalytic Inc. (formerly Nutech Environmental) is developing the titanium dioxide (TiO_2) photocatalytic air treatment technology to remove and destroy volatile organic compounds (VOC) and semivolatile organic compounds from airstreams. The technology is an ambient temperature solid-state process in which contaminated air flows through a fixed TiO_2 catalyst bed activated by light. Typically, destruction of organic contaminants occurs in fractions of a second.

Major technology advantages include the following:

- 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. The full-scale and field-scale systems are shown in Figures 1 and 2, 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

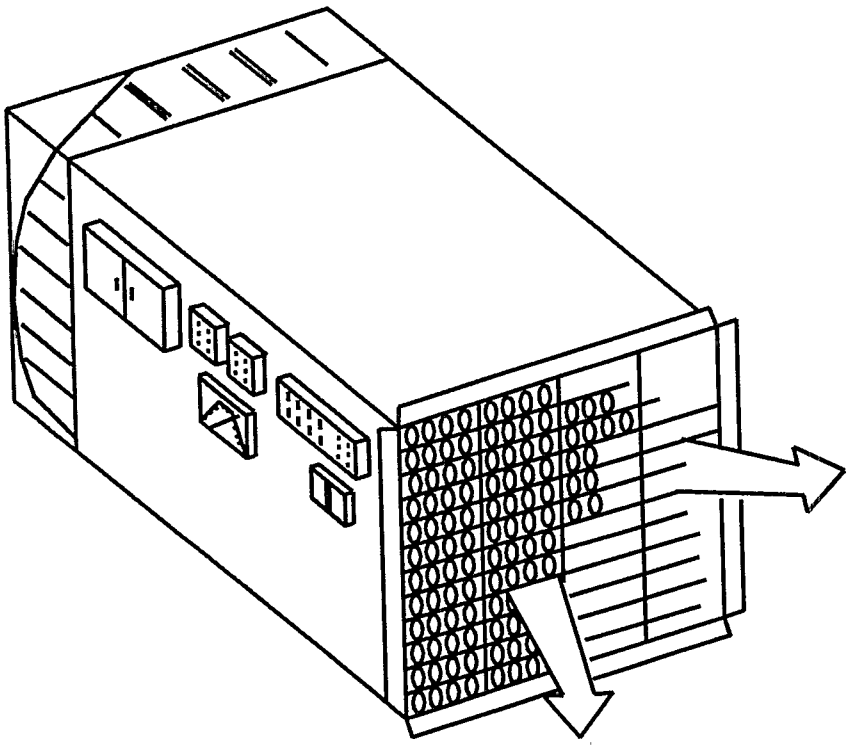

Figure 1: Full-Scale System

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treatment, soil venting, and the manufacture of ultrapure air for residential, automotive, instrument, and medical needs.

STATUS:

The TiO_2 photocatalytic air technology was accepted into SITE Emerging Technology Program in October 1992. Advancements in the first year of the program include the following:

- 100 percent improvement in performance
- Ability to destroy carbon tetrachloride and other saturated compounds
- Sustained destruction of PCE and TCE of high concentration without generating phosgene

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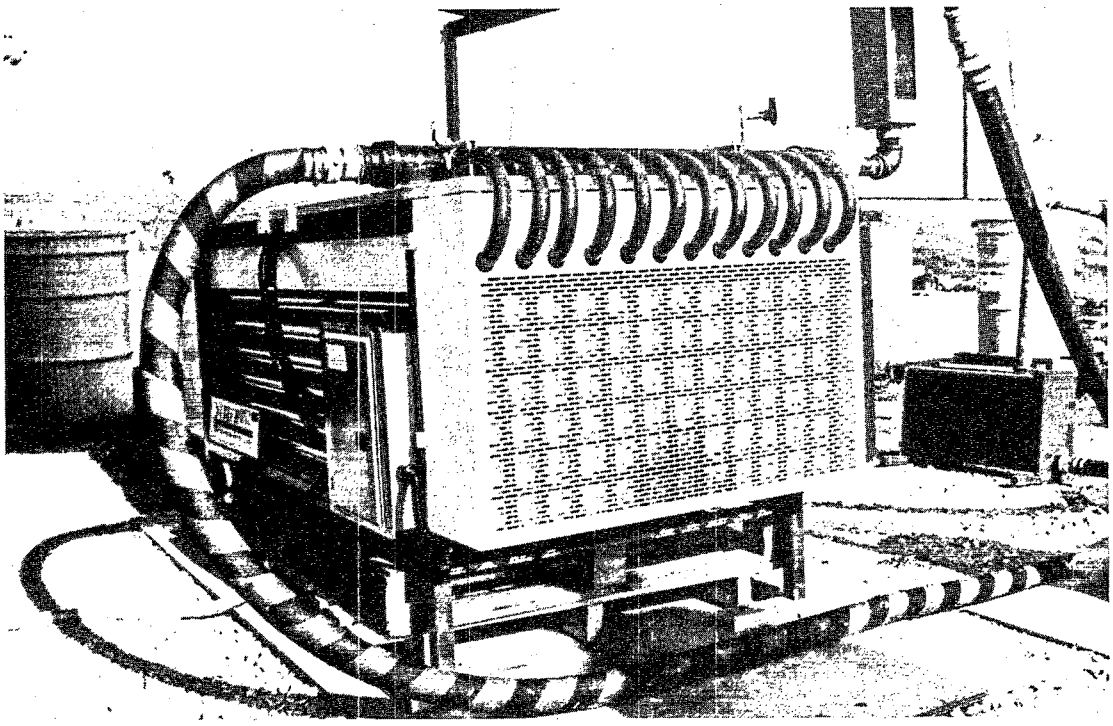

Figure 2: Field-Scale System Treating TCE and PCE on a Soil Vapor Extraction Site at Savannah River

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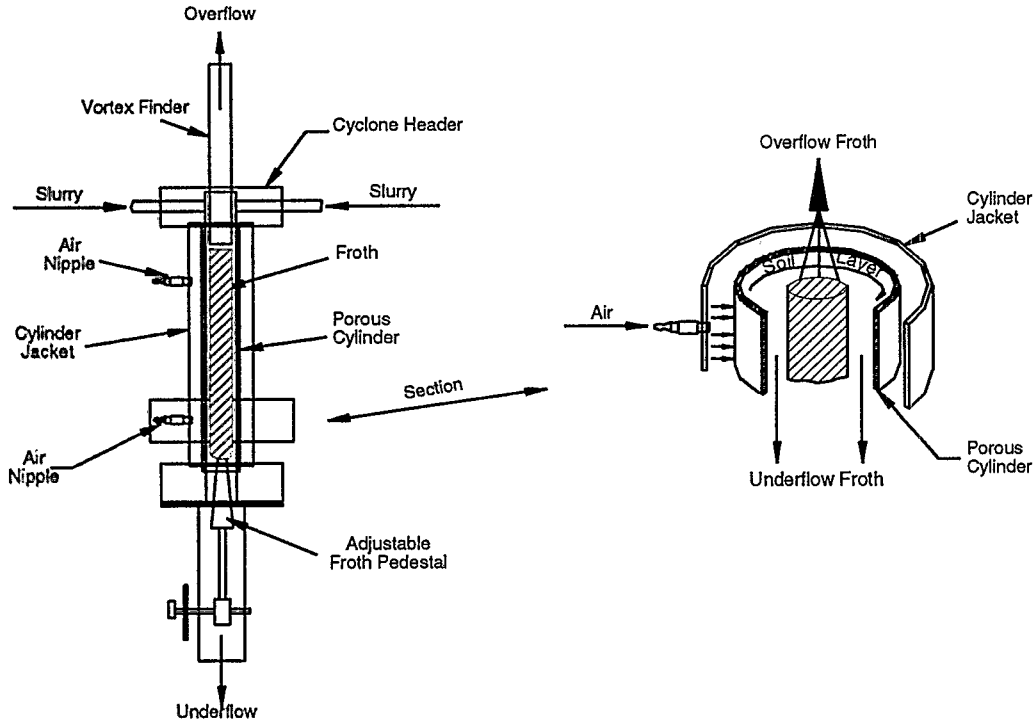
MONTANA COLLEGE OF MINERAL SCIENCE & TECHNOLOGY
(Air-Sparged Hydrocyclone)

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 (see figure below) consists of two concentric right-vertical tubes with a conventional cyclone header at the top and a froth pedestal at the bottom. 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.

The 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) and is discharged through an annular opening between the insides of the porous tube wall and the froth pedestal. Air is sparged through the jacketed inner porous tube wall and is sheared into small bubbles that are 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 is discharged as an overflow product. Hydrophilic particles (water wetted) 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 (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, leading to a number of industrial installations. Nevertheless, for both mechanical and column



Air-Sparged Hydrocyclone

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cells, the specific flotation capacity is generally limited to 1 to 2 tons per day (tpd) per cubic foot of cell volume.

In contrast with conventional flotation equipment, this ASH has a specific flotation capacity of at least 100 tpd per cubic foot of cell volume.

Standard flotation techniques used in industrial mineral processing are effective ways of concentrating materials. However, metal value recovery using standard flotation is never complete. The valuable material escaping the milling process is frequently concentrated in the very fine particle fraction.

WASTE APPLICABILITY:

This technology can remove fine mineral particles that are amenable to the froth flotation process. These 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 through gravity concentration methods, which did not effectively capture fine particles and left tailings containing 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 been in operation for the past 2 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 preparation of the final report is in progress. 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)

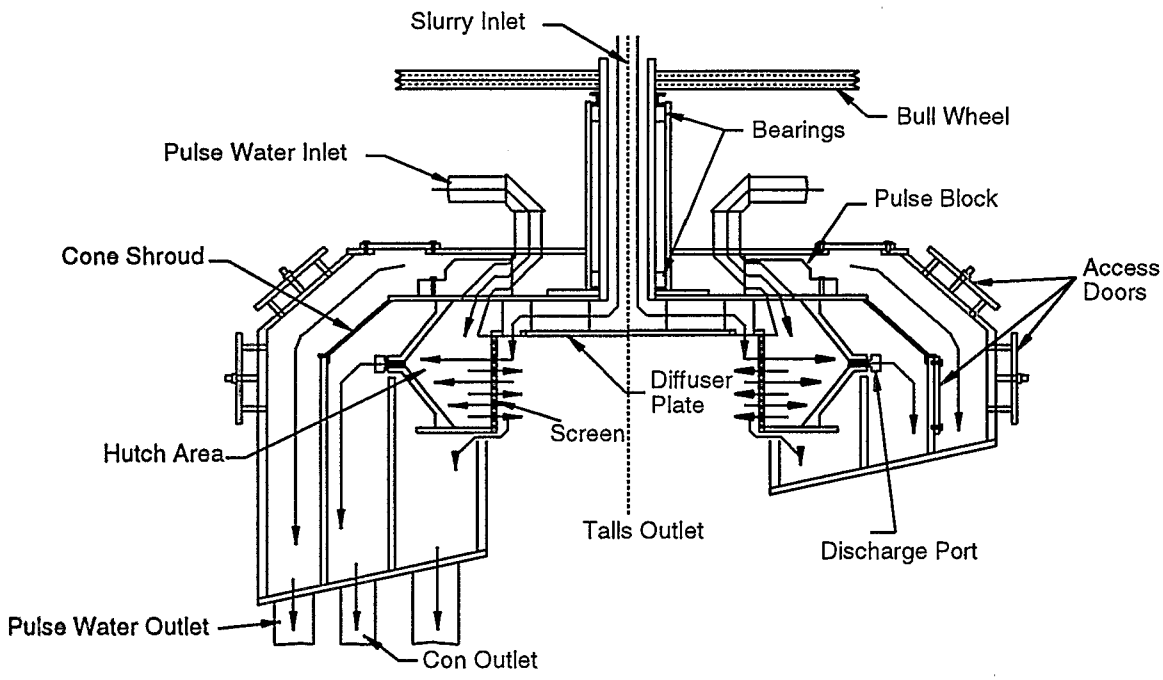
TECHNOLOGY DESCRIPTION:

The Campbell Centrifugal Jig (CCJ) separates fine heavy mineral and metal particles from waste materials. The CCJ combines jigging and centrifuging to cause separation in a liquid medium.

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 waste. It can recover particles ranging in size from 1 to about 500 microns, depending upon whether the particle is sufficiently liberated from the host material. The liberated particle should have a specific gravity that is at least 50 percent greater than the waste material from which it is to be separated. The CCJ does not require chemicals to perform the solid-solid separation.

Appropriately sized slurried material is fed (the jig feed top size should be smaller than the screen size) into the CCJ through a hollow shaft at the top of the machine. The material discharges from the shaft onto a diffuser plate, which has vanes that distribute the material radially to the jig bed. The jig bed contains ragging (usually stainless-steel shot that is slightly coarser than the screen aperture) that is pulsated by pressurized water admitted under the screen by four rotating pulse blocks. The pulsing water sets up a tetter column in the bed



Campbell Centrifugal Jig (CCJ)

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and causes heavier particles to separate to the concentrate port, while lighter particles are rejected and migrate to the tailings port.

The effectiveness of separation depends upon how well the solids to be recovered by the jig are liberated from the waste material. The waste feed may require grinding before processing by the CCJ. Operating parameters include pulse pressure, speed (g-load), screen aperture, ragging (type and size), weir height, and feed percent solids.

The CCJ process results in heavy mineral or metal concentrates which, depending upon the waste material, may be further processed for extraction or sale. The treated material can be returned to the environment.

WASTE APPLICABILITY:

The CCJ can separate and concentrate a wide variety of materials, ranging from base metals to fine ash in coal and fine (1 micron) gold particles. Applications include remediation of heavy metal contaminated soils, tailings, or harbor areas containing spilled concentrates; removal of pyritic sulfur and ash from fine coal; and treatment of sandblasting grit.

STATUS:

The CCJ was accepted into the SITE Emerging Technology Program in May 1992. Evaluation will take place at the Montana College of Mineral Science & Technology (Montana Tech). Montana Tech has equipped a pilot plant to evaluate the Series 12 CCJ (capacity 1 to 3 tons per hour). Tests are underway in the Montana Tech facility using (1) clean soil spiked with bismuth as a surrogate for plutonium and uranium and (2) base-metal mine tailings from various locations in western Montana.

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

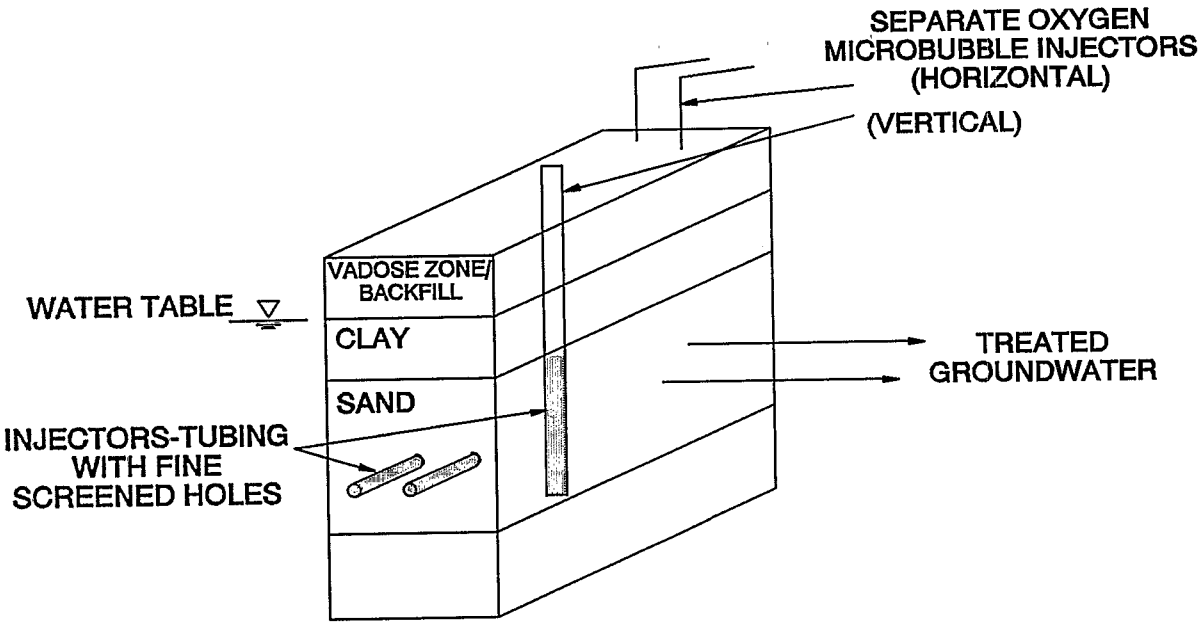
OHM REMEDIATION SERVICES CORPORATION
(Oxygen Microbubble In Situ Bioremediation)

TECHNOLOGY DESCRIPTION:

This process uses in situ bioremediation to remediate 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 generated continuously 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 though 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 more coarse zones. Contaminated groundwater flows through the treatment zone, and bioremediation occurs with the available oxygen. Indigenous microorganisms and nutrients already in place or introduced as part of the dispersion mixture provide the environment for in situ degradation of contaminants in groundwater or soil.

WASTE APPLICABILITY:

OHM Remediation Services Corporation has successfully treated a number of organic con-



Oxygen Microbubble In Situ Bioremediation of Groundwater

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taminants, including petroleum hydrocarbons, organic solvents, creosote, and pentachlorophenol.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. It will be demonstrated at a jet fuel spill site at Tyndall Air Force Base in Panama City, FL.

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

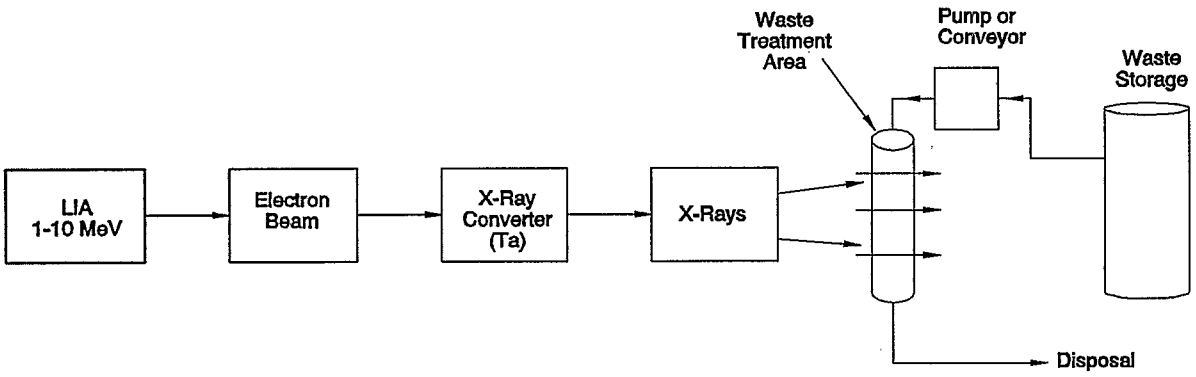
PULSE SCIENCES, INC.
(X-Ray Treatment of Aqueous Solutions)

TECHNOLOGY DESCRIPTION:

X-ray treatment of organically contaminated aqueous solutions is based on the in-depth deposition of ionizing radiation. Collisions of energetic photons (x-rays) with matter generate a shower of lower energy secondary electrons within the contaminated waste material. The secondary electrons cause ionization and excitation of the atomic electrons, break up the complex molecules of the contaminants, and form radicals that react with contaminant materials to form compounds such as water, carbon dioxide, and oxygen. Direct electron beam processing is a highly effective means of destroying organic compounds in aqueous solutions, with residual organic contaminant levels in the micrograms per liter (μg/L) range. Since the electrons do not penetrate deeply (about 7 millimeters for a 1.5-million-electron-volt [MeV] electron in water) material handling can be a problem, especially if the contaminated liquid is stored in a sealed container. The deeper penetration of similar energy x-rays addresses this problem by allowing in situ 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 chosen 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 the container and waste material.

The physical mechanism by which volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) are removed primarily depends on the contaminant present. 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, the complete



X-Ray Treatment Process

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

conversion of contaminants and by-products may be achieved at sufficiently high dose levels without undesirable waste residuals or air pollution.

The effective penetration depth of x-rays produced by converting 10-MeV electrons is about 43 centimeters in water. Large volumes can, therefore, be easily treated, and standard container walls will not absorb a significant fraction of the ionizing radiation. Either flowing waste or waste contained in drums can be treated. No additives are required for the process; therefore, sealed containers can also be accommodated. In situ treatment may also be feasible. Moreover, electron accelerators offer a high level of safety; the x-ray (or gamma) output of the LIA is easily turned off by disconnecting the electrical power. The cost of 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 (1) benzene, (2) trichloroethane, (3) trichloroethene, (4) tetrachloroethene, (5) toluene, (6) carbon tetrachloride, (7) chloroform, and (8) xylene. The penetration depth of x-rays, combined with the high flux of the x-rays generated by the LIA, allow waste to be treated in disposable containers, flowing systems, or in situ.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in May 1991. A 1.4-MeV, 800-amp LIA is being used in the experiments. Twenty-one matrices have been characterized for low contaminant levels, including two matrices from Superfund sites. For concentrations in the range of 100 to 4,000 parts per billion in deionized water, the contaminants listed above can be decomposed at x-ray doses of less than 200 kilorads. Higher concentrations of VOCs and SVOCs in aqueous solutions are being treated with x-rays to investigate the potential for hazardous by-product formation.

One objective of these tests is to determine the x-ray dose required to reduce organic contaminants in liquid wastes to acceptable levels. The experimental database will be used to develop a conceptual design and estimated cost for a high-throughput x-ray treatment system. Preliminary equations have been developed for preparing multiple VOC matrices and matrices containing OH scavengers, such as bicarbonate and carbonate ions. The scaling equations are based on the "G-values" calculated from the concentration-dose curves from the experiments. G-value is defined as the number of molecules formed per 100 electron volts. The G-value constant is commonly used to scale chemical reactions in the presence of ionizing radiation. The G-value does, however, change with concentration and may be substantially less than 1.0 for low VOC contaminants. The G-value is a measure of the efficiency of the reaction: the higher the G-value, the more efficient the reaction. Based on the preliminary rate constant equations derived, it may be possible to predict or scale the peak G-values. This concept will be the basis for the pilot plant scale-up.

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

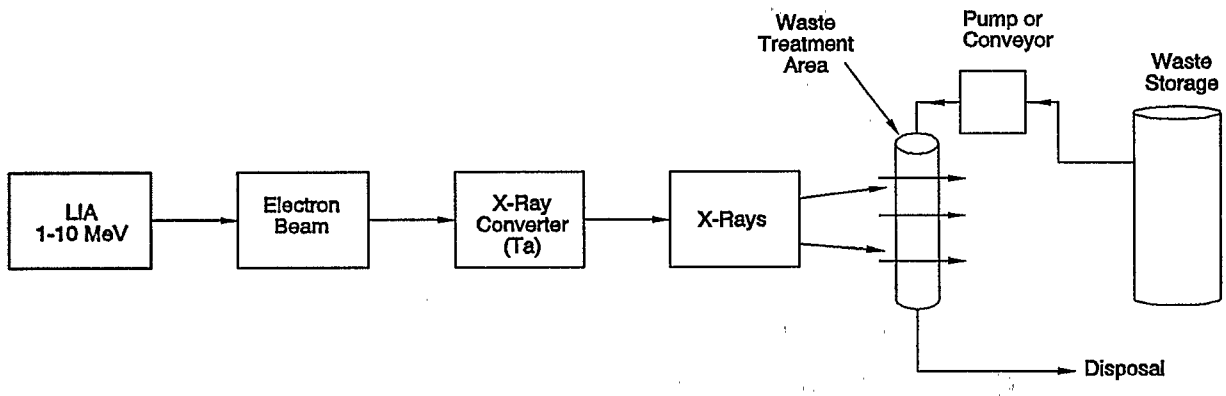
PULSE SCIENCES, INC.
(X-Ray Treatment of Organically Contaminated Soils)

TECHNOLOGY DESCRIPTION:

X-ray treatment of organically contaminated soils is based on the in-depth deposition of ionizing radiation. Collisions of energetic photons (x-rays) with matter generate a shower of lower energy secondary electrons within the contaminated waste material. These secondary electrons cause ionization and excitation of the atomic electrons, break 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 material being treated deeply enough (ultraviolet radiation heats only the surface layer, while a 1.5-million-electron-volt (MeV) electron has a penetration depth of approximately 4 millimeters in soil). The deeper penetration of x-rays, up to 20 centimeters, addresses this problem and allows the 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 chosen 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



X-Ray Treatment Process

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

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, the complete conversion of contaminants and by-products may be achieved at sufficiently high dose levels without undesirable waste residuals or air pollution.

The effective penetration depth of x-rays produced by converting 10-MeV electrons is about 27 centimeters in soil. Large volumes can, therefore, be more easily treated, and standard container walls will not absorb a significant fraction of the ionizing radiation. Either solid waste on a conveyor or waste contained in disposal barrels can be treated. No additives are required for the process; therefore, sealed containers can also be accommodated. In situ treatment may also be feasible. Moreover, electron accelerators offer a high level of safety; the x-ray (or gamma) output of the LIA is easily turned off by disconnecting the electrical power. The cost of x-ray processing is estimated to be competitive with alternative processes.

WASTE APPLICABILITY:

X-ray processing of organically contaminated soils has the potential for treating a large number of contaminants with minimum waste extraction or preparation. Organic wastes that may be treated include (1) benzene, (2) trichloroethane, (3) trichloroethene, (4) carbon tetrachloride, and (5) polychlorinated biphenyls. The penetration depth of the x-rays, combined with the high flux of the x-rays generated by the LIA, allow waste to be treated in disposable containers, or conveyor systems, or in situ.

STATUS:

The x-ray treatment of organically contaminated soils was accepted into the SITE Emerging Technology Program in 1993. A 1.4-MeV, 800-amp LIA will be used in the experiments. The primary objective of the program is to demonstrate that x-ray treatment can reduce VOC and SVOC levels in soils to acceptable levels and determine any hazardous byproduct that may be produced. Another objective will specifically determine the x-ray dose required to reduce organic contamination level in solid matrix and determine scaling factor needed: this will provide crucial information on the x-ray dose requirements that will be used to size the conceptual treatment system. The experimental database will be used to develop a conceptual design and estimated cost 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.
(Methanotrophic Biofilm Reactor)

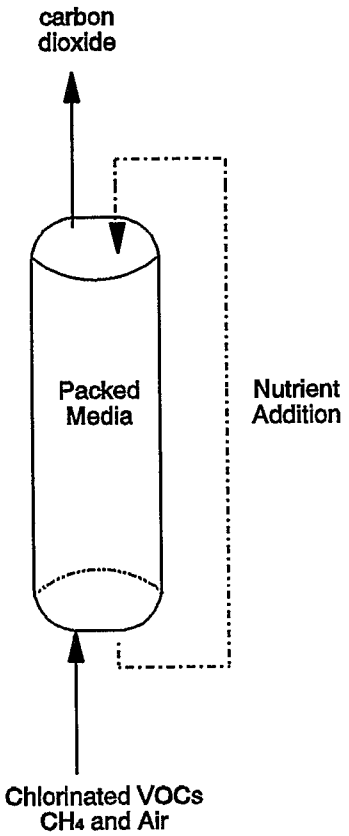
TECHNOLOGY DESCRIPTION:

The Remediation Technologies, Inc., biological treatment technology uses methanotrophic organisms in fixed-film biological reactors to treat chlorinated volatile organic compounds (VOC). Treatment occurs while the VOCs are in a gas phase. Gases enter the bottom of the reactor and flow up through a medium that has a high surface area and favorable porosity for gas distribution (see figure below).

Methane must be supplied to the biofilm reactor to maximize biomass. In the reactor, the methanotrophic organisms oxidize the methane as an energy source. Volatile chlorinated hydrocarbons are cometabolized into various acids and chlorides that are subsequently degraded to carbon dioxide and chloride by other heterotrophic bacteria. A methane-VOC feeding strategy is being developed to maximize methanotrophic bacteria efficiency.

The following four bioreactor designs are being investigated:

- A compost biofilter that uses a medium with some adsorption capacity, high surface area, and small particle size to improve gas flow distribution
- A high density plastic media that minimizes plugging and is easy to operate



Methanotrophic BioFilm Reactor

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

- A silica media with high porosity and favorable surfaces for high biomass growth
- A granular activated carbon bed to better handle load variations

WASTE APPLICABILITY:

This technology can treat chlorinated volatile hydrocarbons in gaseous streams, such as those produced from air stripping or in situ vacuum extraction operations.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in summer 1992. Methanotrophic bacteria from various soils have been tested to determine potential VOC compound degradation. The optimal culture from this testing was isolated and transferred to a biofilm reactor, where substrate degradation rates are now being determined. Media testing in the larger bioreactors is ongoing.

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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 to treat sediments contaminated with polychlorinated biphenyls (PCB) and other chlorinated organic contaminants. This system, shown in Figures 1 and 2, includes a reactor that consists of three chambers connected in series. The first chamber (Chamber A) receives contaminated sediments from a dredge, backhoe, or other device. In Chamber A, the sediment is continuously agitated to allow separation of the suspended and bottom sediment fractions, and a titanium dioxide 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 and radiation, promoting catalytic degradation.

Following continued treatment in Chamber B, the suspended sediment fraction is gravity-discharged to Chamber C 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, drawn through a florisil filter, and treated.

This technology offers the following benefits over extraction, solidification/stabilization, and decomposition:

- The reactor can be operated at ambient pressure and temperature without the addition of organic solvents.
- The catalyst, titanium dioxide, is environmentally inert.

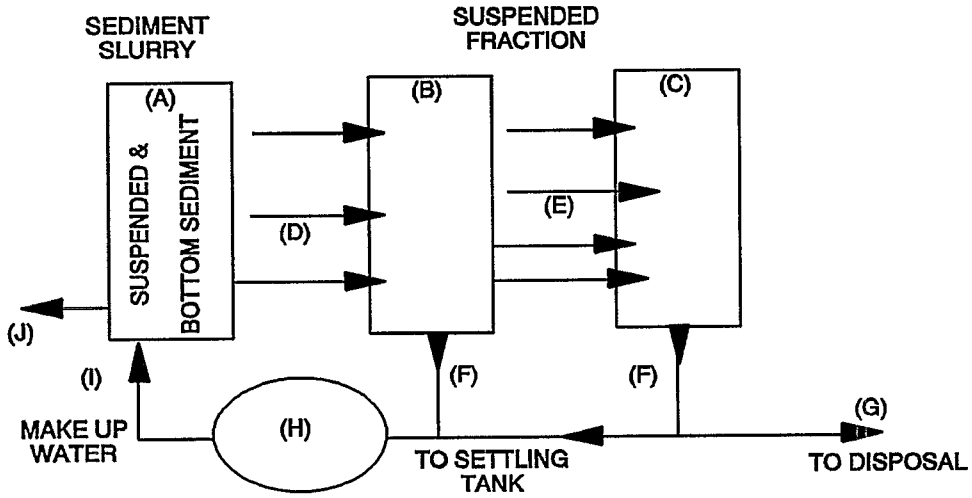

Figure 1: PCB Treatment System

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

- The photocatalytic process can occur using sunlight or artificially produced ultraviolet light.
- The technology requires little energy and may have potential for in situ applications.

WASTE APPLICABILITY:

This technology is designed to treat sediment contaminated with PCBs and other chlorinated organic contaminants on site. It may either reduce levels of PCBs to below detection limits, or it may be used as a pretreatment in conjunction with other technologies such as microbial degradation.

STATUS:

SUNY was accepted into the SITE Emerging Technology Program in 1993. During the first phase of the program, SUNY will conduct experiments to determine optimal operating conditions. Information gathered during this phase will be used to construct a pilot-scale reactor designed to treat up to 5 kilograms of sediment. Sediments from hazardous waste sites in the Massena, New York area will be used for these experiments.

During experiments conducted from June to September 1992, the photocatalytic process reduced PCBs in sediment by 62 and 68 percent after 4 and 6 hours of sunlight irradiation, respectively.

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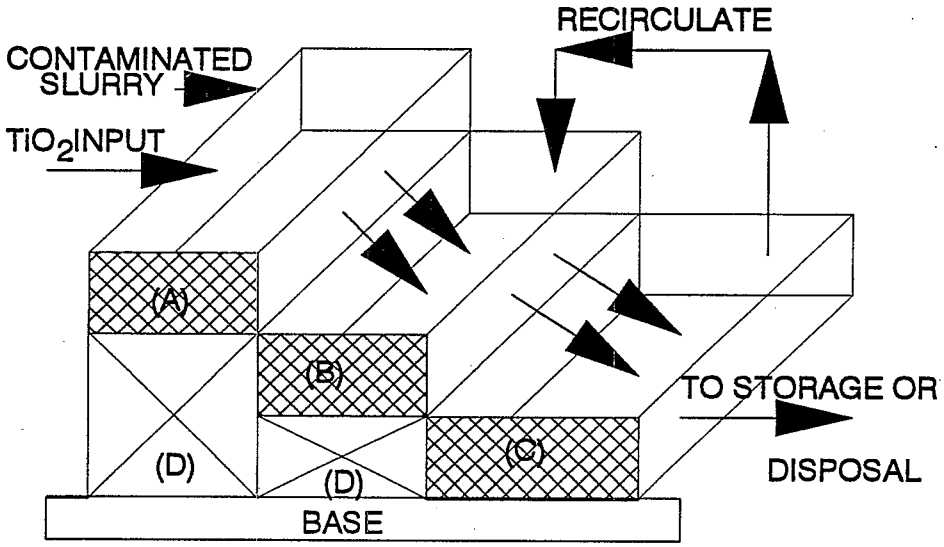


Figure 2: Cross Sectional Schematic of Three Phased Treatment of Contaminated Sediments

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

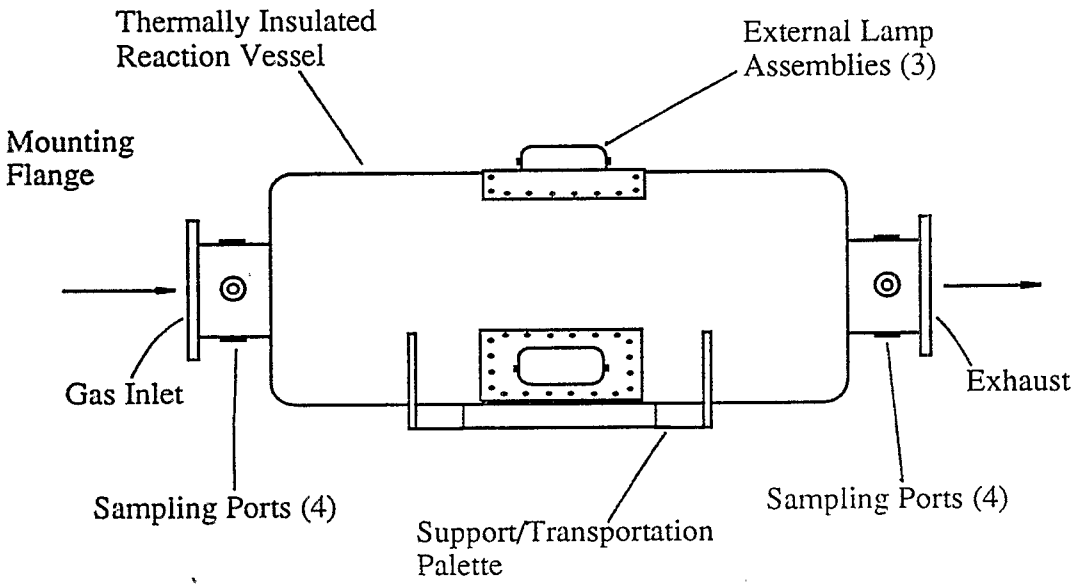
UNIVERSITY OF DAYTON RESEARCH INSTITUTE
(Photothermal Detoxification Unit)

TECHNOLOGY DESCRIPTION:

Photolytic reactions (reactions induced by exposure to light) can destroy certain hazardous organic wastes at relatively low temperatures (such as room temperature). Unfortunately, the success of these reactions in large-scale hazardous waste remediation has been limited. Specifically, most photochemical processes have relatively small throughput rates and cannot completely destroy the targeted wastes. For special cases such as aqueous waste streams, these problems have been partially addressed by using indirect photochemical reactions involving highly reactive photolytic initiators such as hydrogen peroxide or heterogeneous catalysts. The University of Dayton Research Institute has developed a photolytic detoxification process that is extremely 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 °C versus 20 °C) but lower than combustion temperatures (typically greater than 1,000 °C). At these elevated temperatures, photothermal reactions destroy wastes quickly and efficiently without producing complex and potentially hazardous by-products.

The PDU consists of an insulated reactor vessel illuminated with high intensity ultraviolet (UV) lamps. As shown in the figure below, the lamps are mounted externally for easy maintenance and inspection. Remediation technologies that generate high temperature gas streams (such as thermal desorption or in situ steam stripping) can incorporate the PDU with only slight modifications to the equipment. The PDU can be equipped with a preheater for use with low temperature extraction technologies. Furthermore, the PDU can also be equipped with conventional air pollution control devices for removal of acids and suspended particulates from the treated process stream. For groundwater remediation processes, the PDU can be used with an air stripping operation. The PDU



Photothermal Detoxification Unit (PDU)

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

shown in the figure also includes built-in sampling ports for measuring the composition of the inlet and effluent streams and monitoring the performance of the unit.

WASTE APPLICABILITY:

The PDU has proven extremely effective in destroying 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 waste destruction operation. Furthermore, the PDU can readily treat noncombustible mixtures as well as waste streams with low concentrations of hazardous waste.

STATUS:

The technology was accepted into the Emerging Technology Program in August 1992, and development work began in December 1992. Under programs sponsored by the U.S. Department of Energy the technology's effectiveness was thoroughly investigated using relatively long wavelength UV light (that is, concentrated sunlight with wavelengths greater than 300 nanometers). Limited data have also been generated for shorter wavelengths (higher energy) using available industrial UV illumination systems.

Preliminary data from the Emerging Technology Program have shown the technology performs as expected for chlorinated aromatic wastes (such as dichlorobenzene), and better than expected for relatively low molecular weight chlorinated solvents (such as trichloroethene). During the remaining first year of the program, the technology will be further tested using typical wastes found at hazardous waste sites. The resulting information will be used during the second year of the program to develop a general PDU reactor model and a detailed prototype design.

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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:

This technology addresses the acid drainage problem associated with exposed sulfide-bearing minerals (such as mine waste rock and abandoned metallic mines). Acid drainage forms under natural conditions when iron disulfides (such as fool's gold) are exposed to the atmosphere and water, spontaneously oxidizing to produce a complex of highly soluble iron sulfates. 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.

During mine construction, surface depressions are installed to collect surface runoff and funnel it into the waste rock dump through chimneys constructed of the limestone. Acidic material is

Overview of Site Lysimeters

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

capped with impermeable material to divert water from the acid cores. Through this design, the net acid load will be lower than the alkaline load, resulting in benign, nonacid drainage.

WASTE APPLICABILITY:

The technology migrates 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) have been constructed and lined with 20-mil polyvinyl chloride plastic. The lysimeters are drained through an outlet pipe into 55-gallon collection barrels. Piezometers in the lysimeter floor monitor 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 has been 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 has been installed at the site for mass balance measurements. An ancillary study correlating laboratory and field results is complete.

Due to the drought in the Southeast, little, if any, leachate has been collected. With the return of normal climatic conditions, leachates indicative of treatment effects will be produced and collected.

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

WARREN SPRING LABORATORY
(Physical and Chemical Treatment)

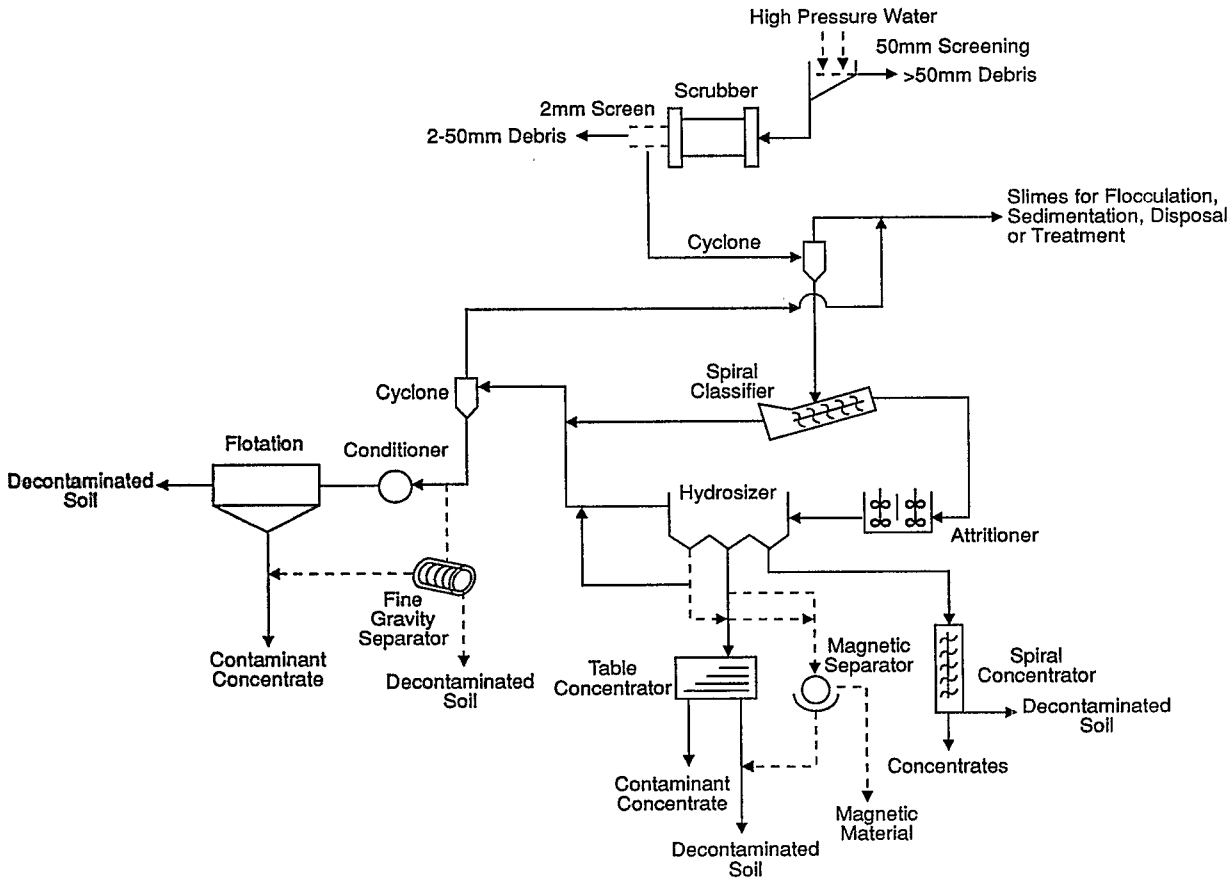
TECHNOLOGY DESCRIPTION:

Warren Spring Laboratory is investigating the use of feed preparation and mineral processing techniques to treat soil contaminated with metals, petroleum hydrocarbons, and polynuclear aromatic hydrocarbons (PAH).

Feed preparation processes being evaluated include scrubbing, classifying, and cycloning. Mineral processing techniques including flotation, flocculation, high- and low-intensity magnetic separation, and gravity techniques are also being investigated. The processes will be tested at the pilot scale to produce an integrated system that treats contaminated soil.

A typical process flow for the physical treatment of contaminated soil is shown below. Feed preparation samples undergo scrubbing, attritioning, size fractionation, and chemical analysis. The samples then undergo magnetic separation using high-gradient and high-intensity matrices for metals separation.

Flotation procedures for selected removal of organics will use several frother types (alcohols, polyglycols, and cresols) with pH values ranging



Physical Treatment of Soil

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

from 5 to 10 to maximize organics recovery and increase selectivity of solids. Metals flotation will be evaluated by comparing different sulfydric collectors including xanthates, thiophosphates, thiocarbonates, and xanthogen formates. The separation of organic and metal phases will be examined using selective flocculation techniques.

The pilot-scale treatment system under development will process a sample of up to 50 tons and have a throughput of 1 to 2 tons per hour. However, capacities for a full-scale system would range from 20 to 60 tons per hour.

The principal objective of the techniques under development is to separate components of the soil that are contaminated from components that are not. The contaminated components then form a concentrate needing further treatment or safe disposal. Because the treatment method is essentially a wet process that treats the soil as a slurry, some of the contamination may be transferred to the liquid phase and require further treatment.

WASTE APPLICABILITY:

This technology is being developed to remove metals, petroleum hydrocarbons, and PAHs from soil. Sediments and certain industrial wastes such as sludges may also be candidates for treatment.

Applications include gas works, petrochemical plants, pickling plants, industrial chemical plants, coke manufacturers, scrapyards, ship repair yards and foundries.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. Initial laboratory-scale tests have been completed, and a soil has been selected for further investigation. More detailed unit process investigations using this selected soil are underway. When these tests are completed, a final pilot-scale test will be performed using up to 50 tons of the soil. The pilot plant test is scheduled for a 3-week run in November or December 1993.

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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)

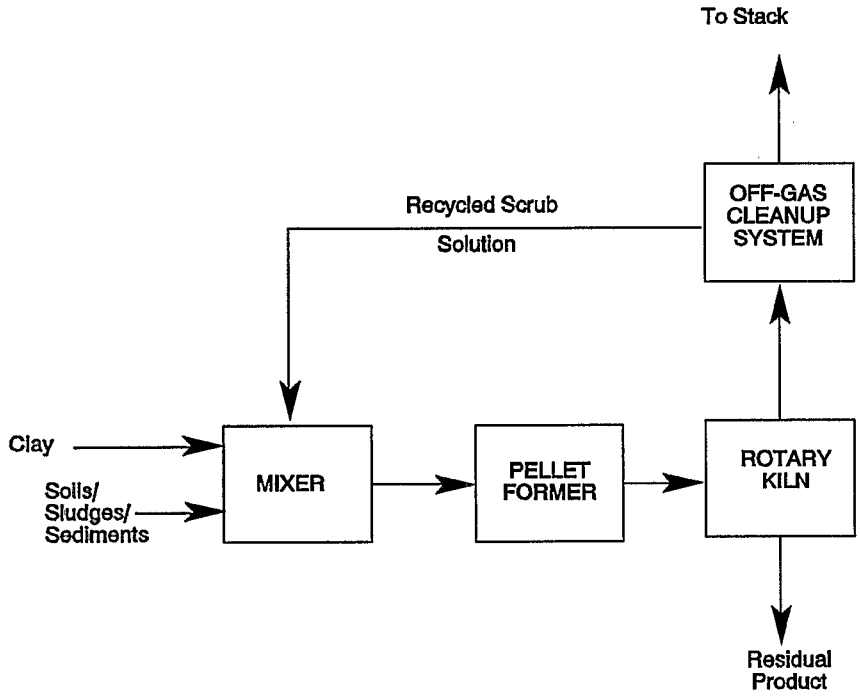
TECHNOLOGY DESCRIPTION:

The coordinate, chemical bonding and adsorption (CCBA) process converts heavy metals in soils, sediments, and sludges to nonleaching silicates. The process (see figure below) can also oxidize organics in the waste stream and incorporate the ash into the ceramic pellet matrix. The consistency of the solid residual varies from a soil and sand density and size distribution to a controlled size distribution ceramic aggregate form. The residue can be (1) placed back in its original location or (2) used as a substitute for conventional aggregate.

The technology uses specific clays with 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 is 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 °F creating the ceramic nature of the fired pellet. Organics on the surface of the pellet are oxidized, and organics inside the pellet are pyrolyzed, as the pellet 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 residue from the process is an inert ceramic product, free of organics, with metal silicates providing the molecular bonding structure to preclude leaching. The off-gas from the kiln is processed in an afterburner and wet scrub sys-



CCBA Process

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

tem before release to the atmosphere. Excess scrub 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 weight solids. This process can treat wastewater sludges, sediments, and soils contaminated with mixed organic and heavy metal wastes.

STATUS:

This technology 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 organics. The initial SITE studies will be done 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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513-569-7348
Fax: 513-569-7676

TECHNOLOGY DEVELOPER CONTACT:
Donald Kelly
Western Product Recovery Group, Inc.
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Houston, TX 77279
713-493-9321
Fax: 713-493-9434

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

ROY F. WESTON, INC.
(Ambersorb® 563 Adsorbent)

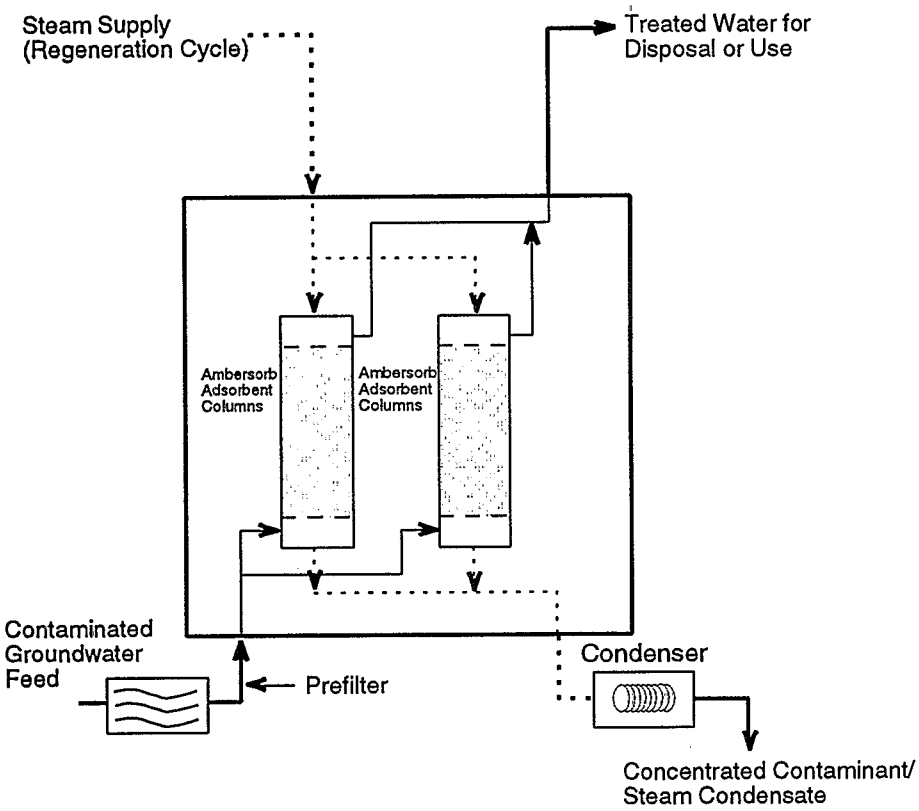
TECHNOLOGY DESCRIPTION:

This technology is a regenerable adsorption system to treat groundwater contaminated with hazardous organics. Ambersorb® 563 is a synthetic adsorbent with 5 to 10 times the capacity of granular activated carbon (GAC) for volatile organic compounds (VOC) present at low concentrations.

Current adsorption techniques that use GAC 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.

The unique properties of Ambersorb® 563 carbonaceous adsorbent 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.



Remediation of Contaminated Groundwater Using Ambersorb® 563 Carbonaceous Adsorbent

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

- Its higher flow rate operation as compared with GAC translates into a smaller, more compact system.
- Ambersorb® adsorbents are hard, non-dusting, spherical beads with excellent physical integrity, thus eliminating handling problems and attrition losses typically associated with GAC.
- Ambersorb® 563 Adsorbent is not prone to bacterial fouling.
- Ambersorb® adsorbents have extremely low ash levels (less than 0.05 percent).
- Because of stringent quality control during manufacturing, Ambersorb® adsorbents can be manufactured with very little variation.

In addition, the Ambersorb® 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. Alternatively, removed organics could be burned as 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 results in a more cost-effective alternative to currently available technologies for the treatment of low-level VOC-contaminated groundwater.

WASTE APPLICABILITY:

This technology 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.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Ambersorb® is a registered trademark of the Rohm and Haas Company.

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 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 expert 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.

In conjunction with the demonstration of the Base-Catalyzed Decomposition technology held at the Koppers Wood Preserving site in Morrisville, North Carolina, four pentachlorophenol (PCP) test kits and a Field Analytical Screening Program (FASP) method were demonstrated under MMTP. Three were immunoassay kits, developed by Ensys, Inc., Millipore, Inc., and Ohmicron Corporation, that were used to detect and quantify the PCP concentrations. The fourth kit, developed by HNU Systems, used a Friedel-Crafts reaction that can quantify the concentration of several organic contaminants. The FASP method, developed by EPA, is an abbreviated standard analytical method for PCP using gas chromatography. Soil and water samples from the Winona Post Wood treating site in Missouri were also analyzed so the effect of different carrier solvents on test results could be evaluated.

Two demonstrations are in the planning phase, one for field-portable x-ray fluorescence technologies and one for cone-penetrometer-mounted chemical sensors. Developers interested in participating should contact J. Lary Jack at 703-798-2373.

Evaluations or demonstrations have been completed for 22 projects in the MMTP. These technologies are presented in alphabetical order in Table 4, and most are included in the technology profiles that follow.

TABLE 5

Completed SITE Monitoring and Measurement Technologies Program Projects as of October 1993

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	J. Lary Jack or Stephen Billets 702-798-2373	Water, Air Streams	Not Applicable	VOCs
Binax Corporation, Antox Division, South Portland, ME	Equate® Immunoassay	Roger Piasio 207-772-3544	Jeanette Van Emon 702-798-2154	Water	Not Applicable	BTX (benzene, toluene, xylene)
Bruker Instruments, Billerica, MA	Bruker Mobile Environmental Monitor	John Wronka 508-667-9580	J. Lary Jack or Stephen Billets 702-798-2373	Air Streams, Water, Soil, Sludge, Sediment	Not Applicable	VOCs, SVOCs, and PCBs, PAHs
Dexsil Corporation, Hamden, CT (2 Demonstrations)	Environmental Test Kits	Steve Finch 203-288-3509	J. Lary Jack 702-798-2373	Soil	Not Applicable	PCBs
EnSys, Inc. (developed by Westinghouse Bio-Analytical Systems),* (2 demonstrations) Research Triangle Park, NC	Immunoassay for PCP	Stephen Friedman 914-941-5509	Jeanette Van Emon 702-798-2154	Groundwater	Not Applicable	PCP
Graseby Ionics, Ltd., Watford, Herts, England and PCP, Inc., West Palm Beach, FL (2 Demonstrations)	Ion Mobility Spectrometry	John Brokenshire 011-44-923-816166 Martin Cohen 407-683-0507	J. Lary Jack 702-798-2373	Air Streams, Vapor, Soil, Water	Not Applicable	VOCs
HNU Systems, Incorporated,* Newtown, MA	PCP Test Kit	Bob Laliberk 800-726-6690 ext. 184	Jeanette Van Emon 702-798-2154	Soil, Water	Not Applicable	PCPs
HNU Systems, Incorporated, Newtown, MA	Portable Gas Chromatograph	Clayton Wood 617-964-6690	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs, Aromatic Compounds, Halocarbons
MDA Scientific, Incorporated, Norcross, GA	Fourier Transform Infrared Spectrometer	Orman Simpson 404-242-0977	William McClenny 919-541-3158	Air Streams	Nonspecific Inorganics	Nonspecific Organics

* This technology is not profiled in this document. For further information, please contact either the Technology Contact or the EPA Project Manager.

TABLE 5 (Continued)

Completed SITE Monitoring and Measurement Technologies Program Projects as of October 1993

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
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	Jeanette Van Emon 702-798-2154	Soil	Not Applicable	PCBs
Millipore Corporation,* Bedford, MA	Immunoassay for PCP	Alan Weiss 800-225-1380 ext. 2968	Jeanette Van Emon 702-798-2154	Soil, Water	Not Applicable	PCPs
MTI Analytical Instruments (formerly Microsensor Technology, Incorporated), Fremont, CA	Portable Gas Chromatograph	Kent Hammarstrand 510-490-0900	Richard Berkley 919-541-2439	Air Streams	Nonspecific Inorganics	Nonspecific Organics
Ohmicron Corporation* Newtown, MA	Immunoassay for PCP	Dave Herzog 215-860-5115	Jeanette Van Emon 702-798-2154	Soil, Water	Not Applicable	PCPs
Photovac International, Incorporated, Deer Park, NY	Photovac 10S PLUS	Mark Collins 516-254-4199	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
Sentex Sensing Technology, Incorporated, Ridgefield, NJ	Portable Gas Chromatograph	Amos Linenberg 201-945-3694	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
SRI Instruments, Torrance, CA	Gas Chromatograph	Dave Quinn 310-214-5092	Richard Berkley 919-541-2439	Air Streams	Not Applicable	VOCs
United States Environmental Protection Agency Las Vegas, NV	Field Analytical Screening Program PCB Method	Not Available	J. Lary Jack 702-798-2373	Soil	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

* This technology is not profiled in this document. For further information, please contact either the Technology Contact or the EPA Project Manager.

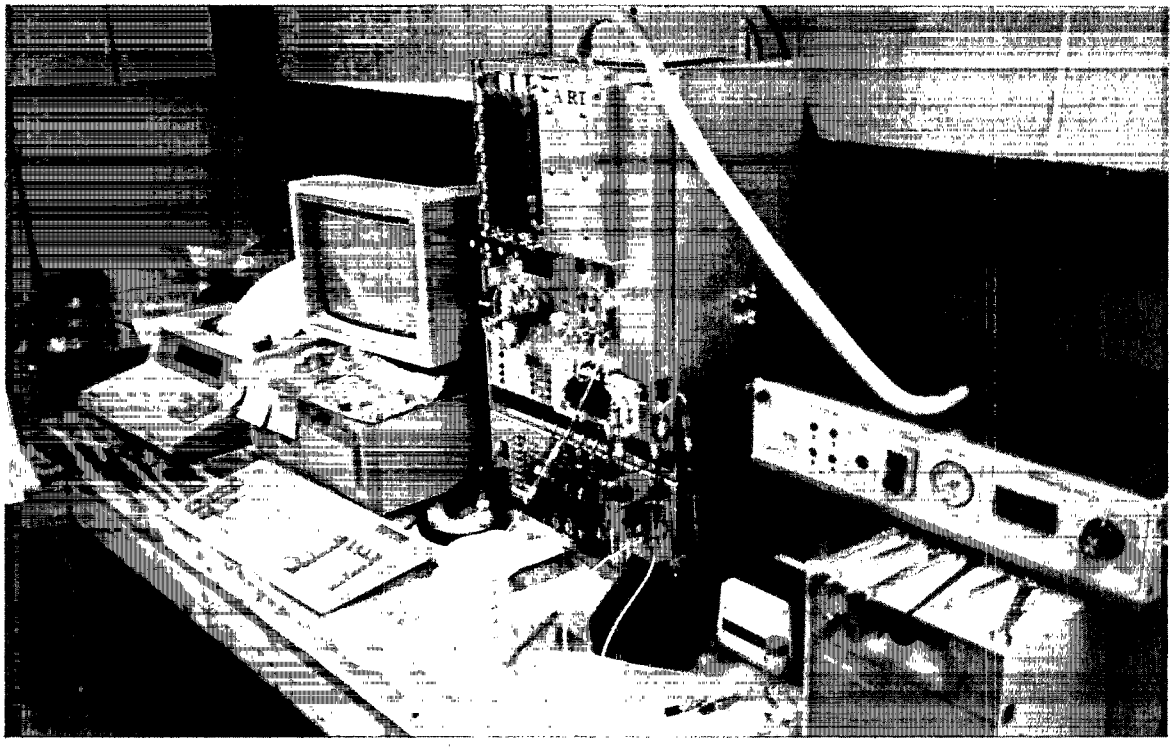
ANALYTICAL AND REMEDIAL TECHNOLOGY, INC.
(Automated Volatile Organic Analytical System)

TECHNOLOGY DESCRIPTION:

The automated volatile organic analytical system (AVOAS) permits the continuous monitoring of a water stream. The instrument (see photograph below) consists of a sampling manifold that automatically samples at predetermined collection points within the process under study. The samples are then shunted directly into a chamber where a conventional purge-and-trap procedure is carried out. The analytes are collected on a sorbent trap, which is then thermally desorbed. The sample is then 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 system is designed for the automated determination of volatile organic compounds in aqueous samples, as may be 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



Automated Volatile Organic Analytical System (AVOAS)

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

provide real-time analytical data during the remediation and long-term monitoring phases at a Superfund site.

STATUS:

A demonstration was conducted 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 engineering study. For purposes of this demonstration, EPA Method 502.2 was evaluated. 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.

FOR FURTHER INFORMATION:

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U.S. EPA
Environmental Monitoring Systems
Laboratory-Las Vegas
P.O. Box 93478
Las Vegas, NV 89193
702-798-2373

TECHNOLOGY DEVELOPER CONTACT:
D. MacKay
Analytical and Remedial Technology, Inc.
206 West O'Conner Street
Menlo Park, CA 94025
415-324-2259

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

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.

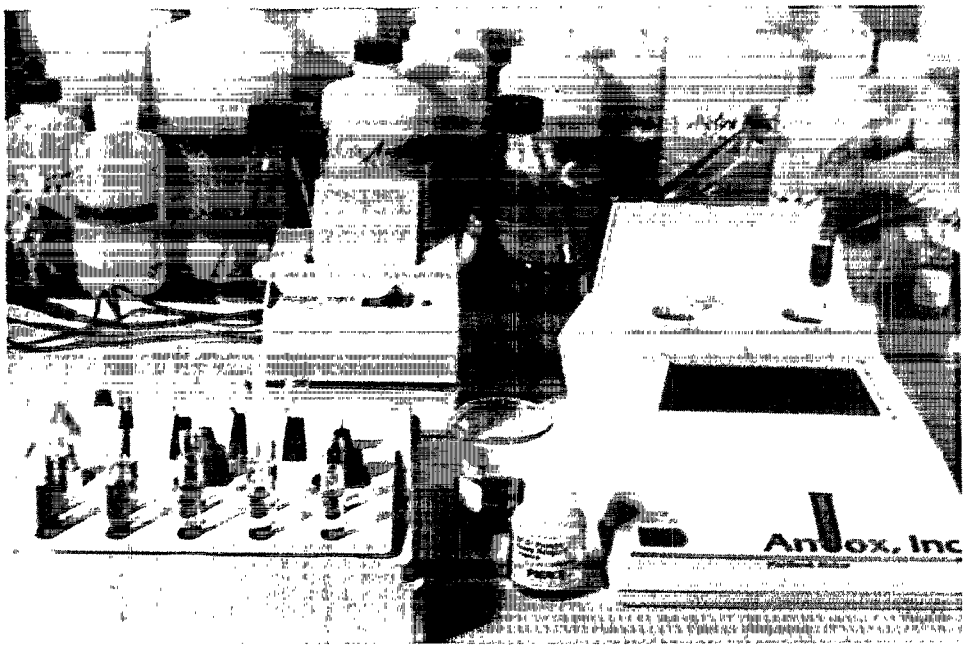
As with other competitive enzyme-linked immunosorbent assays, the color intensity of the enzymatic product is inversely proportional to the sample analyte concentration. Each sample is run with a reference sample of deionized water. The optical density of the colored enzymatic product is read on a portable 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.

STATUS:

The Environmental Monitoring System Laboratory-Las Vegas evaluated several successful versions of the immunoassay. The evaluation



Equate® Immunoassay Kit

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

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.

FOR FURTHER INFORMATION:

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207-772-3544
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The SITE Program assesses but does not approve or endorse technologies.

BRUKER INSTRUMENTS
(Bruker Mobile Environmental Monitor)

TECHNOLOGY DESCRIPTION:

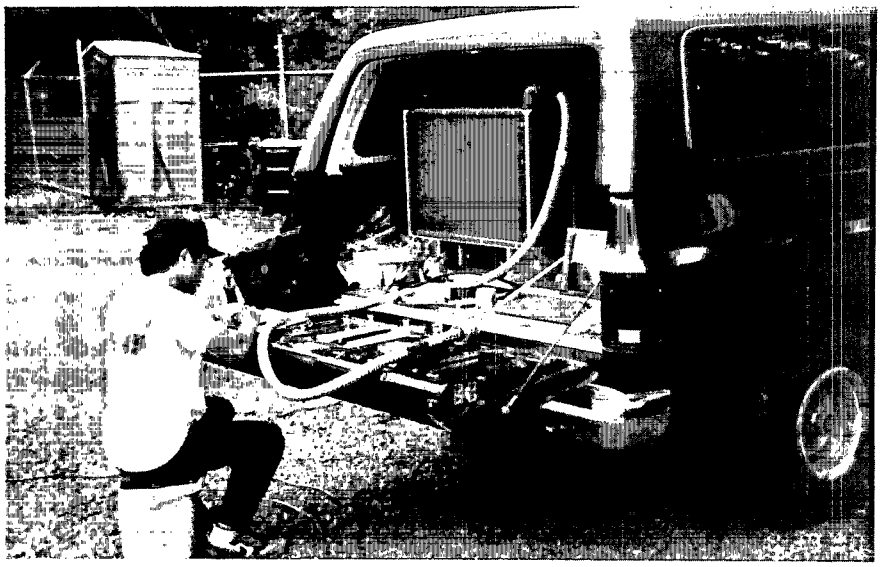
This mobile environmental monitor (see photograph below) is a field transportable mass spectrometer designed to identify and measure organic pollutants in various environmental media. The spectrometer uses a quadruple mass analyzer similar to most conventional instruments. Like conventional mass spectrometers, this instrument can be used to identify and quantify organic compounds on the basis of their retention time, molecular weight, and characteristic fragment pattern. The design and electronics of the Bruker instrument are specially designed for field use.

The instrument is designed to operate by battery power and can be used in various environmental situations with minimum support requirements. The integrated gas chromatograph allows for the 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 reduction and analysis are carried out. 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 extracts of water, soil, sediment, sludge, and hazardous waste. 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 Re-Solve Inc., and Westborough Superfund site in EPA Region 1. The technology was used to analyze polychlorinated biphenyls and poly-nuclear aromatics in soil and the full range of Superfund-targeted volatile organic compounds in water. 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 (May 1991) and at the Superfund Hazardous Waste Conference (July 1991). A recent survey of regional laboratories identified additional testing of this technology as a priority need.

Environmental Monitoring Systems Laboratory–Las Vegas purchased a field portable gas chromatograph/mass spectrometer system in fiscal year 1992 to pursue other applications and to expand the scope of this project.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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508-667-9580

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 extracts PCBs from soil and dissociates the PCBs with a sodium reagent, freeing chloride ions (Cl^-). These ions are then exposed to mercuric ions to form a mercury chloride compound. The extract is then treated with diphenyl carbazone, which reacts with free mercury 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 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.

WASTE APPLICABILITY:

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 quantitates specific concentrations of PCBs in a sample over the range of 2 to 2000 ppm PCB. The applicability of these methods depends on the data quality needs of a specific project. Both tech-

Dexsil Clor-N-Soil PCB Screening Kit

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

nologies can be used on site for site characterization or removal action.

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 Contract Laboratory Program (CLP) 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 CLP data. These data also were 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 1994.

FOR FURTHER INFORMATION:

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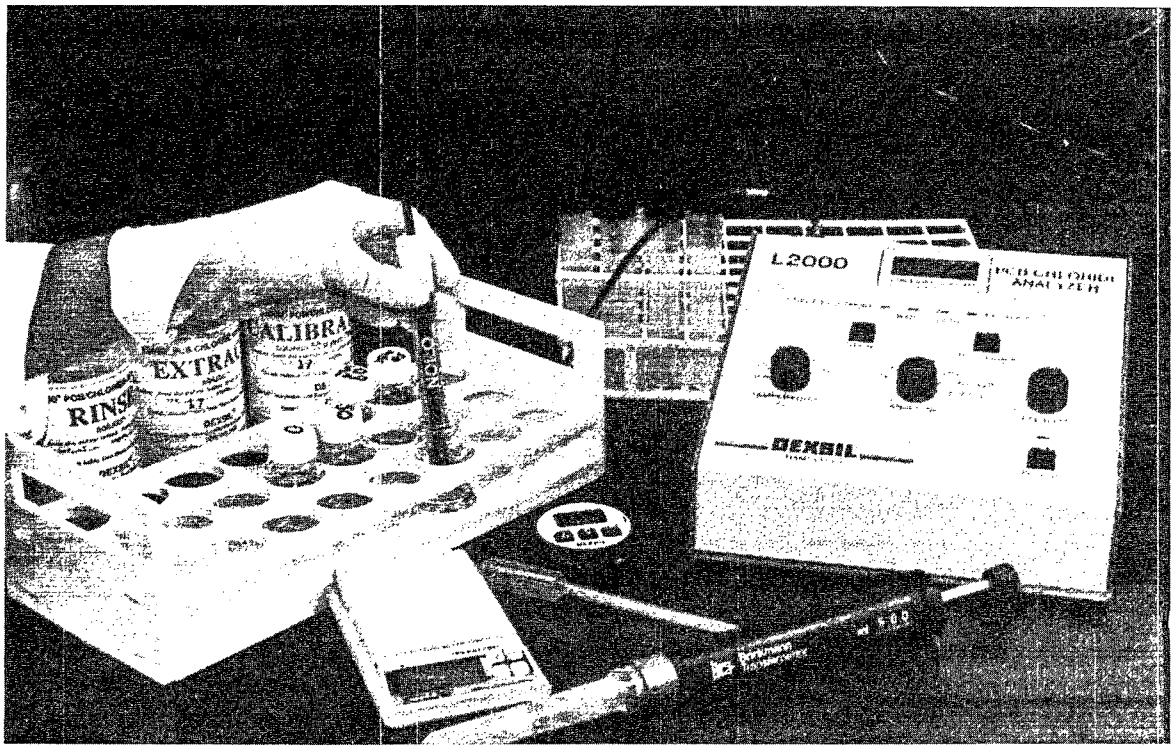


Dexsil L2000 PCB/Chloride Analyzer

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

GRASEBY IONICS, LTD., and PCP, INC.
(Ion Mobility Spectrometry)

TECHNOLOGY DESCRIPTION:

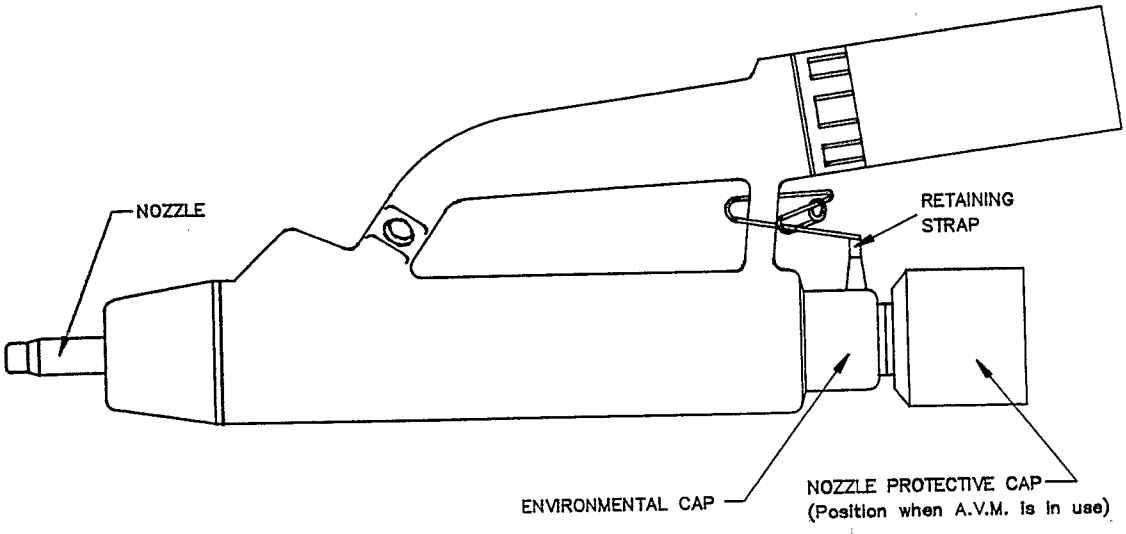
Ion mobility spectrometry (IMS) is a technique used to detect and characterize organic vapors in air. IMS involves the ionization of molecules and their subsequent temporal drift through an electric field. Analysis and characterization are based on analyte separations resulting from ionic mobilities rather than masses; this distinguishes IMS from mass spectrometry. IMS is operated at atmospheric pressure, a characteristic that has practical advantages 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 one of several chemicals, such as chloroform, ethylbenzene, and other volatile organic compounds (VOC), in a defined situation. They can be used to analyze air, vapor, soil, and water samples. However, for analysis of 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 for these developers to test their instruments using environmental samples. Though the potential of IMS is known, the results of the laboratory demonstration highlighted, for the first time, the technology's



Airborne Vapor Monitor

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

limitations. Two main needs must be met 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

A Technology Evaluation Report on the IMS laboratory demonstration is being prepared.

FOR FURTHER INFORMATION:

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2155 Indian Road
West Palm Beach, FL 33409–3287
407–683–0507

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

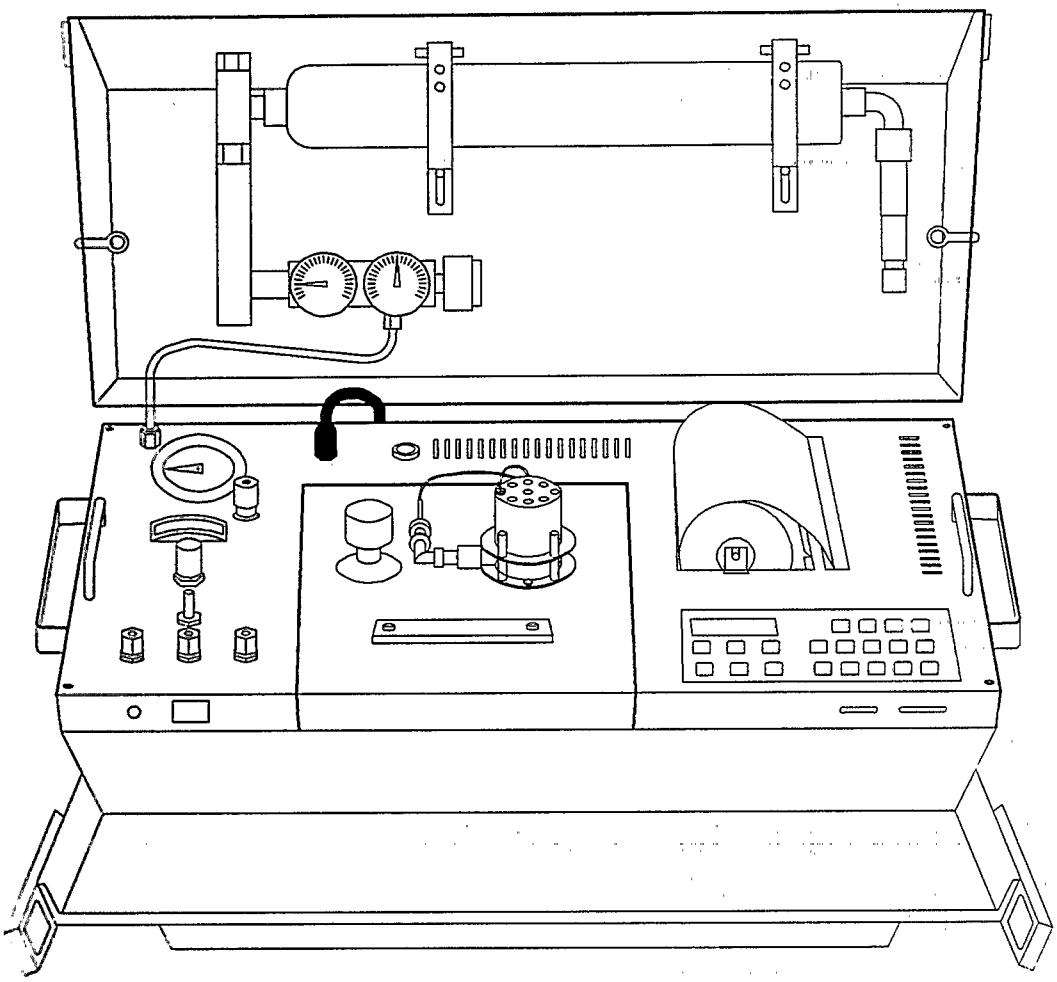
HNU SYSTEMS, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The HNU GC 311 portable isothermal gas chromatograph (see figure below) is specially designed to be field-deployable. It has an internal carrier gas supply, operates on 110-volt line power, and is microprocessor-controlled. Chromatograms are plotted, and data are printed on an internal printer plotter. 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 can be used to monitor volatile organic compound emissions from hazardous waste sites and other emissions sources before and during remediation. It 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:

Field evaluation at a Superfund site under remediation was conducted during January 1992. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure
Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
Clayton Wood
HNU Systems, Incorporated
160 Charlemont Street
Newtown, MA 02161-9987
617-964-6690

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

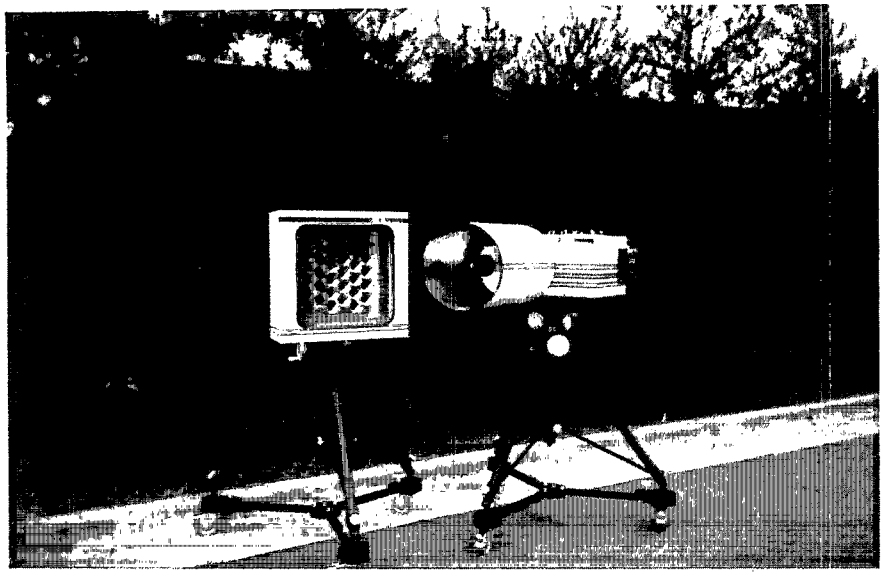
MDA SCIENTIFIC, INCORPORATED
(Fourier Transform Infrared Spectrometer)

TECHNOLOGY DESCRIPTION:

This long-path monitoring system (see photograph below) is a field-deployable long-path Fourier transform infrared spectrometer that measures infrared absorption by infrared-active molecules. An infrared beam is transmitted along a path to a retroflector that returns it to the detector. The total path can be up to 1 kilometer long. The system does not need calibration in the field. Analysis is performed by using a reference spectrum of known concentration and classical least squares fitting routines. It does not require the acquisition of 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 long-path monitor can measure various airborne vapors, including both organic and inorganic compounds, especially those that are too volatile to be collected by preconcentration methods. It can be used to monitor emissions



Fourier Transform Infrared Spectrometer

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

from hazardous waste sites during remediation. Under proper conditions, it may be possible to estimate emission rates of vapors from the site.

STATUS:

The long-path monitor has been evaluated in several field studies and has been 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. A field evaluation of this instrument was conducted 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).

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
William McClenny
U.S. EPA
Atmospheric Research and Exposure
Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-3158

TECHNOLOGY DEVELOPER CONTACT:
Orman Simpson
MDA Scientific, Incorporated
3000 Northwoods Parkway
Norcross, GA 30071
404-242-0977

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

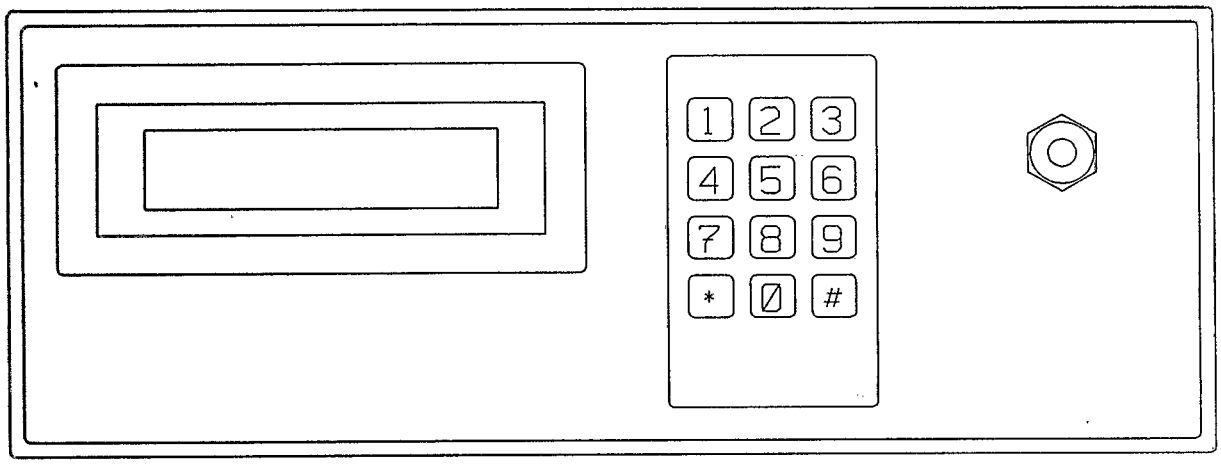
MICROSENSOR SYSTEMS, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The MSI-301A vapor monitor (see figure below) is a portable, temperature-controlled gas chromatograph with a highly selective surface acoustic wave detector and an on-board computer. It preconcentrates samples and uses scrubbed ambient air as a carrier gas. It analyzes a limited group of preselected compounds (for example, benzene, toluene, and xylenes) at part-per-billion levels. It is battery-powered and includes an RS-232 interface. It can be operated automatically as a stationary sampler or manually as a mobile unit.

WASTE APPLICABILITY:

The MSI-301A vapor monitor can be used to 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. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure
Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
N. L. Jarvis
Microsensor Systems, Incorporated
62 Corporate Court
Bowling Green, KY 42103
410-939-1089
Fax: 410-939-1168

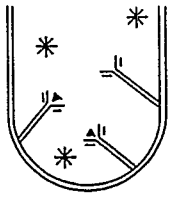
The SITE Program assesses but does not approve or endorse technologies.

MILLIPORE CORPORATION
(EnviroGard™ PCB Immunoassay Test Kit)

TECHNOLOGY DESCRIPTION:

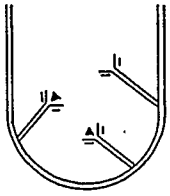
The EnviroGard™ polychlorinated biphenyl (PCB) immunoassay test kit performs rapid analysis of PCBs in soils. The test kit procedure is shown below. Soil sample extracts are added to test tubes coated with antibodies that bind PCB molecules. The soil extracts are washed away after incubation, and a PCB conjugate (horse radish peroxidase enzyme), which mimics free PCB molecules, 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 added to the test tube. The color intensity is measured at 405 nanometers using a small, portable spectrophotometer. The color intensity is inversely proportional to PCB con-

Incubation 1:
Dilution of sample or calibrator is incubated in tube containing immobilized antibodies.

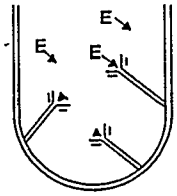


▲ = PCB
✳ = Non-PCB Material in Filtrate or Calibrator
= PCB Antibody

Wash 1:
Non-PCB material is washed away, leaving only PCBs bound to antibodies.

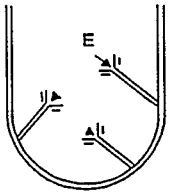


Incubation 2:
PCB-HRP binds to free anti-PCB sites on immobilized antibodies.

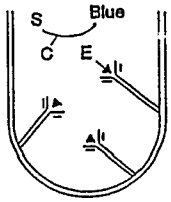


E = HRP (Horse Radish Peroxidase Enzyme)

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.

centration 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 can be 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. The developer can provide optional protocols to perform more detailed quantitative analysis.

WASTE APPLICABILITY:

The PCB immunoassay measures PCBs in soil. The test is equally sensitive 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, 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™ test kit has been used for screening and quantifying 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 to implement 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 actual contaminant levels. Test results were confirmed by off-site analysis using EPA Method 8080.

Soils contaminated with Aroclor 1242 in ranges from 0 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 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 (OSW) methods panel in summer 1992. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Jeanette Van Emon
U.S. EPA
Environmental Monitoring Systems
Laboratory-Las Vegas
P.O. Box 93478
Las Vegas, NV 89193-3478
702-798-2154

TECHNOLOGY DEVELOPER CONTACT:
Alan Weiss
Analytical Division
Millipore Corporation
80 Asby Road
Bedford, MA 01730
617-275-9200, ext. 2968

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

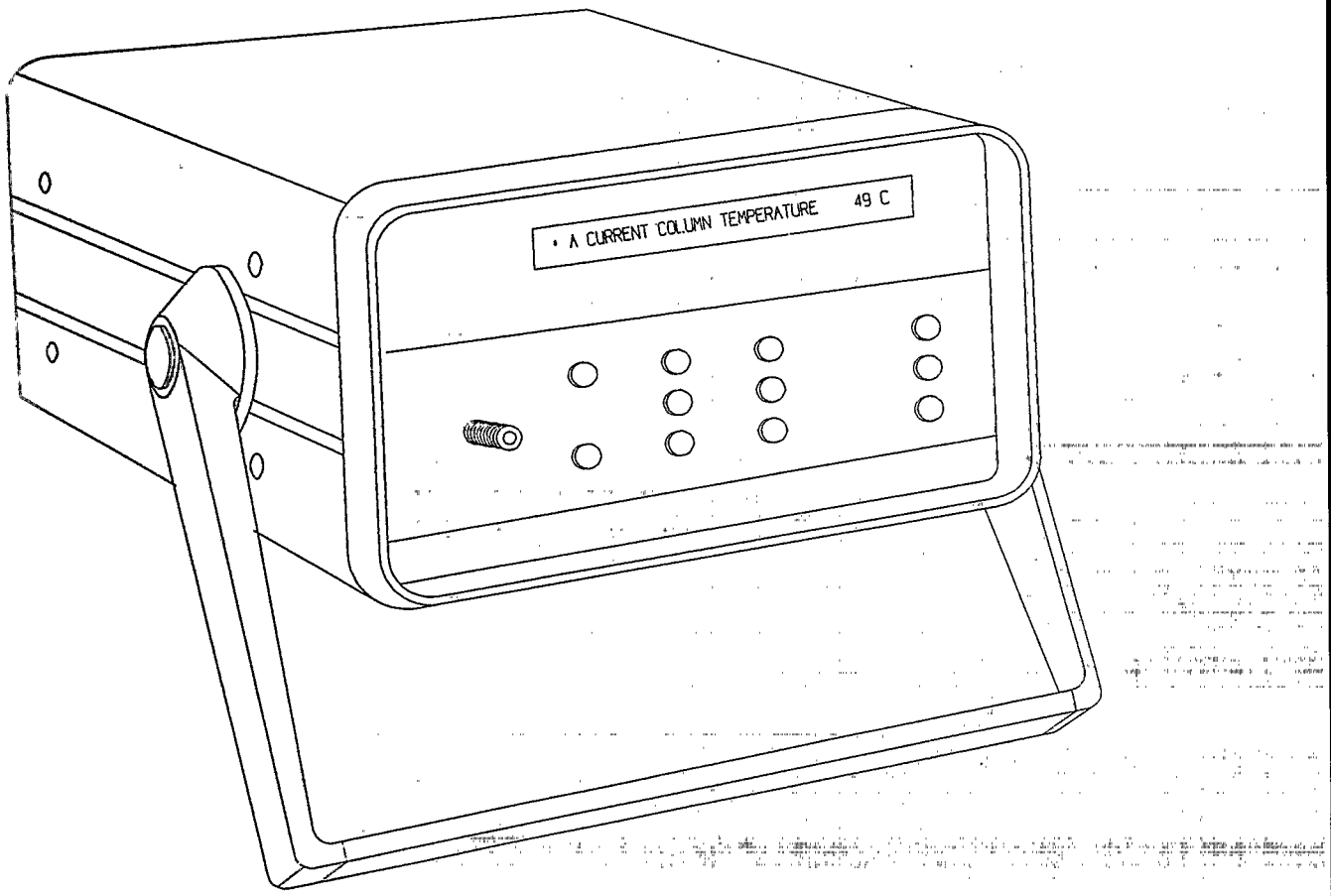
MTI ANALYTICAL INSTRUMENTS
(formerly MICROSENSOR TECHNOLOGY, INCORPORATED)
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The MTI Analytical Instruments M200 gas analyzer (see figure below) is a dual-channel portable isothermal gas chromatograph. 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, then placed in line with the carrier stream. Concentrations as low as 1 part per million (ppm) can be detected from a wide variety of volatile organic compounds (VOC) without preconcentration. Chromatograms are completed in less than 5 minutes.

WASTE APPLICABILITY:

The M200 gas analyzer can potentially be used to monitor VOC emissions from hazardous waste sites before and during remediation. Analysis of concentrations below 1 ppm requires the use of a preconcentrator. Because of the universal sensitivity of its thermal conductivity detector, it is potentially applicable to many types of vapor phase compounds, both organic



M200 Gas Analyzer

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

and inorganic. However, its performance characteristics in field operation have not been evaluated because a suitable preconcentrator is not available.

STATUS:

Laboratory evaluation of this instrument was conducted during 1990 through 1992. The instrument's sensitivity was inadequate for field operation without preconcentration.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
Kent Hammarstrand
Microsensor Technology, Incorporated
41762 Christy Street
Fremont, CA 94538
510-490-0900

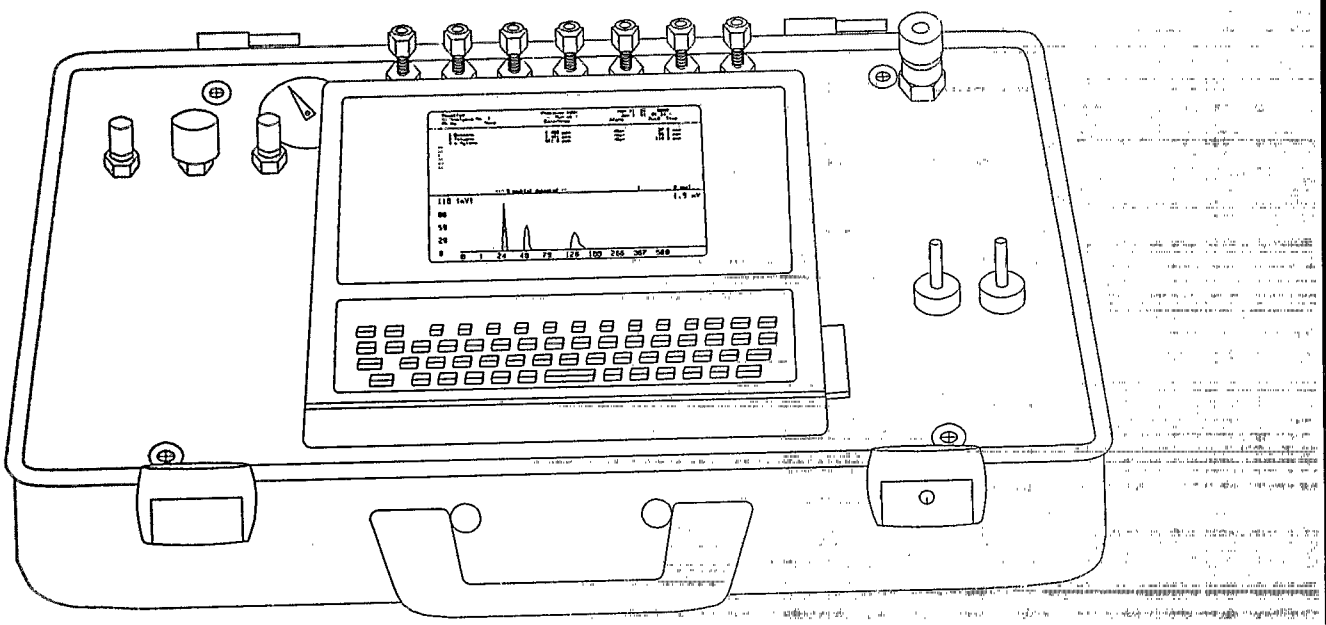
The SITE Program assesses but does not approve or endorse technologies.

PHOTOVAC INTERNATIONAL, INCORPORATED
(Photovac 10S PLUS)

TECHNOLOGY DESCRIPTION:

The Photovac 10S PLUS (see figure below) is a redesigned version of the Photovac 10S70, a battery-powered portable isothermal gas chromatograph. The 10S PLUS addresses many of the design problems in the 10S70 and includes the following characteristics:

- 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.
- For a limited number of compounds that ionize below 10.6 eV and are volatile enough to elute at 50° C or below, it is highly selective and more sensitive than any other detector.
- This unit is capable of detecting benzene, toluene, xylenes, and chlorinated ethylenes in samples that are small enough to be chromatographed, without



Photovac 10S PLUS

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

preconcentration, at concentrations well below 1 part per billion.

WASTE APPLICABILITY:

The Photovac 10S PLUS can be used to monitor volatile organic compound (VOC) emissions from hazardous waste sites and other emission sources before and during remediation. Its predecessor, the 10S70 is an effective — though somewhat unreliable — monitor for volatile aromatic and chlorinated olefin compounds at ambient background levels.

STATUS:

Field evaluation at a Superfund site under remediation was conducted in January 1992. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure Assessment Laboratory
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Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
Mark Collins
Photovac International, Incorporated
25B Jefryn Boulevard West
Deer Park, NY 11729
516-254-4199

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

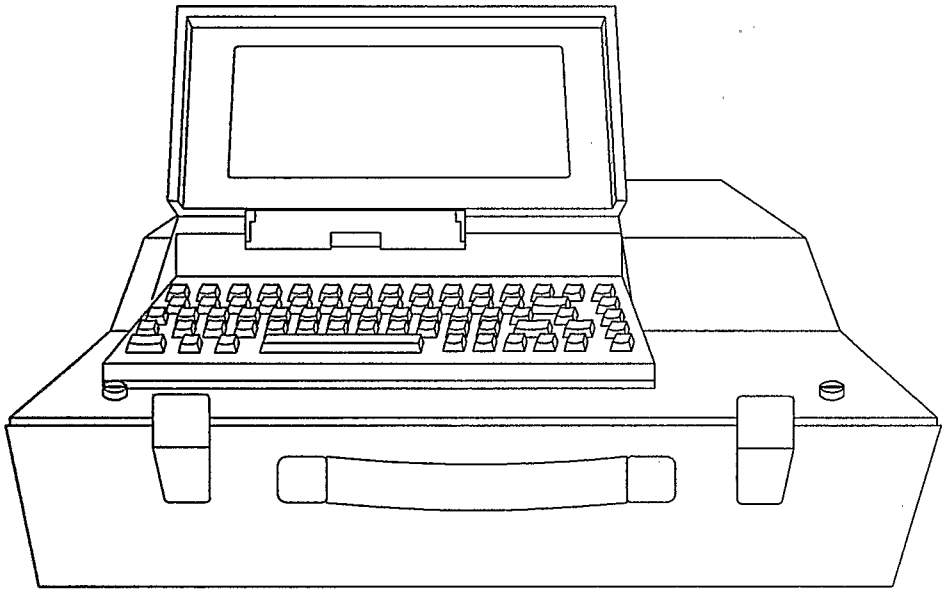
SENTEX SENSING TECHNOLOGY, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The scentograph portable gas chromatograph (see figure below) can operate for several hours on internal batteries and has internal carrier gas and calibrant tanks. 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. Autosampling is performed by drawing air through a sorbent bed, followed by rapid thermal desorption into the carrier stream. The detector may be operated in either argon ionization or electron-capture modes. The 11.7-electron-volt (eV) ionization energy makes the detector unit nearly universal with a detection limit of about 1 part per billion. The instrument is controlled through an attached IBM PC/XT compatible laptop computer.

WASTE APPLICABILITY:

The scentograph portable gas chromatograph can be used to monitor volatile organic compound emissions from hazardous waste sites and other emission sources before and during remediation.



Portable Gas Chromatograph

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

It has been used for several years in water and soil analyses and can analyze all kinds of vapor phase pollutants.

STATUS:

Field evaluation at a Superfund site under remediation was conducted in January 1992. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
Amos Linenberg
Sentex Sensing Technology, Incorporated
553 Broad Avenue
Ridgefield, NJ 07657
201-945-3694

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

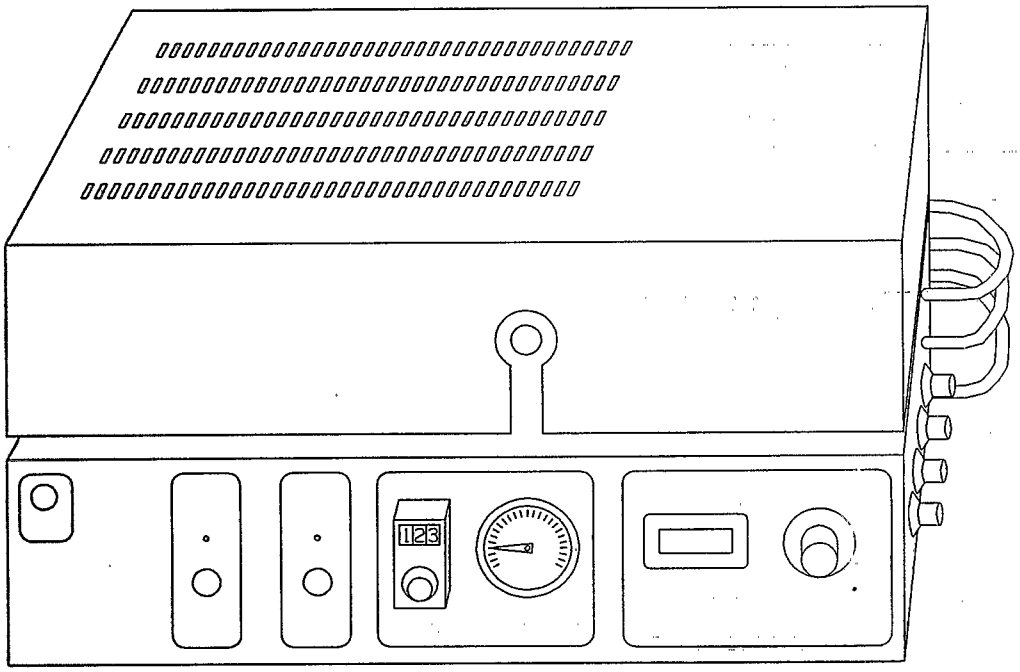
SRI INSTRUMENTS
(Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The SRI 8610 gas chromatograph (see figure below) is a small low-cost laboratory instrument that is field-deployable. 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 be used to monitor airborne emissions from hazardous waste sites and other emission sources before



8610 Gas Chromatograph

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

and during remediation. It can be applied to volatile organic compounds, but its performance characteristics in the field have not been evaluated.

STATUS:

Field evaluation of the SRI 8610 gas chromatograph at a Superfund site under remediation was conducted in January 1992. The final report is undergoing peer review and will be published in 1994.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Berkley
U.S. EPA
Atmospheric Research and Exposure Assessment Laboratory
MD-44
Research Triangle Park, NC 27711
919-541-2439

TECHNOLOGY DEVELOPER CONTACT:
Dave Quinn
SRI Instruments
3870 Del Amo Boulevard, Suite 506
Torrance, CA 90503
310-214-5092

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) 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 from 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 analysis to continue without the presence of an operator.

The FASP PCB method has several advantages and limitations when used under field conditions. The method can quickly provide results with an accuracy statistically equal to fixed laboratories and can provide Aroclor identification. It can also provide results at detection limits comparable with those of fixed laboratories.

Instrumentation and equipment required for the FASP PCB method are not highly portable. However, when mounted in a mobile laboratory trailer, the method can be operated 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 experience in using a GC and 1 month experience in analyzing PCBs.

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 GC must then undergo an initial calibration

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

(ICAL), which involves analyzing standards containing three different concentrations of seven Aroclors. When an acceptable ICAL has been completed, soil sample analysis can begin.

Sample extracts in microliter (μL) amounts are injected into the GC, which must be equipped with a megabore capillary column. Peak patterns and retention times from the sample extract chromatograms are compared to PCB standard chromatograms to identify and quantitate PCBs. Daily continuing calibrations (CCAL) are performed for four of the seven Aroclors. CCALs are used to monitor the performance of the GC. The detection limit for the method is reported to be 0.4 milligram per kilogram (mg/kg). During the demonstration, however, the method was found to achieve a detection limit as low as 0.1 mg/kg. The highest number of samples analyzed in an 8-hour day was 21; the average number analyzed was 15. Reported control limit results for the precision of the FASP PCB method were deemed acceptable.

WASTE APPLICABILITY:

The FASP PCB method can be used to identify and quantify PCBs in soil samples.

STATUS:

The FASP PCB method was demonstrated under the SITE Program at a well characterized PCB-contaminated site. This demonstration consisted of analyzing 112 soil samples, 32 field duplicates, and 2 performance evaluation samples with the FASP PCB method. A confirmatory laboratory analyzed the samples by 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.

FOR FURTHER INFORMATION:

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J. Lary Jack
U.S. Environmental Protection Agency
944 East Harmon
Las Vegas, NV 89193-3478
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Fax: 702-798-2692

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

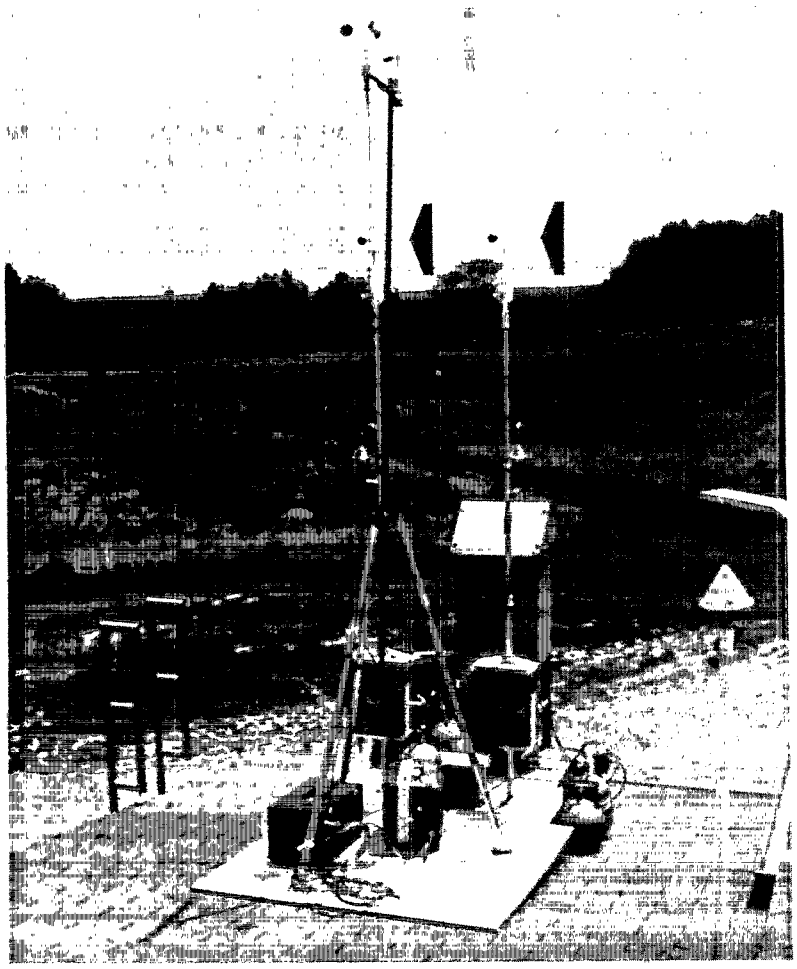
XONTECH INCORPORATED
(XonTech Sector Sampler)

TECHNOLOGY DESCRIPTION:

The XonTech sector sampler (see figure below) collects time-integrated whole air samples in Summa™-polished canisters. 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 other canister is filled. When the wind velocity falls below 0.37 m/s either canister or neither canister may be selected to receive the sample. Over an extended period of time, a target sample and a background sample are produced.

WASTE APPLICABILITY:

The XonTech sector sampler can be used to 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.



Sector Sampler

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

Long-term monitoring can be used to assess effects of an emission source on the local population.

STATUS:

The usefulness of this method 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:
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U.S. EPA
Atmospheric Research and Exposure
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Research Triangle Park, NC 27711
919-541-4680

TECHNOLOGY DEVELOPER CONTACT:
Matt Young
XonTech Incorporated
6862 Hayvenhurst Avenue
Van Nuys, CA 91406
818-787-7380

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

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 _____

EPA plans to issue two requests for proposals during the coming year; one in January 1994 for the Demonstration Program (SITE 009), and the other in July 1994 for the Emerging Technology Program (E08). 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: Progress and Accomplishments for FY91—A Fifth Report to Congress (EPA/540/R-92/076)
- ❑ SITE Profiles, Fifth Edition (EPA/540/R-92/077)
- ❑ 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)
- ❑ Technology Demo. Summary (EPA/540/SR-93/509)
- ❑ Demonstration Bulletin (EPA/540/MR-93/509)
- ❑ Applications Analysis (EPA/540/AR-93/509)

American Combustion—Oxygen Enhanced Incineration

- ❑ Technology Evaluation (EPA/540/5-89/008)
- ❑ Applications Analysis (EPA/540/A5-89/008) PB90-258427[2]
- ❑ Technology Demo. Summary (EPA/540/S5-89/008)
- ❑ Demonstration Bulletin (EPA/540/M5-89/008)[3]

AWD Technologies, Inc.—Integrated Vapor Extraction and Steam Vacuum Stripping

- ❑ Applications Analysis (EPA/540/A5-91/002)
- ❑ Demonstration Bulletin (EPA/540/M5-91/002)

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)
- ❑ 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)

Biotrol—Biotreatment of Groundwater

- ❑ Technology Evaluation (EPA/540/5-91/001) PB92-110048
- ❑ Applications Analysis (EPA/540/A5-91/001) PB91-227983
- ❑ Technology Demo. Summary (EPA/540/S5-91/001)
- ❑ Demonstration Bulletin (EPA/540/M5-91/001)

Biotrol—Soil Washing System

- o 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) PB92-115245
- ❑ Technology Demo. Summary (EPA/540/S5-91/003)
- ❑ Demonstration Bulletin (EPA/540/M5-91/003)

Cav-Ox Ultraviolet/Oxidation Process Magnum Water Technology

- ❑ Demonstration Bulletin (EPA/540/MR-93/524)

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)

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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
National Technical Information Service
5285 Port Royal Road
Springfield VA 22161
Telephone 703-487-4650.

[3] Out of stock

Demonstration Project Results (continued)

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