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SITE

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Technology Profiles
Fourth Edition

EPA

Risk Reduction Engineering Laboratory
Office of Research and Development
26 West Martin Luther King Drive
Cincinnati, Ohio 45268

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DISCLAIMER

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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 an authoritative, defensible engineering basis for EPA policies, programs, and regulations concerning drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one product of that research and provides a vital communication link between the researcher and the user community.

The Superfund Innovative Technology Evaluation (SITE) Program, now in its sixth 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 innovative technology developers. Through these collaborative efforts, innovative technologies are refined at bench- and pilot-scale and demonstrated at hazardous waste sites. EPA collects and evaluates extensive performance and cost data on each technology, which can aid in future decision-making for hazardous waste site remediation.

The successful implementation of innovative technologies requires a team approach. SITE's demonstration team works closely with EPA's regional offices, the states, the technology developer, the Superfund Technology Assistance Response Team (START), the Environmental Monitoring System Laboratory-Las Vegas (EMSL-LV), and the Technology Innovation Office (TIO) to provide full service technology evaluations and information dissemination. SITE also uses EPA's research facilities such as the Test and Evaluation Facility (T&E) and the Center Hill Facility to perform evaluations of innovative technologies. Capitalizing on these various resources has proven to be effective for evaluating many of the innovative technologies in the SITE program.

This document profiles 129 demonstration, emerging, and monitoring and measurement technologies being evaluated under the SITE Program. Each technology profile contains a description of the technology, a discussion of its applicability to various wastes, an update on its development or demonstration status, any available demonstration results, and demonstration and technology contacts. This document is intended for environmental decision makers and other interested individuals involved in hazardous waste site cleanup.

E. Timothy Oppelt

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The Superfund Innovative Technology Evaluation (SITE) Program evaluates new and promising treatment 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 July 1991 and October 1991, is intended as a reference guide for decision makers and others interested in technologies under the SITE Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs. Reference tables for the SITE Program participants precede the individual profiles and contain EPA and developer contacts. Inquiries about a specific SITE technology or the SITE Program should be directed to the EPA Project Manager and inquiries on the technology process should be directed to the technology developer contacts. The technologies are described in two-page profiles, and are presented in alphabetical order by developer name.

Each technology profile contains: (1) a technology developer and process name, (2) a technology description, (3) a schematic diagram or photograph of the process, (4) a discussion of waste applicability, (5) a project status report, and (6) EPA Project Manager and technology developer contacts. For projects that have been completed, the profiles also include a summary of results and reports if available.

New features included in this document...

- Table of Waste Applicability (page x)

  The following waste categories are included: arsenic, chlorinated organics, cyanide, dioxins, heavy metals, other halogenated organics, other inorganics, other metals, other organics, PAHs, PCBs, pesticides/herbicides, petroleum hydrocarbons, radioactive elements/metals, and volatile organics.

- Monitoring and Measurement Technologies Program Section (page 263)

  This section contains 14 profiles of innovative technologies useful for site characterization or contaminant monitoring.

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Emerging

Battelle Memorial Institute 186

Vortec Corporation 252

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Allied-Signal, Inc. 26

AWD Technologies, Inc. 30

Babcock & Wilcox Co. 32

BioTrol, Inc.
(Biological Aqueous Trmt System) 36

BioTrol, Inc.
(Soil Washing) 38

BioVersal USA, Inc. 40

CET Environmental Services –
Sanivan Group 42

CF Systems Corporation 44

Dehydro-Tech Corporation 58

Ecova Corporation
(In Situ Biological Treatment) 66

ELI Eco Logic International, Inc. 70

EmTech Environmental Services, Inc. . 72

ENSITE, Inc. 74

Geosafe Corporation 84

Hayward Baker, Inc. 86

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In-Situ Fixation Company 94

International Waste Technologies/
Geo-Con, Inc. 98

NOVATERRA, Inc. 100

Ogden Environmental Services 102

Peroxidation Systems, Inc. 104

Remediation Technologies, Inc.
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Resources Conservation Company 116

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Demonstration (cont.)

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(Base-Catalyzed Dechlorination Process) . . 120

Risk Reduction Engineering Laboratory and
IT Corporation
(Debris Soil Washing) 124

Risk Reduction Engineering Laboratory and
USDA Forest Products Laboratory
(Fungal Treatment Technology) 128

SBP Technologies, Inc. 132

SoilTech, Inc. 140

Terra-Kleen Corporation 146

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BioTrol, Inc.
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Electron Beam Research Facility
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and University of Miami 204

Energy and Environmental
Engineering, Inc. 206

Energy and Environmental Research
Corporation 208

Enviro-Sciences, Inc./
ART International, Inc. 210

Institute of Gas Technology
(Chemical and Biological Treatment) 218

IT Corporation
(Photolytic and Biological
Soil Detoxification) 228

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PSI Technology Company 238
Pulse Sciences, Inc. 240
Purus, Inc 242
Trinity Environmental Technologies, Inc. 246
Vortec Corporation 252
Wastewater Technology Centre 256
Western Research Institute 260

MMTP

HNU Systems, Inc. 278
Photovac International, Inc. 286

Cyanide

Demonstration

Excalibur Enterprises, Inc. 78
Exxon Chemical Company/ Rio Linda Chemical Company 80
Ogden Environmental Services 102
Silicate Technology Corporation 138

Emerging

Battelle Memorial Institute 186
Davy Research and Development, Ltd. 198
Nutech Environmental 236
Vortec Corporation 252

Dioxins

Demonstration

BioTrol, Inc. (Soil Washing) 38
BioVersal USA, Inc. 40
CF Systems Corporation 44
Excalibur Enterprises, Inc. 78
In-Situ Fixation Company 94
Ogden Environmental Services 102
Risk Reduction Engineering Laboratory and USDA Forest Products Laboratory (Fungal Treatment Technology) 128

Dioxins (cont.)

Emerging

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IT Corporation (Photolytic and Biological Soil Detoxification) 228
Nutech Environmental 236
Trinity Environmental Technologies, Inc. 246
Vortec Corporation 252

Heavy Metals

Demonstration

Babcock & Wilcox Co. 32
Bio-Recovery Systems, Inc. 34
BioTrol, Inc. (Soil Washing) 38
Chemfix Technologies, Inc. 46
Chemical Waste Management, Inc. (PO*WW*ER) 50
Colorado Department of Health 54
E.I. DuPont de Nemours and Company/ Oberlin Filter Company 60
Dynaphore, Inc. and H_2O Company . . . 62
EmTech Environmental Services, Inc. . 72
EPOC Water, Inc. 76
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Electrokinetics, Inc. 202
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New Jersey Institute of Technology . . . 234
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Warren Spring Laboratory 254
Western Product Recovery Group, Inc. 258

Other Halogenated Organics

Demonstration

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Allied-Signal, Inc. 26
AWD Technologies, Inc. 30
BioTrol, Inc.
(Biological Aqueous Trmt System) 36

Other Halogenated Organics (cont.)

Demonstration (cont.)

BioTrol, Inc.
(Soil Washing) 38
BioVersal USA, Inc. 40
CET Environmental Services –
Sanivan Group 42
CF Systems Corporation 44
Dehydro-Tech Corporation 58
Ecova Corporation
(In Situ Biological Treatment) 66
ENSITE, Inc. 74
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University of South Carolina 248

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Demonstration

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Chemical Waste Management, Inc.
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Chemical Waste Management, Inc.
(X*TRAX) 52

Colorado Department of Health 54

E.I. DuPont de Nemours and Company/
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Recycling Sciences International 110

Risk Reduction Engineering Laboratory/
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S.M.W. Seiko, Inc. 134

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Demonstration

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Chemical Waste Management, Inc.
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Chemical Waste Management, Inc.
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Demonstration (cont.)

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Dynaphore, Inc. and H_2O Company . . 62

Ecova Corporation
(Bioslurry Reactor) 64

Ecova Corporation
(Infrared Thermal Destruction) 68

EmTech Environmental Services, Inc. . 72

Exxon Chemical Company/
Rio Linda Chemical Company 80

In-Situ Fixation Company 94

International Waste Technologies/
Geo-Con, Inc. 98

NOVATERRA, Inc. 100

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Recycling Sciences International, Inc. . 110

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Babcock & Wilcox Co. 184

Electron Beam Research Facility
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Energy and Environmental
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Groundwater Technology Government
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Institute of Gas Technology
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Ecova Corporation
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Ecova Corporation
(In Situ Biological Treatment) 66
ELI Eco Logic International, Inc. 70
ENSITE, Inc. 74
Geosafe Corporation 84
In–Situ Fixation Company 94
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Recycling Sciences International, Inc. . 110
Remediation Technologies, Inc.
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Resources Conservation Company 116
Risk Reduction Engineering Laboratory/
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Risk Reduction Engineering Laboratory and
USDA Forest Products Laboratory
(Fungal Treatment Technology) 128
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S.M.W. Seiko, Inc. 134
Zimpro/Passavant
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Energy and Environmental Research
Corporation 208
Enviro–Sciences, Inc./
ART International, Inc. 210
Institute of Gas Technology
(Chemical and Biological Treatment) 218
Institute of Gas Technology
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IT Corporation
(Photolytic and Biological
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Nutech Environmental 236
Pulse Sciences, Inc. 240
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Western Product Recovery Group, Inc. 258

PCBs

Demonstration

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(Biological Aqueous Trmt System) 36
BioTrol, Inc.
(Soil Washing) 38
BioVersal USA, Inc. 40
CET Environmental Services –
Sanivan Group 42
CF Systems Corporation 44
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Davy Research
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IT Corporation
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IT Corporation
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Nutech Environmental 236

PCBs (cont.)

Emerging (cont.)

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Trinity Environmental
Technologies, Inc. 246
Vortec Corporation 252
Warren Spring Laboratory 254

MMTP

Bruker Instruments 270

Pesticides/Herbicides

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(Soil Washing) 36
BioVersal USA, Inc. 40
CET Environmental Services -
Sanivan Group 42
Dames & Moore 56
ELI Eco Logic International, Inc. 70
EPOC Water, Inc. 76
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and University of Miami 204
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Engineering, Inc. 206
Enviro-Sciences, Inc./
ART International, Inc. 210
Groundwater Technology Government
Services, Inc., ... 214
Pulse Sciences, Inc. 240
J.R. Simplot Company 244
Trinity Environmental
Technologies, Inc. 246
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Western Research Institute 260

Petroleum Hydrocarbons

Demonstration

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Allied-Signal, Inc. 26
BioTrol, Inc.
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BioTrol, Inc.
(Soil Washing) 38
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SoilTech, Inc. 140
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Terra Vac, Inc. 148
Texaco Syngas, Inc. 150
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WASTECH, Inc. 160
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Hazardous Substance Management
Research Center at New Jersey
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Institute of Gas Technology
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Retech, Inc. 118
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Electro-Pure Systems, Inc. 200
Electrokinetics, Inc. 202
Ferro Corporation 212
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Volatile Organics

Demonstration

Accutech Remedial Systems, Inc. 24
Allied-Signal, Inc. 26
American Combustion, Inc. 28
AWD Technologies, Inc. 30
Babcock & Wilcox Co. 32
BioTrol, Inc.
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BioVersal USA, Inc. 40
CET Environmental Services -
Sanivan Group 42
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Demonstration (cont.)

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(In Situ Biological Treatment) 66
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(Infrared Thermal Destruction) 68
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EmTech Environmental Services, Inc. . 72
ENSITE, Inc. 74
Geosafe Corporation 84
Hayward Baker, Inc. 86
Horsehead Resource
Development Co., Inc. 90
Hughes Environmental Systems, Inc. . . 92
In-Situ Fixation Company 94
International Environmental Technology 96
NOVATERRA, Inc. 100
Ogden Environmental Services 102
Peroxidation Systems, Inc. 104
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SITE PROGRAM DESCRIPTION

INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program, now in its sixth 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." Currently, the SITE Program is administered by the ORD's Risk Reduction Engineering Laboratory, 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 future site characterization and cleanup decision-making;

- **Emerging Technology Program** – Provides funding to developers to continue research efforts at the bench- and pilot- scale levels to promote the development of emerging 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, focuses on the Demonstration, Emerging Technology, and Monitoring and Measurement Technologies Programs. The Demonstration and Emerging Technology Programs are designed to assist private developers in commercializing alternative technologies for site remediation. The Monitoring and Measurement Technologies Program is designed to accelerate the development, demonstration, and use of innovative monitoring and measurement, as well as characterization, technologies at Superfund sites. The Technology Transfer Program distributes technical information on innovative technologies participating in the SITE Program. Figure 1 depicts the process of technology development from initial concept to commercial use, and shows the interrelationship between the programs.

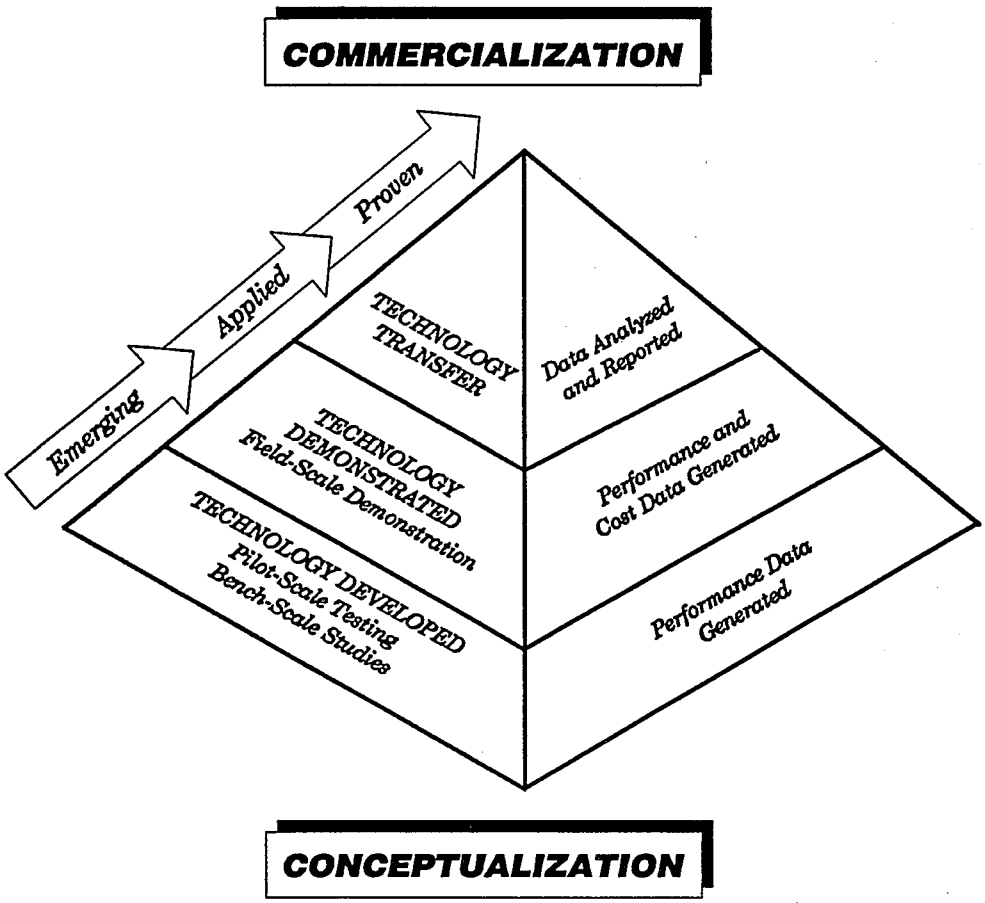

Figure 1: Development of innovative technologies.

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 have already been proven on the conceptual level. The program compares the applicability of particular technologies to Superfund site waste characteristics and supports promising technologies that may be evaluated in the Demonstration Program. The technology's performance is documented in an EPA report.

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 for a particular site cleanup. 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.

At the conclusion of the SITE Demonstration, EPA prepares an Applications Analysis Report (AAR) to evaluate all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. A second report, the Technology Evaluation Report (TER), presents demonstration data such as testing procedures, performance and cost data collected, and quality assurance and quality control standards.

Preparation of these reports as well as videos, bulletins, and project summaries is the responsibility of the SITE Technology Transfer Program. This information is distributed to (1) provide reliable technical data for environmental decision-making and (2) promote the technology's commercial use.

EPA has provided technical and financial support on 44 projects in the Emerging Technology Program. Thirty-seven of these projects are currently active in the program, three graduated to the Demonstration Program, two are expected to graduate, and two have exited from SITE participation. These technologies are divided into the following categories: thermal destruction (7), physical and chemical treatment (21), solidification and stabilization (2), biological degradation (10), and materials handling (4). Figure 2 displays the breakdown of technologies in the Emerging Technology Program.

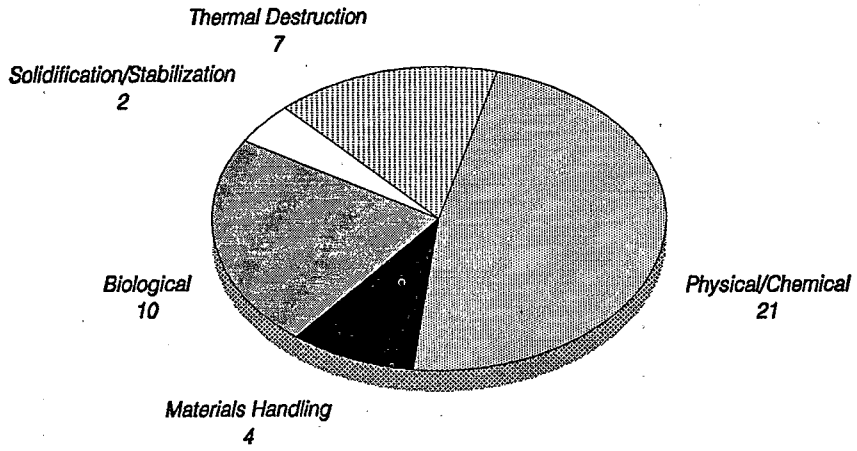

Figure 2: Innovative technologies in the Emerging Technology Program.

The Demonstration Program has 64 developers providing 76 demonstrations (one project, Maecorp, is not profiled in this document). The projects are divided into the following categories: thermal destruction (8), biological degradation (15), physical and chemical treatment (24), solidification and stabilization (11), physical/chemical - radioactive waste treatment (2), physical/chemical - thermal desorption (13), and materials handling (3). Several of these technologies involve combinations of these treatment categories. Figure 3 shows the breakdown of technologies currently in the Demonstration Program.

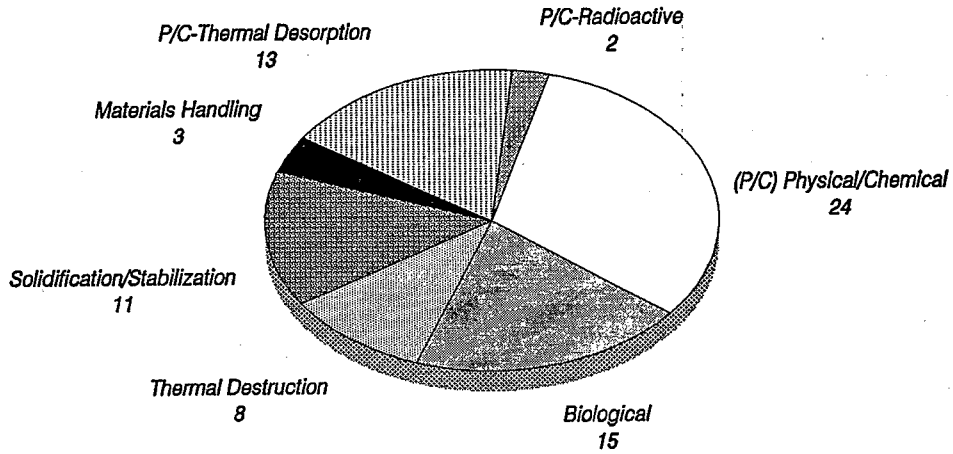

Figure 3: Innovative technologies in the Demonstration Program.

To date, 31 technology demonstrations have been completed (25 in the Demonstration Program and 6 in the Monitoring and Measurement Technologies Program); several reports have been published and others are in various stages of production. Table 1 lists these demonstrations, in alphabetical order by developer's name, along with information on the technology transfer opportunities for the project.

The Monitoring and Measurement Technologies Program's (MMTP) goal is to assess innovative and alternative monitoring, measurement, and site characterization technologies. The MMTP has identified fourteen technologies that are potential candidates for field demonstration under the program. During fiscal year 1991, two technologies were demonstrated. Additionally, the MMTP plans to demonstrate three to four monitoring and measurement technologies in fiscal year 1992.

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 develop interactive communication among individuals requiring up-to-date technical information.

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

- Program-specific regional, state, and industry brochures
- On-site Visitor's Days and Demonstration Videos
- Project-specific fact sheets, Applications Analysis Reports, and Technology Evaluation Reports
- SITE exhibit displayed nationwide at conferences
- Networking through forums and associations, regions, and states
- Technical assistance to regions, states, and remediation cleanup contractors

SITE information is available through on-line information clearinghouses such as:

Alternative Treatment Technology Information Center (ATTIC)
System operator: 301-670-6294

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

Technical reports may be obtained by calling the Center for Environmental Research Information (CERI) in Cincinnati, Ohio at 513-569-7562. If you would like to be placed on the SITE mailing list, write to:

ORD Publications
26 West Martin Luther King Drive (G72)
Cincinnati, Ohio 45268

TABLE 1

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
American Combustion Technologies, Inc., Norcross, GA	Pyretron Thermal Destruction	EPA's Combustion Research Facility in Jefferson, AK Soil from Stringfellow Acid Pit Superfund Site in Glen Avon, CA	*Visitor's Day:* January 1988 *Demonstration:* November 16, 1987 – January 29, 1988	American Combustion Pyretron Destruction System EPA/540/A5–89/008, April 1989	SITE Program Demonstration Test – The American Combustion Pyretron Thermal Destruction System at the U.S. EPA's Combustion Research Facility, EPA/540/5–89/008, April 1989	Laurel Staley EPA ORD, 513–569–7863	28
AWD Technologies Inc., San Francisco, CA	Integrated Vapor Extraction and Steam Vacuum Stripping	San Fernando Valley Groundwater Basin Superfund Site in Burbank, CA	*Visitor's Day:* September 20, 1990 *Demonstration:* September 1990	EPA/540/A5–91/002	In preparation	Christine Stubbs EPA Region 9 415–744–2248	30
BioTrol, Inc., Chaska, MN	Biological Aqueous Treatment	MacGillis & Gibbs Superfund Site in New Brighton, MN	*Visitor's Day:* September 27, 1989 *Demonstration:* July – September 1989	BioTrol, Inc. EPA/540/A5–91/001 May, 1991	In preparation	Rhonda McBride EPA Region 5 312–886–7242	36
BioTrol, Inc., Chaska, MN	Soil Washing	MacGillis & Gibbs Superfund Site in New Brighton, MN	*Visitor's Day:* September 27, 1989 *Demonstration:* September – October 1989	In preparation	In preparation	Rhonda McBride EPA Region 5 312–886–7242	38
CF Systems Corporation, Waltham, MA	Solvent Extraction	New Bedford Harbor Superfund Site in New Bedford, MA	*Visitor's Day:* August 26–27, 1988 *Demonstration:* September 1988	CF Systems Organics Extraction System, New Bedford, MA EPA/540/A5–90/002, August 1990	SITE Program Demonstration Test – CF Systems Corporation Solvent Extraction, EPA/540/5–90/002, August 1990	David Lederer EPA Region 1 617–573–9665	44

TABLE 1 (Continued)

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
Chemfix Technologies, Inc., Metairie, LA	Solidification and Stabilization	Portable Equipment Salvage Company in Clackamas, OR	*Visitor's Day:* March 15, 1989 *Demonstration:* March 1989	Chemfix Technologies, Inc. EPA/540/A5-89/011, May 1991	SITE Program Demonstration Test - Chemfix Technologies, Inc. Solidification/ Stabilization EPA/540/5-89/011a	John Sainsburg EPA Region 10 206-553-0125	46
Dehydro-Tech Corporation, East Hanover, NJ	Carver-Greenfield Process for Extraction of Oily Waste	EPA Facility in Edison, NJ	*Visitor's Day:* August 20, 1991 *Demonstration:* August 1991	In preparation	In preparation	Laurel Staley EPA ORD 513-569-7863	58
E.I. DuPont de Nemours and Co., Newark, DE, and Oberlin Filter Co., Waukesha, WI	Membrane Microfiltration	Palmerton Zinc Superfund Site in Palmerton, PA	*Visitor's Day:* April 10, 1990 *Demonstration:* April 1990	In preparation	In preparation	Tony Koller EPA Region 3 215-597-3923	60
Ecova Corporation Redmond, WA	Bioslurry Reactor	EPA Test and Evaluation Facility in Cincinnati, OH	*Visitor's Day:* Not Held *Demonstration:* October 1991	In preparation	In preparation	Ron Lewis EPA ORD 513-569-7856	64
Ecova Corporation [developed by Shirco Infrared Systems], Redmond, WA	Infrared Thermal Destruction	Rose Township Superfund Site in Oakland County, MI	*Visitor's Day:* November 4, 1987 *Demonstration:* November 1987	Shirco Infrared Incineration System EPA/540/A5-89/007, June 1989	SITE Program Demonstration Test, Shirco Pilot-Scale Infrared Incineration System at the Rose Township Demode Road Superfund Site, EPA/540/5-89/007a, Vol. 1, April 1989 Vol. 2, In Preparation	Kevin Adler EPA Region 5 312-886-7078	68

TABLE 1 (Continued)

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
Ecova Corporation [developed by Shirco Infrared Systems], Redmond, WA	Infrared Thermal Destruction	Peak Oil Superfund Site in Brandon, FL	*Visitor's Day:* August, 1987 *Demonstration:* August 1, - August 5, 1987	Shirco Infrared Incineration System EPA/540/A5-89/010, June 1989	SITE Program Demonstration Test Shirco Infrared Incineration System, Peak Oil, Brandon, Florida, September 1988, EPA/540/5-88/002a	Fred Stroud EPA Region 4 404-347-3931	68
EmTech (formerly Hazcon, Inc.), Oakwood, TX	Solidification and Stabilization	Douglassville Superfund Site, Berks County, near Reading, PA	*Visitor's Day:* October 14, 1987 *Demonstration:* October 1987	Hazcon, Inc., Solidification Process EPA/540/A5-89/001, May 1989	SITE Program Demonstration Test Hazcon, Inc., Solidification Process, Douglassville, PA, EPA/540/5-89/001a, Vol. 1, May 1989	Victor Janosik EPA Region 3 215-597-8996	72
Horsehead Research Development, Inc., Monaca, PA	Flame Reactor	National Smelting and Refining Company Superfund Site in Atlanta, GA	*Visitor's Day:* March 22, 1991 *Demonstration:* March 18 - 22, 1991	In preparation	In preparation	Marta Richards EPA ORD 513-569-7783	90
International Waste Technologies, Wichita, KS, and Geo-Con, Inc., Pittsburgh, PA	In Situ Solidification and Stabilization	General Electric Service Shop in Hialeah, FL	*Visitor's Day:* April 14, 1988 *Demonstration:* April - May 1988	International Waste Tech/Geo-Con, Inc. EPA/540/A5-89/004, August 1989	SITE Program Demonstration Test - International Waste Technologies In Situ Stabilization/ Solidification, Hialeah, Florida, EPA/540/5-89/004a, June 1989	Mary Stinson EPA ORD 908-321-6683	98

TABLE 1 (Continued)

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
NOVATERRA, Inc., [formerly Toxic Treatment USA, Inc.], Torrance, CA	In Situ Steam and Air Stripping	Annex Terminal in San Pedro, CA	*Visitor's Day:* September 7, 1989 *Demonstration:* September 1989	EPA/540/A5-90/008 June 1991	In preparation	Paul dePercin EPA ORD 513-569-7797	100
Ogden Environmental Services, San Diego, CA	Circulating Bed Combustor	Ogden's Facility in La Jolla, CA	*Visitor's Day:* Not applicable *Demonstration:* March 1989	Not available	In preparation	John Blevins EPA Region 9 415-744-2241	102
Retech, Inc., Ukiah, CA	Plasma Arc Vitrification	DOE Component Development and Integration Facility in Butte, MT	*Visitor's Day:* August 8, 1991 *Demonstration:* July 22 - 26, 1991	In preparation	In preparation	Laurel Staley EPA ORD 513-569-7863	118
Risk Reduction Engineering Laboratory and IT Corporation, Edison, NJ	Debris Washing System	Superfund Sites in Detroit, MI; Hopkinsville, KY; and Walker County, GA	*Visitor's Day:* Not applicable *Demonstrations:* September 1988, December 1989, and August 1990	In preparation	Design and Development of a Pilot-Scale Debris Decontamination System EPA/540/5-91/006a May 1991	Naomi Barkley EPA ORD 513-569-7854	124
Silicate Technology Corporation, Scottsdale, AZ	Solidification and Stabilization Treatment Technology	Selma Pressure Treating Site in Selma, CA	*Visitor's Day:* November 15, 1990 *Demonstration:* November 1990	In preparation	In preparation	Ed Bates EPA ORD 513-569-7774	138
SoilTech, Inc., Englewood, CO	Anaerobic Thermal Processor	Wide Beach Superfund Site in Brant , NY	*Visitor's Day:* Not Applicable *Demonstration:* May 1991	In preparation	In preparation	Herbert King EPA Region 2 212-264-1129	140

TABLE 1 (Continued)

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
Soliditech, Inc., Houston, TX	Solidification and Stabilization	Imperial Oil Company/Champion Chemicals Superfund Site in Morganville, NJ	*Visitor's Day:* December 7, 1988 *Demonstration:* December 1988,	Soliditech Inc. Solidification/ Stabilization Process EPA/540/A5-89/005 September 1990	SITE Program Demonstration Test – Soliditech, Inc. Solidification/ Stabilization Process, Vol. I EPA/540/5-89/005a, February 1990 Vol. II EPA/540/5-89/005b	Trevor Anderson EPA Region 2 212-264-5391	142
Terra Vac, Inc., San Juan, Puerto Rico	In Situ Vacuum Extraction	Groveland Wells Superfund Site, Valley Manufactured Product in Groveland, MA	*Visitor's Day:* January 15, 1988 *Demonstration:* December 1987 – April 1988	Terra Vac In Situ Vacuum Extraction System, EPA/540/A5-89/003, July 1989	SITE Program Demonstration Test Terra Vac In Situ Vacuum Extraction System, Groveland, Massachusetts, EPA/540/5-89/003a, April 1989	Robert Leger EPA Region 1 617-573-5734	148
Ultrox International, Inc., Santa Ana, CA	Ultraviolet Radiation and Oxidation	Lorentz Barrel and Drum Company in San Jose, CA	*Visitor's Day:* March 8, 1989 *Demonstration:* March 1989	Ultrox International Ultraviolet Radiation/ Oxidation Technology EPA/540/A5-89/012 September 1990	SITE Program Demonstration Test – Ultrox International, Inc., Ultraviolet Radiation/Oxidation Technology, EPA/540/5-89/012, January 1990	Joseph Healy EPA Region 9 415-744-2231	156

TABLE 1 (Continued)

COMPLETED TREATMENT TECHNOLOGY DEMONSTRATIONS AS OF NOVEMBER 1991

DEVELOPER	TECHNOLOGY	SITE LOCATION	VISITOR'S DAY AND DEMONSTRATION DATE	APPLICATIONS ANALYSIS REPORT	TECHNOLOGY EVALUATION REPORT	EPA CONTACT	PROFILE PAGE NO.
U.S. Environmental Protection Agency	Excavation Techniques and Foam Suppression	McColl Superfund Site in Fullerton, CA	*Visitor's Day:* Not held *Demonstration:* June and July 1990	In preparation	In preparation	S. Jackson Hubbard EPA ORD 513-569-7507 and John Blevins EPA Region 9 415-744-2241	158
Wastech, Inc., Oakridge, TN	Solidification and Stabilization	Robins AFB, Warner Robins, GA	*Visitor's Day:* August 22, 1991 *Demonstration:* August 1991	In preparation	In preparation	Terry Lyons EPA ORD 513-569-7589	160

Please see Table 4 for Monitoring and Measurement Technologies Program completed Demonstrations or Evaluations.

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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Las Vegas, Nevada 89193-3478
702-798-2432
FTS: 545-2432

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 sites (NPL), 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). Proposals are reviewed by EPA 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 graduated to the Demonstration Program.

The SITE demonstration process typically consists of five steps: (1) matching an innovative technology with an appropriate site; (2) preparing a four-part Demonstration Plan consisting of a test plan, a sampling and analysis plan, a quality assurance project plan, and a health and safety plan; (3) performing community relations activities to gain public acceptance; (4) conducting the demonstration (ranging in length from days to months); and (5) documenting results in two main reports - an Applications Analysis Report and a Technology Evaluation Report.

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, sampling and analysis, quality assurance and quality control, preparing reports, and disseminating information. If the developer is unable to obtain financing elsewhere, EPA may consider bearing a greater portion of the total project cost.

Data collected during a 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 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.

To date, six solicitations have been completed -- SITE 001 in 1986 through SITE 006 in 1991. The RFP for SITE 007 will be issued in January 1992. The Demonstration Program currently includes 64 developers and 76 projects. These projects are presented in alphabetical order by project name in Table 2 and in the technology profiles that follow. One developer, Maecorp, is not profiled in this document.

TABLE 2
SITE Demonstration Program Participants

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 FTS: 340-6626	Soil, Rock	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
Allied-Signal Corporation, Morristown, NY (003)	ICB Biotreatment System	Ralph Nussbaum/ Tim Love 201-455-3190	Ronald Lewis 513-569-7856 FTS: 684-7856	Groundwater, Wastewater	Not Applicable	Readily Biodegradable Organic Compounds
American Combustion, Inc., Norcross, GA (001)	PYRETRON® Oxygen Burner	Gregory Gitman 404-564-4180	Laurel Staley 513-569-7863 FTS: 684-7863	Soil, Sludge, Solid Waste	Not Applicable	Non-Specific Organics
AWD Technologies, Inc., San Francisco, CA (004)	Integrated Vapor Extraction and Steam Vacuum Stripping	David Bluestein 415-227-0822	Norma Lewis/ Gordon Evans 513-569-7665/ 513-569-7684	Groundwater, Soil	Not Applicable	VOCs
Babcock & Wilcox Co., Alliance, OH (006)	Cyclone Furnace	Lawrence King 216-829-7576	Laurel Staley 513-569-7863 FTS: 684-7863	Solids, Soil	Non-Specific	Non-Specific Organics
Bio-Recovery Systems, Inc.[1], Las Cruces, NM (005)/(E01)	Biological Sorption	Godfrey Crane 505-523-0405	Naomi Barkley 513-569-7854 FTS: 684-7854	Groundwater, Electroplating Rinsewater	Heavy Metals	Not Applicable
BioTrol, Inc., Chaska, MN (003)	Biological Aqueous Treatment System	Dennis Chilcote/ Pamela Sheehan 612-448-2515/ 609-951-0314	Mary Stinson 908-321-6683 FTS: 340-6683	Liquid Waste, Groundwater	Nitrates	Chlorinated and Nonchlorinated Hydrocarbons, Pesticides
BioTrol, Inc., Chaska, MN (003)	Soil Washing System	Dennis Chilcote/ Pamela Sheehan 612-448-2515/ 609-951-0314	Mary Stinson 908-321-6683 FTS: 340-6683	Soil	Metals	High Molecular Weight Organics, PAHs, PCP, PCBs, Pesticides

* Solicitation number
1 Graduate of Emerging Technology Program

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
BioVersal USA, Inc., Des Plaines, IL (005)	BioGenesis℠ Soil Cleaning Process	Mohsen Amiran/ Charles Wilde 708-827-0024 703-250-3442	Annette Gatchett 513-569-7697 FTS: 684-7697	Soil	Not Applicable	Volatile and Nonvolatile Hydrocarbons, PCBs
CET Environmental Services – Sanivan Group, Montreal, Canada (005)	Soil Treatment With Extraksol™	Jean Paquin 514-353-9170	Mark Meckes 513-569-7348 FTS: 684-7348	Soil	Not Applicable	SVOCs, PCBs, PCPs, PAHs
CF Systems Corporation, Waltham, MA (002)	Solvent Extraction	Chris Shallice 617-937-0800	Laurel Staley 513-569-7863 FTS: 684-7863	Soil, Sludge, Wastewater	Not Applicable	PCBs, VOCs, SVOCs, Petroleum Wastes
Chemfix Technologies, Inc., Metairie, LA (002)	Solidification and Stabilization	Philip Baldwin 504-831-3600	Edwin Barth 513-569-7669 FTS: 684-7669	Soil, Sludge, Solids, Waste, Electroplating Wastes	Heavy Metals	High Molecular Weight Organics
Chemical Waste Management, Inc., Geneva, IL (006)	Dechlor/KGME	John North 708-513-4867	Paul dePercin 513-569-7797 FTS: 684-7797	Waste Streams, Soils	Not Applicable	Halogenated Aromatic Compounds, PBCs
Chemical Waste Management, Inc., Geneva, IL (005)	PO*WW*ER™ Evaporation and Catalytic Oxidation of Wastewater	Erick Newman 708-513-4500	Randy Parker 513-569-7271 FTS: 684-7271	Wastewater, Leachate, Ground Water	Metals, Volatile Inorganic Compounds, Salts	VOCs and Nonvolatile Organic Compounds
Chemical Waste Management, Inc., Geneva, IL (003)	X*TRAX™ Thermal Desorptionremediation	Carl Swanstrom 708-513-4578	Paul dePercin 513-569-7797 FTS: 684-7797	Soil, Sludge, Other Solids	Not Applicable	VOVs, SVOCs, PCBs
Colorado Department of Health[2] [developed by Colorado School of Mines], Denver, CO (005) (E01)	Wetlands-Based Treatment	Rick Brown 303-331-4404	Edward Bates 513-569-7774 FTS: 684-7774	Acid Mine Drainage	Metals	Not Applicable

2 Graduate of Emerging Technology Program

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Dames & Moore, Tallahassee, FL (005)	Hydrolytic Terrestrial Dissipation	Stoddard Pickrell 904-942-5615	Ronald Lewis 513-569-7865 FTS: 684-7856	Soil	Not Applicable	Low Level Toxaphene and Other Pesticides
Dehydro-Tech Corporation, East Hanover, NJ (004)	Carver-Greenfield Process for Extraction of Oily Waste	Thomas Holcombe 201-887-2182	Laurel Staley 513-569-7863 FTS: 684-7863	Soil, Sludge	Not Applicable	PCBs, Dioxin, Oil-Soluble Organics
E.I. DuPont de Nemours and Co. and Oberlin Filter Co., Newark, DE, and Waukesha, WI (003)	Membrane Microfiltration	Ernest Mayer 302-366-3652	John Martin 513-569-7758 FTS: 684-7758	Groundwater, Leachate, Wastewater, Electroplating Rinsewaters	Heavy Metals, Cyanide, Uranium	Organic Particulates
Dynaphore, Inc./H_2O Company, Richmond, VA/Knoxville, TN (006)	Use of FORAGER™ Sponge To Remove Dissolved Metals	Norman Rainer 804-288-7109	Carolyn Esposito 908-906-6895 FTS: 340-6895	Industrial Discharge, Municipal Sewage Process Streams, Acid Mine Drainage Wastes	Metals	Aliphatic Organic Chlorides and Bromides
Ecova Corporation, Redmond, WA (006)	Bioslurry Reactor	William Mahaffey 206-883-1900	Ronald Lewis 513-569-7856 FTS: 684-7856	Soil	Not Applicable	Creosote
Ecova Corporation, Redmond, WA (003)	In Situ Biological Treatment	Michael Nelson 206-883-1900	Naomi Barkley 513-569-7854 FTS: 684-7854	Water, Soil, Sludge, Sediment	Not Applicable	Biodegradable Organics
Ecova Corporation, [developed by Shirco Infrared Systems, Inc.], Redmond, WA (001) [2 Demonstrations]	Infrared Thermal Destruction	John Cioffi 206-883-1900	Howard Wall 513-569-7691 FTS: 684-7691	Soil, Sediment	Not Applicable	Non-Specific Organics
ELI Eco Logic International, Inc., Rockwood, Ontario Canada (006)	Thermal Gas Phase Reduction Process	Jim Nash 519-856-9591	Gordon Evans 513-569-7684 FTS: 684-7684	Soil, Sludge, Liquids, Gases	Not Applicable	PCBs, PAHs, Chlorophenols, Pesticides

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
EmTech Environmental Services [formerly Hazcon, Inc.], Fort Worth, TX (001)	Chemical Treatment and Immobilization	Ray Funderburk 800-227-6543	Paul dePercin 513-569-7797 FTS: 684-7797	Soil, Sludge, Sediments	Heavy Metals	Non-Specific Organics
ENSITE, Inc., Tucker, GA (006)	Safesoil™ Biotreatment Process	Andrew Autry 404-934-1180	Doug Grosse 513-569-7844 FTS: 684-7844	Soil	Not Applicable	Petroleum Hydrocarbons, TCE, Aliphatic Solvents, PAHs
EPOC Water, Inc., Fresno, CA (004)	Precipitation and Microfiltration, and Sludge Dewatering	Ray Groves 209-291-8144	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Sludge, Wastewater, Leachable Soil	Heavy Metals	Pesticides, Oil, Grease
Excalibur Enterprises, Inc., New York, NY (004)	Soil Washing and Catalytic Ozone Oxidation	Lucas Boeve/ Gordon Downey 809-571-3451/ 303-752-4363	Norma Lewis 513-569-7665 FTS: 684-7665	Soil, Sludge, Leachate, Groundwater	Cyanide	SVOCs, Pesticides, PCBs, PCP, Dioxin
Exxon Chemicals, Inc. and Rio Linda Chemical Co., Long Beach, CA (004) [2 Demonstrations]	Chemical Oxidation and Cyanide Destruction	Denny Grandle 713-406-6816	Teri Shearer 513-569-7949 FTS: 684-7949	Groundwater, Wastewater, Leachate,	Cyanide	Non-Specific Organics
Filter Flow Technologies, Inc., League City, TX (006)	Heavy Metals and Radionuclide Filtration	Tod Johnson 713-334-2522	Annette Gatchett 513-569-7697 FTS: 684-7697	Groundwater, Industrial Wastewater	Heavy Metals, Radionuclides	Not Applicable
GeoSafe Corporation, Kirkland, WA (002)	In Situ Vitrification	James Hansen 206-822-4000	Teri Shearer 513-569-7949 FTS: 684-7949	Soil, Sludge	Non-Specific Inorganics	Non-Specific Organics
Hayward Baker, Inc., Odenton, MD (006)	Hydraulic Soil Mixing	Joseph Welsh 301-551-8200	Daniel Sullivan 908-321-6677 FTS: 340-6677	Soil, Sludges	Not Applicable	PCBs, PCP, Hydrocarbons
Hazardous Waste Control, Fairfield, CT (006)	NOMIX® Technology	David Babcock 203-336-7955	Teri Shearer 513-569-7949 FTS: 684-7949	Drum Waste, Waste Lagoons, Spills	Metals	Not Applicable

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Horsehead Resources Development Co., Inc., Monaca, PA (004)	Flame Reactor	Regis Zagrocki 412-773-2289	Donald Oberacker/ Marta Richards 513-569-7510/ 513-569-7783	Soil, Sludge, Industrial Solid Residues	Metals	Not Applicable
Hughes Environmental Systems, Inc., Manhattan Beach, CA (005)	Steam Injection and Vacuum Extraction	John Dablow 213-536-6548	Paul dePercin 513-569-7797 FTS: 684-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs
In-Situ Fixation Co., Chandler, AZ. (005)	Deep In Situ Bioremediation	Richard Murray 602-821-0409	Edward Opatken 513-569-7855 FTS: 684-7855	Soil, Sludge	Not Applicable	Biodegradable Organics
International Environmental Technology, Perrysburg, OH (005)	Geolock/Bio-drain Treatment	Lynn Sherman 419-856-2001	Randy Parker 513-569-7271 FTS: 684-7271	Soil	Not Applicable	Biodegradable Organics
International Waste Technologies and Geo-Con, Inc., Wichita, KS (001)	In Situ Solidification and Stabilization	Jeff Newton/ Brian Jasperse 316-269-2660/ 412-856-7700	Mary Stinson 908-321-6683 FTS: 340-6683	Soil, Sediment	Non-Specific Inorganics	PCBs, PCP, Other Non-Specific Organics
Maecorp,[3] Chicago, IL (006)	MAECTITE Treatment Process	Karl Yost 213-372-3300	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Soil, Sludge, Lead Battery Sites	Metals	Non-specific Organics
NOVATERRA, Inc. (formerly Toxic Treatments USA, Inc.), Torrance, CA (003)	In Situ Steam and Air Stripping	Philip LaMori 310-328-9433	Paul dePercin 513-569-7797 FTS: 684-7797	Soil	Not Applicable	VOCs, SVOCs, Hydrocarbons
Ogden Environmental Services, San Diego, CA (001)	Circulating Bed Combustor	Sherin Sexton 619-455-4622	Douglas Grosse 919-541-7844 FTS: 684-7844	Soil, Sludge, Slurry, liquids	Not Applicable	Halogenated and Nonhalogenated Organic Compounds, PCBs

3 This technology is not profiled in the Demonstration section.

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Peroxidation Systems, Inc., Tucson, AZ (006)	perox-pure™	Chris Giggy 602-790-8383	Norma Lewis 513-569-7665 FTS: 684-7665	Groundwater, Wastewater	Not Applicable	Fuel Hydrocarbons, Chlorinated Solvents, PCBs
Purus, Inc., San Jose, CA (006)	Photolytic Oxidation Process	Paul Blystone 408-453-7804	Norma Lewis 513-569-7665 FTS: 684-7665	Groundwater	Not Applicable	Fuel Hydrocarbons
QUAD Environmental Technologies Corp., Northbrook, IL (004)	Chemtact™ Gaseous Waste Treatment	Robert Rafson 312-564-5070	Ronald Lewis 513-569-7856 FTS: 684-7856	Gaseous Waste Streams	Non-Specific Inorganics	Volatile Organics
Recycling Sciences International, Inc., Chicago, IL (004)	Desorption and Vapor Extraction System	Mark Burchett 312-559-0122	Laurel Staley 513-569-7863 FTS: 684-7863	Soil, Sludge, Sediment	Volatile Inorganics	VOCs and SVOCs including PCBs, PAHs, PCP, some Pesticides
Remediation Technologies, Inc., Pittsburgh, PA (006)	High Temperature Thermal Processor	David Nakles 412-826-3340	Ronald Lewis 513-569-7856 FTS: 684-7856	Soils, Sediments, Sludges	Mercury	VOCs and SVOCs
Remediation Technologies, Inc., Seattle, WA (002)	Liquid and Solids Biological Treatment	Merv Cooper 206-624-9349	Ronald Lewis 513-569-7856 FTS: 684-7856	Soil, Sludge,	Not Applicable	Biodegradable Organics, Pesticides
Resources Conservation Co., Ellicott City, MD (001)	Solvent Extraction	Lanny Weimer 301-596-6066	Mark Meckes 513-569-7348 FTS: 684-7348	Soil, Sludge	Not Applicable	Oil, PCBs, PAHs
Retech, Inc., Ukiah, CA (002)	Plasma Arc Vitrification	R. C. Eschenbach 707-462-6522	Laurel Staley 513-569-7863 FTS: 684-7863	Soils, Sludge	Metals	Non-Specific Organics
Risk Reduction Engineering Laboratory, Cincinnati, OH (006)	Base-Catalyzed Dechlorination Process	Chris Rogers 513-569-7626 FTS: 684-7626	Laurel Staley 513-569-7863 FTS: 684-7863	Soils, Sediments	Not Applicable	PCBs, PCPs
Risk Reduction Engineering Laboratory, Cincinnati, OH (006)	Bioventing	Paul McCauley 513-569-7444 FTS: 684-7444	Mary Gaughan 513-569-7341 FTS: 684-7341	Soil	Not Applicable	Biodegradable Organics

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Risk Reduction Engineering Laboratory and IT Corporation Cincinnati, OH (004)	Debris Washing System	Michael Taylor 513-782-4700	Naomi Barkley 513-569-7854 FTS: 684-7854	Debris	Non-Specific Inorganics	Non-Specific Organics, PCBs, Pesticides
Risk Reduction Engineering Laboratory and University of Cincinnati, Cincinnati, OH (005)	Hydraulic Fracturing	Larry Murdoch 513-569-7897	Naomi Barkley 513-569-7854 FTS: 684-7854	Soil	Non-specific Inorganics	Non-specific Organics
Risk Reduction Engineering Laboratory and USDA Forest Products Laboratory, Cincinnati, OH (006)	Fungal Treatment Technology	Richard Lamar 608-231-9469	Kim Lisa Kreiton 513-569-7328 FTS: 684-7328	Soil	Not Applicable	PCPs, PAHs, Chlorinated Organics
Rochem Separation Systems, Inc., Torrance, CA (006)	Rochem Disc Tube Module System	David LaMonica 213-370-3160	Douglas Grosse 513-569-7844 FTS: 684-7844	Liquids	Non-Specific Inorganics	Organic Solvents
SBP Technologies, Inc., Stone Mountain, GA (005)	Membrane Separation and Bioremediation	Heather Ford 404-498-6666	Kim Lisa Kreiton 513-569-7328 FTS: 684-7328	Groundwater, Soils, Sludges	Not Applicable	Organic Compounds, PAHs, PCBs, TCEs
S.M.W. Seiko, Inc., Redwood City, CA (004)	In Situ Solidification and Stabilization	David Yang/ Osamu Taki 415-591-9646	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Soil	Metals	SVOCs, PCBs, PAHs
Separation and Recovery Systems, Inc., Irvine, CA (002)	SAREX Chemical Fixation Process	Joseph DeFranco 714-261-8860	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Sludge, Soil	Low Level Metals	Non-specific Organics
Silicate Technology Corp., Scottsdale, AZ (003)	Solidification and Stabilization Treatment Technology	Steve Pelger/ Scott Larsen 602-948-7100	Edward Bates 513-569-7774 FTS: 684-7774	Soil, Sludge, Wastewater	Metals, Cyanide, Ammonia	High Molecular Weight Organics
SoilTech, Inc., Englewood, CO (005)	Anaerobic Thermal Processor	Martin Vorum 303-790-1747	Paul dePercin 513-569-7797 FTS: 684-7797	Soil, Sludge, Refinery Wastes	Not Applicable	PCBs, Chlorinated Pesticides, VOCs

TABLE 2 (Continued)
SITE Demonstration Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Soliditech, Inc., Houston, TX (002)	Solidification and Stabilization	Bill Stallworth 713-497-8558	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Soil, Sludge	Metals	Non-Specific Organics
TechTran, Inc., Houston, TX (005)	Chemical Binding, Precipitation and Physical Separation	Charles Miller/ C. P. Yang 713-896-4343	Annette Gatchett 513-569-7697 FTS: 684-7697	Aqueous Solutions	Heavy Metals, Radionuclides	Non-Specific
Terra-Kleen Corporation, Oklahoma City, OK (006)	Soil Restoration Unit	Alan Cash 405-728-0001	Mark Meckes 513-569-7348 FTS: 684-7348	Soil	Not Applicable	PCBs, PCPs, Creosote, Chlorinated Solvents, Naphthaline, Diesel Oil, Used Motor Oil, Jet Fuel, Grease, Organic Pesticides
Terra Vac, Inc., San Juan, PR (001)	In Situ Vacuum Extraction	James Malot 809-723-9171	Mary Stinson 908-321-6683 FTS: 340-6683	Soil	Not Applicable	VOCs and SVOCs
Texaco Syngas, Inc., White Plains, NY (006)	Entrained-Bed Gasification	Richard Zang 914-253-4047	Marta Richards 513-569-7783 FTS: 684-7783	Soils, Sludges, Sediments	Not Applicable	Non-specific Organics
TEXAROME, Inc., Leakey, TX (006)	Mobile Solid Waste Desorption	Gueric Boucard 512-232-6079	Mary Gaughan 513-569-7341 FTS: 684-7341	Soils, Wood Wastes, Mop-up Materials	Volatile Inorganics	VOCs, SVOCs, PCBs, PCPs, Creosote, Organic Fungicides, Pesticides
Udell Technologies, Inc., Emeryville, CA (005)	In Situ Steam Enhanced Extraction	Lloyd Steward 510-653-9477	Paul dePercin 513-569-7797 FTS: 684-7797	Soils, Ground Water	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Ultrox International, Inc., Santa Ana, CA (003)	Ultraviolet Radiation and Oxidation	Jerome Barich 714-545-5557	Norma Lewis 513-569-7665 FTS: 684-7665	Groundwater, Leachate, Wastewater	Not Applicable	Halogenated Hydrocarbons, VOCs, Pesticides, PCBs
U.S. Environmental Protection Agency	Excavation Techniques and Foam Suppression Methods	Dick Gerstle 513-782-4700	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Soil	Volatile Inorganics	Volatile Organics

TABLE 2 (Continued)
SITE Demonstration Program Participants

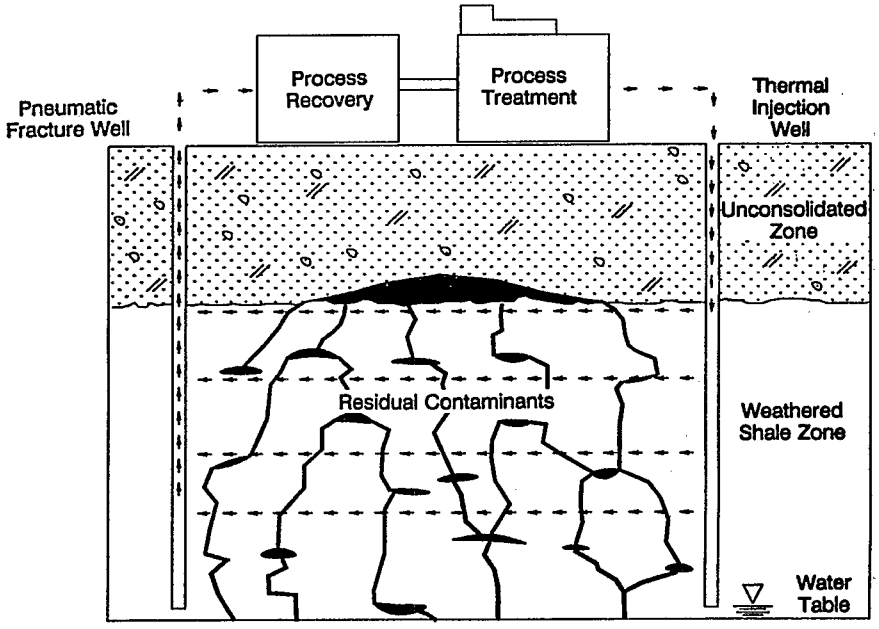
Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Wastech Inc., Oak Ridge, TN (004)	Solidification and Stabilization	E. Benjamin Peacock 615-483-6515	Edward Bates 513-569-7774 FTS: 684-7774	Soil, Sludge, Liquid Waste	Non-Specific, Radioactive	Non-Specific Organics
Western Research Institute[4], Laramie, WY (005) (E01)	Contained Recovery of Oily Wastes	James Speight 307-721-2011	Eugene Harris 513-569-7862 FTS: 684-7862	Soil	Not Applicable	Coal Tar Derivatives, Petroleum Byproducts
Weston Services, Inc., West Chester, PA (006)	Low Temperature Thermal Treatment (LT³®)	Mike Cosmos 215-430-7423	Paul dePercin 513-569-7797 FTS: 684-7797	Soil	Not Applicable	VOCs and SVOCs
Zimpro/Passavant, Environmental Systems, Inc., Rothschild, WI (002)	PACT® Wastewater Treatment System	William Copa 715-359-7211	John Martin 513-569-7758 FTS: 684-7758	Groundwater, Industrial Wastewater, Leachate	Not Applicable	Biodegradeable VOCs and SVOCs

4 Graduate of Emerging Technology Program

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

TECHNOLOGY DESCRIPTION:

An integrated treatment system incorporating Pneumatic Fracturing Extraction (PFE) and Catalytic Oxidation has been jointly developed by Accutech Remedial Systems Inc., and the Hazardous Substance Management Research Center located at the New Jersey Institute of Technology in Newark, New Jersey. The system provides a cost-effective accelerated remedial approach to sites with Dense Non-Aqueous Phase Liquid (DNAPL) contaminated aquifers. The patented PFE process has been demonstrated both in the laboratory and in the field to establish a uniform subsurface airflow within low permeability formations such as clay and fractured rock. The PFE process (see figure below) coupled with an in situ thermal injection process is designed to recover residual contamination entrapped in the vadose zone. A groundwater recovery system is first implemented to suppress the water table below the zone of highest contamination. Recovered groundwater is treated by an aeration process. DNAPL contaminants removed from the groundwater are combined with the PFE recovery process stream. The combined DNAPL vapor stream is fed into a catalytic oxidation unit for destruction. The oxidation unit contains a catalyst which has been shown to resist process deactivation. Heat from the catalytic/oxidation unit is utilized in the in situ thermal injection component of the treatment system. The treatment system also has the



Pneumatic Fracturing Extraction
and Catalytic Oxidation

ability to utilize activated carbon treatment technology when contaminant concentrations decrease to levels where catalytic technology is no longer cost-effective.

WASTE APPLICABILITY:

The integrated treatment system is cost-effective for treating soils and rock where conventional in situ technologies are limited in their effectiveness because of the presence of low permeability geologic formations. Halogenated and nonhalogenated volatile and semivolatile organic compounds can be remediated by this system.

STATUS:

This technology was accepted into the SITE Demonstration Program in December 1990. The demonstration is planned for fall 1991 and will be performed at a New Jersey Department of Environmental Protection and Energy Environmental Cleanup Responsibility Act (ECRA) site in South Plainfield, New Jersey, where trichloroethene (TCE) will be removed from a fractured shale aquifer.

The demonstration will also include the development of engineering cost data for catalytic oxidation and carbon adsorption technologies by alternating between the two treatment methods.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Uwe Frank
U.S. EPA, Building 10, MS-104
2890 Woodbridge Avenue
Edison, NJ 08837
908-321-6626
FTS: 340-6626

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

ALLIED-SIGNAL, INC.
Environmental Systems
(ICB Biotreatment System)

TECHNOLOGY DESCRIPTION:

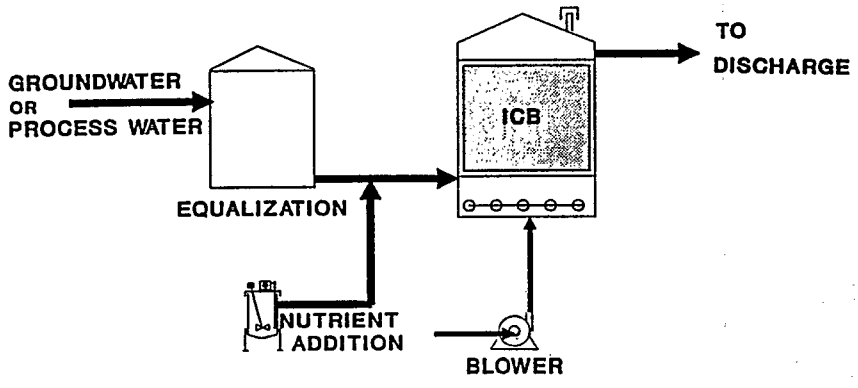
The immobilized cell bioreactor (ICB) biotreatment system is an aerobic fixed-film bioreactor system designed to remove organic contaminants (including nitrogen-containing compounds and chlorinated solvents) from process wastewater, contaminated groundwater, and other aqueous streams. The system offers improved treatment efficiency through the use of (1) a unique, proprietary reactor medium that maximizes the biological activity present 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 slow sludge production.

Basic system components include the bioreactor and medium, nutrient mix tank and feed pump, and a blower to provide air to the reactor. 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 the 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 polycyclic aromatic hydrocarbons (PAH), phenols, gasoline, chlorinated solvents, diesel fuel, and



Allied-Signal immobilized cell bioreactor

chlorobenzene. Industrial streams amenable to treatment include wastewaters generated from chemical manufacturing, petroleum refining, wood treating, tar and pitch manufacturing, food processing, and textile fabricating. Allied-Signal Corp. 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.

Table 1. Current Applications

Applications	Contaminants	Scale
Pipeline Terminal Wastewater	COD, Benzene, MTBE, Xylenes	Bench
Specialty Chemical Wastewater	Cresols, MTBE, PAH, Phenolics	Pilot
Groundwater	Chlorobenzene, TCE	Pilot
Tar Plant Wastewater	Phenol, Cyanide, Ammonia	Pilot
Wood Treating Wastewater	Phenolics, Creosote	Commercial

STATUS:

The G&H Landfill in Utica, Michigan, was selected for the demonstration of the ICB system. Treatability studies have shown the system's ability to biodegrade all the priority pollutants present to low part per billion levels. Currently, the demonstration plan is being finalized. The actual SITE Demonstration is tentatively planned for summer 1992. Allied-Signal, Inc., is currently operating an anaerobic system to reduce the concentrations of trichloroethylene and other chlorinated compounds in contaminated groundwater.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Ronald Lewis
U.S. EPA
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7856
FTS: 684-7856

TECHNOLOGY DEVELOPER CONTACTS:
Ralph Nussbaum
or Timothy Love
Allied-Signal, Inc.
P.O. Box 1087
Morristown, NJ 07962
201-455-3190
FAX: 201-455-6840

AMERICAN COMBUSTION, INC.
(PYRETRON® Thermal Destruction)

TECHNOLOGY DESCRIPTION:

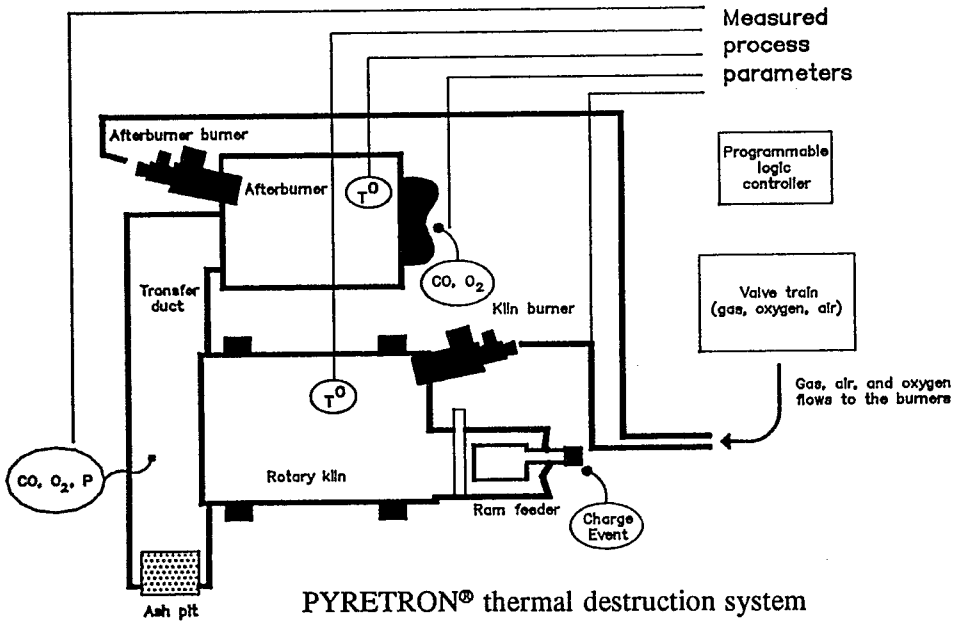
The PYRETRON® thermal destruction technology (see figure below) provides an integrated combustion system responsible for controlling the heat input into an incineration process by using the PYRETRON® oxygen-air-fuel burners and the dynamic control of the level of excess oxygen available for oxidation of hazardous waste. The PYRETRON® combustor uses an advanced combustion concept that relies on a new technique for mixing auxiliary fuel, oxygen, and air in order to (1) provide the flame envelope with enhanced stability, luminosity, and flame core temperature and (2) provide a reduction in the combustion volume per million British thermal units (Btu) of heat released.

The combustion system operation is computer controlled to automatically adjust the temperatures of the primary and secondary combustion chambers and the amount of excess oxygen being supplied to the combustion process. The system has been designed to dynamically adjust the amount of excess oxygen in response to sudden changes in the rate of volatilization of contaminants from the waste.

The burner system can be fitted onto any conventional incineration unit and used for the burning of liquids, solids, and sludges. Solids and sludges can also be coincinerated when the burner is used in conjunction with a rotary kiln or similar equipment.

WASTE APPLICABILITY:

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



PYRETRON® thermal destruction system

STATUS:

A demonstration project was conducted at EPA's Combustion Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund site in California and 60 percent decanter tank tar sludge from coking operations (RCRA listed waste K087). 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 polycyclic aromatic hydrocarbons 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 advantages 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.
- Costs savings can be achieved in many situations.

APPLICATIONS ANALYSIS SUMMARY:

The field evaluations conducted under the SITE Demonstration Program yielded the following conclusions:

- The PYRETRON® burner system is a viable technology for treating Superfund wastes.
- The system is capable of doubling the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values.
- In situations where particulate carryover causes operational problems, the PYRETRON® system may increase reliability.
- The technology can be an economical addition to an incinerator when operating and fuel costs are high and oxygen costs are relatively low.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Laurel Staley
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AWD TECHNOLOGIES, INC.

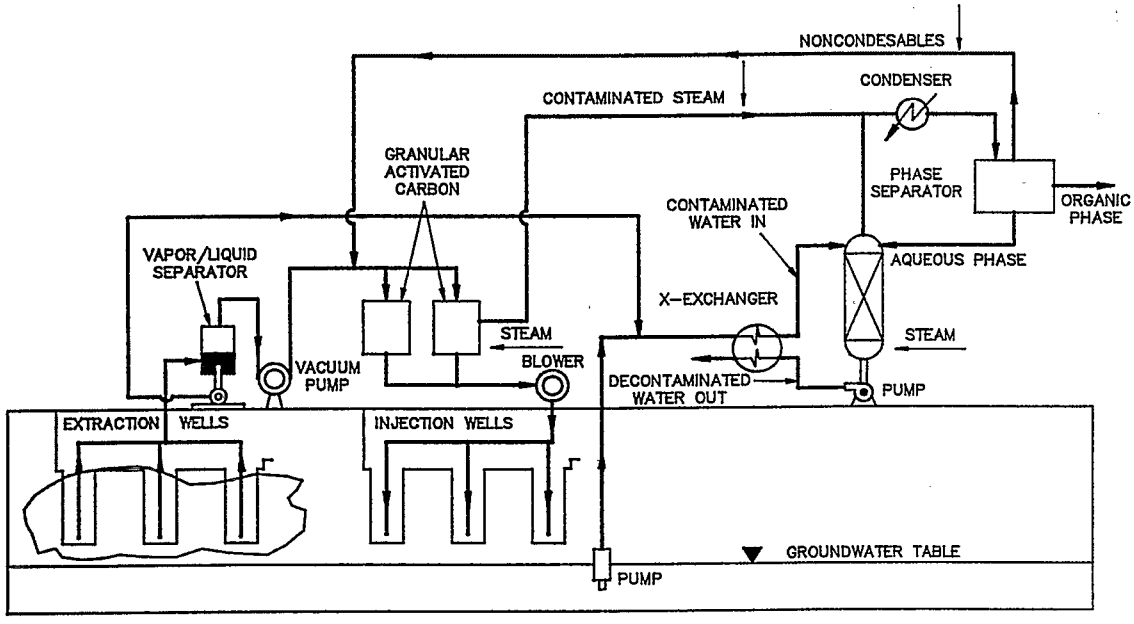
(Integrated Vapor Extraction and Steam Vacuum Stripping)

TECHNOLOGY DESCRIPTION:

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

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

A key component of the closed-loop system is a vent header unit designed to collect the noncondensable gases extracted from the groundwater or air that may leak into the portion of the process operating below atmospheric pressure. Further, the steam used to regenerate the carbon beds is condensed and treated in the AquaDetox system.



Zero air emissions integrated AquaDetox/SVE system

WASTE APPLICABILITY:

This technology removes VOCs, including chlorinated hydrocarbons, in groundwater and soil. Sites with contaminated groundwater and soils containing trichloroethylene (TCE), perchloroethylene (PCE), and other VOCs are suitable for this on-site treatment process. AquaDetox is capable of effectively removing over 90 of the 110 volatile compounds listed in 40 CFR Part 261, Appendix VIII.

STATUS:

The AWD AquaDetox/SVE system is currently being used at the Lockheed Aeronautical Systems Company in Burbank, California. At this site, the system is treating groundwater contaminated with as much as 2,200 parts per billion (ppb) of TCE and 11,000 ppb PCE; and soil gas with a total VOC concentration of 6,000 parts per million (ppm). Contaminated groundwater is being 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 (cfm). The system occupies approximately 4,000 square feet.

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

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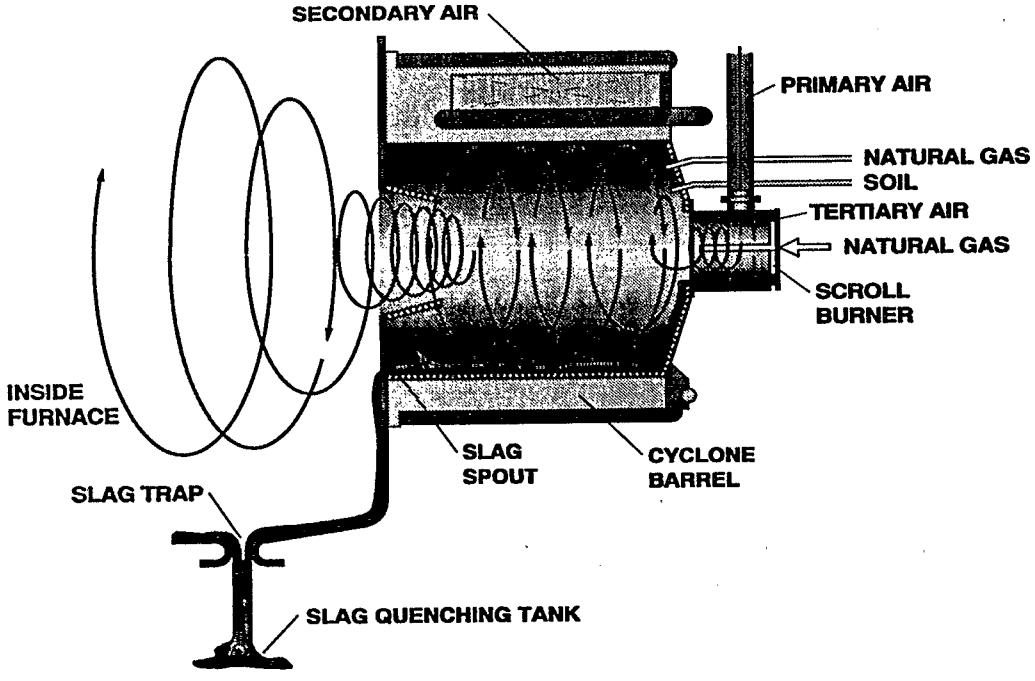
BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

This furnace technology is designed to decontaminate wastes containing both organic and metal contaminants. The cyclone furnace retains heavy metals in a non-leachable slag and vaporizes and incinerates the organic materials in the wastes.

The treated soils resemble natural obsidian (volcanic glass), similar to the final product from vitrification.

The furnace is a horizontal cylinder (see figure below) and is designed for heat release rates greater than 450,000 British thermal units (Btu) per cubic foot (coal) and gas temperatures exceeding 3,000 degrees Fahrenheit (°F). Natural gas and preheated primary combustion air (820°F) enter the furnace tangentially. Secondary air (820°F), natural gas, and the synthetic soil matrix (SSM) enter tangentially along the cyclone barrel (secondary air inlet location). The resulting swirling action efficiently mixes air and fuel and increases combustion gas residence time. Dry SSM has been tested at pilot-scale feed rates of both 50 and 200 pounds per hour (lb/hr). The SSM is retained on the furnace wall by centrifugal action; it melts and captures a portion of the heavy metals. The organics are destroyed in the molten slag layer. The slag exits the cyclone furnace (slag temperature at this location is 2,400°F) and is dropped into a water-filled slag tank where it solidifies into a nonleachable vitrified material. A small quantity of the soil also exits as flyash from the furnace and is collected in a baghouse.



Cyclone furnace

WASTE APPLICABILITY:

This technology may be applied to high-ash solids (such as sludges and sediments) and soils containing volatile and nonvolatile organics and heavy metals. The less volatile metals are captured in the slag more readily. The technology would be well-suited to mixed waste soils contaminated with organics and nonvolatile radionuclides (such as plutonium, thorium, uranium). Because vitrification has been listed as Best Demonstrated Achievable Technology (BDAT) for arsenic and selenium wastes, the cyclone furnace may be applicable to these wastes.

STATUS:

This technology was accepted into the SITE Demonstration Program in August 1991. The demonstration will be conducted at the developer's facility in winter 1991 using synthetic soil matrices spiked with heavy metals, semivolatile organics, and radionuclide surrogates.

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BIO-RECOVERY SYSTEMS, INC.
(Biological Sorption)

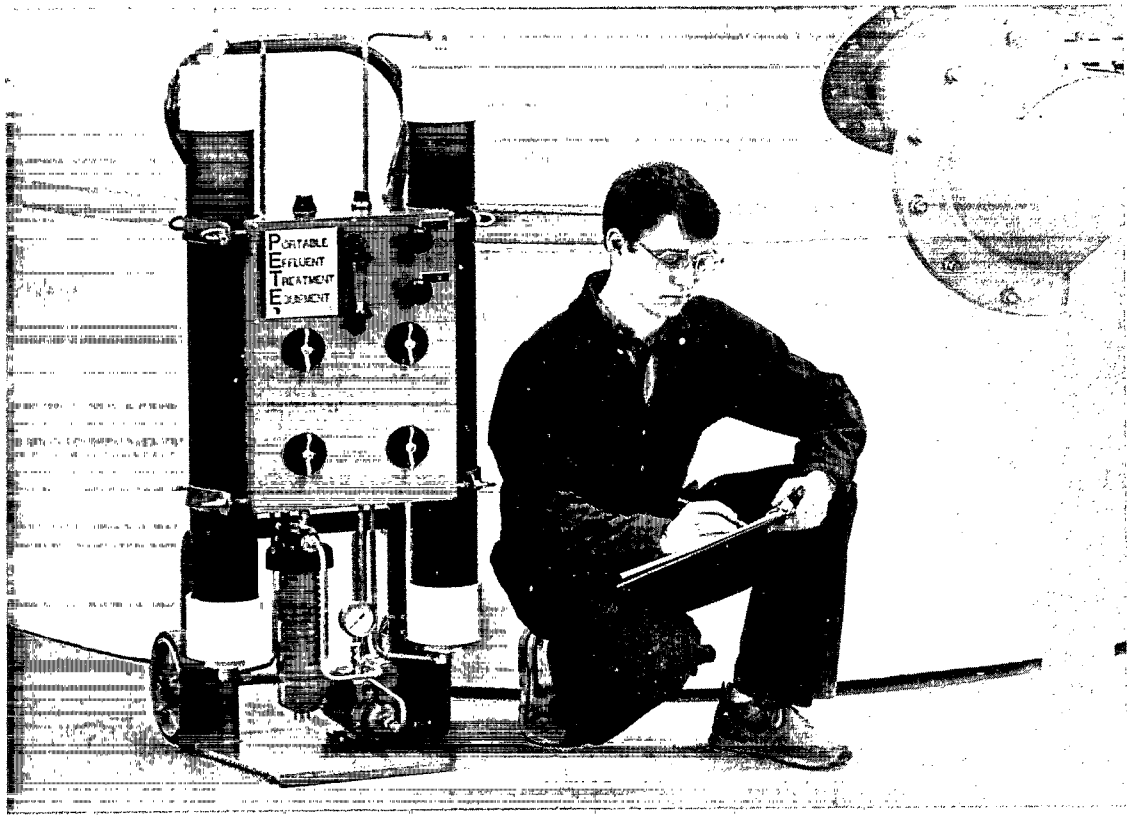
TECHNOLOGY DESCRIPTION:

The AlgaSORB™ sorption process is designed to remove heavy metal ions from aqueous solutions. The process is based on the natural affinity of the cell walls of algae for heavy metal ions.

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



PETE Unit

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

The photograph on the previous page 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 PETE unit is capable of treating flows of approximately 1 gallon per minute (gpm). Larger systems have been designed and manufactured to treat flow rates greater than 100 gpm.

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.

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:

Based on the results from the SITE Emerging Technology Program, Bio-Recovery Systems, Inc. has been invited to participate in the Demonstration Program.

Under the Emerging Technology Program, the AlgaSORB™ sorption process was tested on mercury-contaminated ground water at a hazardous waste site in Oakland, California, in fall 1989. The final report (EPA/540/5-90/005a) is now available.

The process is being commercialized for groundwater treatment and industrial point source treatment. Treatability studies are required as the next stage in development.

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BIOTROL, INC.
(Biological Aqueous Treatment System)

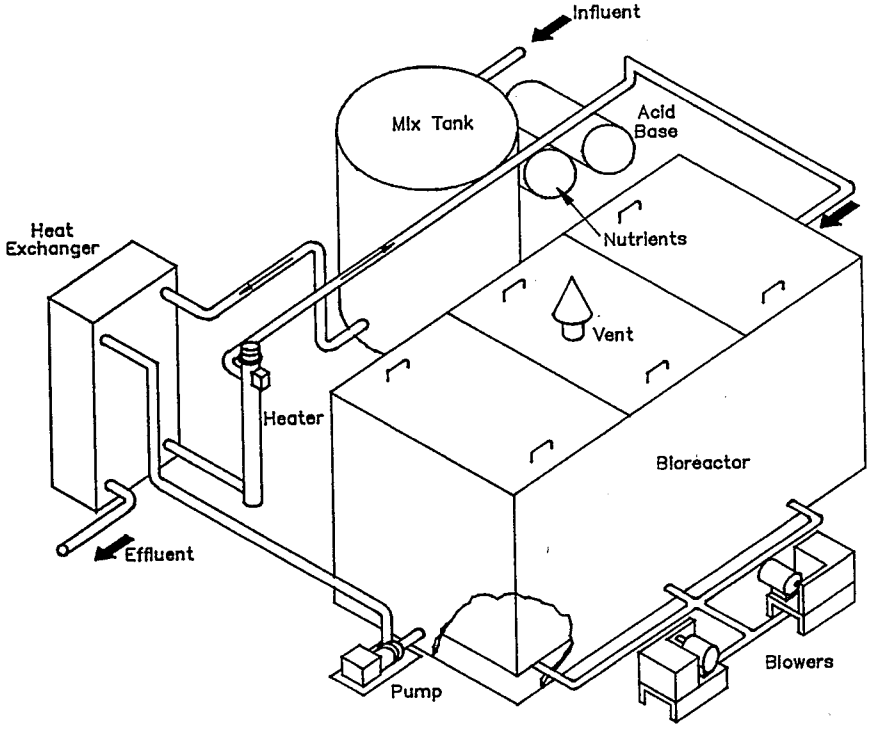
TECHNOLOGY DESCRIPTION:

The BioTrol aqueous treatment system (BATS) is a patented biological treatment system that is effective for treating contaminated ground water and process water. The system uses an amended microbial mixture, which is a microbial population indigenous to the wastewater to which a specific microorganism has been added. This system removes the target contaminants, as well as the naturally-occurring background organics.

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 reactor, 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 may be reused on-site. In some cases,



Bioreactor processing system

discharge with a National Pollutant Discharge Elimination System (NPDES) permit may be possible.

WASTE APPLICABILITY:

This technology may be applied to a wide variety of wastewaters, including ground water, 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 nine 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.

DEMONSTRATION RESULTS:

Results of the demonstration indicate that pentachlorophenol (PCP) was reduced to less than 1 part per million at all flow rates. Removal percentage was as high as 97 percent at the lowest flow rate. The Applications Analysis Report (AAR) (EPA/540/A5-91/001) has been published. The Technology Evaluation Report (TER) will be available in 1992.

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BIOTROL, INC.
(Soil Washing System)

TECHNOLOGY DESCRIPTION:

The BioTrol Soil Washing System is a patented, water-based, volume reduction process for treating excavated soil. Soil washing may be applied to contaminants concentrated in the fine-size fraction of soil (silt, clay, and soil organic matter) and the mainly surficial contamination associated with the coarse (sand and gravel) soil fraction. The goal is for the soil product to meet appropriate cleanup standards.

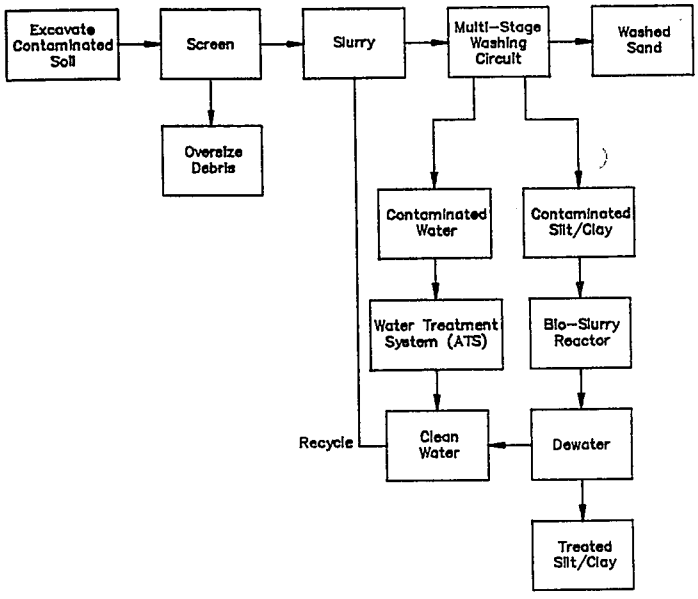
After debris is removed, soil is mixed with water and subjected to various unit operations common to the mineral processing industry. Process steps can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering operations (see figure below).

The core of the process is a multi-stage, counter-current, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles from the coarser sand and gravel. 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.

The contaminated residual products 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 polycyclic aromatic hydrocarbons (PAH) and pentachlorophenol (PCP). The technology may also be applied to soils contaminated with petroleum hydrocarbons, pesticides,



BioTrol Soil washing System process diagram

polychlorinated biphenyls (PCB), various industrial chemicals, and metals.

STATUS:

The SITE demonstration of the soil washing technology 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 Technology Evaluation Report (TER) and the Applications Analysis Report (AAR) are expected to be available in early 1992.

DEMONSTRATION RESULTS:

- 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 achieved up to 89 percent removal of PCPs and 88 percent of total PAHs, based on the difference between parts per million (ppm) levels in the contaminated (wet) feed soil and the washed soil.
- The system degraded up to 94 percent of PCP in the process water from soil washing. PAH removal could not be determined due to 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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BIOVERSAL USA, INC.
(BioGenesis℠ Soil Cleaning Process)

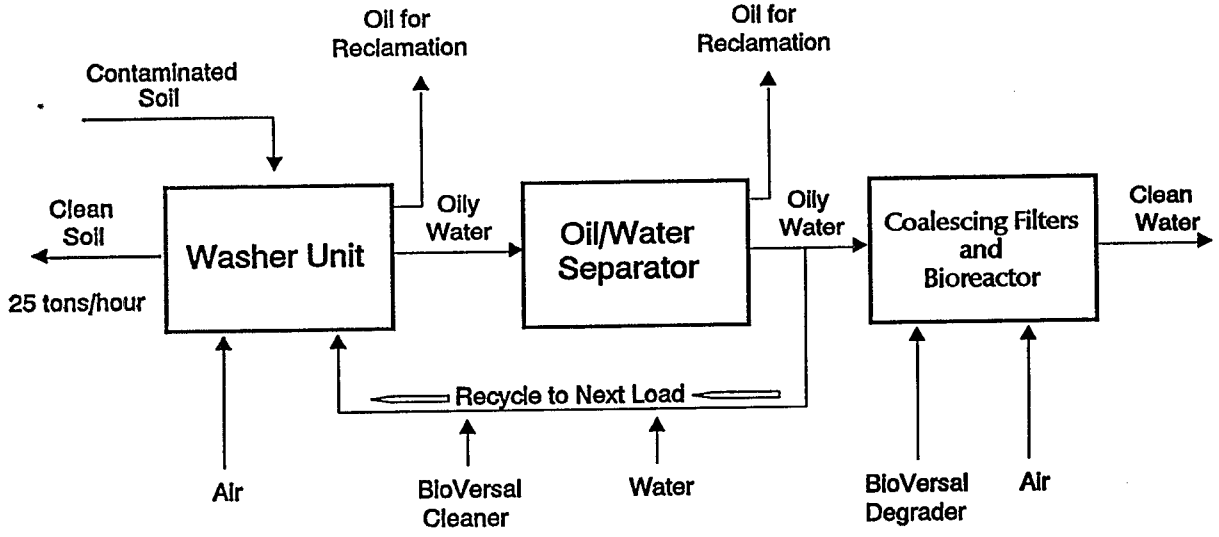
TECHNOLOGY DESCRIPTION:

The BioGenesis℠ process uses a specialized truck, water, and a complex surfactant to clean contaminated soil. Ancillary equipment includes gravity oil and water separators, coalescing filters, and a bioreactor. The cleaning rate for oil contamination of 5,000 parts per million (ppm) is about 25 tons/hour; lesser rates apply for more contaminated soil. One single wash removes 95 to 99 percent of hydrocarbon contamination of up to 15,000 ppm. One or two additional washes are used for concentrations of up to 50,000 ppm.

BioGenesis℠ washing uses a complex surfactant and water. The BioVersal℠ cleaner is a light alkaline mixture of natural and organic materials containing no hazardous or petrochemical ingredients. The figure below shows the soil washing procedure. Twenty-five tons of contaminated earth are loaded into a washer unit containing water and BioVersal℠ cleaner.

For 15 to 30 minutes, aeration equipment agitates the mixture, thus washing the soil, and encapsulating oil molecules with BioVersal℠ 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), are extracted in the same manner and then processed by using treatment methods specific to that hazard. All equipment is mobile, and treatment is normally on-site.

The advantages of BioGenesis℠ include (1) treatment of soils containing both volatile and nonvolatile oils, (2) treatment of soil containing clay, (3) high processing rates, (4) on-site



Soil washing procedure

treatment, (5) transformation of contamination to reusable oil, treatable water, and active soil suitable for on-site treatment, (6) backfill, (7) the absence of air pollution, except during excavation, (8) and accelerated biodegradation of oil residuals in the soil.

WASTE APPLICABILITY:

This technology is capable of extracting volatile and nonvolatile oils, chlorinated hydrocarbons, pesticides, and other organics from most types of soils, including clays. These contaminants include asphalteens, heating oils, diesel fuel, gasoline, PCBs, and polycyclic aromatic hydrocarbons.

STATUS:

BioGenesis℠ technology was commercialized in Germany during 1990. It was accepted into the SITE Demonstration Program in June 1990. Beale Air Force Base in California is the planned location for the SITE demonstration, which is tentatively planned for the fall of 1991. Full commercial operations are scheduled for Wisconsin and California in the spring of 1992, with subsequent expansion to other regions.

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

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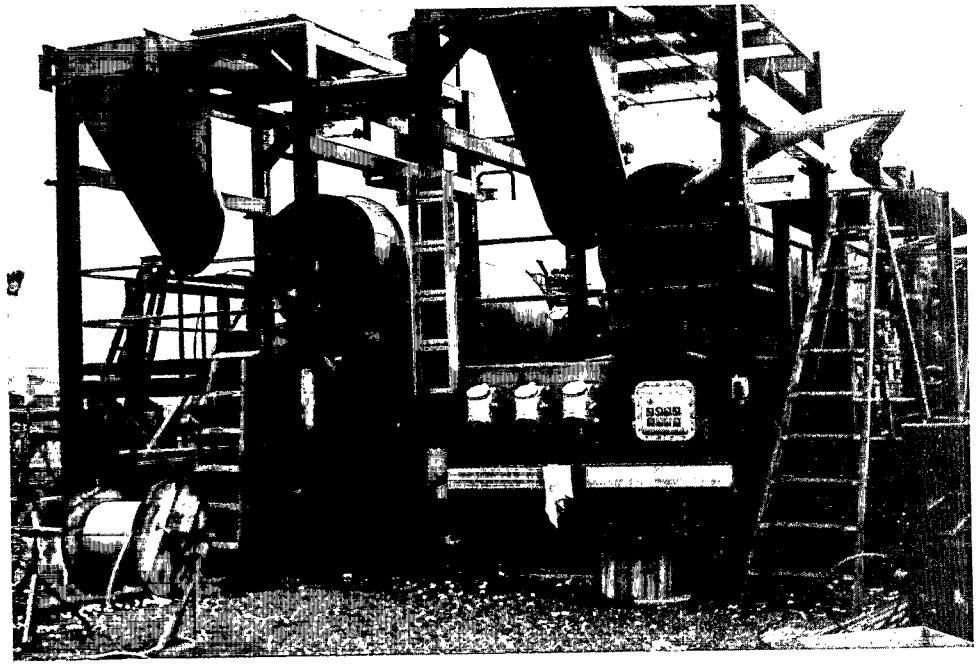
CET ENVIRONMENTAL SERVICES–SANIVAN GROUP
(Soil Treatment with Extraksol™)

TECHNOLOGY DESCRIPTION:

Extraksol™ is a solvent extraction technology on a modular transportable system. This batch process extracts organic contaminants from the soil using proprietary nonchlorinated, organic solvents. The solvents are regenerated by distillation, and the contaminants are concentrated in the distillation residues.

The three treatment steps -- soil washing, soil drying, and solvent regeneration -- occur on a flatbed trailer for the smaller unit (1 ton/hour) and on a skid-mounted rig for the larger unit (3 to 6 tons/hour). The extraction fluid (solvent) is circulated through the contaminated matrix within an extraction chamber (see photogtraph below) to wash the soil. Controlled temperature and pressure optimize the washing procedure. Hot inert gas dries the soil. The gas vaporizes the residual extract fluid and carries it from the extraction chamber to a condenser, where the solvent is separated from the gas. The solvent-free gas is reheated and reinjected into the soil, as required, for complete drying. After the drying cycle, the decontaminated soil may be returned to its original location.

Distillation of the contaminated solvent achieves two major objectives: (1) it minimizes the amount of solvent required to perform the extraction, by regenerating it in a closed loop, and (2) it significantly reduces the volume of contaminants requiring further treatment or off-site disposal by concentrating them in the still bottoms.



Extraction chamber

WASTE APPLICABILITY:

The process extracts organic contaminants from solids. It is capable of extracting a range of contaminants, including polychlorinated biphenyls (PCB), pentachlorophenol (PCP), polycyclic aromatic hydrocarbons (PAH), monocyclic aromatic hydrocarbon (MAH), pesticides, oils, and hydrocarbons. The process has the following soil restrictions:

- A maximum clay fraction of 40 percent
- A maximum water content of 30 percent
- A maximum size, if porous material, of approximately 2 inches (preferably 1/4 inch or smaller)
- A maximum size, if nonporous material, of 1 to 2 feet, but the maximum size is not recommended. Rather, particles with a diameter of 4 inches or less are preferred.

The process can also extract volatile contaminants, such as gasoline and solvents, through stripping and condensation.

STATUS:

The process has been tested in several pilot projects on a range of contaminants. This technology was accepted into the SITE Demonstration Program in June 1990. The unit will be used to decontaminate 3,500 tons of PCB-contaminated soil in Washburn, Maine, in 1992.

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CF SYSTEMS CORPORATION
(Solvent Extraction)

TECHNOLOGY DESCRIPTION:

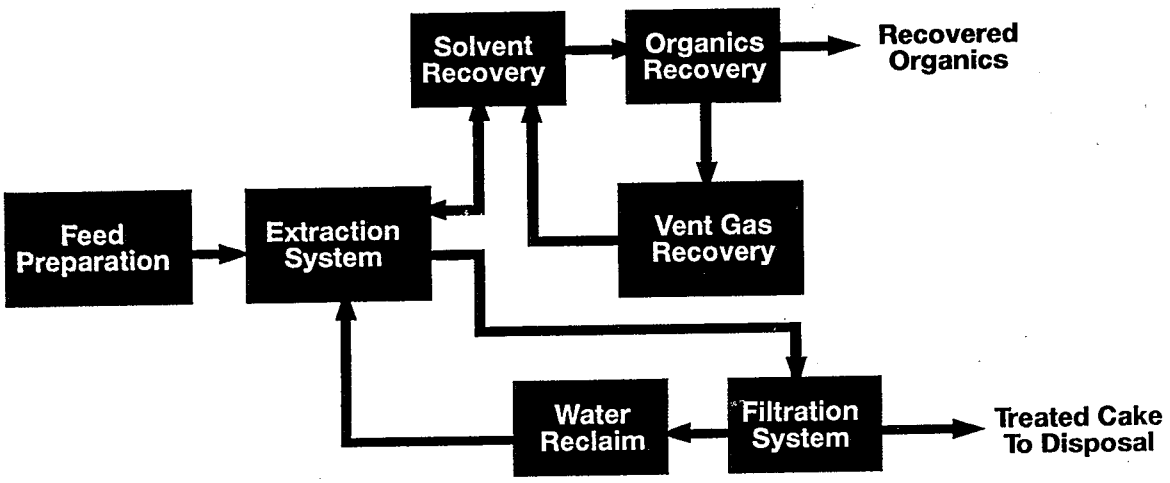
CF Systems Corporation technology uses liquified gases as solvent to extract organics from sludges, contaminated soils, and wastewater. Propane is the solvent typically used for sludges and contaminated soils, while carbon dioxide is used for wastewater streams. The system is available as either a continuous flow unit for pumpable wastes or a batch system for dry soils.

Contaminated solids, slurries, or wastewaters are fed into the extractor (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, treated water is removed from the extractor while the mixture of solvent and organics passes to the solvent recovery system. 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.

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

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 polychlorinated biphenyls (PCB), dioxins, and pentachlorophenols (PCP). Also, this process can treat refinery wastes and organically contaminated wastewater.



CF systems solvent extraction remediation process

STATUS:

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

A full-scale commercial system is currently operating under contract at a major Gulf Coast refinery treating refinery K-wastes to meet best demonstrated available technology (BDAT) standards for solids disposal. The unit has operated at better than 85 percent since acceptance in early March 1991. Treatment costs are competitive with all other on-site treatment processes.

Commercial systems have been sold to Clean Harbors, Braintree, Massachusetts, for wastewater cleanup; and ENSCO of Little Rock, Arkansas, for incinerator pretreatment. The startup of the Clean Harbors wastewater unit is currently scheduled to begin in September 1991. The technology has been selected by EPA and Texas Water Commission on a "sole source" basis for clean up of the 80,000 cubic yard United Creosoting site at Conroe, Texas.

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.

Development of full-scale commercial systems has eliminated problems associated with cross-contamination in the pilot plant design.

APPLICATIONS ANALYSIS SUMMARY:

- Extraction efficiencies of 90 to 98 percent were achieved on sediments containing between 360 and 2,575 ppm PCBs. PCB concentrations were as low as 8 ppm in the treated sediment.
- In the laboratory, extraction efficiencies of 99.9 percent have been obtained for volatile and semivolatile organics in aqueous and semi-solid wastes.
- Operating problems included solids being retained in the system hardware and foaming in receiving tanks. The vendor identified corrective measures to be implemented in the full-scale commercial unit.
- Projected costs for PCB cleanups are estimated at approximately $150 to $450 per ton, including material handling and pre- and post-treatment costs. These costs are highly sensitive to the utilization factor and job size, which may result in lower costs for large cleanups.

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CHEMFIX TECHNOLOGIES, INC.
(Solidification and Stabilization)

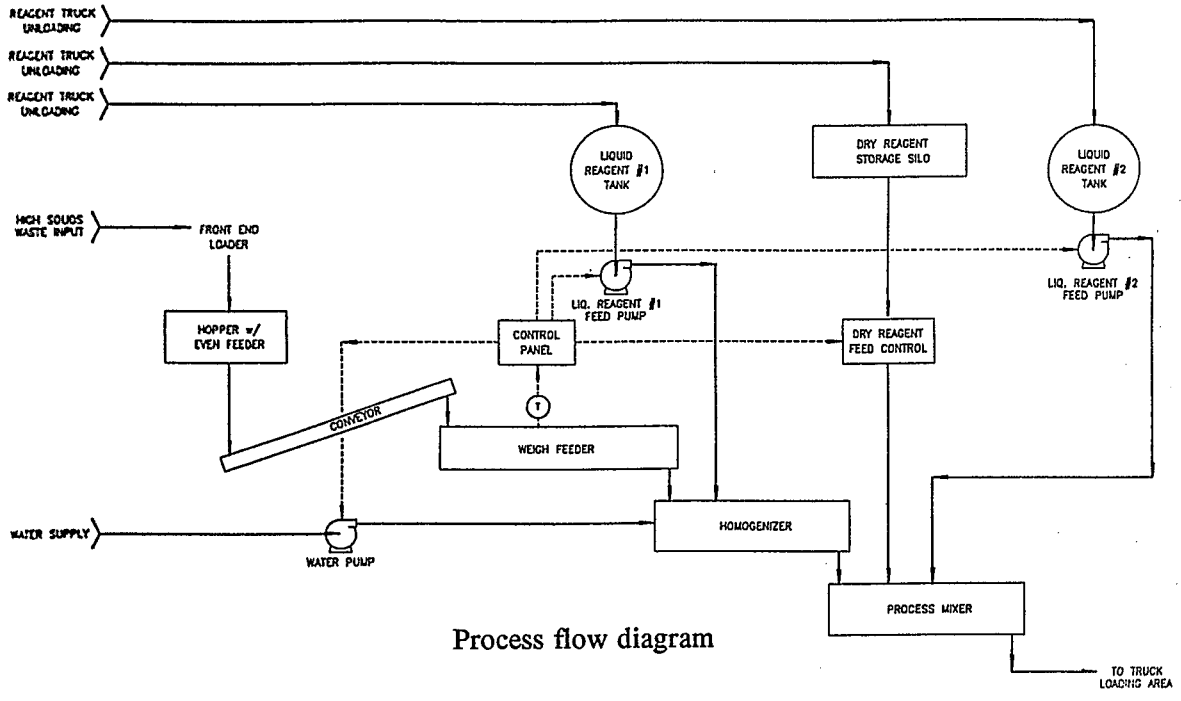
TECHNOLOGY DESCRIPTION:

This solidification and stabilization process is an inorganic system in which soluble silicates and silicate setting agents react with polyvalent metal ions and other waste components, to produce a chemically and physically stable solid material. The treated waste matrix displays good stability, a high melting point, and a friable texture. The treated matrix may be similar to soil, depending upon the water content of the feed waste.

The feed waste is first blended in the reaction vessel (see figure below) with dry alumina, calcium, and silica based reagents that are dispersed and dissolved throughout the aqueous phase. The reagents react with polyvalent ions in the waste and form inorganic polymer chains (insoluble metal silicates) throughout the aqueous phase. These polymer chains physically entrap the organic colloids within the microstructure of the product matrix. The water-soluble silicates then react with complex ions in the presence of a silicate setting agent, producing amorphous, colloidal silicates (gels) and silicon dioxide, which acts as a precipitating agent.

Most of the heavy metals in the waste become part of the silicate gel. Some of the heavy metals precipitate with the structure of the silicate gel. A very small percentage (estimated to be less than one percent) of the heavy metals precipitates between the silicates and is mechanically immobilized.

Since some organics may be contained in particles larger than the silicate gel, all of the waste is pumped through processing equipment, creating sufficient shear in combination with surface active chemicals to emulsify the organic constituents. Emulsified organics are then microencapsulated and solidified and discharged to a prepared area, where the gel continues to set and stabilize. The resulting solids, though friable, microencapsulate any organic substances that may have escaped emulsification. The system can be operated at 5 to 100 percent solids in the waste feed; water is added for drier



Process flow diagram

wastes. Portions of the water contained in the wastes are involved in three reactions after treatment: (1) hydration, similar to that of cement reactions; (2) hydrolysis reactions; and (3) equilibration through evaporation. There are no side streams or discharges from this process.

WASTE APPLICABILITY:

This technology is suitable for contaminated soils, sludges, and other solid wastes. The process is applicable to electroplating wastes, electric arc furnace dust, and municipal sewage sludge containing heavy metals such as aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc.

STATUS:

The technology was demonstrated in March 1989 at the Portable Equipment Salvage Co., site in Clackamas, Oregon. Preliminary results are available in a Demonstration Bulletin (October 1989). The Technology Evaluation Report (TER) was published in September 1990 (EPA/540/5-89/011a). The Applications Analysis Report (AAR) was completed in May 1991 (EPA/540/A5-89/011).

From fall 1989 through winter 1990, Chemfix Technologies, Inc.'s subsidiary, Chemfix Environmental Services, Inc. (CES), applied a high solids CHEMSET® reagent protocol approach to the treatment of about 30,000 cubic yards of heavy metal-contaminated waste. The goal of reducing leachable hexavalent chromium to below 0.5 parts per million (ppm) in the toxicity characteristics leaching procedure (TCLP) was met, as well as the goal of producing a synthetic clay cover material with low permeability (less than 1×10^{-6} centimeters per second). The production goal of exceeding 400 tons per day was also met. This included production during many subfreezing days in December, January, and March. In Summer 1990, CES engaged in another high solids project involving lead.

DEMONSTRATION RESULTS:

- The Chemfix Technology was effective in reducing the concentrations of copper and lead in the TCLP extracts. The concentrations in the extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations of the untreated waste approached 14 percent.
- The volume of the excavated waste material increased from 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. Permeability decreased by more than one order of magnitude.
- The air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls (PCB) during the treatment process.
- The cost of the treatment process was $73 per ton of raw waste treated, exclusive of excavation, pretreatment, and disposal.

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CHEMICAL WASTE MANAGEMENT, INC.
(DeChlor/KGME Process)

TECHNOLOGY DESCRIPTION:

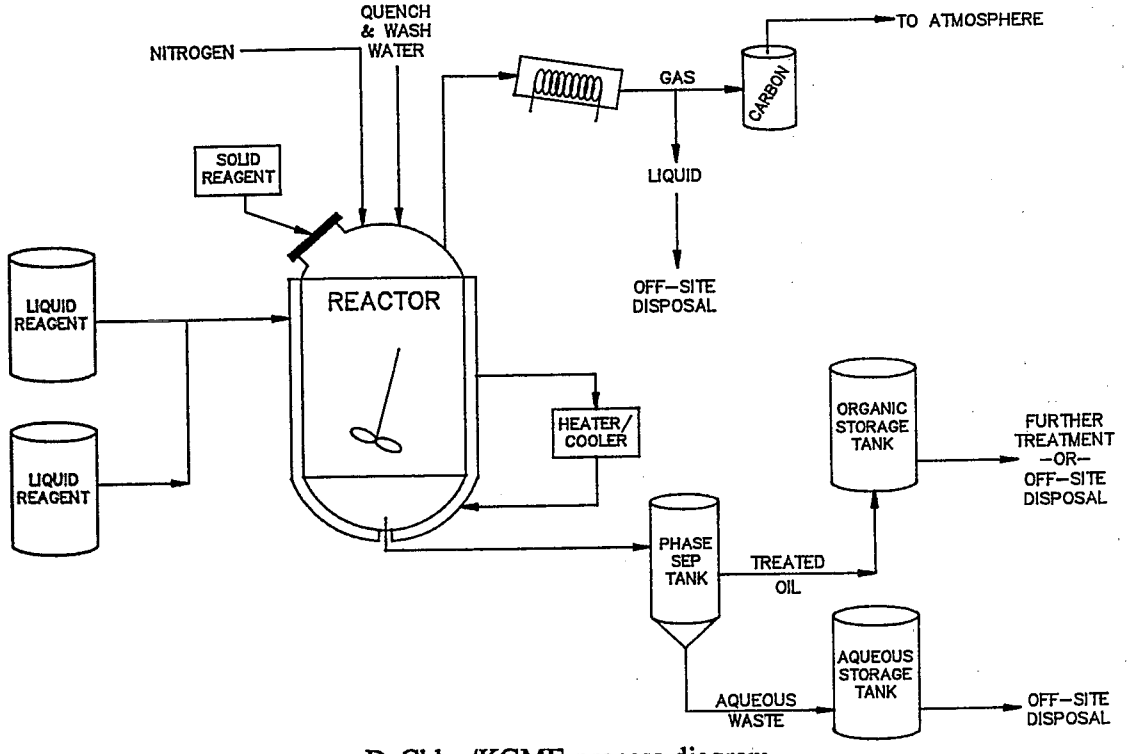
Chemical Waste Management's (CWM) DeChlor/KGME process involves the dechlorination of liquid-phase halogenated compounds, particularly polychlorinated biphenyls (PCB). KGME, a CWM proprietary reagent, is the active species in a nucleophilic substitution reaction, in which the chlorine atoms on the halogenated compounds are replaced with fragments of the reagent. The products of the reaction are a substituted aromatic compound, which is no longer a PCB aroclor, and an inorganic chloride salt.

KGME is the potassium derivative of 2-methoxyethanol (glyme) and is generated in situ by adding stoichiometric quantities of potassium hydroxide (KOH) and glyme. The KOH and glyme are added to the a reactor vessel, along with the contaminated waste (see figure below). The KGME is formed by slowly raising the temperature of the reaction mixture to about 110°C (230°F), although higher temperature can be beneficial.

The nucleophilic substitution reaction that takes place in the reactor vessel is summarized by the following generalized equation:

$$Ph_2Cl_n + mCH_3OCH_2CH_2OK \rightarrow Ph_2Cl_{n-m}(OCH_2CH_2OCH_3)_m + mKCl$$

where Ph_2Cl_n is a PCB (n = 1 to 10), $CH_3OCH_2CH_2OK$ is the KGME reagent, m is the number of substitutions (from 1 to 10), and $Ph_2Cl_{n-m}(OCH_2CH_2OCH_3)_m$ is the product of the treatment process. A similar mechanism is



DeChlor/KGME process diagram

involved in the KPEG (or APEG) technology, in which the nucleophile is the anion formed by the removal of one terminal hydrogen molecule from a molecule of PEG 440, that is, $H(OCH_2CH_2)_nO^-$.

The DeChlor/KGME technology is preferable to the older sodium (Na) dispersion treatment method because it is less expensive and because the KGME reagent is much more tolerant of water in the reaction mixture; the water can cause a fire or explosion in the presence of Na metal. One advantage of the DeChlor/KGME process over KPEG or APEG methods is that only about one-quarter the weight of KGME is required for dehalogenation as would be required if KPEG were used. Also, considerably less waste is produced, and no polymeric treatment residue, which is difficult to handle, is formed.

The reaction product mixture is a fairly viscous solution containing reaction products and the unreacted excess reagent. After this mixture has cooled to about 93°C (200°F), water is added to help quench the reaction, improve the handling of the mixture, extract the inorganic salts from the organic phase for disposal purposes, and help clean out the reaction vessel for the next batch of material to be treated. The two resulting phases, aqueous and organic, are separated, analyzed, and transferred to separate storage tanks, where they are held until disposal.

WASTE APPLICABILITY:

The DeChlor/KGME process is applicable to liquid-phase halogenated aromatic compounds, including PCBs, chlorobenzenes, polychlorinated dibenzodioxins (PCDD), and polychlorinated dibenzofurans (PCDF). Waste streams containing less than 1 ppm PCBs to 100 percent aroclors can be treated. Laboratory tests have shown destruction removal efficiencies greater than 99.98 percent for materials containing 220,000 ppm PCBs.

This process is also applicable to the liquid-phase treatment of halogenated aliphatic compounds and has been successfully used for the treatment of contaminated soils on the laboratory scale. Pilot-scale equipment for the treatment of solid materials using this process is in the development stage.

STATUS:

A SITE demonstration of this process at the Resolve Superfund site in Massachusetts is scheduled for 1992.

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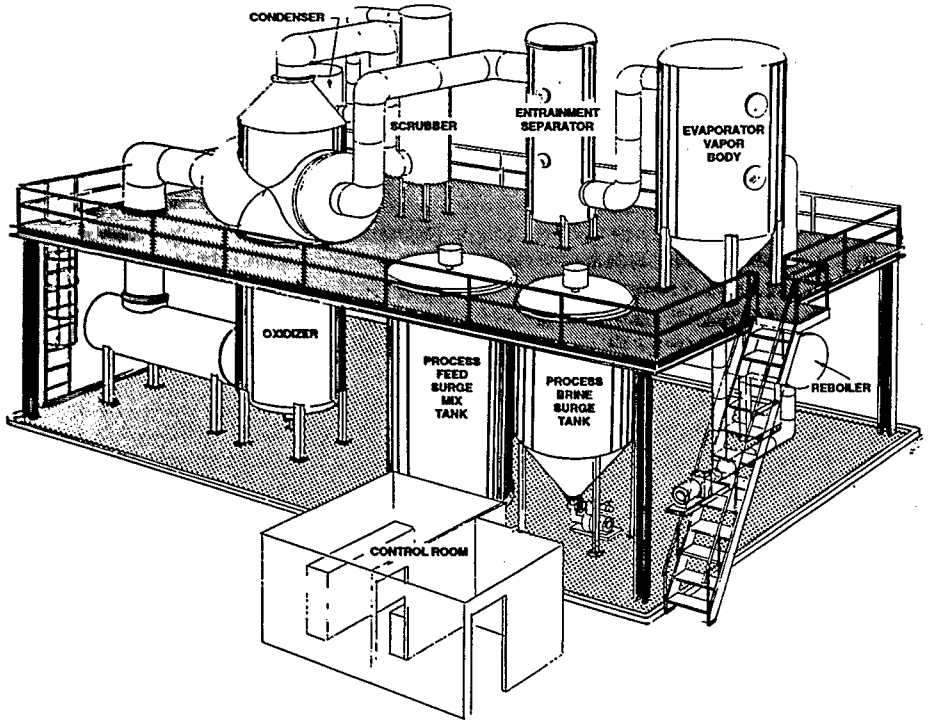
CHEMICAL WASTE MANAGEMENT, INC.
(PO*WW*ER Evaporation and Catalytic Oxidation of Wastewater)

TECHNOLOGY DESCRIPTION:

PO*WW*ER™ is a technology developed to treat wastewaters, such as leachates, groundwaters, and process waters, containing mixtures of salts, metals, and organic compounds. The proprietary technology is a combination of evaporation and catalytic oxidation processes. Wastewater is concentrated in an evaporator by boiling off most of the water and the volatile contaminants, both organic and inorganic. Air or oxygen is added to the vapor, and the mixture is forced through a catalyst bed, where the organic and inorganic compounds are oxidized. This stream, composed of mainly steam, passes through a scrubber, if necessary, to remove any acid gases formed during oxidation. The stream is then condensed or vented to the atmosphere. The resulting brine solution is either disposed of or treated further, depending on the nature of the waste. A schematic of a commercial PO*WW*ER™ is presented in figure below.

WASTE APPLICABILITY:

The PO*WW*ER™ technology can be used to treat complex wastewaters that contain volatile and nonvolatile organic compounds, salts, metals, and volatile inorganic compounds. Suitable wastes include leachates, contaminated groundwaters, and process waters. The system can be designed for any capacity, depending on the application and the volume of the wastewater. Typical commercial systems range from 10 to 1,000 gallons per minute (gpm).



Schematic of PO*WW*ER® technology

STATUS:

The PO*WW*ER™ technology is currently being tested on landfill leachates, process wastewaters, and other aqueous wastes at the developer's Lake Charles, Louisiana, facility. The pilot plant (capacity, 0.25 gpm) has been in operation since 1988; 20 pilot-scale demonstrations have been completed. A commercial system (50 gpm) is currently being built by Waste Management International, Inc., at its Hong Kong Chemical Waste Treatment Facility. The SITE program is determining which site to use for evaluating the technology.

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

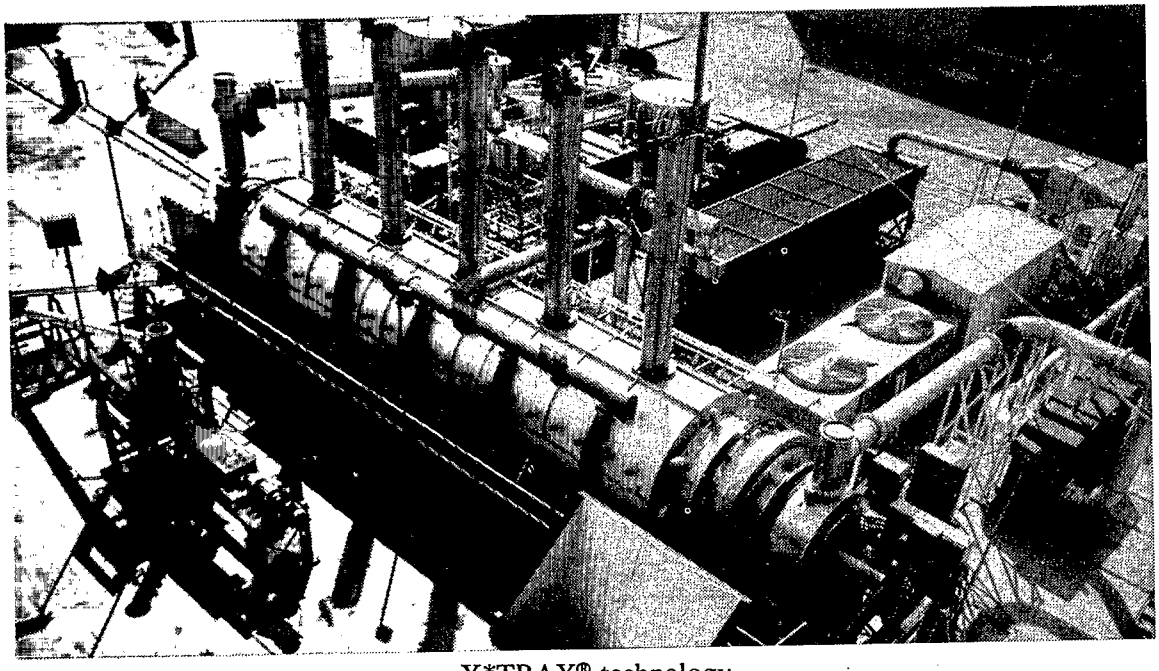
TECHNOLOGY DESCRIPTION:

The X*TRAX™ technology (see figure below) is a thermal desorption process designed to remove 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 British thermal unit (Btu) 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 degrees Fahrenheit) and gas flow rates, this process is less expensive than incineration.

An externally-fired rotary dryer is used to volatilize 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 are ready to be placed and compacted in their original location.

The organic contaminants and water vapor driven from the solids are transported out of the dryer by an inert nitrogen carrier gas. The carrier gas flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed and recovered from the gas. The gas first passes through a high-energy scrubber. Dust particles and 10 to 30 percent of the organic contaminants are removed by the scrubber. The gas then passes through two heat condensers in series, where it is cooled to less than 40 degrees Fahrenheit.

Most of the carrier gas passing through the gas treatment system is reheated and recycled to the dryer. Approximately 5 to 10 percent of the gas is cleaned by passing it through a particulate filter and a carbon adsorption system before it is discharged to the atmosphere. The volume of



X*TRAX® technology

gas released from this process vent is approximately 100 to 200 times less than an equivalent capacity incinerator. This discharge helps maintain a small negative pressure within the system and prevents potentially contaminated gases from leaking. The discharge also allows makeup nitrogen to be added to the system, preventing oxygen concentrations from exceeding combustibility limits.

WASTE APPLICABILITY:

The process can remove and collect volatiles, semivolatiles, and polychlorinated biphenyls (PCB), and 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 PCBs have been reduced to 2 to 25 ppm. Removal efficiencies from 96 to 99+ percent have been demonstrated for soils contaminated with various organic pesticides.

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 150 tons per day at a cost of $150 to $250 per ton.

STATUS:

Chemical Waste Management (CWM) currently has three X*TRAX systems available: laboratory-, pilot-, and full-scale. Two laboratory-scale systems are being used for treatability studies. One system is operated by Chem Nuclear systems, Inc., in Barnwell, South Carolina, for mixed (Resource Conservation and Recovery Act [RCRA]/Radioactive) wastes; the other is operated by CWM Research and Development at its facility in Geneva, Illinois, for RCRA and Toxic Substance Control Act (TSCA) wastes. More than 60 tests have been completed since January 1988. Both laboratory systems are available for performing treatability studies. A draft report is furnished within 12 weeks of sample receipt.

A pilot-scale system is in operation 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 (R&D) permit, which expired in January 1990. The system is currently operating under both an EPA Research Development and Demonstration and a California Department of Health and Safety R&D permit for RCRA materials. Pilot testing is planned through November 1992.

The first Model 200 full-scale X*TRAX system was completed in early 1990 and is shown in the figure on the previous page. The system will be used to remediate 35,000 tons of PCB-contaminated soil at the Resolve Superfund site in Massachusetts. Startup is scheduled for the first quarter of 1992. EPA plans to conduct a SITE demonstration during this remediation.

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COLORADO DEPARTMENT OF HEALTH
(Developed by COLORADO SCHOOL OF MINES)
(Wetlands-Based Treatment)

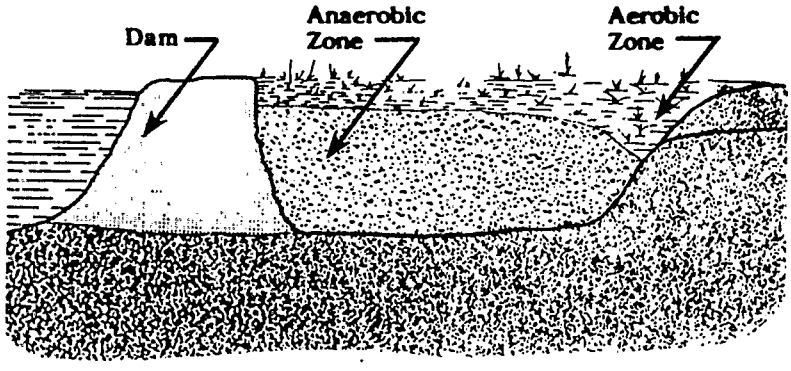
TECHNOLOGY DESCRIPTION:

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, which contain high metal concentrations and have a 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 come into contact with 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 in nature. Wetlands treatment has been applied with some success to wastewater in the eastern regions of the United States. The process may have to be adjusted to account for differences in



Typical wetland ecosystem

geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.

STATUS:

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

The final year of the project under the Emerging Technology Program was 1991. Results of a study of drainage from the Big Five Tunnel near Idaho Springs, Colorado, have shown that by optimizing design parameters, removal efficiency of heavy metals from the discharge can approach the removal efficiency of chemical precipitation treatment plants.

One of the final goals of this project will be the development of a manual that discusses design and operating criteria for construction of a full-scale wetland for treating acid mine discharges. This manual will be available in fall 1991.

The Demonstration Program will evaluate the effectiveness of a full-scale wetland. Construction of a full-scale wetland is the proposed remedial action for 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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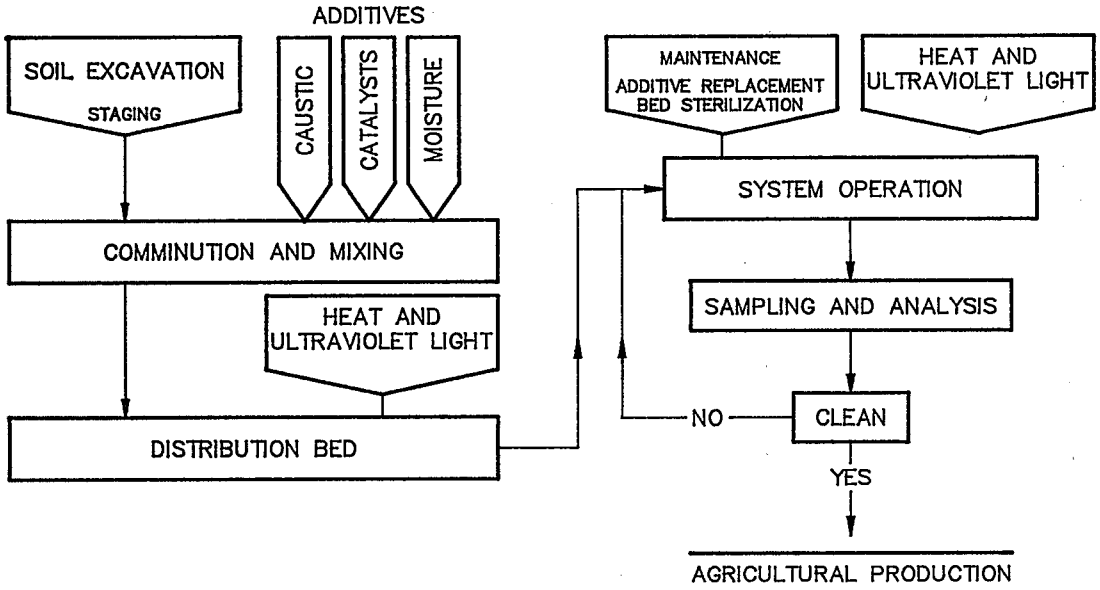
DAMES & MOORE
(Hydrolytic Terrestrial Dissipation)

TECHNOLOGY DESCRIPTION:

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

HTD involves excavating contaminated soils and comminuting (mixing and cutting) soils so that metal complexes and organic chemicals in the soil are uniformly distributed. During the mixing process, caustic addition raises 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. Iron, copper, or aluminum can be introduced to catalyze the hydrolysis.

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. Since lighter weight toxaphene compounds are reported to be volatile, volatility will enhance dissipation. Toxaphene's volatility will increase as heavier compounds are dehalogenating to lower molecular weights. Ultraviolet light is also known to cause toxaphene dechlorination, so toxaphene gases in the atmosphere will slowly degrade to still lower molecular weights while liberating chlorine. Since lighter compounds have fewer chlorines in their molecular structure, only minor amounts of chlorine gas are emitted to the atmosphere. In fact,



Hydrolytic terrestrial dissipation schematic

throughout the entire study, chlorine gas emission is estimated to be less than 0.25 grams per day over the study area.

Soils in the distribution bed are periodically sampled to evaluate any residual contamination. Also, monitoring of underlying groundwater assures maintenance of environmental quality during HTD system operation. After treated soils meet established criteria, the land may be returned to agricultural production or other beneficial use. Since toxaphene is chlorinated camphene, dehalogenation reduces the insecticide to a naturally occurring compound. The treatment capacity of one staging unit is approximately 5,000 to 6,000 tons per year.

HTD takes advantage of the metal-catalyzed alkaline hydrolysis reactions to liberate chlorine ions that form various metal salts, depending on the characteristics of the contaminated media. Camphene ($C_{10}H_{16}$) will ultimately be left to degrade to water and carbon oxides (CO_x). The figure on the previous page is a schematic of the process.

WASTE APPLICABILITY:

HTD has applications at sites where large quantities of soil are contaminated by small amounts of toxaphene or other pesticides. Depending on the pesticide, metal catalysts other than copper and iron could be effective. The process involves a hydrolysis reaction; however, flash points, vapor pressures, and other elements of physical chemistry can be used to enhance dissipation and should be considered when designing the remedial measure. 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 the Spring 1991. The SITE demonstration will be carried out at the Chemairspray facility after the completion of treatability studies. A simulation tank has been constructed to evaluate rates of hydrolysis under laboratory conditions. A quality control program has been instituted to validate laboratory results. A Quality Assurance Project Plan was prepared and is being reviewed by EPA.

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DEHYDRO-TECH CORPORATION

(Carver-Greenfield® Process for Extraction of Oily Waste)

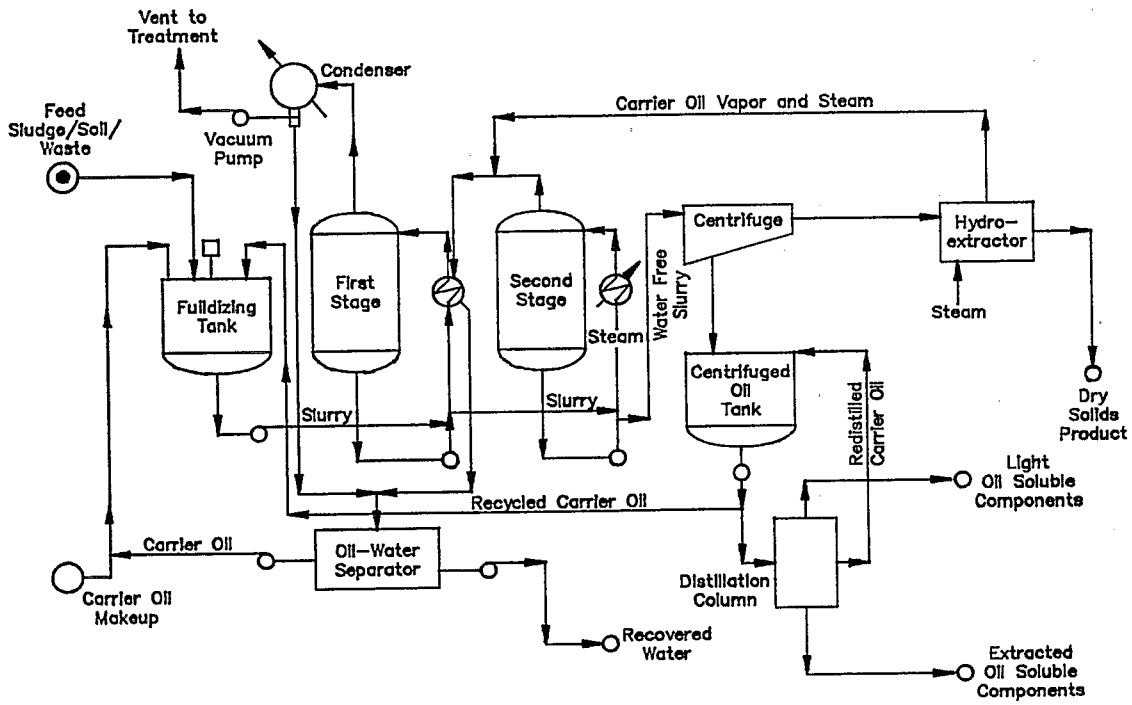
TECHNOLOGY DESCRIPTION:

The Carver-Greenfield Process® is designed to separate materials into their constituent solid, oil (including oil-soluble substances), and water phases. It is intended mainly for soils and sludges contaminated with oil-soluble hazardous compounds. The technology uses a food-grade carrier oil to extract the oil-soluble contaminants (see figure below). Pretreatment is necessary to achieve particle sizes of less than ¼ inch.

The carrier oil, with a boiling point of 400 degrees Fahrenheit, is typically mixed with waste sludge or soil, and the mixture is placed in an evaporation system to remove any water. The oil serves to fluidize the mix and maintain a low slurry viscosity to ensure efficient heat transfer, allowing virtually all of the water to evaporate.

Oil-soluble contaminants are extracted from the waste by the carrier oil. Volatile compounds present in the waste are also stripped in this step and condensed with the carrier oil or water. After the water is evaporated from the mixture, the resulting dried slurry is sent to a centrifuging section that removes most of the carrier oil and contaminants from the solids.

After centrifuging, residual carrier oil is removed from the solids by a process known as "hydroextraction." The carrier oil is recovered by evaporation and steam stripping. The



Carver-Greenfield® process schematic

hazardous constituents are removed from the carrier oil by distillation. This stream can be incinerated or reclaimed. In some cases, heavy metals in the solids will be complexed with hydrocarbons and will also be extracted by the carrier oil.

WASTE APPLICABILITY:

The Carver-Greenfield Process® can be used to treat sludges, soils, and other water-bearing wastes containing oil-soluble hazardous compounds, including polychlorinated biphenyls (PCB), polycyclic 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 demonstration of this technology was completed in August 1991, at EPA's Edison, New Jersey, research facility. Petroleum wastes (drilling muds) from the PAB oil site in Abbeville, Louisiana, were used for the demonstration.

Preliminary results indicate a successful separation of oily drilling muds into their constituent oil, water, and solid phases. Laboratory analysis on process residuals will be conducted during the late summer and fall 1991.

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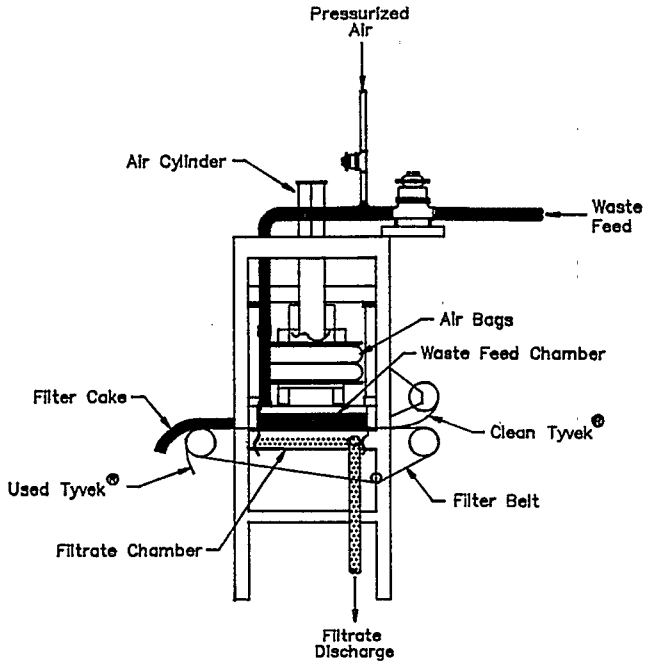
E.I. DUPONT DE NEMOURS AND COMPANY, and OBERLIN FILTER COMPANY
(Membrane Microfiltration)

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 (Oberlin)], combined with a special Tyvek filter material (Tyvek T-980) made of spunbonded olefin [invented by E.I. DuPont De Nemours and Company (DuPont)]. The filter material is a thin, durable plastic fabric with tiny openings (about 1 ten-millionth of a meter in diameter) that allow 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



DuPont/Oberlin microfiltration system

square inch, and used to remove any liquid remaining in the upper chamber and to further dry the cake. When the cake is considered to be dry, the upper chamber is lifted, and the filter cake is automatically discharged. Clean filter material is then drawn from a roll into the system for the next cycle. Both the filter cake and the filtrate can be collected and treated further 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. 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. Pilot studies on the groundwater indicated that the microfiltration system could produce a 35 to 45 percent-solids filter cake, and a filtrate with nondetectable levels of heavy metals.

The demonstration was conducted over a 4-week period in April and May 1990. A Demonstration Bulletin summarizing the results at the demonstration was prepared in August 1990. A Technology Evaluation Report, an Applications Analysis Report, and a video of the demonstration have also been completed.

DEMONSTRATION RESULTS:

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

- Zinc and total suspended solids removal efficiencies ranged from 99.75 to 99.99 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 EP toxicity and toxicity characteristic leaching procedure (TCLP) tests for metals.

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DYNAPHORE, INC./H_2O COMPANY
(FORAGER™ Sponge)

TECHNOLOGY DESCRIPTION:

The FORAGER™ sponge is an open-celled cellulose sponge incorporating an amine-containing polymer that has a selective affinity for heavy metals in cationic and anionic states in aqueous solution. 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 order of affinity of the polymer for metals is influenced by solution parameters such as pH, temperature, and total ionic content. The following affinity sequence for several representative ions can generally be expected:

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

The removal efficiency for transition-group heavy metals is about 90 percent at a flow rate of one bed volume per minute. The

FORAGER® sponge treating water

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. In column operations, flow rates of 3 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 by techniques typically employed for regeneration of ion exchange resins and activated carbons. Following elution, the sponge is ready for 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.

The sponge can also remove trace amounts of aliphatic organic chlorides and bromides from water.

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 from three locations in Colorado.

The FORAGER® sponge will be demonstrated as part of H_2O Company's E-Process. Site selection for the demonstration is underway.

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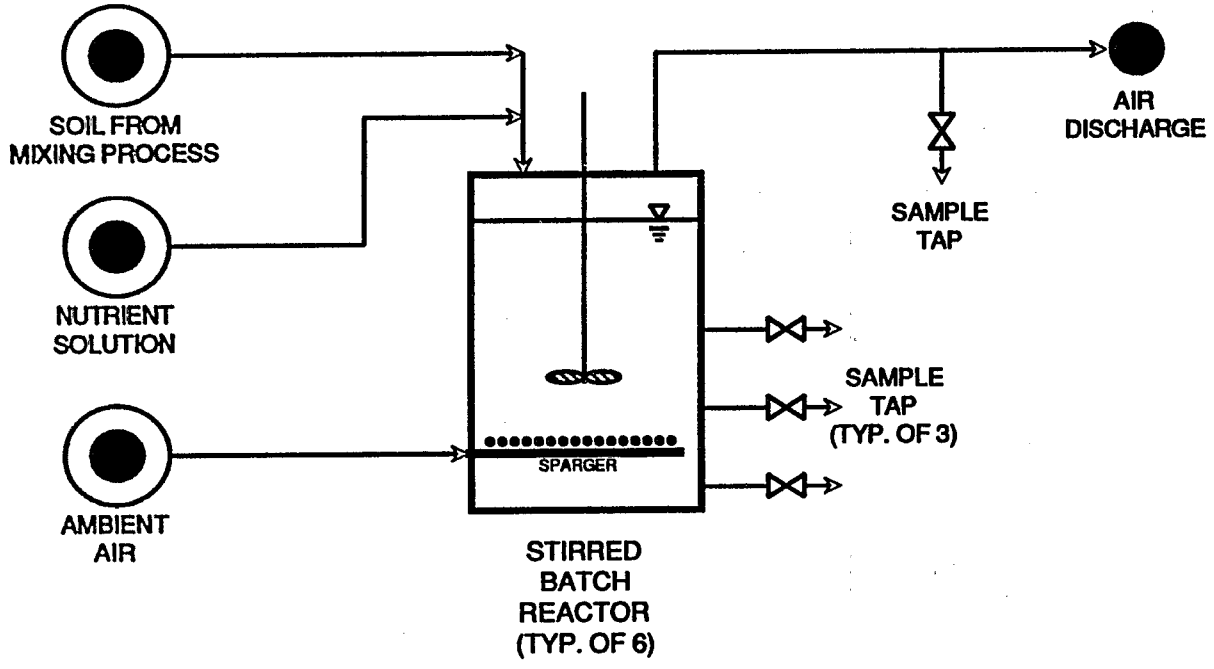
ECOVA CORPORATION
(Bioslurry Reactor)

TECHNOLOGY DESCRIPTION:

ECOVA Corporation's slurry-phase bioremediation (bioslurry) technology is designed to biodegrade creosote contaminated materials by employing aerobic bacteria that use the contaminants as their carbon source. The technology uses batch and continuous flow bioreactors to process polycyclic aromatic hydrocarbon (PAH) contaminated soils, sediments, and sludges. 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 biomass, relatively harmless byproducts of microbial metabolism, such as carbon dioxide, methane, and inorganic salts. A process flow diagram is shown in the figure below.

ECOVA Corporation conducted bench- and pilot-scale process development studies using a slurry phase biotreatment design to evaluate bioremediation of PAHs in creosote contaminated soil collected from the Burlington Northern Superfund site in Brainerd, Minnesota. Bench-scale studies are performed prior to pilot-scale evaluations in order to collect data to determine the optimal treatment protocols. Data obtained from the optimized pilot-scale program will be used to establish treatment standards for K001 wastes as part of the EPA's Best Demonstrated Available Technology (BDAT) program.

Slurry-phase biological treatment was shown to significantly improve biodegradation rates of 4- to 6-ring PAHs. The bioreactors are supplemented with oxygen, nutrients, and a



Process flow diagram

specific inocula of microorganisms to enhance the degradation process. Biological reaction rates are accelerated in a slurry system because of the increased contact efficiency between contaminants and microorganisms. Results from the pilot-scale bioreactor evaluation showed an initial reduction of 89.3 percent of the total soil-bound PAHs in the first two weeks. An overall reduction of 93.4 percent was seen over a 12–week treatment period.

WASTE APPLICABILITY:

Slurry-phase biological treatments can be applied in the treatment of highly contaminated creosote wastes. It can also be used to 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, with ranges conducive to the desired microbial activity.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1991. From May through September 1991, EPA conducted a SITE demonstration using six bioslurry reactors at EPA's Test and Evaluation Facility in Cincinnati, Ohio. The reactors processed creosote-contaminated soil taken from the Burlington Northern Superfund site in Brainerd, Minnesota.

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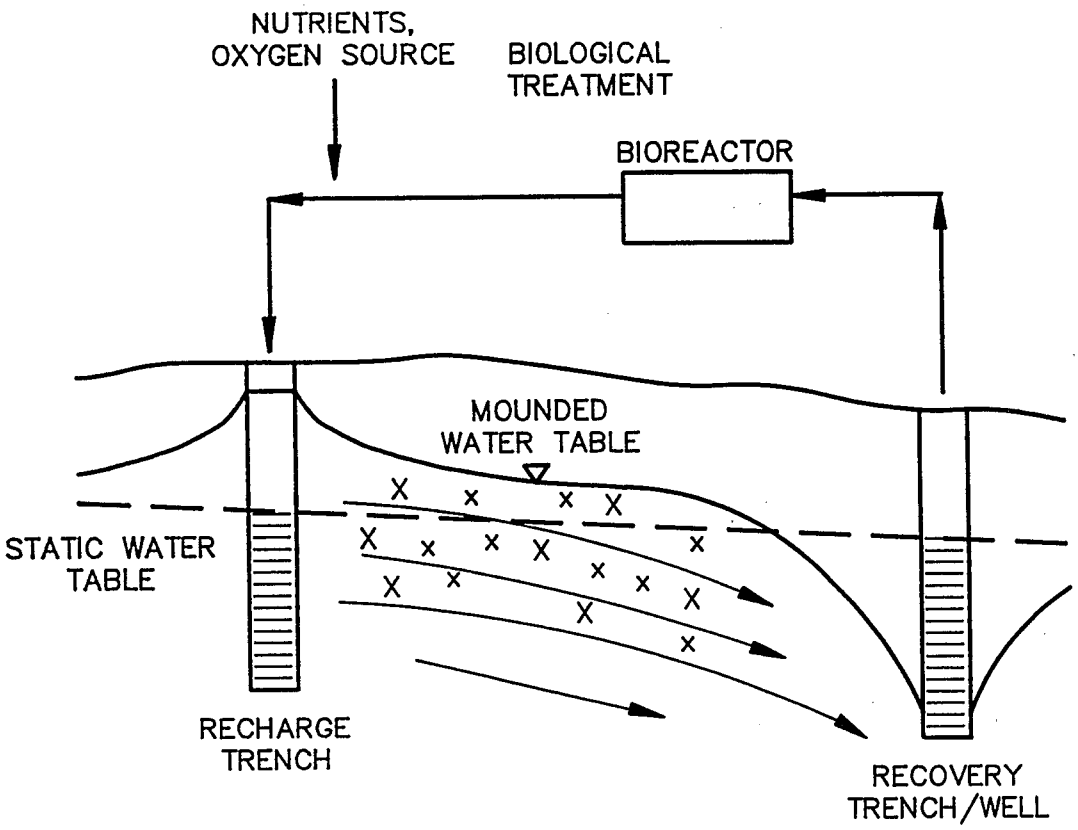
ECOVA CORPORATION
(In Situ Biological Treatment)

TECHNOLOGY DESCRIPTION:

Ecova Corporation's bioremediation technology (see figure below) is designed to biodegrade chlorinated and nonchlorinated organic contaminants by employing aerobic bacteria that use the contaminants as their carbon source. This proposed technology has two configurations: in situ biotreatment of soil and water and on-site bioreactor treatment of contaminated groundwater.

An advantage of in situ bioremediation is that contaminants in subsurface soils and ground water can be treated without excavating overlying soil. The technology uses special strains of cultured bacteria and naturally occurring microorganisms in on-site soils and groundwater. Since the treatment process is aerobic, oxygen and soluble forms of mineral nutrients must be introduced throughout the saturated zone. The end products of the aerobic biodegradation are carbon dioxide, water, and bacterial biomass. Contaminated groundwater can also be recovered and treated in an aboveground bioreactor. Nutrients and oxygen can then be added to some or all of the treated water, and the water can be recycled through the soils as part of the in situ soil treatment.

Because site-specific environments influence biological treatment, all chemical, physical, and



Schematic of the in situ biological treatment

microbiological factors are designed into the treatment system. Subsurface soil and groundwater samples collected from a site are analyzed for baseline parameters, such as volatile organics, metals, pH, total organic carbon, types and quantities of microorganisms, and nutrients. A treatability study, which includes flask and column studies, determines the effects of process parameters on system performance. The flask studies test biodegradation under optimum conditions, and the column studies test the three field applications: (1) soil flushing, (2) in situ biotreatment, and (3) in situ biotreatment using groundwater treated in a bioreactor.

WASTE APPLICABILITY:

Biological processes can be applied to water, soil, sludge, sediment, and other types of materials contaminated with organic constituents. The system must be engineered to maintain parameters such as pH, temperature, and dissolved oxygen (if the process is aerobic), within ranges conducive to the desired microbial activity. The technology can be applied to chlorinated solvents and nonchlorinated organic compounds.

STATUS:

Ecova Corporation's planned demonstration of this technology on a wide range of toxic organic compounds at the Goose Farm Superfund site in Plumstead Township, New Jersey, was canceled after the completion of treatability studies in April 1990.

Although the demonstration was canceled at the Goose Farm Superfund site, the technology may be demonstrated at another hazardous waste site in the future.

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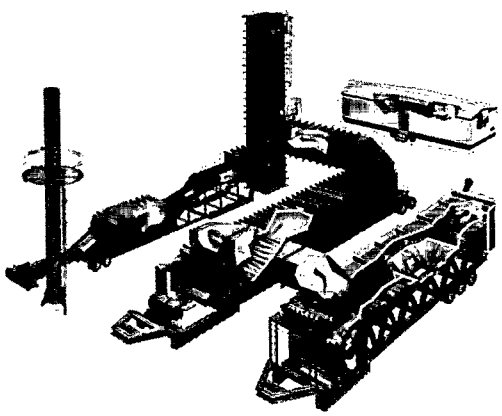
ECOVA CORPORATION
(Developed by SHIRCO INFRARED SYSTEMS, INC.)
(Infrared Thermal Destruction)

TECHNOLOGY DESCRIPTION:

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

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



Mobile thermal processing system

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 biphenyl (PCB) content.

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

STATUS:

EPA conducted two evaluations of the infrared system. An evaluation of a full-scale unit was conducted during August 1987, at the Peak Oil site in Tampa, 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.

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 testing 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.

APPLICATIONS ANALYSIS SUMMARY:

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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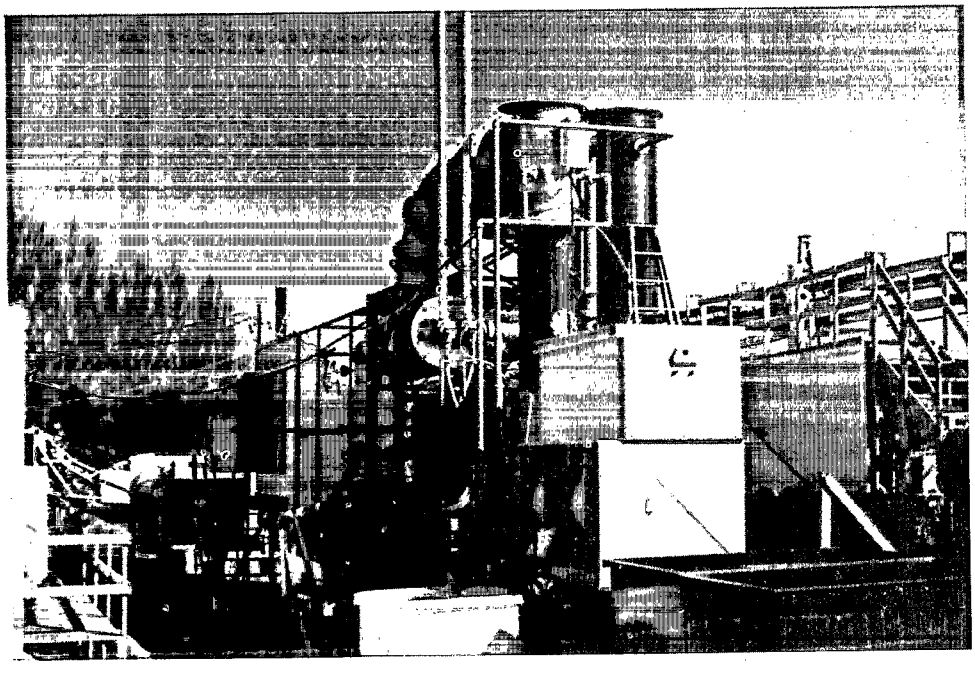
ELI ECO LOGIC INTERNATIONAL, INC.
(Thermal Gas Phase Reduction Process)

TECHNOLOGY DESCRIPTION:

This patented process (see photograph below) is based on the gas-phase, thermo-chemical reaction of hydrogen with organic and chlorinated organic compounds at elevated temperatures. At 850 degrees Celsius (°C) or higher, hydrogen reacts with organic compounds in a process known as reduction to produce smaller, lighter hydrocarbons. This reaction is enhanced by the presence of water, which can also act as a reducing agent. Because hydrogen is used to produce a reducing atmosphere devoid of free oxygen, the possibility of dioxin or furan formation is eliminated.

The thermo-chemical reaction takes place within a specially designed reactor. In the process, a mixture of preheated waste and hydrogen is injected through nozzles mounted tangentially near the top of the reactor. The mixture swirls around a central ceramic tube past glo-bar heaters. By the time the mixture passes through the ports at the bottom of the ceramic tube, it has been heated to 850°C. Particulate matter up to 5 millimeters in diameter not entrained in the gas stream will impact the hot refractory walls of the reactor. Organic matter associated with the particulate is volatilized, and the particulate exits out of the reactor bottom to a quench tank, while finer particulate entrained in the gas stream flows up the ceramic tube into an exit elbow and through a retention zone. The reduction reaction takes place from the bottom of the ceramic tube onwards, and takes less than one second to complete. Gases enter a scrubber where hydrogen chloride fine particulates are removed. The gases that exit the scrubber consist only of excess hydrogen, methane, and a small amount of water vapor. Approximately



Thermal gas phase reduction process

95 percent of this gas is recirculated back into the reactor. The remaining 5 percent is fed to a boiler where it is used as supplementary fuel to preheat the waste.

Because this process is not incineration, the reactor does not require a large volume for the addition of combustion air. The small reactor size and the capability to recirculate gases from the reaction make the process equipment small enough to be mobile.

In addition, the process includes a sophisticated on-line mass spectrometer unit as a part of the control system. As the unit is capable of measuring many organic chemicals on a continuous basis, increases in chlorobenzene or benzene concentrations (signalling a decrease in destruction efficiency) halt the input of waste and alert the operator.

WASTE APPLICABILITY:

The technology is suitable for many types of waste including polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), chlorophenols, pesticides, landfill leachates, and lagoon bottoms. The system can handle most types of waste media, including soils, sludges, liquids, and gases. Even those wastes with a high water content are easily handled by the technology. The maximum concentration level is 30 percent sediments and 10 percent chlorine.

In the case of chlorinated organic compounds, such as PCBs, the products of the reaction include chloride, hydrogen, methane, and ethylene. Other non-chlorinated hazardous contaminants, such as PAHs, are also reduced to smaller, lighter hydrocarbons, primarily methane and ethylene.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. A demonstration-scale reactor, two meters in diameter and three meters tall, capable of handling 7 tons per day, has been used for processing PAH- and PCB-contaminated harbor sediments in Hamilton, Ontario. Bench-scale testing with trichlorobenzene has shown that the reduction reaction can achieve 99.9999 percent destruction efficiency or better. A possible location for holding the SITE demonstration has been identified.

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EMTECH ENVIRONMENTAL SERVICES, INC.
(formerly HAZCON)
(Chemical Treatment and Immobilization)

TECHNOLOGY DESCRIPTION:

This treatment system is capable of chemically destroying certain chlorinated organics and immobilizing heavy metals. The technology mixes hazardous wastes, cement or flyash, water, and one of 18 patented reagents commonly known as "Chloranan." In the case of chlorinated organics, the process uses metal-scavenging techniques to remove chlorine atoms and replace them with hydrogen atoms. Metals are fixed at their lowest solubility point.

Soils, sludges, and sediments can be treated in situ or excavated and treated ex situ. Sediments can also be treated underwater. Blending is accomplished in batches, with volumetric throughput rated at 120 tons per hour.

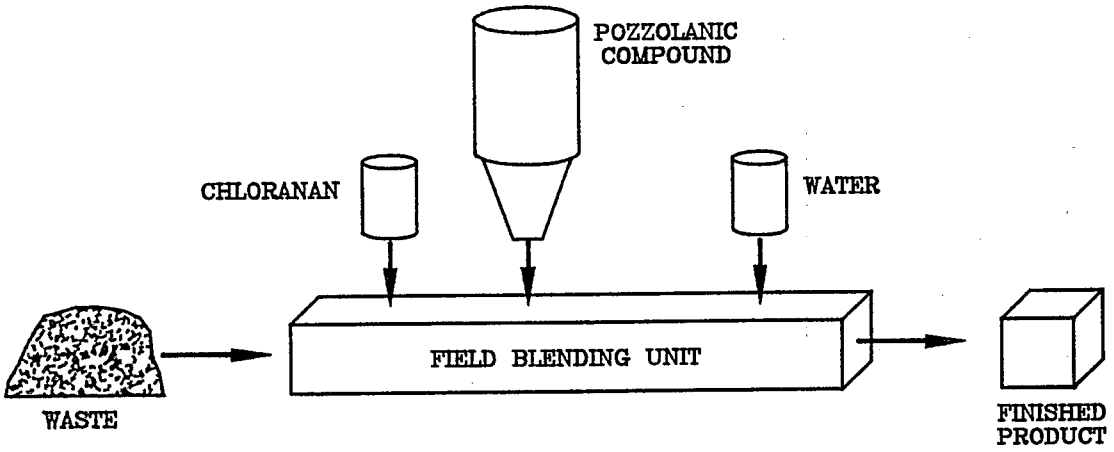
The treatment process (see figure below) begins by adding Chloranan and water to the blending unit, followed by the waste and mixing for 2 minutes. The cement is added and mixed for a similar time. After 12 hours, the treated material hardens into a concrete-like mass that exhibits unconfined compressive strengths (UCS) in the 1,000 to 3,000 pounds per square inch (psi) range, with permeabilities in the 10^{-9} centimeters per second range. Results may vary see "Demonstration Results" section. It is capable of withstanding several hundred cycles of freeze and thaw weathering.

WASTE APPLICABILITY:

This technology has been refined since the 1987 SITE demonstration and is now capable of destroying certain chlorinated organics and also immobilizing other wastes, including very high levels of metals. The organics and inorganics can be treated separately or together with no impact on the chemistry of the process.

STATUS:

This technology was demonstrated in October 1987 at a former oil processing plant in Douglassville, Pennsylvania. The site soil contained high levels of oil and grease (250,000 parts per million [ppm]) and heavy metals (22,000 ppm lead), and low levels of volatile organic compounds (VOC)(100 ppm) and



Schematic diagram of the chemical treatment/immobilization

polychlorinated biphenyls (PCB)(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.

Since the demonstration in 1987, the technology has been greatly enhanced through the development of 17 more reagent formulations that expand dechlorination of many chlorinated organics to include PCBs, ethylene dichloride (EDC), trichlorethylene (TCE), and others.

Remediation of heavily contaminated oily soils and sludges has been accomplished, as well as remediation of a California Superfund site with up to 220,000 ppm of zinc. The Canadian Government selected this process as one to test for underwater treatment of PCBs and VOCs found in sediments.

DEMONSTRATION RESULTS:

Comparisons of the 7-day, 28-day, 9-month, and 22-month sample test results for the soil are generally favorable. The physical test results were very good, with UCS between 220 and 1,570 psi. Very low permeabilities 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 less additives reduces strength, but toxicity reduction is not affected. There appears to be an inverse relationship between physical strength and organic contaminant concentration.

The results of the leaching tests were mixed. The toxicity characteristics leaching procedure (TCLP) results of the stabilized wastes were very low; essentially, all concentrations of metals, VOCs, and semivolatile organics were below 1 ppm. Lead leachate concentrations dropped by a factor of 200 to below 100 parts per billion. Volatile and semivolatile organic concentrations, however, did not change from the untreated soil TCLP. Oil and grease concentrations were greater in the treated waste TCLPs (4 ppm) than in the untreated waste (less than 2 ppm).

APPLICATIONS ANALYSIS SUMMARY:

The process can treat contaminated material with high concentrations (up to 25 percent) of oil. However, during the SITE demonstration, volatiles and base and neutral extractables were not immobilized significantly.

Heavy metals were immobilized. In many instances, leachate reductions were greater by a factor of 100.

The physical properties of the treated waste include high unconfined compressive strengths, low permeabilities, and good weathering properties.

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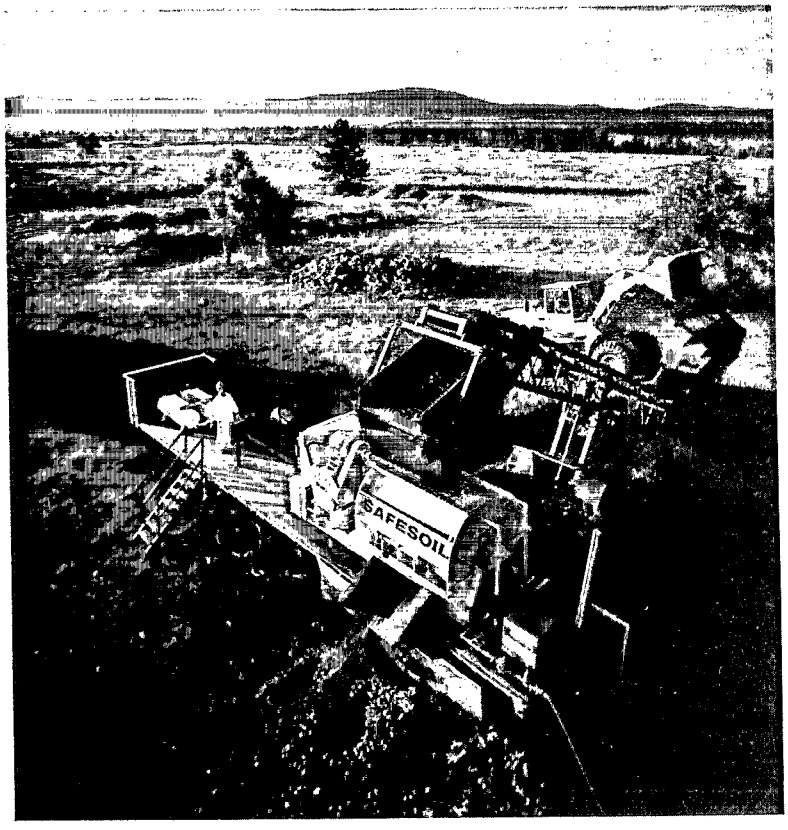
ENSITE, INC.
(SafeSoil™ Biotreatment Process)

TECHNOLOGY DESCRIPTION:

The SafeSoil™ Biotreatment System (see photograph below) is a bioremediation technology that involves excavation and powerscreening of contaminated soil. The screened soil is then transported to a paddle shaft mixer, where it is mixed with a combination of nutrients and surfactants. The mixed soil is then placed in "curing" piles on site for the "curing" portion of the treatment process, during which time biodegradation by naturally occuring microorganisms, utilizing biochemical pathways mediated by enzymes, will occur. All nutrients that are required are supplied during initial processing. The unique air entrainment feature of the treatment system provides an initial supply of oxygen and provides for passive air diffusion, by the generation of a honeycomb-like matrix.

The process relies solely on the indigenous microorganisms of the soil to mediate biological degradation of organic compounds and does not use laboratory adapted or genetically engineered microorganisms (GEMs). The additive contains inorganic nutrients, organic supplements (as simple sugars and protein), and naturally occurring surfactants. The surfactants emulsify volatile organics and solubilize hydrophobic contaminants, thereby facilitating microbial attack of the contaminants.



SafeSoil™ Biotreatment System

As with all bioremediation technologies, the end products of the treatment process are carbon dioxide (CO_2) and microbial biomass (additional microbial cells). For chlorinated organic compounds, the chlorine moieties are stoichiometrically converted to inorganic chloride anions. While several intermediates are formed during biodegradation, the end result is mineralization of all the resident organic compounds.

WASTE APPLICABILITY:

This technology has shown to be effective on organic contaminants. Specific contaminants that have been successfully treated using the SafeSoil technology include (1) petroleum hydrocarbons derived from gasoline, kerosene, jet fuel, diesel fuel, motor oil, and crude oil; (2) trichloroethylene (TCE); (3) monoaromatic compounds (benzene, toluene, ethylbenzene, and xylene) derived from both gasoline and commercial solvents; (4) aliphatic solvents (methyl isobutyl ketone); and (5) polycyclic aromatic hydrocarbons (PAH) derived from creosote. In all cases, soil contaminated with the above constituents was the treated media.

STATUS:

At the field-scale level, this technology was effective for the remediation of soil contaminated with (1) petroleum hydrocarbon compounds derived from gasoline, diesel, jet fuel, kerosene, motor oil, and quenching oil; (2) monoaromatics derived from solvents; and (3) TCE. At the laboratory-scale level, SafeSoil effectively remediated soil contaminated with creosote-derived PAHs and crude oil. ENSITE Inc., plans to field test the effectiveness of the process on these compounds during 1991. It has been used at eight sites, successfully treating over 60,000 cubic yards of contaminated soil.

The technology was accepted into the SITE Demonstration Program in June 1991.

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EPOC WATER, INC.

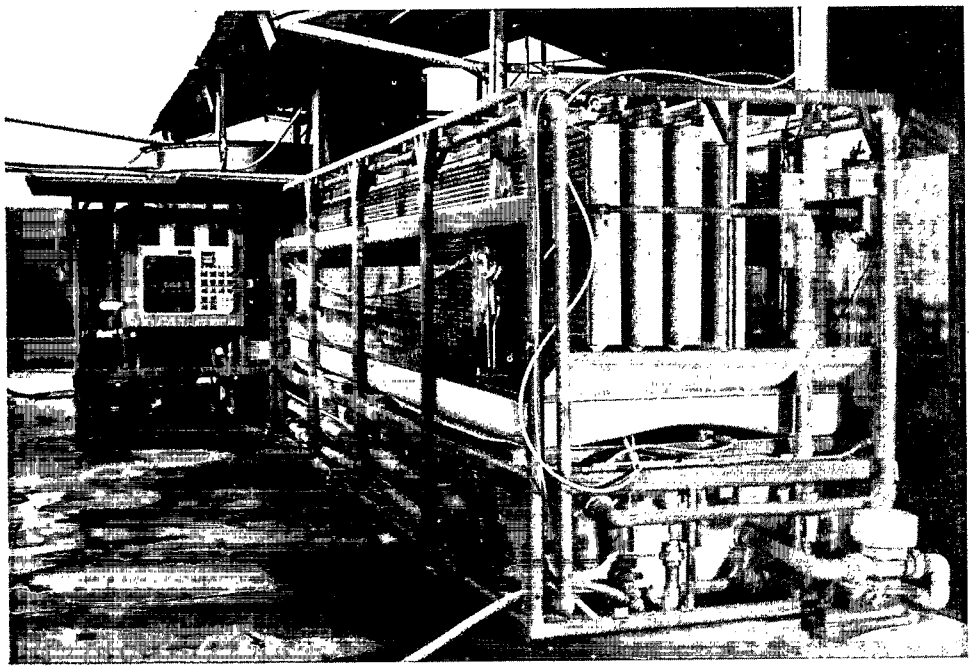
(Precipitation, Microfiltration, and Sludge Dewatering)

TECHNOLOGY DESCRIPTION:

In the first step of this process, heavy metals are chemically precipitated. The precipitates along with all particles down to 0.2 to 0.1 micron, are filtered through a unique fabric crossflow microfilter (EXXFLOW). The concentrate stream is then dewatered in an automatic tubular filter press of the same fabric material (EXXPRESS).

EXXFLOW microfilter modules are fabricated from a proprietary woven polyester array of tubes. Wastes are pumped into the tubes from a dynamic membrane, which produces a high quality filtrate removing all particle sizes greater than 0.2 – 0.1 micron. The membrane is continually cleaned by the flow velocity, thereby minimizing production declines and cleaning frequencies.

Metals are removed via precipitation by adjusting the pH in the EXXFLOW feed tank. The metal hydroxides or oxides form the dynamic membrane with any other suspended solids. The concentrate stream will contain up to 5 percent solids for discharge to the EXXPRESS system. The EXXFLOW concentrate stream enters the EXXPRESS modules with the discharge valve closed. A semi-dry cake, up to 1/4 inch thick, is formed on the inside of the tubular cloth. When the discharge valve is opened, rollers on the outside of the tube move to form a venturi within the



EXXFLOW/EXXPRESS demonstration unit

tube. The venturi creates an area of high velocity within the tubes, which aggressively cleans the cloth and discharges the cake in chip form onto a wedge wire screen. The discharge water is recycled back to the feed tank. The EXXPRESS filter cakes are typically 40 to 60 percent solids by weight.

Other constituent removals are possible 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 seeded, powdered activated carbon or powdered ion exchange adsorbents.

In cases where the solids in the raw feed are extremely high, EXXPRESS can be used first, with EXXFLOW acting as a final polish for the product water.

The EXXFLOW/EXPRESS demonstration unit (see photograph on previous page) is transportable and is skid-mounted. The unit is designed to process approximately 30 pounds of solids per hour and 10 gallons per minute of wastewater.

WASTE APPLICABILITY:

This technology is applicable to water containing heavy metals, pesticides, oil and grease, bacteria, suspended solids, and constituents that can be precipitated into particle sizes greater than 0.1 micron. The system can handle waste streams containing up to 5 percent solids and produce a semi-dry cake of 40 to 60 percent weight per 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 sludges from municipal, industrial, and power plant clarifiers can also be treated by using this process.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. Bench-scale tests were conducted in 1990. The first EPA application will be on acid mine drainage at the Iron Mountain Mine Superfund site in Redding, California, in late 1991.

Since 1988, this technology has been applied to over 35 sites worldwide. System capacities range from 1 gallon per minute to over 2 million gallons per day. Applications include (1) industrial laundries, (2) circuit board shops, (3) ceramics, (4) agricultural chemicals, (5) oil produced water, (6) oil field waste, (7) scrubber waste, (8) municipal waste, (9) water purification, (10) water softening, (11) clarifier sludge dewatering, and (12) wine and juice filtration.

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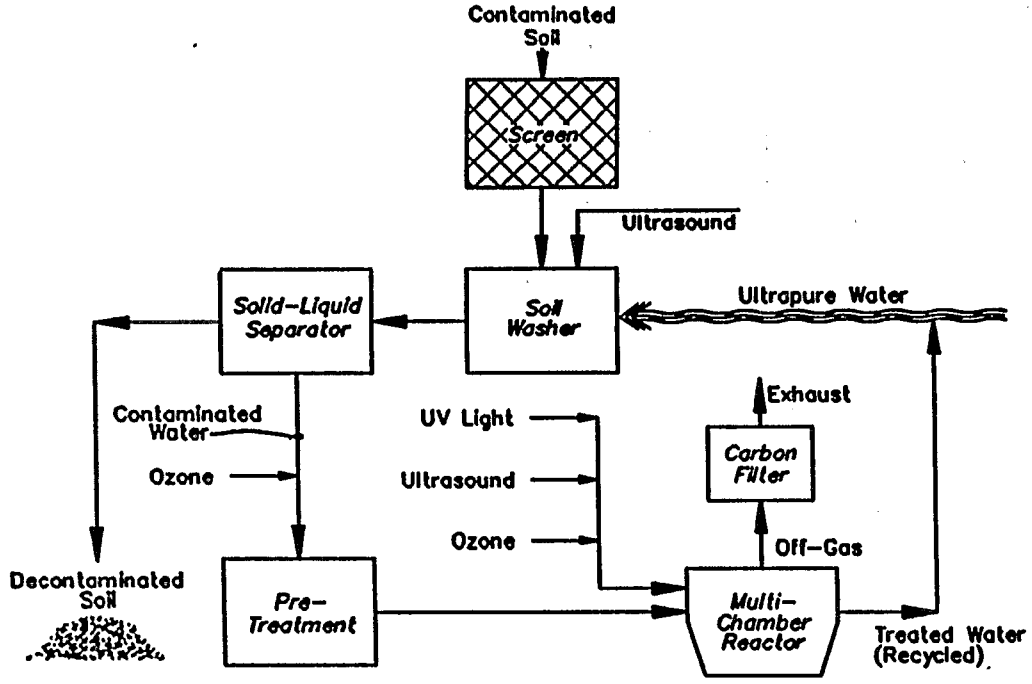
EXCALIBUR ENTERPRISES, INC.
(Soil Washing/Catalytic Ozone Oxidation)

TECHNOLOGY DESCRIPTION:

The Excalibur technology is designed to treat soils with organic and inorganic contaminants. The technology is a two-stage process: the first stage extracts the contaminants from the soil, and the second stage oxidizes contaminants present in the extract. The extraction is carried out using ultrapure water and ultrasound. Oxidation involves the use of ozone, and ultraviolet light. The treatment products of this technology are decontaminated soil and inert salts.

A flow schematic of the system is shown in the figure below. After excavation, contaminated soil is passed through a 1-inch screen. Soil particles retained on the screen are crushed using a hammermill and sent back to the screen. Soil particles passing through the screen are sent to a soil washer, where ultrapure water extracts the contaminants from the screened soil. Ultrasound acts as a catalyst to enhance soil washing. Typically, 10 volumes of water are added per volume of soil, generating a slurry of about 10–20 percent solids by weight. This slurry is conveyed to a solid/liquid separator, such as a centrifuge or cyclone, to separate the decontaminated soil from the contaminated water. The decontaminated soil can be returned to its original location or disposed of appropriately.

After the solid/liquid separation, any oil present in the contaminated water is recovered using an oil/water separator. The contaminated water is ozonated prior to oil/water separation to aid in oil recovery. The water then flows through a filter to remove any fine particles. After the particles are filtered, the water flows through a carbon filter and a deionizer to reduce the contaminant load on the multichamber reactor.



Excalibur treatment system flow diagram

In the multichamber reactor, ozone gas, ultraviolet light, and ultrasound are applied to the contaminated water. Ultraviolet light and ultrasound catalyze the oxidation of contaminants by ozone. The treated water (ultrapure water) flows out of the reactor to a storage tank and is reused to wash another batch of soil. If makeup water is required, additional ultrapure water is generated on-site by treating tap water with ozone and ultrasound.

The treatment system is also equipped with a carbon filter to treat the off-gas from the reactor. The carbon filters are biologically activated to regenerate the spent carbon in situ.

System capacities range from one cubic foot of solids per hour, (water flow rate of one gallon per minute), to 27 cubic yards of solids per hour, (with a water flow rate of 50 gallons per minute). The treatment units available for the SITE demonstration can treat 1 to 5 cubic yards of solids per hour.

WASTE APPLICABILITY:

This technology can be applied to soils, solids, sludges, leachates, and groundwater containing organics such as polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), pesticides and herbicides, dioxins, and inorganics, including cyanides. The technology could effectively treat total contaminant concentrations ranging from 1 part per million (ppm) to 20,000 ppm. Soils and solids greater than 1 inch in diameter need to be crushed prior to treatment.

STATUS:

The Excalibur technology was accepted into the SITE Demonstration Program in July 1989. The Coleman-Evans site in Jacksonville, Florida, has been tentatively scheduled for a SITE demonstration. This project is currently on hold.

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EXXON CHEMICAL COMPANY & RIO LINDA CHEMICAL COMPANY

(Chemical Oxidation and Cyanide Destruction)

TECHNOLOGY DESCRIPTION:

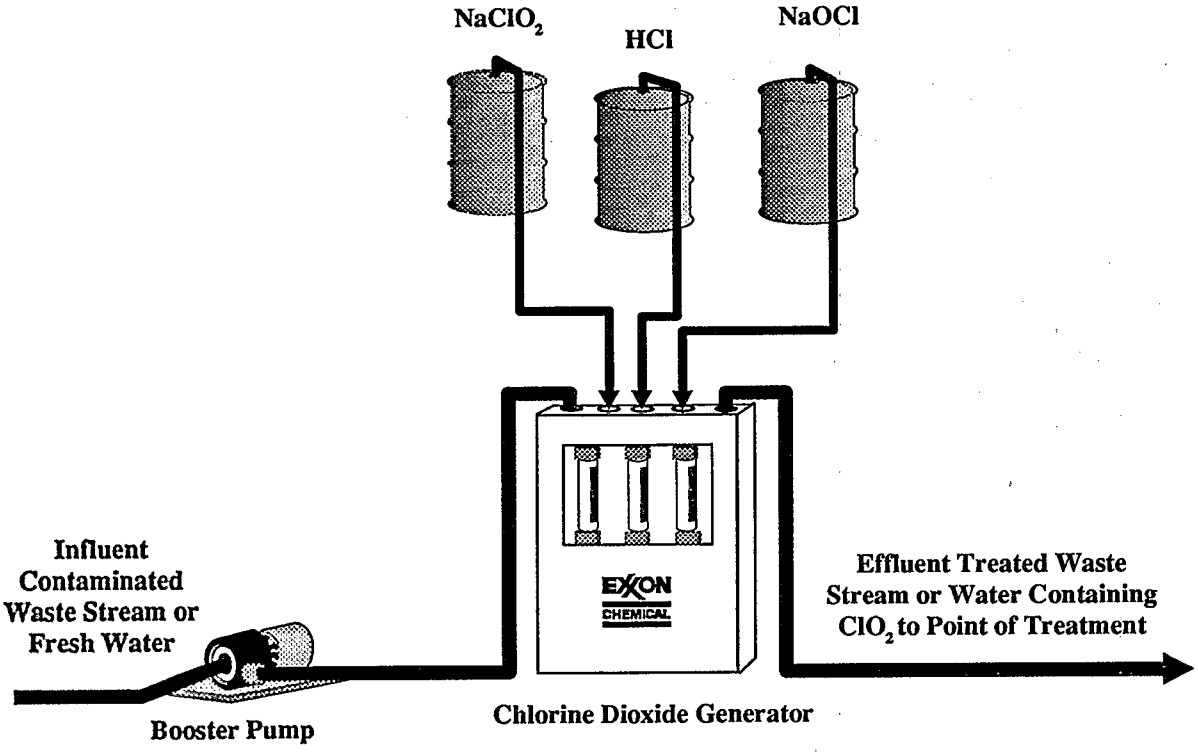
This technology uses chlorine dioxide, generated on site by a patented process, to oxidize organically contaminated aqueous waste streams and simple and complex cyanide in water or solid media. Chlorine dioxide is an ideal oxidizing agent, because it chemically alters contaminants to salts and nontoxic organic acids.

Chlorine dioxide gas is generated by reacting sodium chlorite solution with chlorine gas, or by reacting sodium chlorite solution with sodium hypochlorite and hydrochloric acid. Both processes produce at least 95 percent pure chlorine dioxide.

In aqueous treatment systems (see figure below), the chlorine dioxide gas is fed into the waste stream through a venturi, which is the driving force for the generation system. The amount of chlorine dioxide required depends on the contaminant concentrations in the waste stream and the concentration of oxidizable compounds, such as sulfides.

In soil treatment applications, the chlorine dioxide may be applied in situ through conventional injection wells or surface flushing. The concentration of chlorine dioxide would depend on the level of contaminants in the soil.

Chlorine dioxide treatment systems have been applied to (1) drinking water disinfection,



Typical treatment layout

(2) food processing sanitation, and (3) waste remediation. Chlorine dioxide has also been used as a biocide in industrial process water. Since chlorine dioxide reacts by direct oxidation rather than substitution (as does chlorine), the process does not form undesirable trihalomethanes.

WASTE APPLICABILITY:

This technology may be applied to aqueous waste streams, liquid storage vessels, soils, contaminated groundwater, or any leachable solid media contaminated by a wide range of waste materials. Cyanides, sulfides, organosulfur compounds, phenols, aniline, and secondary and tertiary amines are examples of contaminants that can be remediated with this process.

STATUS:

The SITE Demonstration Program has accepted two proposals from Exxon Chemical Company and Rio Linda Chemical Company to perform two separate demonstrations: one of cyanide destruction and the other of organics treatment. The cyanide destruction technology is scheduled to be demonstrated at EPA's Test and Evaluation facility in Cincinnati, Ohio. Site selection for the organics treatment technology is underway.

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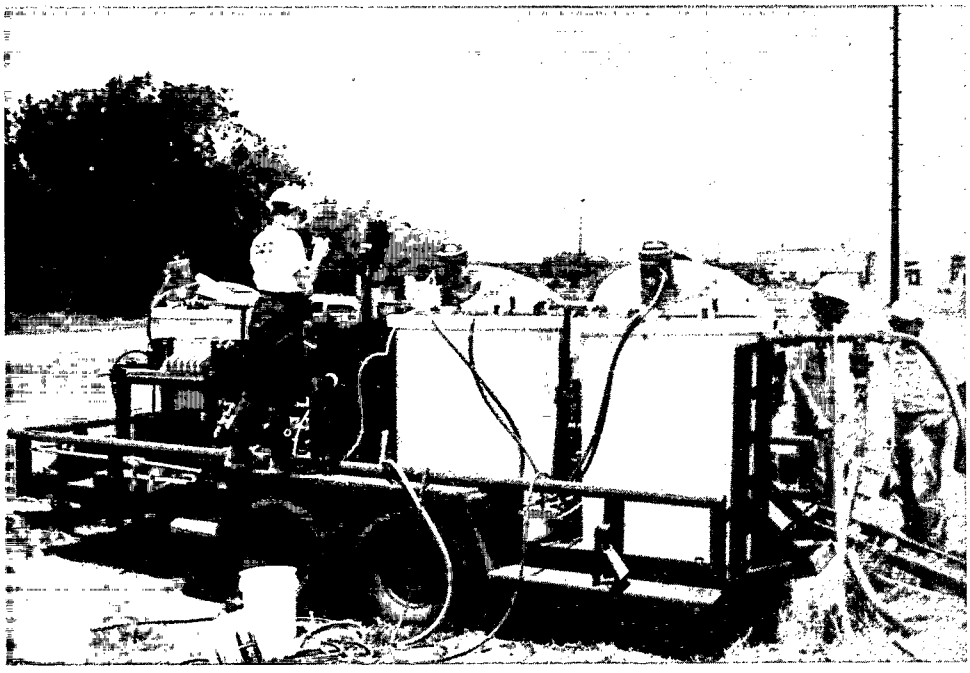
FILTER FLOW TECHNOLOGY, INC.
(Heavy Metals and Radionuclide Filtration)

TECHNOLOGY DESCRIPTION:

A colloid filter method, filtration process removes inorganic heavy metals and non-tritium radionuclides from industrial wastewater and groundwater. The filter unit has an inorganic, insoluble filter bed material (Filter Flow-1000) contained in a dynamic, flow-through configuration resembling a filter plate. The pollutants are removed from the water via sorption, chemical complexing, and physical filtration. By employing site-specific optimization of the water chemistry prior to filtration, the methodology removes the pollutants as ions, colloids, and colloidal aggregates.

A three-step process is used to achieve heavy metal and radionuclide removal (see photograph below). First, water is treated chemically to optimize formation of colloids and colloidal aggregates. Second, a prefilter removes the larger particles and solids. Third, the filter bed removes the contaminants to the compliance standard desired. By controlling the water chemistry, water flux rate, and bed volume, the methodology can be used to remove heavy metals and radionuclides in low to high volume waste streams.

The process is designed for either batch or continuous flow applications at fixed installations or field mobile operations. The field unit can be



Photograph of the process unit

retrofitted to existing primary solids water treatment systems or used as a polishing filter for new installations or on-site remediation applications. Trailer and skid-mounted equipment has been used successfully.

WASTE APPLICABILITY:

The methodology removes heavy metals and radionuclides from pond water, tank water, groundwater, or in-line industrial wastewater treatment systems. The technology also has application for remediation of natural occurring radioactive materials (NORM), man-made low level radioactive wastes (LLRW) and transuranic (TRU) pollutants.

STATUS:

The methodology was accepted into the EPA SITE Demonstration Program in July 1990. EPA and the Department of Energy (DOE) are co-sponsoring the technology evaluation. Bench tests have been conducted at the DOE Rocky Flats Facility, Golden, Colorado, using groundwater samples contaminated with heavy metals and radioactive materials.

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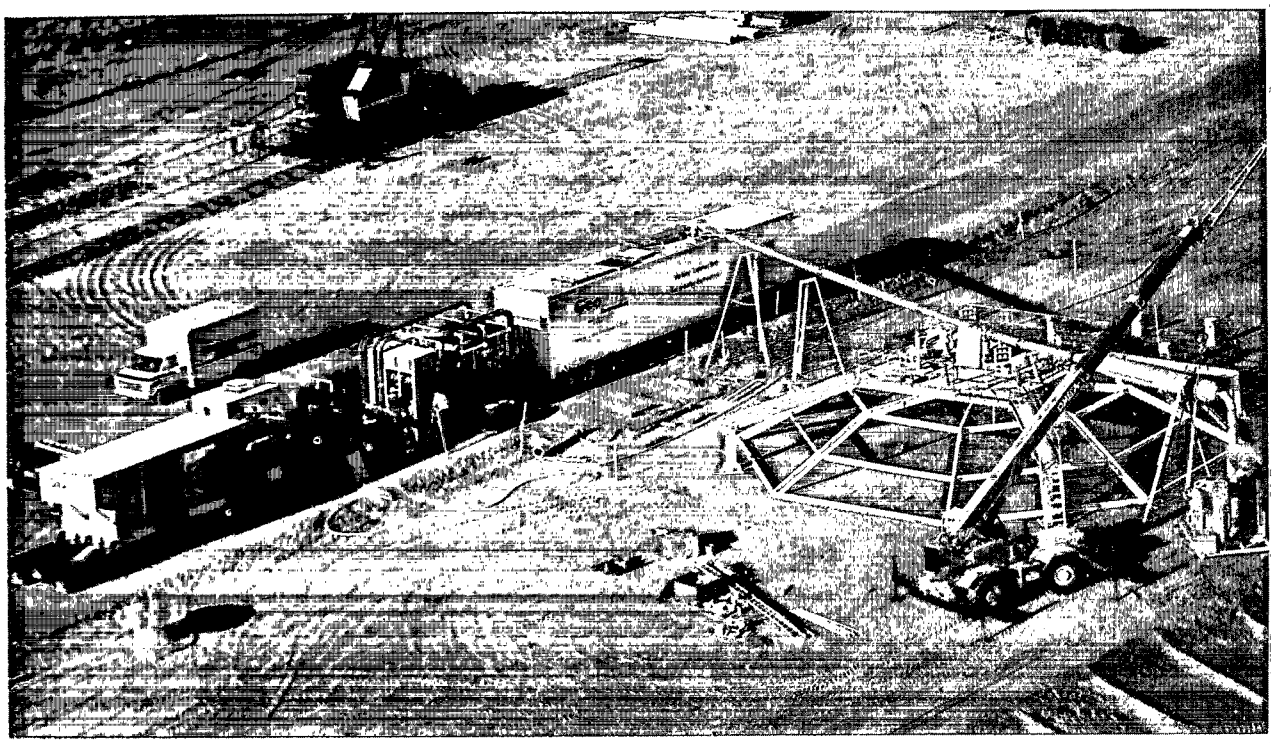
GEOSAFE CORPORATION
(In Situ Vitrification)

TECHNOLOGY DESCRIPTION:

In situ vitrification (ISV) uses an electric current to melt soil or sludge at extremely high temperatures of 1,600 to 2,000 degrees Celsius (°C), thus destroying organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified mass, which has glass properties. Water vapor and organic pyrolysis byproducts are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants.

The vitrification process begins by inserting large electrodes into contaminated zones containing sufficient soil to support the formation of a melt (see photograph below). An array (usually square) of four electrodes is placed to the desired treatment depth in the volume to be treated. Because soil typically has low electrical conductivity, 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 electrodes and begins to melt soil at the surface. As power is applied, the melt continues to grow downward, at a rate of 1 to 2 inches per hour. Individual settings (each single placement of electrodes) may grow to encompass a total melt mass of 1,000 tons and a maximum width of 35 feet. Single-setting depths as great as 25 feet are considered possible. Depths exceeding 19 feet have been achieved with the existing large-scale ISV equipment. Adjacent settings can be positioned



In situ vitrification process

to fuse to each other and to completely process the desired volume at a site. Stacked settings to reach deep contamination are also possible. The large-scale ISV system melts soil at a rate of 4 to 6 tons per hour. Because the void volume present in particulate materials (20 to 40 percent for typical soils) is removed during processing, a corresponding volume reduction occurs. After cooling, a vitrified monolith results, with a silicate glass and microcrystalline structure. This monolith possesses excellent structural and environmental properties.

The mobile ISV system is mounted on three semitrailers . Electric power is usually taken from a utility distribution system at transmission voltages of 12.5 or 13.8 kilovolts; power may also be generated on-site by a diesel generator. The electrical supply system has an isolated ground circuit to provide appropriate operational safety.

Air flow through the hood is controlled to maintain a negative pressure. An ample supply of air provides excess oxygen for combustion of any pyrolysis products and organic vapors from the treatment volume. Off-gases are treated by (1) quenching, (2) pH controlled scrubbing, (3) dewatering (mist elimination), (4) heating (for dewpoint control), (5) particulate filtration, and (6) activated carbon adsorption.

WASTE APPLICABILITY:

The ISV process can be used to destroy or remove organics and to immobilize inorganics in contaminated soils or sludges. In 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 a sufficient amount of glass-forming material (nonvolatile, nondestructible solids) to produce a molten mass that will destroy or remove organic pollutants and immobilize inorganic pollutants.

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 heat value.

STATUS:

The ISV process has been operated at a large scale ten times,including two demonstrations on transuranic-contaminated (radioactive) sites: (1) at Geosafe's test site, and (2) at the Department of Energy's (DOE) Hanford Nuclear Reservation. It has also been used at EPA Superfund, private, and other DOE sites. More than 130 tests at various scales have been performed on a broad range of waste types in soils and sludges. The technology has been selected as a preferred remedy at 10 private, EPA Superfund, and DOE sites. The Parsons/ETM site in Grand Ledge, Michigan has been selected for the SITE demonstration. Geosafe is currently doing further technology testing before any field remediation work.

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HAYWARD BAKER, INC.
(Hydraulic Soil Mixing)

TECHNOLOGY DESCRIPTION:

Hydraulic Soil Mixing (HSM) is a refinement of a 25-year old technology used to treat a wide variety of soil problems because of its proven economies. Two to four hydraulic soil mixing injectors are mounted in a line on various carrier vehicles, including forklifts, crawler tractors, and heavy trucks (see figure 1). Each soil mixer is capable of treating a column of waste from 1 to 3 feet in diameter to depths of 40 feet. With current equipment, the system, which is partially patented, can mix and inject solutions of particulate slurry/grouts up to specific gravities of 1.5 to 1.6 (see figure 2). Approximately 30 tons of dry solids or 20,000 gallons of slurry can be mixed in situ per injector, per working day. Bottom seals or targeted waste strata can be treated with little disturbance of noncontaminated strata. Various solidification and stabilization materials such as portland cement, fine grind cement, lime, fly ash, and sodium silicates are combined with patented materials such as Trifirmex, MC-500, and MC-100, depending on the number and types of contaminants present. HSM also can be a delivery system for other in situ treatment techniques.

WASTE APPLICABILITY:

Soils and sludges contaminated with polychlorinated biphenyls (PCB), pentachlorophenol, refinery waste, and hydrocarbons can be treated. Specific concentration ranges that can be treated will depend on the contaminant and its soil and sludge matrix, and will be predetermined by treatability and site characterization studies.

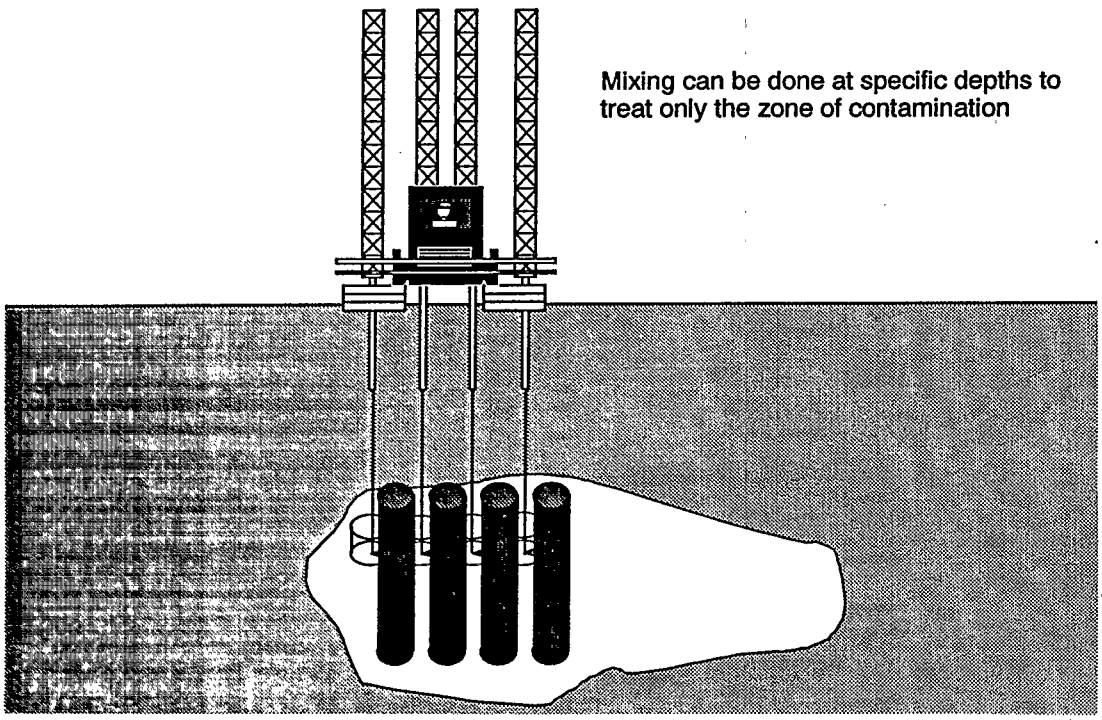

Figure 1: Hydraulic soil mixing

STATUS:

This technology was accepted into the SITE Demonstration program in June 1991. Several pilot-scale and field-scale tests have been conducted on injection of lime and fly ash for various environmental applications. One application occurred at a large petrochemical plant where lime slurry was injected to neutralize sulfuric acid up to 20 feet deep. Another pilot-scale test was performed at a burial pit where in situ grouting was used as a means for remedial action for uranium mill tailing piles. Field tests of the system have been performed under controlled, nonhazardous conditions. The location for the SITE demonstration is undetermined.

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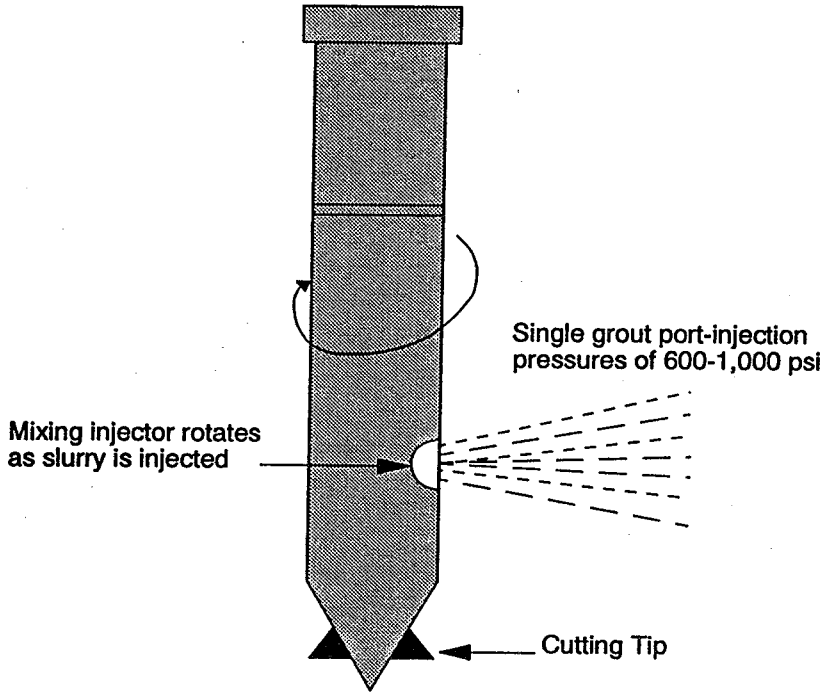


Figure 2: Mixing and injecting slurry/grouts

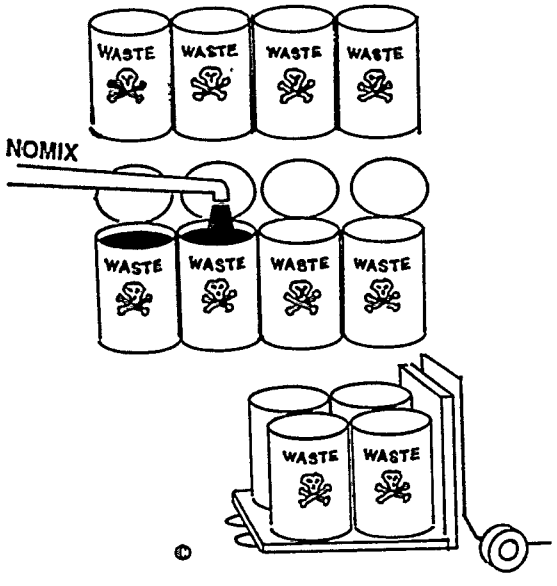
HAZARDOUS WASTE CONTROL
(NOMIX® Technology)

TECHNOLOGY DESCRIPTION:

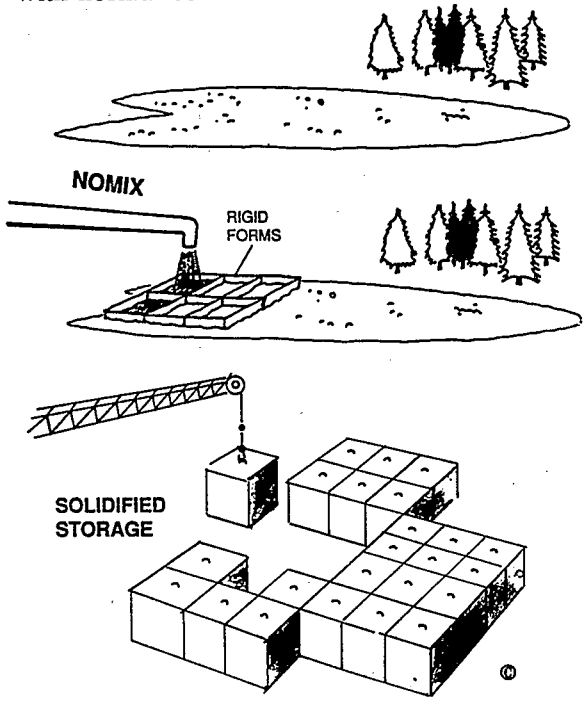
The NOMIX® technology is a patented solidification and stabilization process that can be applied to contaminated media in situ, without the need for mixing or equipment. The technology combines specially formulated cemetitious materials with waste media. Because the material hardens faster than conventional concrete, there is a savings in remediation time.

The NOMIX® solidification compounds consist of specially formulated cements, sands, aggregates, and various combinations thereof. The dry components and their reacting rates with the wet waste are closely controlled, allowing rapid and efficient solidification. The contaminated media may be diluted with water, if necessary, to facilitate the solidification process. If the addition of water is necessary, it may be introduced into the waste media before the addition of the preblended solidification compounds in various ways to create a homogenous solution of waste and water. The solidification compounds are then poured through the waste and water solution in a consistent manner, allowing the complete absorption of the waste solution and the formation of a solid mass. The process produces a relatively homogenous treated mass compared to that produced by solidification processes using mixing equipment.

Applications of the technology require little labor and, because mixing is accomplished simply by pouring the solidification compounds through the waste combination, greater quantities of waste can be solidified by this process than with normal concrete mixtures. The treated



Chemical storage:
solidification of drum waste



Ponding basin or lagoon:
solidification for removal

impermeable with formulation adjustments or coatings when compared with the treated product from systems using formulations of regular concrete mixes, such as ASTM C-109 standard mix.

The process can address contaminated waste contained in drums (or other containers), a minor spill, or even a lagoon (see figures). Each of these situations will require its own particular installation procedures. After solidification, the units can be moved for storage, or left in place for normal situations. For critical situations, the solidified mass may be encased for extra protection with a non-shrink, structural concrete, and/or a high quality waterproof coating.

WASTE APPLICABILITY:

The NOMIX® technology is currently most suitable for solidification and stabilization of aqueous wastes in the following situations:

- Solidification of drum waste
- Solidification of minor spills in situ to minimize soil, facility, or plant contamination
- Solidification of waste lagoons for long-term, in-place storage, or for solidification in preparation for removal.

The technology has been applied to solutions of mercuric chloride, nickel sulfate, phenylene diamene, barium acetate, lead, and phenol. These samples were analyzed using the proven procedures of ASTM Standard C-109, and the resulting strengths were similar to those expected from a standard concrete mix.

As the technology is improved it will become suitable for solidification of various wastes in soils including inorganic wastes.

STATUS:

Solidification and stabilization using the NOMIX® Technology was accepted into the SITE Demonstration Program in March 1991. The date and place of the demonstration are undetermined.

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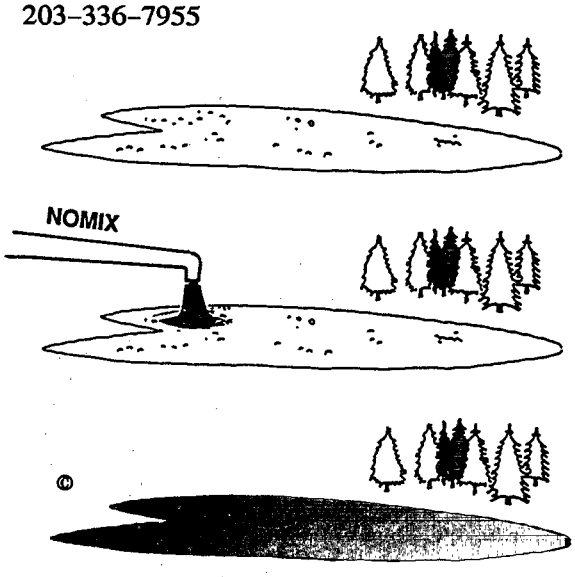

Ponding basin or lagoon:
solidification in situ

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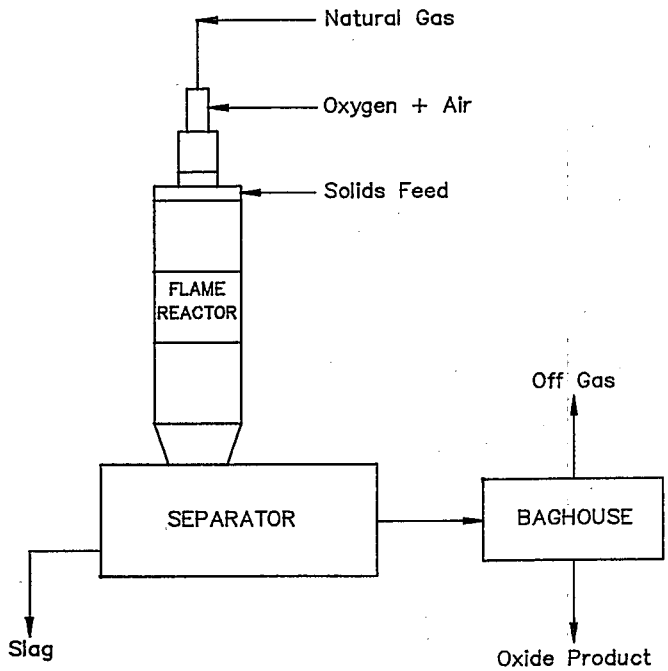
HORSEHEAD RESOURCE DEVELOPMENT CO., INC. (HRD)
(Flame Reactor)

TECHNOLOGY DESCRIPTION:

The flame reactor process (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 degrees Celsius [°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), and a recyclable, heavy metal-enriched oxide, and 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 condense as a molten alloy. The remaining trace levels of metals are encapsulated in the slag. At the elevated temperature of the Flame Reactor technology, organic compounds are destroyed. In general, the process 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.



HRD flame reactor flow schematic

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, iron residues, zinc plant leach residues and purification residues, and brass mill dusts and fumes have been successfully tested.

Metal-bearing wastes previously treated contained zinc (up to 40 percent), lead (up to 10 percent), chromium (up to 4 percent), cadmium (up to 3 percent), arsenic (up to 1 percent), copper, cobalt, and nickel.

Although not yet tested, the process should be applicable to Superfund soils highly 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 1.5 to 3.0 tons/hour in a stationary mode at the developer's facility in Monaca, Pennsylvania. The EPA and the developer believe that it would be technically and economically feasible to design and construct the same or a somewhat larger capacity system in a transportable form.

The SITE demonstration test was run from March 18 to 22, 1991, on secondary lead soda slag from the National Smelting and Refining 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 evaluate (1) the levels of contaminants in the residual slag and their leaching potential, (2) the efficiency and economics of processing, and (3) the reuse potential of the recovered metal oxides.

DEMONSTRATION RESULTS:

Approximately 72 tons of contaminated materials were processed for the test. Partial test results are shown in the table below:

Metal Concentration Ranges in Influent and Effluent Wastes

	Waste Feed (mg/kg)	Effluent Slag (mg/kg)	Product Oxide (mg/kg)
Arsenic	428-582	92.1-675	1,010-1,130
Cadmium	380-512	2.3-13.5	1,080-1,370
Copper	1,460-2,590	2,730-3,890	1,380-1,670
Iron	95,600-111,000	167,000-228,000	29,100-31,800
Lead	48,200-61,700	1,560-11,40	159,000-180,000
Zinc	3,210-4660	709-1,680	10,000-16,200

All effluent slag passed the TCLP-limits criteria. The Applications Analysis Report and Technology Evaluation Report will be issued in 1992.

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HUGHES ENVIRONMENTAL SYSTEMS, INC.

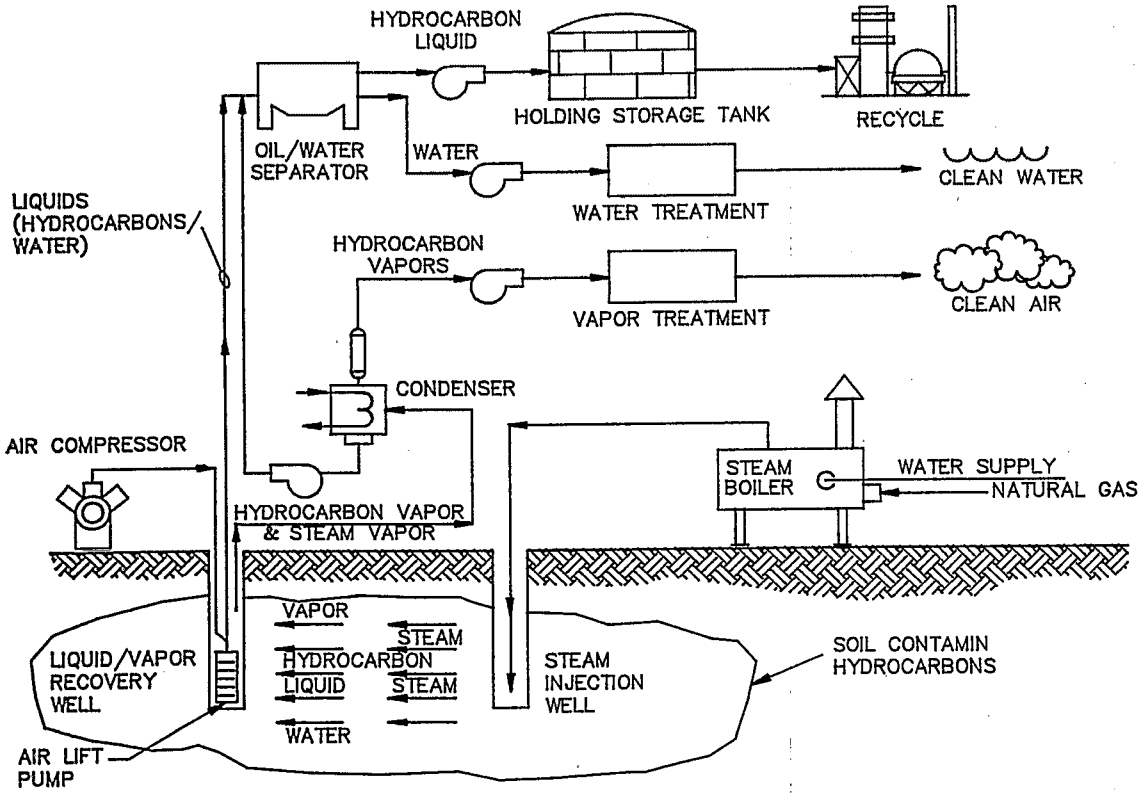
(Steam Injection and Vacuum Extraction (SIVE))

TECHNOLOGY DESCRIPTION:

The steam injection and vacuum extraction (SIVE) process (see figure below), developed by Hughes Environmental Systems, removes most volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils in situ, both above and below the water table. The technology is applicable to in situ remediation of contaminated soils well below ground surface, and can be used to treat below or around permanent structures, 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 vacuum process. The extraction wells have two purposes: to pump and treat groundwater, and to transport steam and vaporized contaminants under vacuum to the extraction well and then to the surface. Recovered contaminants are either condensed and processed with the contaminated ground water or trapped by gas-phase activated carbon filters. 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 is used to extract volatile and semivolatile organic compounds from contaminated soils and perched groundwater.



Steam Injection and Vapor Extraction process

The primary applicable compounds are hydrocarbons such as gasoline, diesel and jet fuel; solvents such as trichloroethylene (TCE), trichloroethane (TCA), and dichlorobenzene (DCB); or a mixture of these compounds. After application of this process, the subsurface conditions are excellent for biodegradation of residual contaminants. 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 geologic barrier exists to prevent downward percolation of a separate phase.

STATUS:

The SITE demonstration, currently underway at a site in Huntington Beach, California, began in August 1991 and will be completed in early 1992. The soil at the site was contaminated by a 135,000 gallon diesel fuel spill.

For more information regarding this technology, see the Udell Technologies, Inc., profile in the Demonstration Program section of this document.

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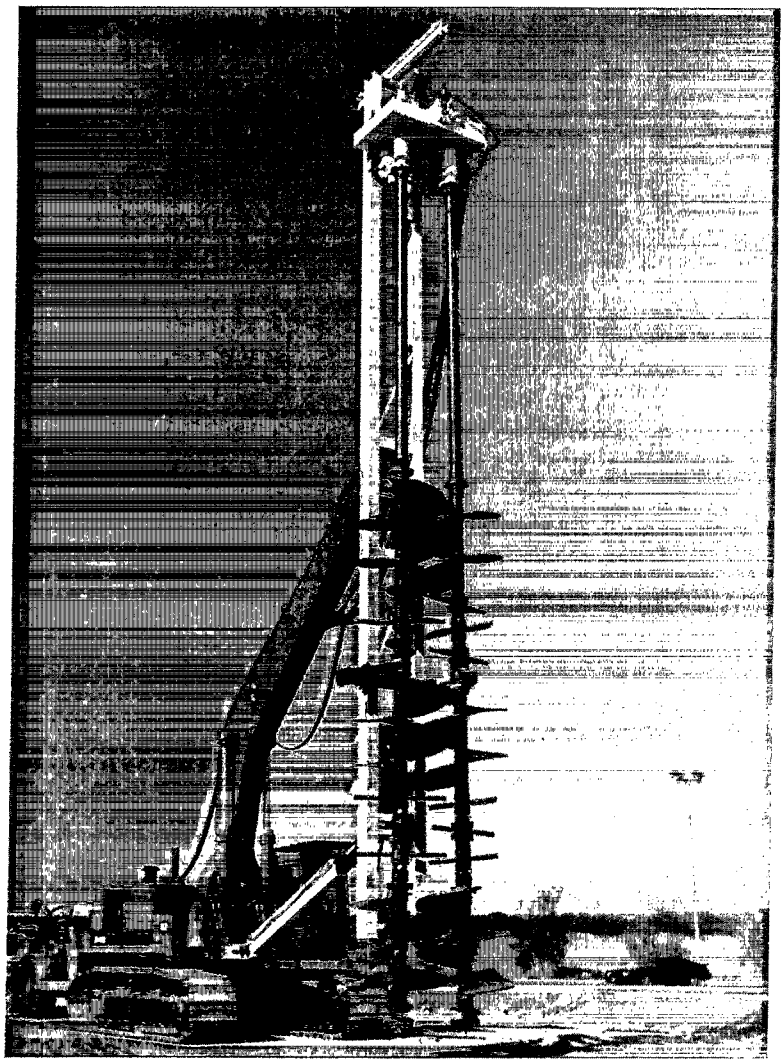
IN-SITU FIXATION COMPANY
(Deep In Situ Bioremediation Process)

TECHNOLOGY DESCRIPTION:

This process increases the efficiency and rate of biodegradation in deep contaminated soils. The specialized equipment system injects site-specific microorganism mixtures, along with the required nutrients, and homogeneously mixes them into the contaminated soils, without requiring any excavation. The injection and mixing process effectively breaks down fluid and soil strata barriers and eliminates pockets of contaminated soil that would otherwise remain untreated.

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



Dual Auger System

auger drills intocontaminated soil, allowing the microorganism and nutrient mixture(s) to be continually injected through a controlled nozzle system. If necessary, water, nutrients, and natural bacteria, are added to the contaminated area, as determined by a site-specific laboratory test program.

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. The 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 may exceed 100 feet.

The development of site-specific microorganisms is an integral part of the process. Laboratory bench-scale tests are performed on the contaminated soil to determine the water, nutrients, and, if necessary, bacteria required for successful biodegradation. Although some contaminants may volatilize during remediation, volatilization has been 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/stabilize contaminated waste.

Additionally, many sites require that an impermeable barrier/containment wall be constructed to prevent the continued migration of pollutants through the soil and water. This special feature 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, non-biodegradable toxic organics, alkaline conditions, or acid conditions could interfere with the degradation process.

No residuals or wastes are generated in this process, as all of the treatment is performed beneath the ground surface. Upon completion of the remedial operations, the treated area can be returned to its original service.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1990. A demonstration project is tentatively planned for early fall 1992, in conjunction with the U.S. Air Force.

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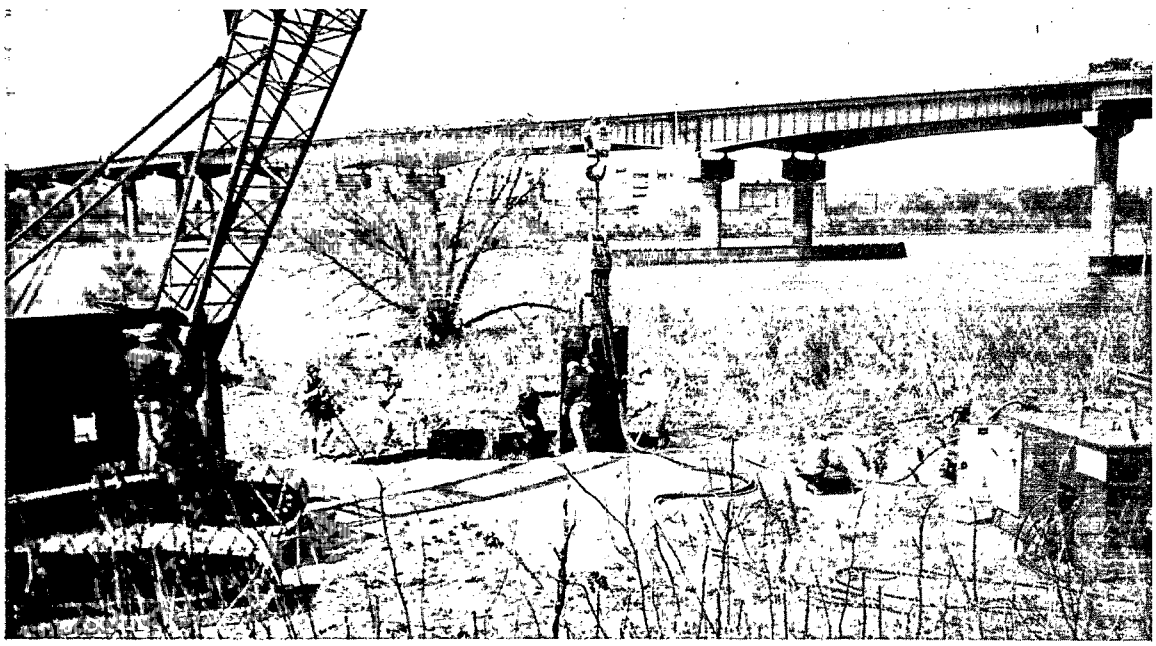
INTERNATIONAL ENVIRONMENTAL TECHNOLOGY
(Geolock and Bio-Drain Treatment Platform)

TECHNOLOGY DESCRIPTION:

The geolock and bio-drain treatment platform (see photograph below) is a bioremediation system that is installed in the soil or waste matrix. The technology can be adapted to soil characteristics, contaminant concentrations, and geologic formations in the area. The system is composed of an in situ tank, an application system, and a bottom water recovery system.

The geolock tank, an in situ structure, is composed of high density polyethylene (HDPE), sometimes in conjunction with a slurry wall. An underlying permeable waterbearing zone facilitates the creation of ingradient water flow conditions. The tank defines the treatment area, minimizes intrusion of off-site clean water, minimizes the potential for release of bacterial cultures to the aquifer, and maintains contaminant concentration levels that facilitate treatment. The ingradient conditions also facilitate reverse leaching or soil washing. The application system, called Bio-drain, is installed within the treatment area. Bio-drain acts to aerate the soil column and any standing water. This creates an aerobic environment in the air pore spaces of the soil. Other gas mixtures can also be introduced to the soil column such as air/methane mixtures used in biodegradation of chlorinated organics. The cost of installation is low, and the treatment platforms can be placed in very dense configurations.

Existing wells or new wells are used to create the water recovery system for removal of water used to wash contaminated soil. By controlling the water levels within the tank, reverse leaching or soil washing can be conducted. The design of the in situ tank also controls and minimizes



Geolock and Bio-drain treatment platform

the volume of clean off-site water entering the system for treatment. In-gradient conditions minimize the potential for off-migration of contaminants. This also creates a condition such that the direction of migration of existing contaminants and bacterial degradation products is toward the surface.

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

WASTE APPLICABILITY:

All types and concentrations of biodegradable contaminants can be treated by this system. Through direct degradation or co-metabolism, microorganisms can degrade most organic substances. Only a limited number of compounds, such as 1,4-dioxane, are resistant to biodegradation. In these cases, the material may be washed from the soil using surfactants. Arochlor 1254 and 1260, both polychlorinated biphenyls (PCB), may now also be biodegradable in light of recent advancements by General Electric.

Extremely dense clays may be difficult to treat with this technology. Rock shelves or boulders may render installation impossible. Until equilibrium conditions are established, the only residuals for management would be the quantity of water withdrawn from the system to create in-gradient conditions. After equilibrium conditions are established the water would be treated in situ to meet National Pollutant Discharge Elimination System (NPDES) or pre-treatment limits.

STATUS:

The technology was accepted into the SITE Demonstration Program in August 1990. Two patents on the system were awarded in July and October of 1991. Site selection for the demonstration is currently underway.

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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's 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 treatment chemicals (see figure below).

The proprietary additives generate a complex, crystalline, connective network of inorganic polymers. The structural bonding in the polymers is mainly covalent. The process involves a two-phased reaction in which the contaminants are first complexed in a fast-acting reaction, and then in a slow-acting reaction, where the building of macromolecules continues over a long period of time. For each type of waste, the amount of additives used varies. Treatability tests are recommended.

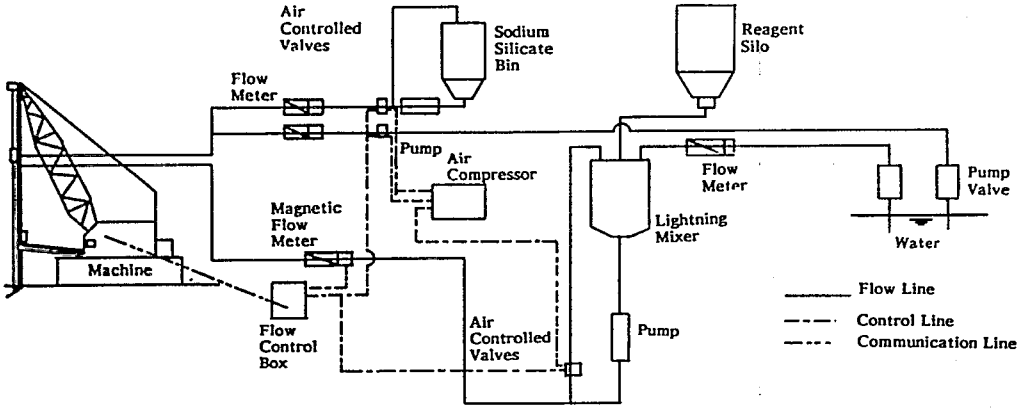
The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 revolutions per minute (rpm). Two conduits in the auger are used to inject the additive slurry and supplemental water. Additive injection occurs 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 can be applied to 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.

STATUS:

A SITE demonstration was conducted at a PCB-contaminated site in Hialeah, Florida, in April 1988. Two 10- by 20-foot test sectors of the site 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



In situ solidification batch mixing plant process diagram

treated sectors. The Technology Evaluation Report and Applications Analysis Report have been published.

DEMONSTRATION RESULTS:

- Immobilization of PCBs appears 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 one 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, 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 one inch per treated foot of soil.
- The unconfined compressive strength (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.
- The microstructural analysis, scanning electron microscopy (SEM), optical microscopy, and x-ray diffraction (XRD), showed that the treated material was dense and homogeneously mixed.

APPLICATIONS ANALYSIS SUMMARY:

- Microstructural analyses of the treated soils indicated a potential for long-term durability. High unconfined compressive strengths and low permeabilities were recorded.
- Data provided by IWT indicate some immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the IWT reagent. There are insufficient data to confirm this immobilization.
- Performance data are limited outside of SITE demonstrations. The developer modifies the binding agent for different wastes. Treatability studies should be performed for specific wastes.
- The process is economic--$194 per ton for the 1-auger machine used in the demonstration and $111 per ton for a commercial 4-auger operation.

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NOVATERRA, INC.

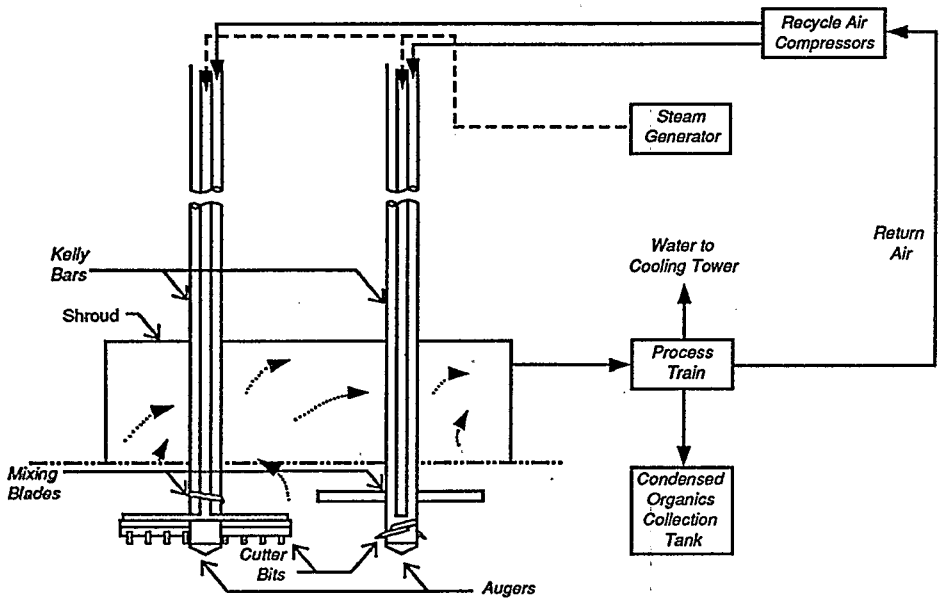
(formerly TOXIC TREATMENTS USA, Inc.)
(In situ Steam and Air Stripping)

TECHNOLOGY DESCRIPTION:

In this technology, a transportable treatment unit Detoxifier™ is used for in situ steam and air stripping of volatile organics from contaminated soil.

The two main components of the on-site treatment equipment are the process tower and process train (see figure). 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 is used to convey steam to the rotating cutting blades. The steam is supplied by an oil-fired boiler at 450 degrees Fahrenheit (°F) and 450 pounds per square inch gauge (psig). The outer pipe conveys air at approximately 300°F and 250 psig to the rotating blades. Steam is piped to the top of the drills and injected through the cutting blades. The steam heats the ground being remediated, increasing the vapor pressure of the volatile contaminants, and thereby increasing the rate at which they can be stripped. Both the air and steam serve as carriers to 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 also



Process schematic

used (1) to regenerate the activated carbon beds and (2) as the heat source 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.

WASTE APPLICABILITY:

This technology is applicable to 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 is also capable of significantly reducing the concentration of semivolatile organic compounds in soil.

STATUS:

A SITE demonstration was performed during the week of September 18, 1989, at the Annex Terminal, San Pedro, California. Twelve soil blocks were treated for VOCs and semivolatile organic compounds (SVOC). Various liquid samples were collected from the process during operation, and the process operating procedures were closely monitored and recorded. Post-treatment soil samples were collected and 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 following results were obtained during the SITE demonstration of the technology:

- More than 85 percent of the VOCs in the soil was removed.
- Up to 55 percent of SVOCs in the soil was removed.
- Fugitive air emissions from the process were very low.
- No downward migration of contaminants resulted from the soil treatment.
- The process was timely with a treatment rate of 3 cubic yards per hour.

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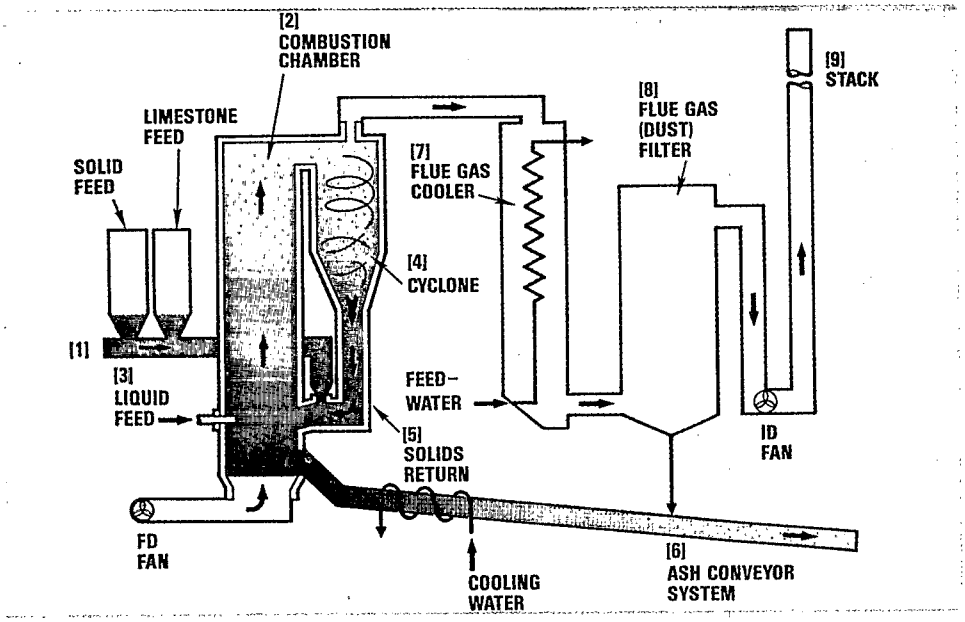
OGDEN ENVIRONMENTAL SERVICES
(Circulating Bed Combustor)

TECHNOLOGY DESCRIPTION:

The Circulating Bed Combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone for the efficient destruction of 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 fairly low temperatures [1450 to 1600 degrees Fahrenheit (°F)] for this class of technology, thus 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 auxilliary fuel is needed for waste streams having 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 promotes the complete mixing of the waste material during combustion. The effective mixing and relatively low combustion temperature also reduce emissions of carbon monoxide and nitrogen oxides. Hot gases produced during combustion pass through a convective gas cooler and baghouse before being released to the atmosphere.

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. The treated ash is transported out of the system by an ash conveyor for proper disposal.



Schematic diagram of the CBC

WASTE APPLICABILITY:

The CBC process may be applied to liquids, slurries, solids, and sludges contaminated with corrosives, cyanides, dioxins/furans, inorganics, metals, organics, oxidizers, pesticides, polychlorinated biphenyls (PCB), phenols, and volatiles.

Industrial wastes from refineries, chemical plants, manufacturing site cleanups, and contaminated military sites are amenable to treatment by the CBC process. The CBC is permitted by EPA, under the Toxic Substance Control Act (TSCA), to burn PCBs in all ten 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 was accepted into the SITE Demonstration Program in March 1989. Ogden Environmental Services (OES) conducted a treatability study and demonstration on wastes obtained from a Superfund site in California (McColl) under the guidance of the program, EPA Region 9, and the California Department of Health Services. The pilot-scale demonstration was conducted by using the 16-inch-diameter CBC at Ogden's Research Facility in San Diego, California.

DEMONSTRATION RESULTS:

The EPA SITE program concluded that the test successfully achieved the desired goals, as follows:

- Obtained DRE values of 99.99 percent or greater for principal organic hazardous constituents (POHC) and minimized the formation of products of incomplete combustion(PIC).
- Met the OES Research Facility permit conditions and the California South Coast Basin emission standards.
- Controlled sulfur oxide emissions by adding limestone, and determined 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 material. The CBC was able to minimize emissions of sulfur oxide, nitrogen oxide, and particulates. Other regulated pollutants were controlled to well below permit levels.

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PEROXIDATION SYSTEMS, INC.
(perox-pure™)

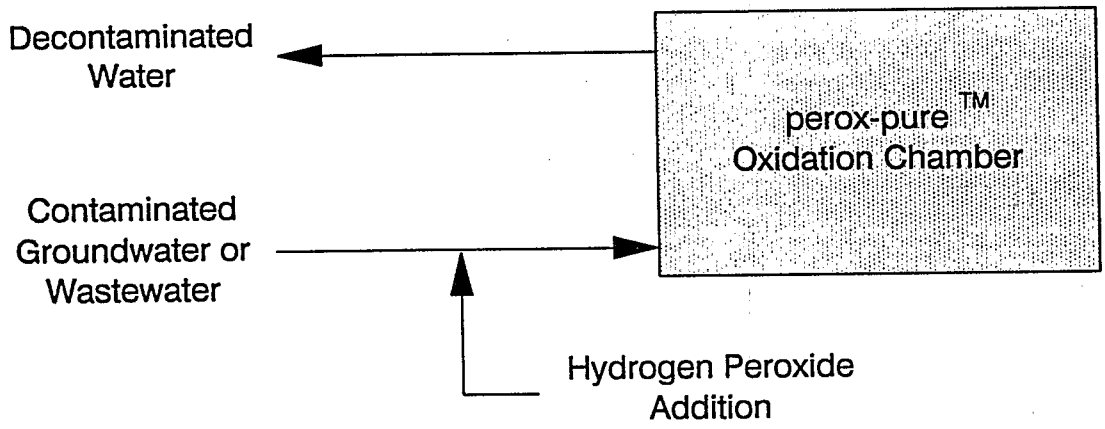
TECHNOLOGY DESCRIPTION:

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 (see figure below). The treatment system contains four or more compartments in the oxidation chamber. Each compartment contains one high intensity UV lamp mounted in a quartz sleeve. 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 the chemical oxidation of the organic contaminants in water by its combined effect upon the organics and its reaction with hydrogen peroxide. First, many organic contaminants that absorb UV light may undergo a change in their 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.

WASTE APPLICABILITY:

This technology treats groundwater and wastewater contaminated with chlorinated solvents, pesticides, polychlorinated biphenyls (PCB), phenolics, fuel hydrocarbons (FHC), and other toxic compounds at concentrations ranging from a few thousand milligrams per liter to one microgram per liter. In cases where the



perox-pure™ chemical oxidation technology

contaminant concentration is greater than the technology alone can handle, the process can be combined with other processes such as air stripping, steam stripping, or biological treatment for optimal treatment results.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration at the Lawrence Livermore National Laboratory (LLNL) Superfund site is scheduled for early 1992. This technology has been successfully applied to over 40 different waters throughout the United States, Canada, and Europe, including National Priorities List, Resource Conservation and Recovery Act (RCRA), Department of Energy, and Department of Defense sites. These units are treating contaminated groundwater, industrial wastewater, landfill leachates, potable water, and industrial reuse streams.

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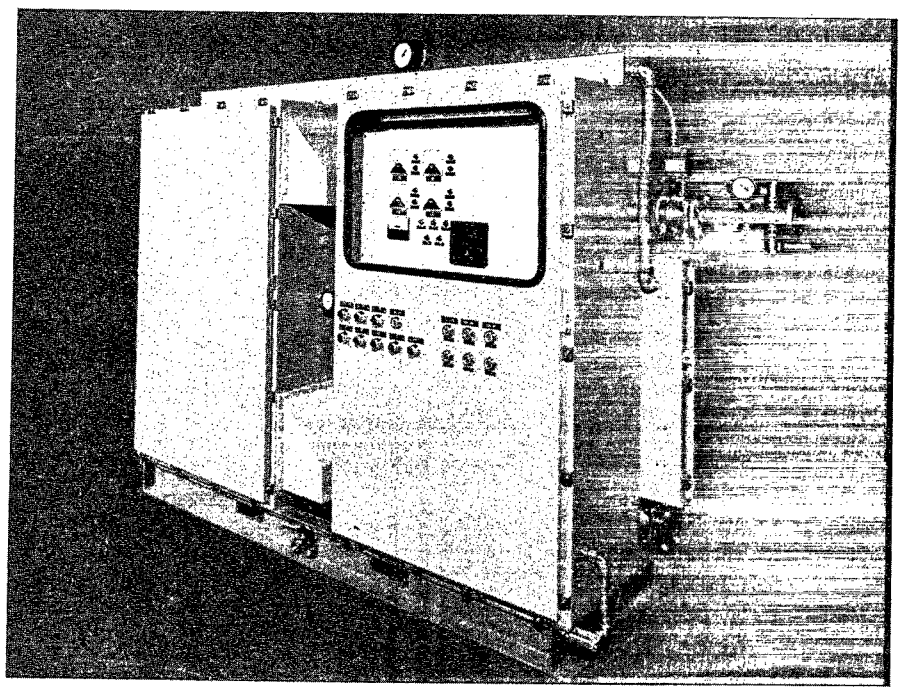


perox-pure™ model LVB-60

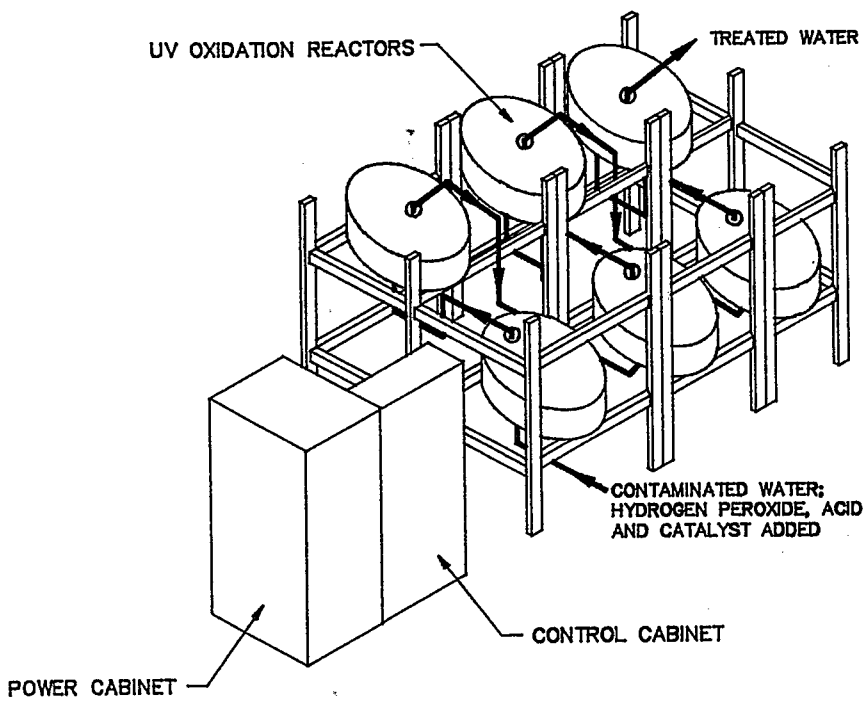
PURUS, INC.
(Photolytic Oxidation Process)

TECHNOLOGY DESCRIPTION:

This technology is designed to destroy organic contaminants dissolved in water through an advanced chemical oxidation process using ultraviolet (UV) radiation, hydrogen peroxide, and a proprietary catalyst. Contaminated water is fed into the system, and hydrogen peroxide and the proprietary catalyst are added (see figure below). The mixture is then pumped to the treatment system consisting of six reactor tanks, where the actual destruction of the organic contaminants takes place. Each reactor tank houses a xenon UV lamp mounted in a quartz sleeve. The water flows in the space between the chamber wall and the quartz tube in which each lamp is mounted.

The UV lamps serve two purposes. First, the combination of UV light and hydrogen peroxide produces hydroxyl radicals, which are powerful chemical oxidants. The hydroxyl radicals oxidize organic contaminants, producing harmless by-products, such as carbon dioxide, salts, and water. Second, the UV light can directly break the molecular bonds of the contaminants, further enhancing the oxidation process.

An advantage of the technology is its ability to shift the UV spectral output to closely match the absorption characteristics of the contaminants of concern. By controlling the output of the xenon UV lamps, the technology maximizes contaminant destruction efficiency.



Purus Ultraviolet Oxidation Technology

The Purus process produces no hazardous by-products or air emissions. The technology is also equipped with safety alarms and an automatic shutdown device in case an emergency should arise.

WASTE APPLICABILITY:

This technology treats groundwater contaminated with fuel hydrocarbons at concentrations up to a few thousand milligrams per liter. The technology can be combined with other processes such as air stripping, steam stripping, or biological treatment for optimal results.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration at the Lawrence Livermore National Laboratory (LLNL) Superfund site is scheduled for January 1992. The treatment system will be tested initially at several operating conditions, followed by three reproducibility runs performed at the best operating conditions. When the best operating conditions have been determined, more extensive sampling will be performed.

A bench-scale treatability study of the technology was recently performed at the LLNL Superfund site. Overall, the Purus Model 1000-4 performed as expected during the study. Benzene, toluene, ethylbenzene, and xylene destruction efficiencies averaged about 99 percent.

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QUAD ENVIRONMENTAL TECHNOLOGIES CORPORATION
(Chemtact™ Gaseous Waste Treatment)

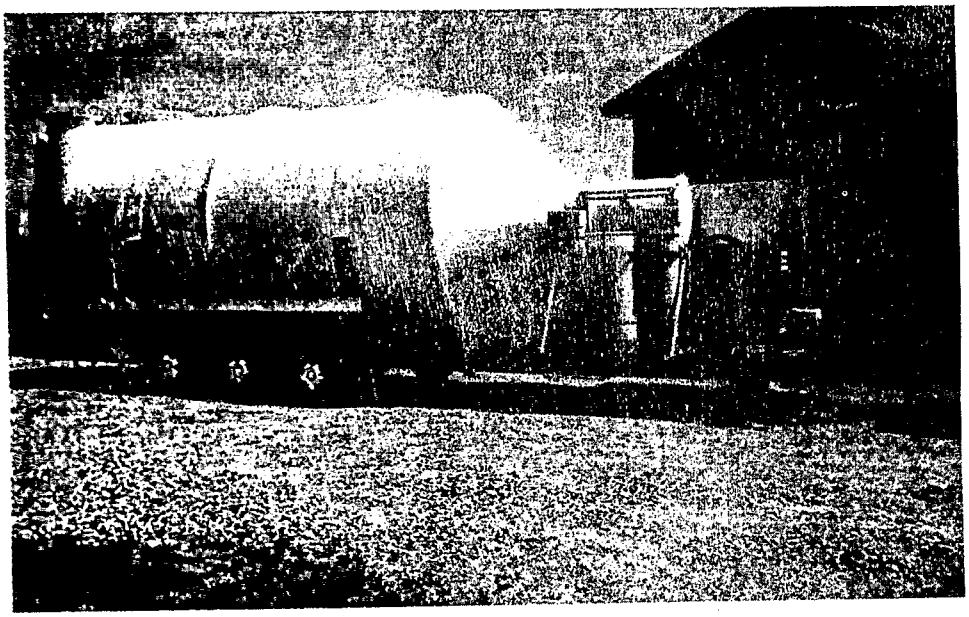
TECHNOLOGY DESCRIPTION:

The Chemtact™ system uses gas scrubber technology to remove organic and inorganic contaminants from gaseous waste streams through efficient gas and liquid contacting. Atomizing nozzles within the scrubber chamber disperse droplets of a controlled chemical solution. Very small droplet sizes, less than 10 microns, and a longer retention time than traditional scrubbers result in a once-through system that generates low volumes of liquid residuals. These residuals are then treated by conventional techniques.

Gas scrubbing is a volume reduction technology that transfers contaminants from the gas phase to a liquid phase. The selection of absorbent liquid is based on the chemical characteristics of the contaminants.

Four mobile units are currently available: (1) a one-stage, 2,500-cubic-feet-per-minute (cfm) system (see photograph below); (2) a two-stage, 800-cfm system; (3) a three-stage, 100-cfm system; and (4) a four-stage, 100-cfm system. The equipment is trailer-mounted and can be transported to waste sites.

Performance tests treating benzene, toluene, xylene, and mixed undefined hydrocarbons have shown removal in the 85 to 100 percent range. Pure streams are easier to adjust to obtain high removals. Additionally, phenol and formaldehyde emission control tests indicate approximately 90 percent removals.



Mobile 2,500 cfm pilot scrubbing unit

WASTE APPLICABILITY:

This technology can be used to treat gaseous waste streams containing a wide variety of organic or inorganic contaminants, but it is best suited for volatile organic compounds. The system can be used with source processes that generate a contaminated gaseous exhaust, such as air stripping of groundwater or leachate, soil aeration, or exhausts from dryers or incinerators.

STATUS:

The developer is currently conducting various treatability studies and appropriate system modifications.

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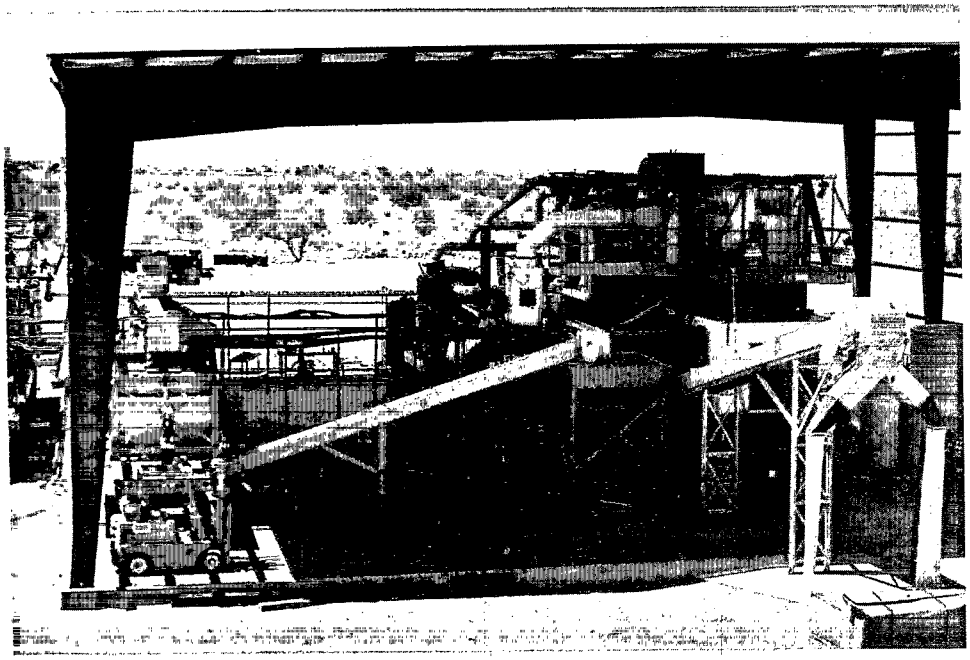
RECYCLING SCIENCES INTERNATIONAL, INC.
(Desorption and Vapor Extraction System)

TECHNOLOGY DESCRIPTION:

The mobile, high-capacity (10.5 to 73 tons per hour capacity with 85 percent solids) desorption and vapor extraction system (DAVES) uses a low-temperature fluidized bed to remove organic and volatile inorganic compounds from soils, sediments, and sludges. Contaminated materials are fed into a co-current, fluidized bed, where they are mixed with hot air [about 1,000 to 1,400 degrees Fahrenheit (°F)] from a gas-fired heater. Direct contact between the waste material and the hot air forces water and contaminants from the waste into the gas stream at a relatively low fluidized-bed temperature (about 320°F). The heated air, vaporized water and organics, and entrained particles flow out of the dryer to a gas treatment system.

The gas treatment system removes solid particles, vaporized water, and organic vapors from the air stream. A cyclone separator and baghouse remove most of the particulates in the gas stream from the dryer. Vapors from the cyclone separator are cooled in a venturi scrubber, counter-current washer, and chiller section, before they are treated in a vapor-phase carbon adsorption system. The liquid residues from the system are centrifuged, filtered, and passed through two activated carbon beds arranged in series (see photograph below).

By-products from the DAVES include (1) approximately 96 to 98 percent of solid waste feed as treated, dry solid, (2) a small quantity of centrifuge sludge containing organics, (3) a small quantity of spent adsorbent carbon,



DAVES system

(4) wastewater that may need further treatment, and (5) small quantities of baghouse and cyclone dust that are recycled back through the process.

The centrifuge sludge containing organics can be bioremediated, chemically degraded, or treated in another manner. Recycling Sciences International, Inc., is currently working with Argonne National Laboratory on an adjunct electrochemical oxidation process that will enable complete contaminant destruction within the DAVES process.

WASTE APPLICABILITY:

This technology can remove volatile and semivolatile organics, including polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), pentachlorophenol (PCP), volatile inorganics (such as tetraethyl lead), and some pesticides from soil, sludge, and sediment. In general, the process treats waste containing less than 10 percent total organic contaminants and 30 to 95 percent solids. The presence of nonvolatile inorganic contaminants (such as metals) in the waste feed does not inhibit the process; however, these contaminants are not treated.

STATUS:

EPA is currently selecting a demonstration site for this process. The wastes preferred for the demonstration are harbor or river sediments containing at least 50 percent solids and contaminated with PCBs and other volatile or semivolatile organics. Soils with these characteristics may also be acceptable. About 300 tons of waste are needed for a 2-week test. Major test objectives are to evaluate feed handling, decontamination of solids, and treatment of gases generated by the process.

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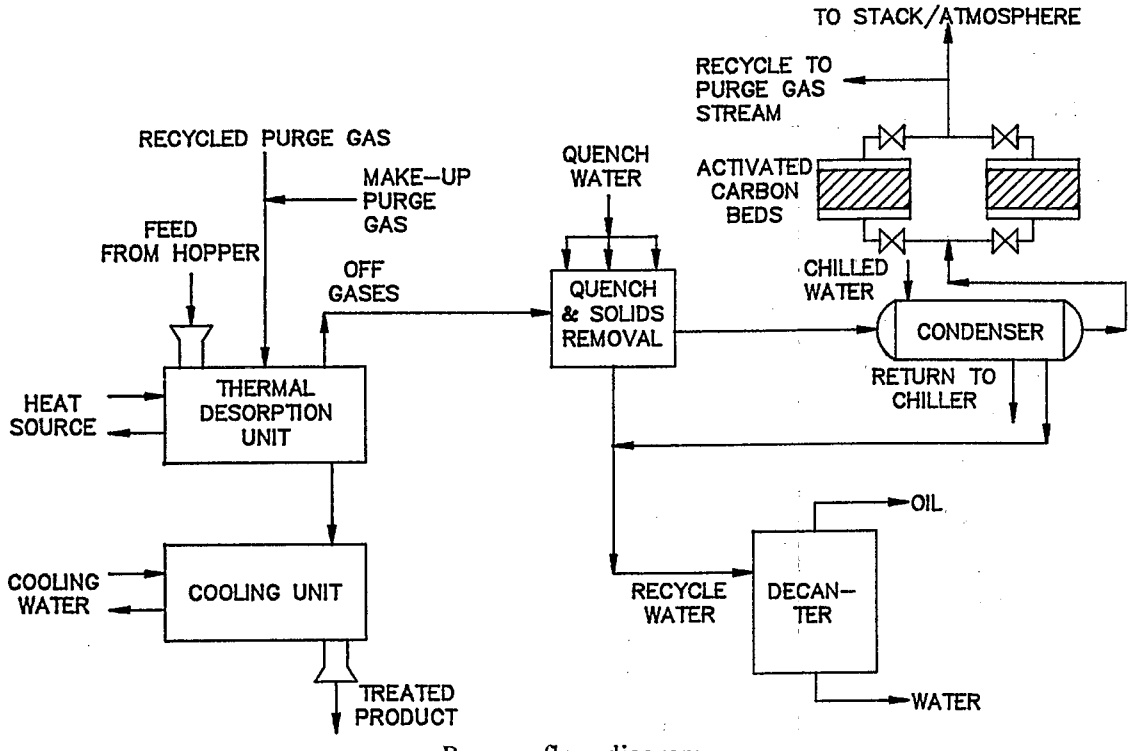
REMEDIATION TECHNOLOGIES, INC.
(High Temperature Thermal Processor)

TECHNOLOGY DESCRIPTION:

Remediation Technologies, Inc.'s (ReTeC), high temperature thermal processor is a thermal desorption system that can treat solids and sludges contaminated with organic constituents. The system consists of material feed equipment, a thermal processor, a particulate removal system, an indirect condensing system, and activated carbon beds. A flow diagram of the system is shown in the figure below.

Waste from the feed hopper is fed to the thermal processor, which consists of a jacketed trough that houses two intermeshing, counter-rotational screw conveyors. The rotation of the screws moves material through the processor. A molten salt eutectic, consisting primarily of potassium nitrate, serves as the heat transfer media. This salt melt has heat transfer characteristics similar to those of oils and allows maximum processing temperatures of up to 850°F. The salt melt is noncombustible, it poses no risk of explosion, and its potential vapors are nontoxic. The heated transfer media continuously circulates through the hollow flights and shafts of each screw and also circulates through the jacketed trough. An electric or fuel oil/gas-fired heater is used to maintain the temperature of the transfer media. Treated product is cooled to less than 150°F for safe handling.

A particulate removal system (such as a cyclone or quench tower), an indirect condensing system, and activated carbon beds are used to control off-gases. The processor operates under slight negative pressure to exhaust the volatilized constituents (moisture and organics) to the



Process flow diagram

off-gas control system. An inert atmosphere is maintained in the headspace of the processor through the use of air lock devices at the feed inlet and solids exit, and through the introduction of an inert carrier gas (such as nitrogen) to maintain an oxygen concentration of less than 3 percent. The oxygen and organic content of the off-gas are continuously monitored as it exits the processor.

Entrained particulate matter is collected and combined with the treated solids on a batch basis. The volatilized moisture and organics are subsequently condensed and decanted. A mist eliminator minimizes carry-over of entrained moisture and contaminants after the condenser. Any remaining noncondensible gases are passed through activated carbon beds to control volatile organic compound emissions.

WASTE APPLICABILITY:

This system can treat soils, sediments, and sludges contaminated with volatile and semivolatile organics, including polychlorinated biphenyls. Preliminary testing indicates the system has the potential to treat cyanide. With the exception of mercury, the process is not suitable for treating heavy metals. Wastes must be prescreened to a particle size of less than 1 inch before treatment.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. The SITE demonstration will be at the Niagara-Mohawk Power Company, a manufacturing gas plant site, in Harbour Point, New York, in spring 1992.

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REMEDIATION TECHNOLOGIES, INC.
(Liquid and Solids Biological Treatment)

TECHNOLOGY DESCRIPTION:

Liquid and solids biological treatment (LST) is a process that can be used to remediate soils and sludges contaminated with biodegradable organics. The process is similar to activated sludge treatment of municipal and industrial wastewaters, but it occurs at substantially higher suspended solids concentrations (such as greater than 20 percent) than are encountered in activated sludge applications. An aqueous slurry of the waste material is prepared and environmental conditions (for example, 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. LST systems can be designed for either batch or continuous operations.

Several physical process configurations are possible for LST of contaminated soil and sludges, depending on site- and waste-specific conditions. Batch or continuous treatment can be conducted in impoundment-based reactors. This is sometimes the only practical and economically viable option for very large (greater than 10,000 cubic yards) projects. Alternatively, tank-based systems may be constructed. Considerable differences can exist between applications in which LST is a viable remedial option. Consequently, selection of the most appropriate operational sequence must be determined on a case-specific basis.

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 (CSTR) systems, particularly those with long residence times. Various technologies (such as carbon adsorption and biofiltration) can be used to manage emissions.

Bioremediation by LST may require a sequence of steps involving pre- and post-treatment operations. The only instance in which multiple unit operations are not required is strictly in situ applications where treated sludge residues are destined to remain in place.

An alternative to landfilling of treated solids from an LST process is to conduct overall bioremediation in a hybrid system consisting of both an LST and land treatment system. Combining these two approaches may, for example, be desired to rapidly degrade volatile constituents in a contained system thereby rendering the material suitable to soils in a land-based system for long-term biostabilization.

Remediation Technologies, Inc., (ReTeC) has constructed a mobile LST pilot system that is available for field demonstrations. The system consists of two reaction vessels, two holding tanks, and associated process equipment. Tank operating volumes are 2,000 gallons. The reactors are aerated using coarse bubble diffusers and mixed using axial flow turbine mixers. The reactors can be operated separately or in combination as batch or continuous systems to allow a range of treatment conditions oxygen, and pH are continuously monitored and recorded. Additional features include antifoaming and temperature control systems. Pre- and post-treatment equipment is provided separately depending on site-specific circumstances and project requirements.

WASTE APPLICABILITY:

The technology is suitable for treating sludges, sediments, and soils containing any biodegradable organic materials. To date, the process has been used mainly for treating sludges containing petroleum and wood preservative organics such as creosote and pentachlorophenol. Polycyclic aromatic hydrocarbons, pentachlorophenol, 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:

ReTeC is currently seeking a private party to cofund a 3- to 4-month demonstration of LST technology on an organic waste.

ReTeC has applied the technology in the field over a dozen times to treat wood preservative sludges in impoundment-type LST systems. In addition, two field-based pilot demonstrations and several laboratory treatability studies have been conducted for the treatment of petroleum refinery impoundment sludges.

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RESOURCES CONSERVATION COMPANY
(BEST Solvent Extraction)

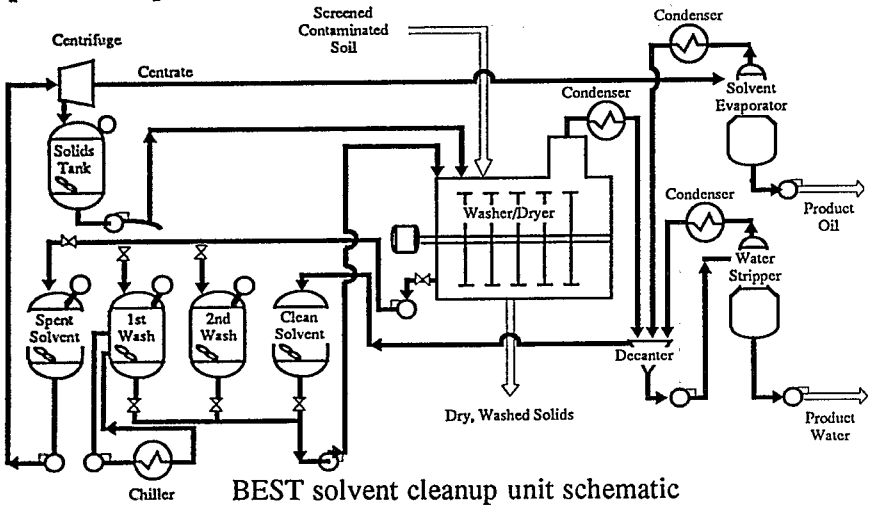
TECHNOLOGY DESCRIPTION:

Solvent extraction is potentially effective in treating oily sludges and soils contaminated with polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), and pesticides by separating the sludges into three fractions: oil, water, and solids. As the fractions separate, contaminants are partitioned into specific phases. For example, PCBs are concentrated in the oil fraction, while metals are separated into the solids fraction. The overall volume and toxicity of the original waste solids are thereby reduced and the concentrated waste streams can be efficiently treated for disposal.

The BEST process is a mobile solvent extraction system (see figure below) that uses one or more secondary or tertiary amines (usually triethylamine [TEA]) to separate organics from soils and sludges. The BEST technology is based on the fact that TEA is completely soluble in water at temperatures below 20 degrees Celsius.

Because TEA is flammable in the presence of oxygen, the treatment system must be sealed from the atmosphere and operated under a nitrogen blanket. Prior to treatment, it is necessary to raise the pH of the waste material to greater than 10, creating an environment where TEA will be conserved effectively for recycling through the process. This pH adjustment may be accomplished by adding sodium hydroxide. Pretreatment also includes screening the contaminated feed solids to remove cobbles and debris for smooth flow through the process.

The BEST process begins by mixing and agitating the cold solvent and waste in an washer/dryer (see figure below). The washer/dryer is a horizontal steam-jacketed vessel with rotating paddles. Hydrocarbons and water in the waste simultaneously solvate with the cold TEA, 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 and fine particles are removed by centrifuging. The resulting dry solids have been cleansed of hydrocarbons but contain most of the original waste's heavy metals, thus further treatment prior to disposal may be required.



BEST solvent cleanup unit schematic

The solvent mixture from the washer/dryer unit (containing the organics and water extracted from the waste) is heated. As the temperature of the solvent increases, the water separates from the organics and solvent. The organics-solvent fraction is decanted and sent to a stripping column, where the solvent is recycled, and the organics are discharged for recycling or disposal. The water phase is passed to a second stripping column where residual solvent is recovered for recycling. The water is typically discharged to a local wastewater treatment plant.

The BEST technology is modular, allowing for on-site treatment. Based on the results of many bench-scale treatability tests, the process significantly reduces the hydrocarbon concentration in the solids. Other advantages of the technology include the production of dry solids, the recovery and reuse of soil, and waste volume reduction. By removing contaminants, the process reduces the overall toxicity of the solids and water streams. It also concentrates the contaminants into a smaller volume, allowing for efficient final treatment and disposal.

WASTE APPLICABILITY:

The BEST process can be used to remove most hydrocarbons or oily contaminants in sludges or soils, including PCBs, PAHs and pesticides (see Table 1). Performance can be influenced by the presence of detergents and emulsifiers, low pH materials, and reactivity of the organics with the solvent.

STATUS:

The first full-scale BEST unit was used at the General Refining Superfund site in Garden City, Georgia. Solvent extraction is the selected remedial action at the Pinnete's Salvage Yard site in Maine, the Ewan Property site in New Jersey, the Norwood PCBs site in Massachusetts and the Alcoa site in Massena, New York. Also it is the preferred alternative at the F. O'Connor site in Maine. The demonstration of the BEST process under the SITE Demonstration Program is scheduled for spring 1992 at Indiana Harbour.

Table 1
SPECIFIC WASTES CAPABLE OF TREATMENT BY SOLVENT EXTRACTION

RCRA Listed Hazardous Wastes

- Creosote-Saturated Sludge
- Dissolved Air Flotation (DAF) Float
- Slop Oil Emulsion Solids
- Heat Exchanger Bundle Cleaning Sludge
- API Separator Sludge
- Leaded Tank Bottoms

Non-Listed Hazardous Wastes

- Primary Oil/Solids/Water Separation Sludges
- Secondary Oil/Solids/Water Separation Sludges
- Bio-Sludges
- Cooling Tower Sludges
- HF Alkylation Sludges
- Waste FCC Catalyst
- Spent Catalyst
- Stretford Unit Solution
- Tank Bottoms
- Treated Clays

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RETECH, INC.
(Plasma Arc Vitrification)

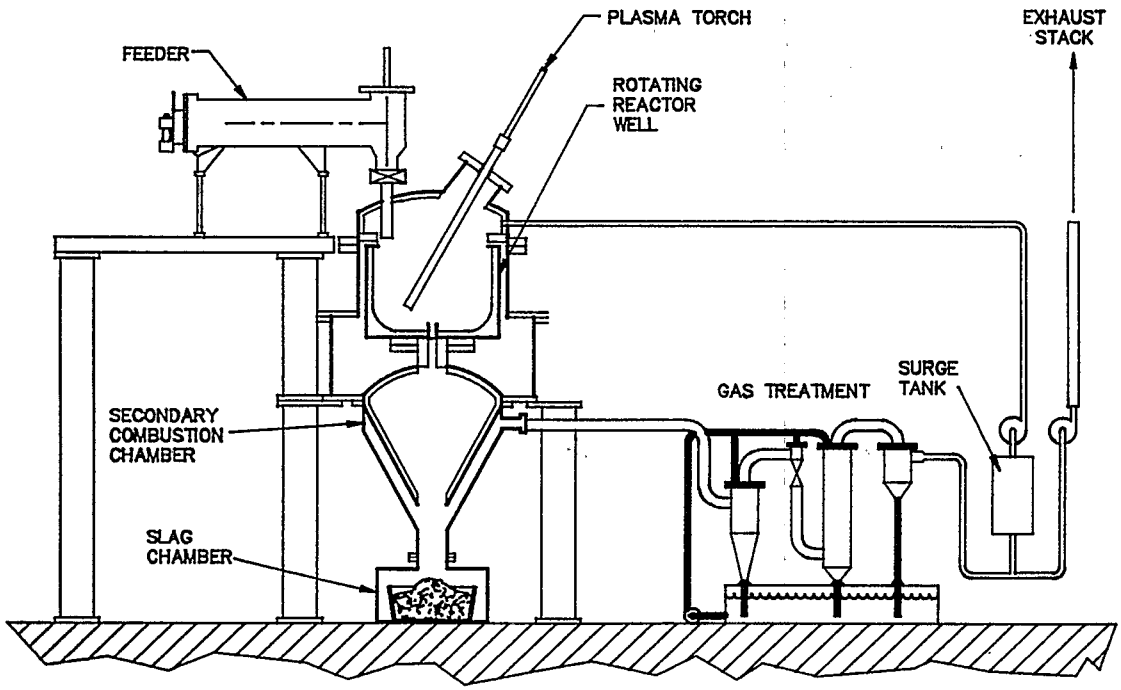
TECHNOLOGY DESCRIPTION:

Plasma Arc Vitrification occurs in a plasma centrifugal furnace by a thermal treatment process where heat from a transferred arc plasma creates a molten bath that detoxifies the feed material. Organic contaminants are vaporized and react at temperatures of 2,000 to 2,500 degrees Fahrenheit (°F) to form innocuous products. Solids melt and are vitrified in the molten bath at 2,800 to 3,000°F. Metals are retained in this phase. When cooled, this phase is a non-leachable, glassy residue which meets the toxicity characteristic leachate procedure (TCLP) criteria.

Contaminated soils enter the sealed furnace through the bulk feeder (see figure below). The reactor well rotates during waste processing. Centrifugal force created by this rotation prevents material from falling out of the bottom and helps to evenly transfer heat and electrical energy throughout the molten phase. Periodically, a fraction of the molten slag is tapped, falling into the slag chamber to solidify.

Off-gas travels through a secondary combustion chamber where it remains at 2,000 to 2,500°F for more than 2 seconds. This allows the complete destruction of any organics in the gas. After passing through the secondary combustion chamber, the gases pass through a series of air pollution control devices designed to remove particulates and acid gases. In the event of a process upset, a surge tank allows retention for reprocessing.

Residuals from the cleanup system can sometimes be fed back to the furnace. Salts resulting from neutralizing chlorides must



Plasma centrifugal furnace

eventually be discarded. In some circumstances, metals can be recovered from the scrubber sludge.

WASTE APPLICABILITY:

Liquid and solid organic compounds and metals can be treated by this technology. It is most appropriate for chemical plant residues and by-products, low-level mixed radioactive wastes, and contaminated soils. It may also be useful for medical wastes, sewage, sludge, and incinerator ash.

STATUS:

The SITE demonstration was conducted in July 1991 at a Department of Energy research facility in Butte, Montana. During the demonstration, the furnace processed approximately 4,000 pounds of waste. All feed and effluent streams were sampled to assess the performance of this technology. A report on the demonstration project will be available in spring or summer 1992.

A production size furnace has been permitted and commissioned in Muttenz, Switzerland. At this installation, the furnace is designed to feed 55-gallon (200-liter) drums. Each drum and its contents are fed and destroyed, one drum at a time.

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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 uses no polyethylene glycol (PEG) and represents a clean and inexpensive process for the remediation of soils and sediments contaminated with chlorinated organic compounds.

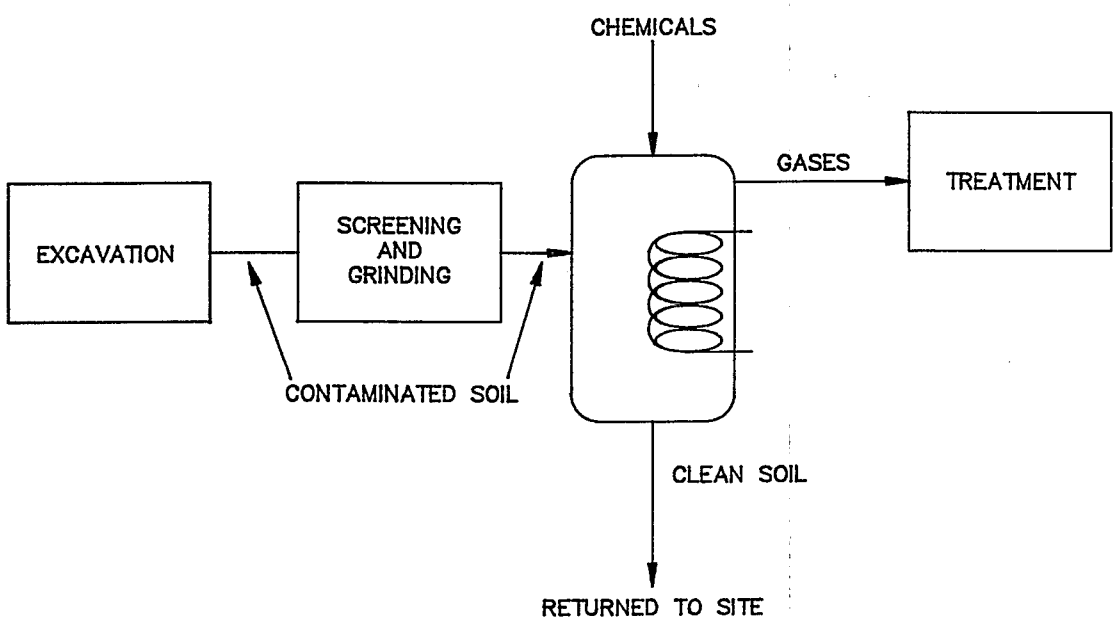
The process (see figure below) begins by mixing the chemicals with the contaminated matrix, such as excavated soil or sediment or liquids containing toxic compounds. This mixture is heated at 340 degrees Celsius (°C) for several hours. The off gases are treated before they are released into the atmosphere. The treated remains are non-hazardous and can be either disposed of according to standard methods or further processed for separating components for reuse.

WASTE APPLICABILITY:

This process is potentially applicable to soils and sediments contaminated with chlorinated organic compounds; mainly polychlorinated biphenyls (PCB), used as a dielectric in transformers and polychlorinated phenols (PCP), used as a wood preserving substance.

STATUS:

Under the SITE Demonstration Program, the BCD process will be used to decontaminate PCB-contaminated soil at a Navy site in Stockton, California, in June 1992. Upon



Process Flow Chart

successful completion of this demonstration, a follow-up decontamination will be done in Guam by the Navy.

In cooperation with Region 7, RREL is attempting to apply BCD technology to dechlorinating liquid and solid formulations of several banned herbicides (containing dioxin) at St. Joseph, Missouri. Recent laboratory tests have yielded promising results. Optimization of reaction conditions and engineering research are ongoing for scaling up the process from laboratory to large-scale operation.

For treatment of contaminated soils, the BCD technology is being made ready for licensing for commercial use. Several companies have shown strong interest in licensing the technology.

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RISK REDUCTION ENGINEERING LABORATORY
(Bioventing)

TECHNOLOGY DESCRIPTION:

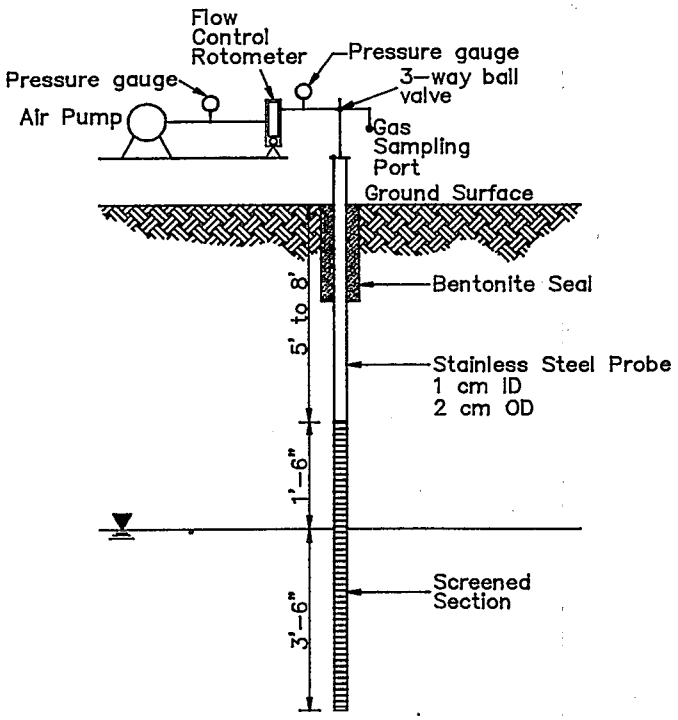
This biological treatment system uses the injection of atmospheric air to treat contaminated soil in situ. This air provides a continuous oxygen source, which enhances the growth of microorganisms naturally present in the soil.

This technology uses a low-pressure air pump (see figure below) attached to one of a series of air injection probes. The air pump operates at extremely low pressures. The low pressures allow for inflow of oxygen without volatilization of contaminants that may be present in the soil. The treatment capacity is limited by the number of injection probes, the size of the air pump, and site characteristics such as soil porosity.

Aerobic microbial growth in contaminated soil is often limited by the lack of oxygen. Additional additives, such as ozone or nutrients, also may be required to stimulate microbial growth. the figure below is a schematic diagram of the air injection/sample system.

WASTE APPLICABILITY:

This technology is typically used to treat soil contaminated by numerous industrial processes. It may be applied to any contamination subject to aerobic microbial degradation. Different contaminants and combinations of contaminants may have varied degrees of success. The SITE Demonstration Program specifically plans to test the effectiveness of bioventing to promote the



Schematic of the air injection/sample system

degradation of polycyclic aromatic hydrocarbons.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. Treatability tests were conducted in July 1991, to determine whether a site owned by Allied-Signal in Ironton, Ohio, will be suitable for the demonstration of this process. If this site is selected, the demonstration is expected to begin in fall 1991.

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

TECHNOLOGY DESCRIPTION:

This technology was developed by EPA's Risk Reduction Engineering Laboratory (RREL) staff and IT Corporation to decontaminate debris currently found at Superfund sites throughout the country. The pilot-scale debris washing system (DWS) was demonstrated under the SITE Program.

The DWS consists of 300-gallon spray and wash tanks, surfactant and rinse water holding tanks, and an oil-water separator (see figure below). The decontamination solution treatment system includes a diatomaceous earth filter, an activated carbon column, and an ion exchange column. Other required equipment includes pumps, a stirrer motor, a tank heater, a metal debris basket, and particulate filters.

The DWS unit is transported on a 48-foot semitrailer. At the treatment site, the DWS unit is assembled on a 25 by 24 foot concrete pad and enclosed in a temporary shelter.

A basket of debris is placed in the spray tank with a forklift, where it is sprayed with an aqueous detergent solution. High-pressure water jets blast contaminants and dirt from the debris. Detergent solution is continually recycled through a filter system that cleans the liquid.

The wash and rinse tanks are supplied with water at 140 degrees Fahrenheit (°F), at a pressure of 60 pounds per square inch gauge (psig). The contaminated wash solution is collected and treated prior to discharge. An integral part of the technology involves treating

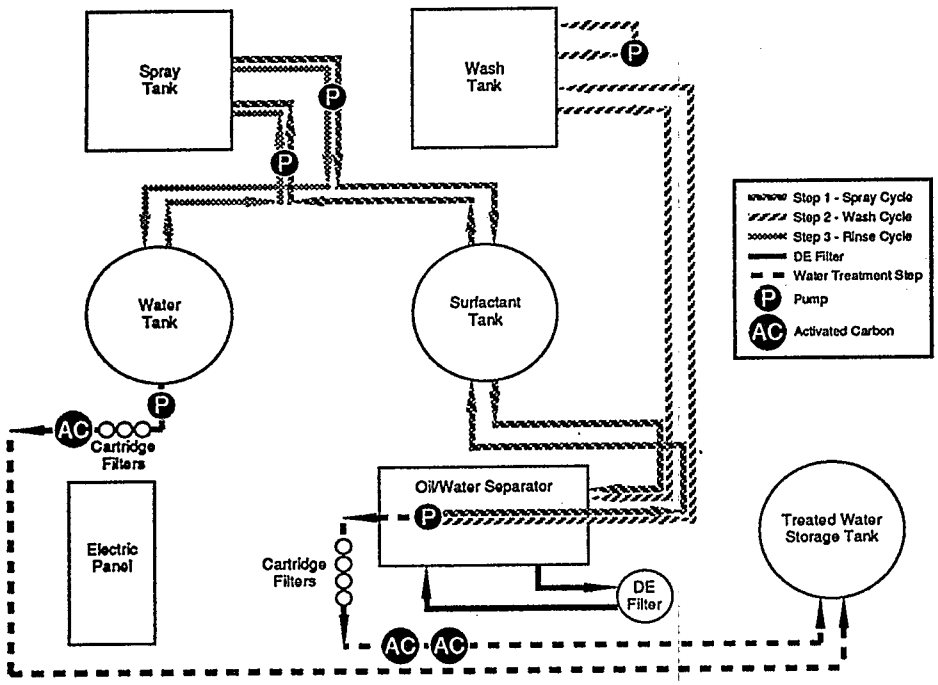

Figure: Schematic of the pilot-scale debris washing system.

the detergent solution and rinse water to reduce the contaminant concentration to allowable discharge levels. Process water treatment consists of particulate filtration, activated carbon adsorption, and ion exchange. Approximately 1,000 gallons of liquid are used during the decontamination process.

WASTE APPLICABILITY:

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

STATUS:

The first pilot-scale test was performed at EPA's Region 5 Carter Industrial Superfund site in Detroit, Michigan. PCB reductions averaged 58 percent in batch 1 and 81 percent in batch 2. Design changes were made and tested on the unit before additional field testing.

Field testing was conducted using an upgraded pilot-scale DWS at a PCB-contaminated Superfund site in Hopkinsville, Kentucky (EPA Region 4), during 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. 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 at another Superfund site in Region 4, the Shaver's Farm site in Walker County, Georgia. The contaminants of concern were benzonitrile and dicamba. After being cut into sections, 55-gallon drums were placed in the DWS and carried through the decontamination process.

Benzonitrile and dicamba levels on the surfaces of drums were reduced from the average pretreatment concentrations of 4,556 and 23 micrograms (μg) per 100 square centimeters to average concentrations of 10 and 1 μg/100 square centimeters, 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."

Further development of this technology by RREL and IT Corporation includes design, development, and demonstration of a full-scale mobile version of the DWS.

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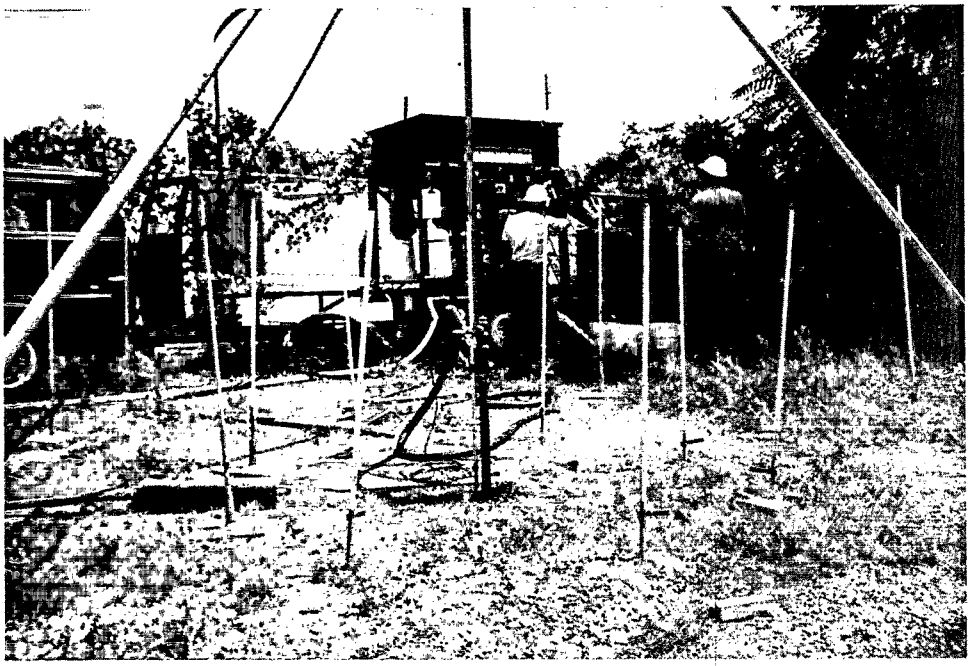
RISK REDUCTION ENGINEERING LABORATORY and THE UNIVERSITY OF CINCINNATI
(Hydraulic Fracturing)

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. This technology has been developed for EPA's Risk Reduction Engineering Laboratory by the University of Cincinnati (UC) at the Center Hill facility under the SITE Program.

The fracturing process (see photograph below) begins with the injection of a fluid (water) into a sealed borehole until the pressure of the fluid exceeds a critical value and a fracture is nucleated, forming a starter notch. A proppant composed of a granular material (sand) and a viscous fluid (guar gum and water mixture) is then pumped into the fracture as the fracture grows away from the well. After pumping, the



Hydraulic fracturing in progress, the well is located at the center of the photograph.

proppant grains hold the fracture open while an enzyme additive breaks down the viscous fluid. The resulting 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 is 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 for delivery of solids to the subsurface. Solid compounds useful in bioremediation, such as nutrients or oxygen-releasing compounds, can be injected as granules into the fractures.

Techniques for measuring deformation of the ground surface have been developed for this technology by UC to monitor the position of the fractures in the subsurface.

WASTE APPLICABILITY:

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

STATUS:

The RREL 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, during July and August 1991, respectively. The hydraulic fracturing process has been integrated with remediation by soil vapor extraction at the Illinois site and with in situ bioremediation at the Ohio site. Additional feasibility study sites are planned. A final full-scale demonstration site will be selected in the near future.

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RISK REDUCTION ENGINEERING LABORATORY and USDA FOREST PRODUCTS LABORATORY

(Fungal Treatment Technology)

TECHNOLOGY DESCRIPTION:

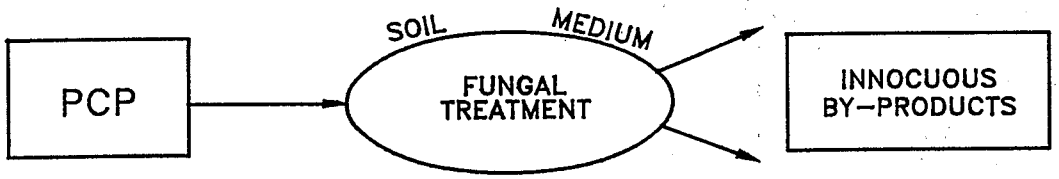
This biological treatment system uses white rot fungi to treat soils in situ. White rot fungi have been found to degrade certain organic contaminants.

Organic material inoculated with the fungi and wood chips are mechanically mixed into the contaminated soil. In the process of wood degradation, the fungi also break down contaminants in the soil.

Because this technology uses a living organism (the fungi), the greatest degree of success occurs with optimal growing conditions. Additives enhance growing conditions and may be required for successful treatment. Moisture control is necessary, and temperature control may be utilized. Addition of wood chips may also be included in the process to decrease the toxicity of the soil. Nutrients, such as peat, may be added to provide a source of organic carbon.

WASTE APPLICABILITY:

This technology is typically used to treat soil contaminated with chemicals found in the wood preserving industry. Contaminants include chlorinated organics and polycyclic aromatic hydrocarbons. Different contaminants and combinations of contaminants may have varied degrees of success. In particular, the SITE Demonstration Program is evaluating the effectiveness of white rot fungi in degradation of pentachlorophenol (PCP).



In–place White Rot Fungal Treatment of contaminated soil

STATUS:

This technology was accepted into the SITE Demonstration Program in April 1991. Treatability tests are scheduled for September 1991, to determine whether the Brookhaven Wood Preserving site in Brookhaven, Mississippi, will be suitable for the demonstration of this process. If this site is selected, the demonstration is expected to start in early spring 1992.

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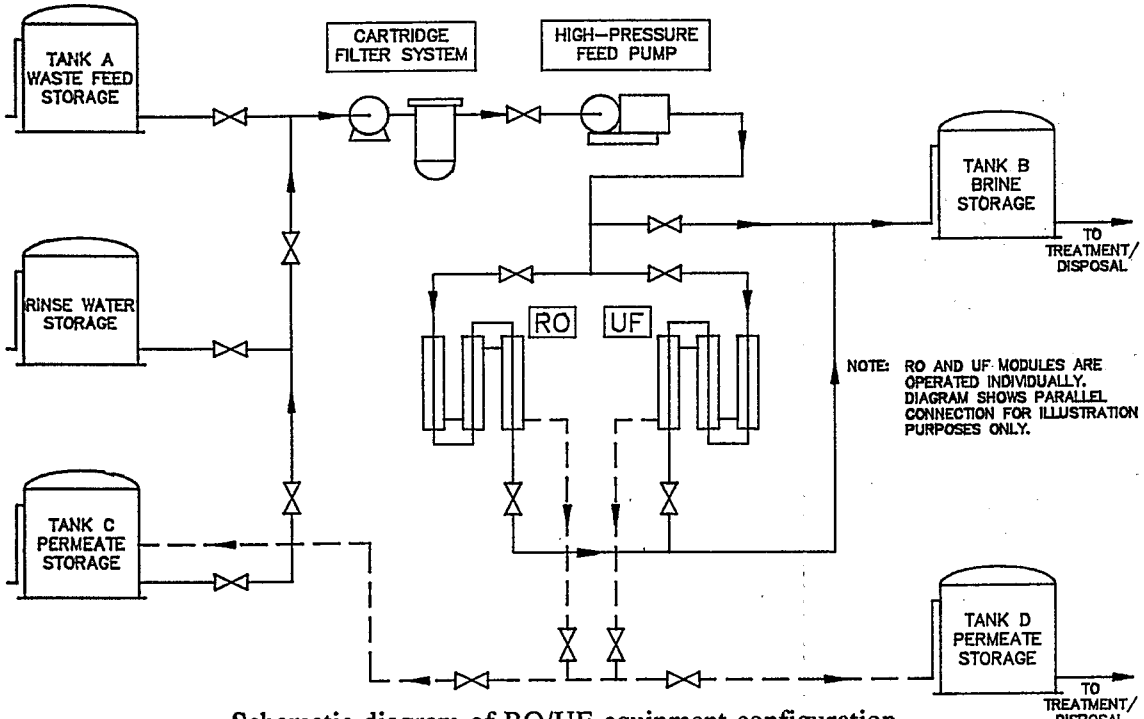
ROCHEM SEPARATION SYSTEMS, Inc.
(Rochem Disc Tube Module System)

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 semi-permeable membrane to separate pure water from contaminated liquids. The application of osmotic theory implies that when a saline solution is separated from pure water by a semi-permeable membrane, the higher osmotic pressure of the salt solution (due to 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. At this point, the salt concentrations of the two solutions will be equal, after which no driving force will remain for any additional mass transfer across the membrane. However, if an external pressure is exerted on the salt solution, water will flow in the reverse direction from the salt solution into the pure water. This phenomenon, known as reverse osmosis (RO), can be employed to separate pure water from contaminated matrices, such as the treatment of hazardous wastes via concentration of hazardous chemical constituents in an aqueous brine, while recovering pure water on the other side of the membrane.

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. The size of the particle rejected by ultrafiltration depends on the inherent properties



Schematic diagram of RO/UF equipment configuration

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 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 purity that RO can. Therefore, 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.

A general schematic of the RO/UF equipment as it will be applied at the SITE demonstration is provided in the figure on the previous page. Waste feed, process permeate, and rinse water are potential feed materials to the RO or UF modules, which are skid-mounted and consist of a tank and a high-pressure feed system. The high pressure feed system consists of a centrifugal feed pump, a prefilter cartridge housing, and a triplex plunger pump to feed the RO/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 types of waste material 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, and solvent/water 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. A Demonstration is planned for early 1992 at a site to be determined. A suitable site would involve the cleanup of contaminated groundwater or landfill leachate. During the demonstration, approximately 2 to 4 gallons per minute of contaminated water will be processed over a 2- to 3-week period. All feed and residual effluent streams will be sampled to evaluate the performance of this technology. A report on the demonstration project will be forthcoming.

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SBP TECHNOLOGIES, INC.
(Membrane Separation and Bioremediation)

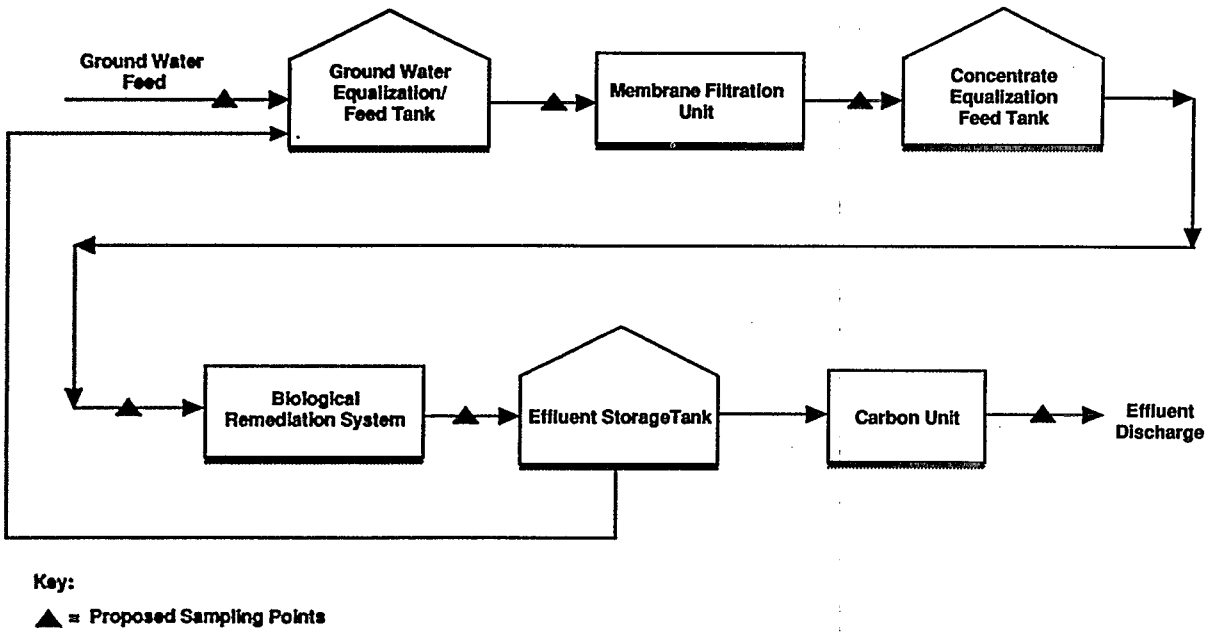
TECHNOLOGY DESCRIPTION:

SBP Technologies, Inc. (SBP), has developed a hazardous waste treatment system consisting of (1) a filtration unit for extraction and concentration of contaminants from groundwater, surface water, or slurries and (2) a bioremediation system for treating concentrated groundwater and soil slurries (see figure below). These two systems are able to treat a wide range of waste materials separately or as part of an integrated waste handling system.

The SITE demonstration will evaluate the effectiveness of these two technologies on creosote-contaminated groundwater in two separate demonstrations.

The filtration unit can remove and concentrate the contaminants by filtering contaminated groundwater through a specially developed membrane. Depending on local requirements and regulations, the filtered water produced can be discharged to the sanitary sewer for further treatment at publicly owned treatment works. The concentrated contaminants are collected in a holding tank.

The bioreactor, using a proprietary microorganism mixture, can biologically destroy concentrated contaminants and can produce effluent with low to nondetectable levels of contaminants. Integrating the two units will allow many contaminants to be removed and destroyed on site.



Membrane separation and biological treatment schematic diagram

WASTE APPLICABILITY:

The bioremediation technology is intended for use in treating groundwater, soils, and sludges contaminated with organic compounds. Current technology has been applied to waste contaminated with polycyclic aromatic hydrocarbons (PAH), creosote, polychlorinated biphenyls, trichloroethylene, oily wastes, and jet and diesel fuels. The two technologies can be used separately or together. For example, on wastewaters or slurries contaminated with inorganics or materials not easily bioremediated, the filtration unit can separate the material for treatment or handling by another process. Both the filtration unit and the bioremediation system can be used as part of a soil cleaning system to handle residuals and contaminated liquids. The system is extremely versatile, depending on site characteristics and waste destruction needs.

STATUS:

These two technologies are being demonstrated from August 1991 to December 1991. The first demonstration, on the filtration unit, occured in October 1991. During treatability testing, PAH removal was sufficient to pass local publicly owned treatment works (POTW) discharge standards.

The second demonstration, on the bioremediation technology, will be conducted in November 1991. Two predemonstration runs will be conducted in order for SBP to monitor and evaluate the effectiveness of the specific proprietary microorganisms. The two demonstrations are being performed on creosote-contaminated groundwater.

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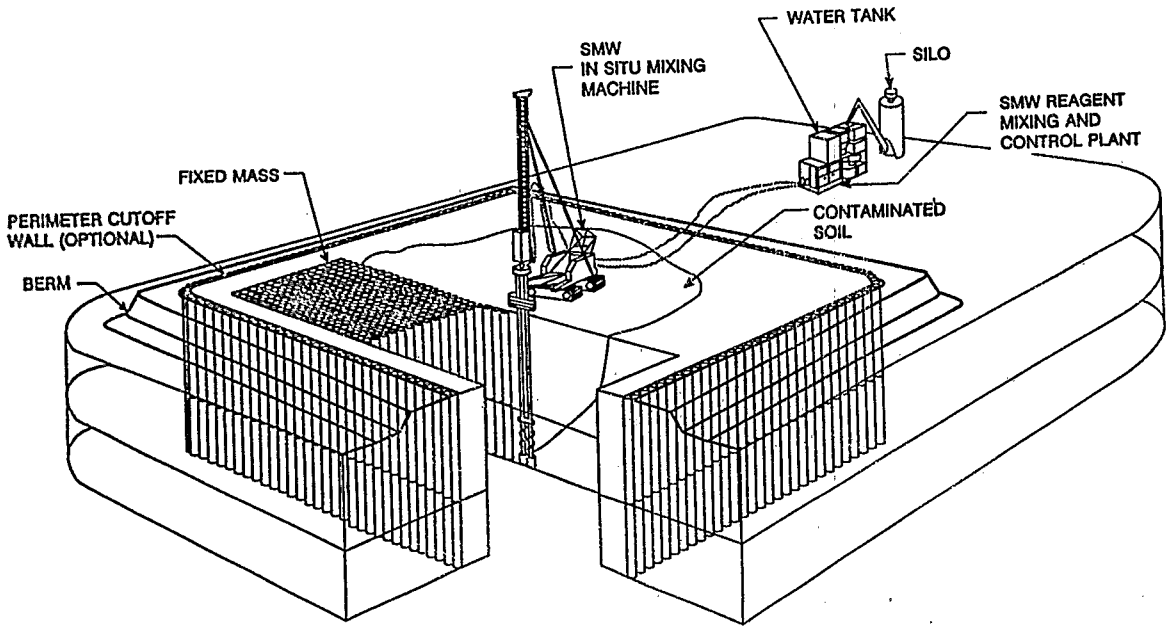
S.M.W. SEIKO, INC.
(In Situ Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

The soil-cement mixing wall (SMW) technology, developed by S.M.W. Seiko, Inc., involves the in situ fixation, solidification, and stabilization of contaminated soils. The technology has been used in mixing soil, cement, and chemical grout for more than 18 years on 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 and blend them with contaminated soils in situ. The augers are mounted on a crawler-type base machine. A batch mixing plant and raw materials storage tanks are also involved. The machine can treat 90 to 140 cubic yards of soil in 8 hours at depths of up to 100 feet.

The product of the SMW technology is 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 fixation reagents and water required for treatment.



Schematic of SMW in situ fixation of contaminated soil at depth

WASTE APPLICABILITY:

This technology can be applied to soils contaminated with metals and semivolatile organic compounds such as pesticides, polychlorinated biphenyls (PCBs), phenols, and polycyclic aromatic hydrocabons (PAHs).

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1989. Site selection is underway.

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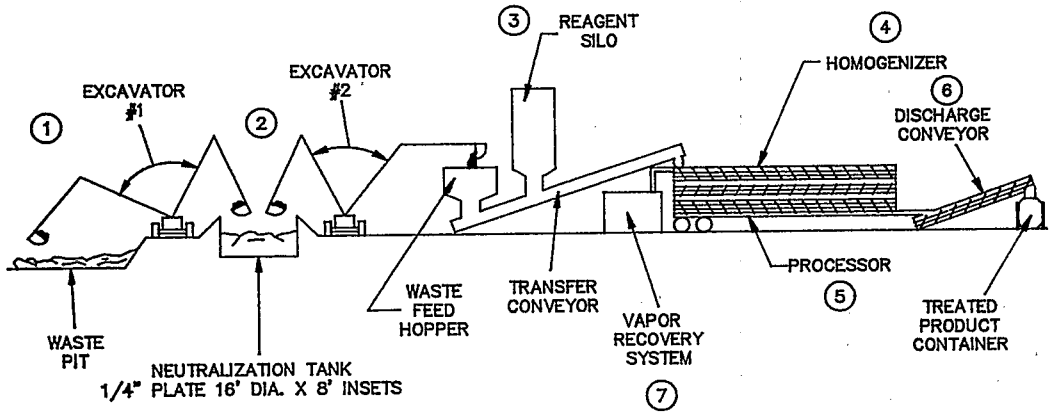
SEPARATION AND RECOVERY SYSTEMS, INC.
(SAREX Chemical Fixation Process)

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 semivolatile organic compounds (SVOC), and the remaining constituents of organic and inorganic sludge materials in a stable matrix. 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 toxic 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.

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 VOCs and SVOCs. 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



NOTES:
1. EXCAVATION/NEUTRALIZATION/VAPOR CONTROL
2. PRE-PROCESS BLENDING/NEUTRALZATION
3. WASTE FEED TO PROCESSOR
4. HOMOGENIZING
5. PROCESSING
6. DISCHARGE CONVEYOR
7. VAPOR RECOVERY SYSTEM (VRS)

SAREX chemical fixation process

complete the process. The processed material exits the processor onto a discharge conveyor for movement into SRS-designed sealed transport containers for delivery to the end use.

Contaminants loss into the air (mobility) during processing is eliminated by use of a specially designed SAREX vapor recovery system and processed prior to release into the air. Dust particles are removed in a baghouse, and the vapors are routed through a series of water scrubbers, which cool the vapors [below 120 degrees Fahrenheit (°F)] and remove any condensates. The vapors then pass through two demisters and a positive displacement blower to remove additional condensates. A freon chilling unit (37°F or 0°F) cools the remaining vapors, which are sent to a storage tank. The final vapor stream is polished in two charcoal vapor packs before being emitted into the air.

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 there may be steaming caused by the exothermic reactions. 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

In addition, metals are captured within the treated matrix and will pass the toxicity characteristics leaching procedure (TCLP). This proves to be advantageous, because most on-site cleanup programs focus on sludge ponds or impoundments that have received many different types of compounds and debris over several years.

STATUS:

During the development of the SAREX CFP technology, data has been gathered from laboratory analysis, process demonstrations, and on-site projects. Samples of sludges from two ponds were analyzed for surface and bottom characteristics. After treatment of the samples, the products were analyzed in powder and molded pellet form.

A field demonstration was conducted during 1987 at a midwest refinery by treating approximately 400 cubic yards of lube oil acid sludges. Two projects each were completed in the midwest, California, and Australia.

SRS expects to conduct a SITE demonstration during 1992. EPA is seeking a suitable site for the demonstration.

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SILICATE TECHNOLOGY CORPORATION
(Solidification and Stabilization Treatment Technology)

TECHNOLOGY DESCRIPTION:

Silicate Technology Corporation's (STC) technology for treating hazardous waste utilizes silicate compounds to solidify and stabilize organic and inorganic constituents in contaminated soils, sludges, and wastewater.

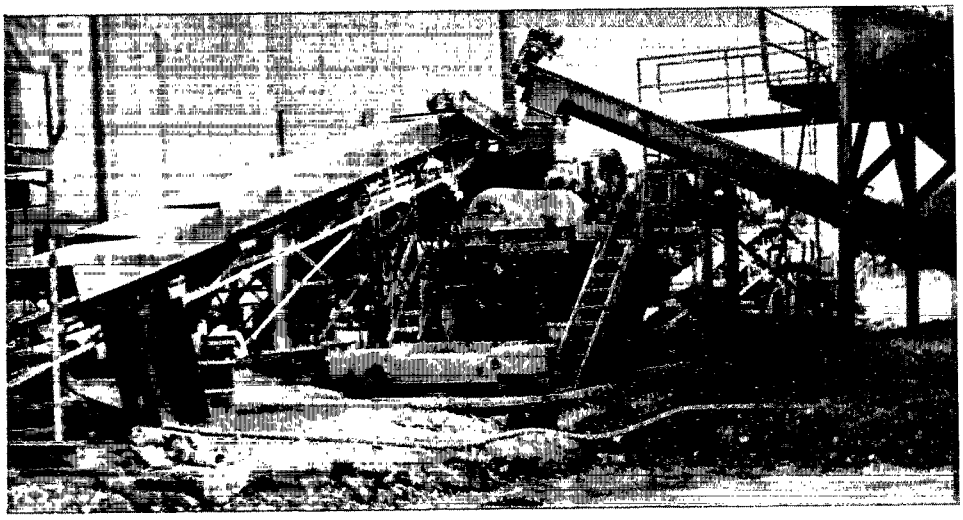
STC's organic chemical fixation/solidification technology involves the bonding of the organic contaminants into the layers of the of an alumino silicate compound. STC's inorganic chemical fixation/solidification technology involves the formation of insoluble chemical compounds which reduces the overall reagent addition compared to generic cementicious processes.

Pretreatment of contaminated soil (see figure below) includes separation of coarse and fine waste materials, and the crushing of coarse material, reducing it to the size required for the solidification and stabilization technology. The screened waste is weighed and a predetermined amount of silicate reagent is added. The material is conveyed to a pug mill mixer where water is added and the mixture is blended. Sludges are placed directly into the pug mill for addition of reagents and mixing. The amount of reagent required for solidification and stabilization can be adjusted according to variations in organic and inorganic contaminant concentrations determined during treatability testing. Treated material is placed in confining pits for on-site curing or cast into molds for transport and disposal off-site.

STC's technology has been successfully implemented on inorganic and organic contaminated hazardous remediation projects, inorganic and organic industrial wastewater treatment systems, industrial in-process treatment, and RCRA landban treatment of F006 and K061 wastes. A typical remediation project would include pretreatment of the waste which consists of screening and crushing operations.

WASTE APPLICABILITY:

STC's technology can be applied to a wide variety of hazardous soils, sludges, and wastewaters. Applicable waste media include the following:



Pretreatment of contaminated soil

- Inorganic contaminated soils and sludges. Contaminants including most metals, cyanides, flourides, arsenates, chromates, and selenium.
- Organic contaminated soils and sludges. Organic compounds including halogenated aromatics, polycyclic aromatic hydrocarbons (PAHs), and aliphatic compounds.
- Inorganic and organic contaminated wastewaters. Heavy metals, emulsified and dissolved organic compounds in groundwater and industrial wastewater, excluding low-molecular-weight organic contaminants such as alcohols, ketones, and glycols.

STATUS:

Under the SITE Demonstration Program, the technology was demonstrated in November 1990 at the Selma Pressure Treating (SPT) wood preserving site in Selma, California. The SPT site was contaminated with both organics, mainly pentachlorophenol (PCP), and inorganics, mainly arsenic, chromium and copper. The Applications Analysis Report and Technology Evaluation Report will be published in winter 1992.

DEMOSTRATION RESULTS:

- STC's technology can treat PCP. Extract and leachate concentrations of PCP were reduced by up to 97 percent.
- The technology can immobilize arsenic. Toxicity characteristic leaching procedure (TCLP) and TCLP-distilled water leachate concentrations were reduced by up to 92 and 98 percent, respectively.
- The technology can immobilize chromium and copper. Initially low TCLP and TCLP-distilled water leachate concentrations of chromium (0.07 to 0.27 ppm) were reduced by up to 54 percent. Initial TCLP and TCLP-distilled water leachate concentrations of copper (0.4 and 9.4 ppm) were reduced by up to 99 and 90 percent, respectively.
- Immobilization of semivolatile organic compounds and volatile compounds other than PCP could not be evaluated due to the low concentrations of these analytes in the wastes.
- Treatment of the wastes resulted in volume increases ranging from 59 to 75 percent (68 percent average).
- After a 28-day curing period, the treated wastes exhibited moderately high unconfined compressive strengths of 260 to 350 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 and dry and 12 freeze and thaw cycles was negligible (less than 1 percent).
- STCs technology is expected to cost approximately $200 per cubic yard when used to treat large amounts (15,000 cubic yards) of waste similar to that found at the SPT demonstration site.

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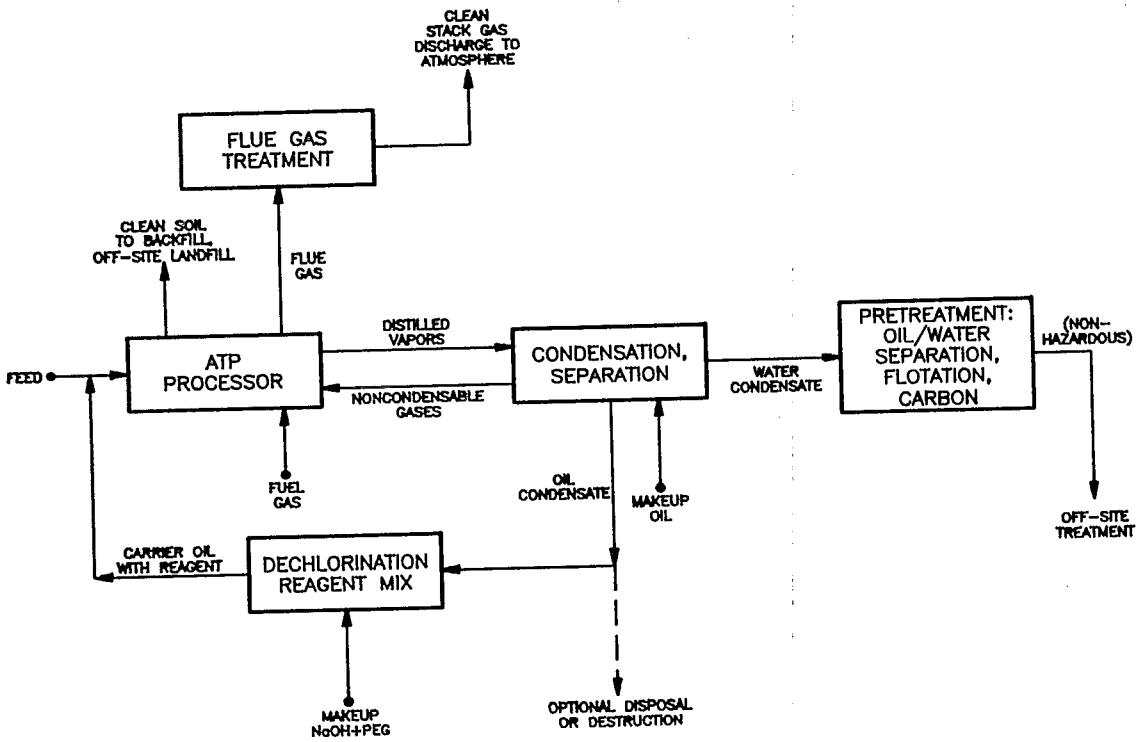
SOILTECH, INC.
(Anaerobic Thermal Processor)

TECHNOLOGY DESCRIPTION:

The SoilTech anaerobic thermal processor (ATP) (see figure below) is a thermal desorption process. It heats and mixes contaminated soils, sludges, and liquids in a special rotary kiln that uses indirect heat for processing. The unit desorbs, collects, and recondenses hydrocarbons from solids. The unit also can be used in conjunction with a dehalogenation process to destroy halogenated hydrocarbons through a thermal and chemical process.

The kiln portion of the system contains four separate internal thermal zones: preheat, retort, combustion, and cooling. In the preheat zone, water and volatile organic compounds vaporize. The vaporized contaminants and water are removed by vacuum to a preheat vapor cooling system consisting of a cyclone to remove solids and a heat exchanger and separator to condense liquids and separate the aqueous oil and noncondenseable gas phases.

From the preheat zone, the hot granular solids and unvaporized hydrocarbons pass through a sand seal to the retort zone. Heavy oils vaporize in the retort zone, and thermal cracking of hydrocarbons forms coke and low molecular weight gases. The vaporized contaminants are removed by vacuum to a retort gas handling system. After cyclones remove dust from gases, the gases are cooled, and condensed oil is separated into its various fractions. The coked soil passes through a second sand seal from the retort zone to the combustion zone. Coke is burned and the hot soil is either recycled back to the retort zone or sent to the cooling zone.



Schematic diagram of the ATP process

Flue gases from the combustion zone are treated prior to discharge. The flue gas treatment system consists of the following units set up in series: (1) cyclone and baghouse for particle removal, (2) wet scrubber for removal of acid gases, and (3) carbon adsorption bed for removal of trace organic compounds.

The combusted soil that enters the cooling zone is cooled in the annular space between the outside of the preheat and retort zones and the outer shell of the kiln. Here, the heat from the soils is transferred to the soils in the retort and preheat zones. The cooled treated soil and coke exiting the cooling zone is quenched with water, then transported by conveyor to a storage pile.

When the ATP is used to dechlorinate contaminants, the contaminated soils are sprayed with an oil mixture containing an alkaline reagent and polyethylene glycol, or other reagents. The oil acts as a carrier for the dehalogenation reagents. In the unit, the reagents dehalogenate or chemically break down chlorinated compounds, including polychlorinated biphenyls (PCB).

WASTE APPLICABILITY:

The technology can be used for (1) oil recovery from tar sands and shales, (2) dechlorination of PCBs and chlorinated pesticides in soils and sludges, (3) separation of oils and water from refinery wastes and spills, and (4) general removal of hazardous organic compounds from soils and sludges.

STATUS:

This technology was accepted into the EPA SITE Demonstration Program in March 1991. The technology will be involved in two SITE demonstrations. In May 1991, the first demonstration used a full-scale unit on soils contaminated with PCBs at the Wide Beach Development Superfund site in Brant, New York. The second demonstration, scheduled for January 1992, will use a full-scale unit at the Outboard Marine Corporation site in Waukegan, Illinois.

DEMONSTRATION RESULTS:

The preliminary SITE Demonstration test results indicated that:

- The SoilTech ATP unit removed over 99 percent of the PCBs in the contaminated soil, resulting in PCB levels below the desired cleanup concentration of 2 parts per million (ppm).
- The SoilTech ATP does not appear to create dioxins or furans.
- No volatile or semivolatile organic degradation products were detected in the treated soil. There were also no leachable volatile organic compounds (VOC) or semivolatile organic compounds (SVOC) detected in the treated soil.
- No operational problems affecting the ATP's ability to treat the contaminated soil were observed.

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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.

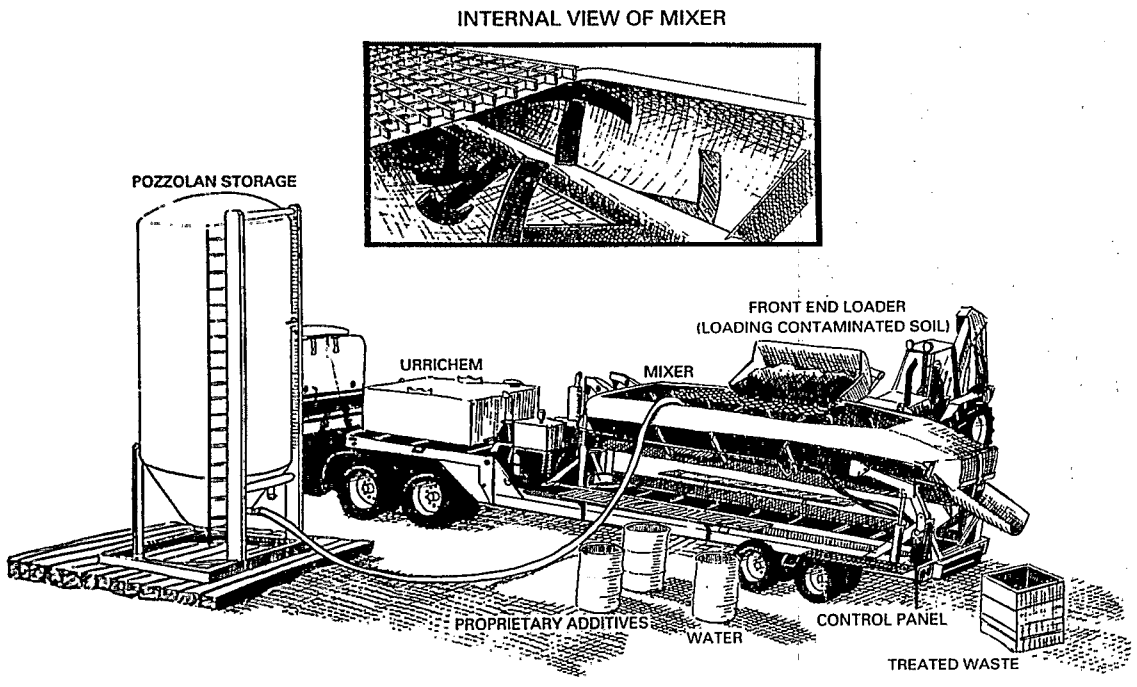
Contaminated waste materials are collected, screened to remove oversized material, and introduced to the batch mixer (see figure below). The waste material is then mixed with (1) water, (2) Urrichem -- a proprietary chemical reagent, (3) proprietary additives, and (4) pozzolanic material (fly ash), kiln 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, high stability, and a rigid texture similar to that of concrete.

WASTE APPLICABILITY:

This technology is intended for treating 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. Wastes treated during the demonstration were soils, filter cake, and oily wastes from an old storage tank. These wastes were contaminated with petroleum



Soliditech processing equipment

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

DEMONSTRATION RESULTS:

Key findings from the Soliditech demonstration are summarized below:

- Chemical analyses of extracts and leachates showed that heavy metals present 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 samples showed: (1) unconfined compressive strengths 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 Leachate 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 contained 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/540/5-89/005A) is the report; Volume II (EPA/540/5-89/005B) contains data to supplement the report. An Applications Analysis Report was published in September 1990 (EPA/4540/A5-89/005).

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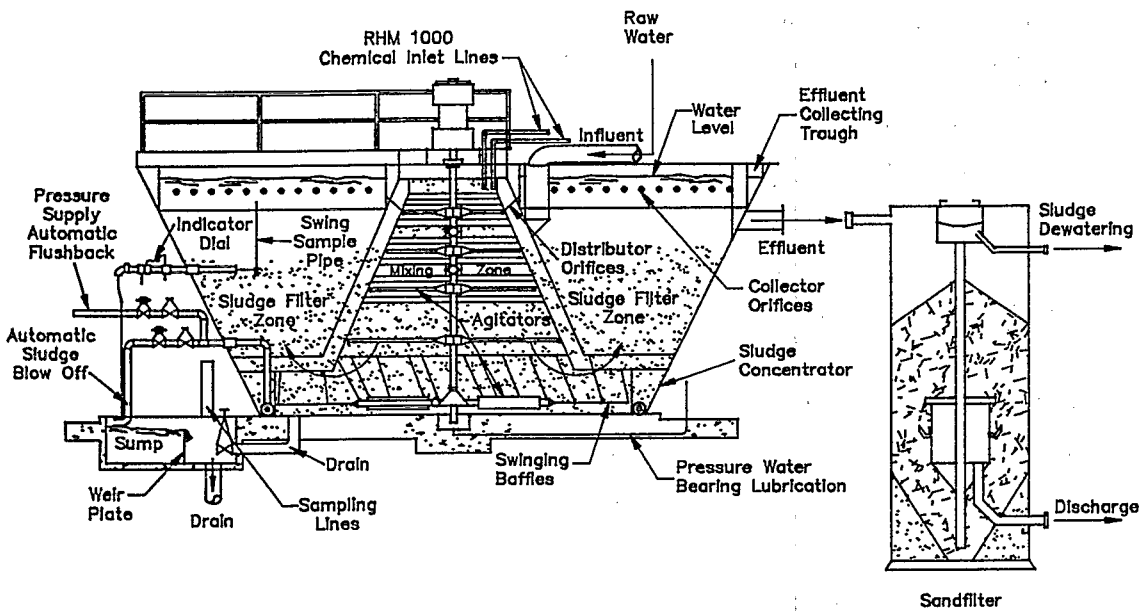
TECHTRAN, INC.
(Combined Chemical Binding and Precipitation, and Physical Separation of Radionuclides)

TECHNOLOGY DESCRIPTION:

This chemical binding and physical separation method involves rapid, turbulent mixing of the proprietary material which consists of a fine powder (RHM 1000) containing complex oxides and other reactive binding agents. RHM 1000 absorbs, adsorbs, and chemisorbs most radionuclides and heavy metals in water, sludges, or soils (preprocessed into slurry), yielding coagulating, flocculating, and precipitating reactions. The pH, mixing dynamics, and processing rates are carefully chosen to optimize the binding of contaminants. Tests have shown that as little as 0.05% RHM 1000 per test run is needed for maximum binding.

Water is separated from the solids by using a reliable, economical, two-stage process based on (1) particle size and density separation, using clarifier technology and microfiltration of all particles and aggregates, and (2) dewatering, using a sand filter to produce a concentrate of radionuclides, heavy metals, and other solids. The material that is collected is stabilized and ready for disposal.

The figure below shows a diagram of the steps employed in this process for water. The process is designed for continuous throughput for water (50 to 1500 gallons per minute [gpm]) (see figure below). This technology can accommodate trace levels of naturally-occurring radioactive materials (NORM), and low-level



Schematic diagram of continuous operation for removing radionuclides and heavy metals from contaminated wastewater.

radioactive wastes. The equipment is trailer-mounted for use as a mobile field system. Larger capacity systems could be skid-mounted.

WASTE APPLICABILITY:

The technology can be used for (1) cleanup and remediation of water, sludges, and soils contaminated with radium, thorium, uranium and heavy metals from uranium mining and milling operations, (2) cleanup of water containing NORM and heavy metals from oil and gas drilling, and (3) cleanup and remediation of man-made radionuclides stored in underground tanks, pits, ponds, or barrels. This technology has not yet been tested for water containing tritium.

STATUS:

This technology was accepted into the EPA SITE Demonstration Program in July 1990. EPA is seeking a suitable site to demonstrate this technology.

Possible disposal methods of the stabilized end product would be those required for low-level radioactive contamination.

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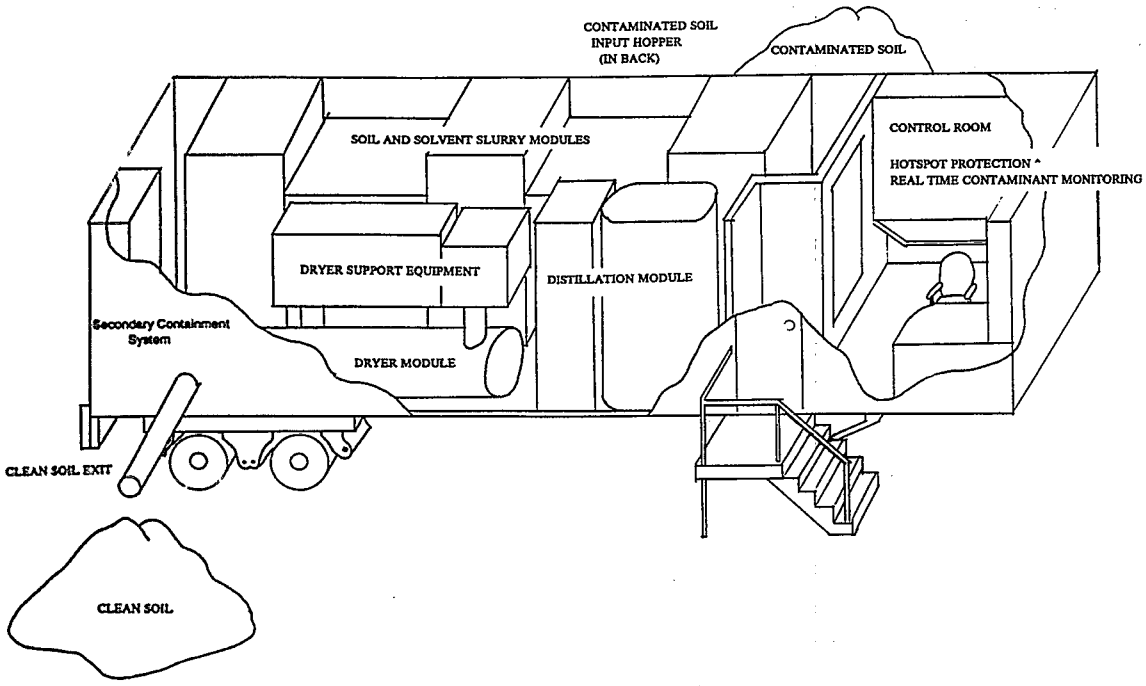
TERRA-KLEEN CORPORATION
(Soil Restoration Unit)

TECHNOLOGY DESCRIPTION:

The soil restoration unit (see figure below) is a mobile solvent extraction remediation device for the on-site removal of 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. Terra-Kleen Corporation uses a combination of up to 14 solvents, each of which can dissolve specific contaminants in the soil and can mix 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 the contaminants from the soil.

Contaminated soil is fed into a hopper, and then transported into the soil and solvent slurry modules. In the modules, the soil is continually leached by clean solvent. The return leachate from the modules is monitored for contaminants so that the soil may be retained within the system until any residual contaminants within the soil are reduced to targeted levels. Terra-Kleen Corporation offers "hotspot protection" in which real-time monitoring of the contaminant levels alleviates the problems of treating localized higher contaminant areas of soil.

The leachate from the soil and solvent modules is stripped of contaminants by distillation in combination with activated charcoal filtering. High boiling point materials extracted from the soil stay in the bottoms of the distillation



Soil restoration unit

columns, and are periodically flushed from the system into labeled 55-gallon drums for off-site disposal. The distillate from the columns is sent through an activated charcoal filter to remove the lower boiling point contaminants from the solvent. The clean solvent is then reused in the system, completing the closed solvent loop.

The soil and solvent slurry, which has had the contamination reduced to its desired levels, is then sent to a closed loop dryer system that removes the solvent from the soil. The solvent vapors in the dryer are monitored with an organic vapor monitor that indicates when the solvent has been removed so the soil can leave the system.

WASTE APPLICABILITY:

Terra-Kleen Corporation's technology is particularly effective in removing polychlorinated biphenyls (PCB), pentachlorophenol (PCP), 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 using contaminated sediments and sludges as feed stock.

STATUS:

The soil restoration unit has been used for remediation of the Treban Superfund site. Results from that site are shown below:

Test	Initial PCB Concentration (ppm)	Final PCB Concentration (ppm)	Required Number of Passes	Percent Reduction
A	740	77	1	90
B	810	3	1	99+
C	2,500	93	4	96

The unit has also been used under an EPA Toxic Substance Control Act (TSCA) Research & Development (R&D) permit as part of the approval process for a nationwide transportable treatment permit for PCB destruction. In the test, PCB in soil was reduced from a maximum of 200 parts per million (ppm) to a final composite of 2.8 ppm.

Spiked soil, with contamination levels of up to 2,200 ppm PCB, was remediated to PCB levels of 12 ppm. Since this test, system modifications have been added to improve removal efficiencies.

Demonstration of the full-scale unit under the SITE Demonstration Program is pending the selection of a site.

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TERRA VAC
(In Situ Vacuum Extraction)

TECHNOLOGY DESCRIPTION:

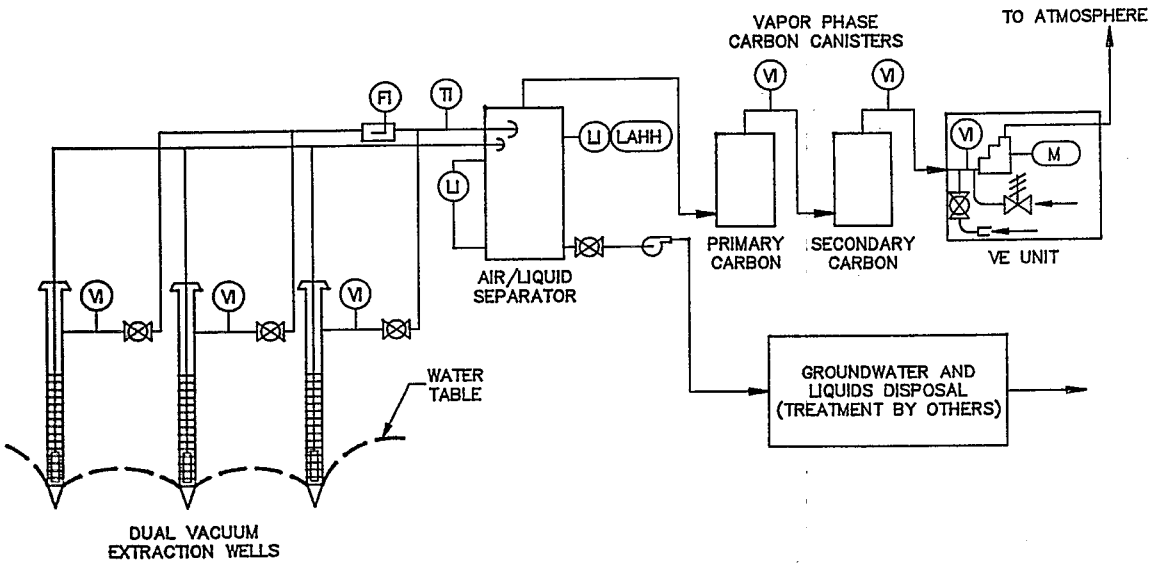
In situ vacuum extraction is the process (see figure below) of removing and treating volatile organic compounds (VOC) from the vadose or unsaturated zone of soils. These compounds can often be removed from the vadose zone before they contaminate groundwater. Removing VOCs from the vadose zone by using a vacuum is patented and licensed to 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 absorption filter). After a contaminated area is completely defined, an extraction well is installed and connected by piping to the vacuum extraction and treatment system.

A vacuum pump draws the subsurface contaminants from the extraction well to the liquid/gas separator. A treatment system consisting of an activated carbon absorption filter or a catalytic oxidizer before the gases are discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations are monitored by using vadose zone monitoring wells. The figure below is a diagram of the process.

The technology has been demonstrated to be effective in virtually all hydrogeological settings and is capable of reducing soil contaminant levels from saturated conditions to nondetectable. The process works in soils of low permeability (clays) if the soil has sufficient air-filled porosity. Dual vacuum extraction of groundwater and vapor have been effective in restoring groundwater quality to drinking water standards relatively quickly. The technology has proved to be less expensive than other methods of remediation, such as incineration.

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



In Situ Vacuum Extraction Process

WASTE APPLICABILITY:

Vacuum extraction technology is effective in treating soils containing virtually any volatile contaminant and has proved successful in removing over 40 different types of chemicals from soils, including gasoline- and diesel-range hydrocarbons. Contaminants should have a Henry's constant of 0.001 or higher for effective removal.

STATUS:

The vacuum extraction process was first demonstrated at a Superfund Site in Puerto Rico, and Terra Vac has since applied the technology at nine additional Superfund sites and at more than 150 other waste sites throughout the United States, Europe, and Japan.

A field demonstration of the process was performed as a part of the SITE Demonstration Program at the Groveland Wells Superfund site in Groveland, Massachusetts, with successful remediation of soils contaminated by trichloroethylene (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 in situ vacuum extraction demonstration at the Groveland Wells Superfund site used four extraction wells to pump contaminants to the process system. During a 56-day operational period, 1,300 pounds of volatile organics, mainly TCE, were extracted from both highly permeable strata and low permeability clays. The process achieved nondetectable levels of VOCs in the soil at some locations at the test area. The VOC concentration in soil gas was reduced by 95 percent. Average reductions in soil concentrations were 92 percent for sandy soils and 90 percent for clays.

APPLICATIONS ANALYSIS SUMMARY:

The Terra Vac system was tested at several Superfund and non-Superfund sites. These field evaluations yielded the following conclusions:

- Cleanup of volatile organic compounds to nondetectable levels in soil can be achieved.
- The major considerations in applying this technology are volatility of the contaminants (Henry's constant) and the site soil. Ideal measured permeabilities are 10^{-4} to 10^{-8} cm/sec.
- Pilot demonstrations are necessary at sites with complex geology or contaminant distributions.
- Based on available data, 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.

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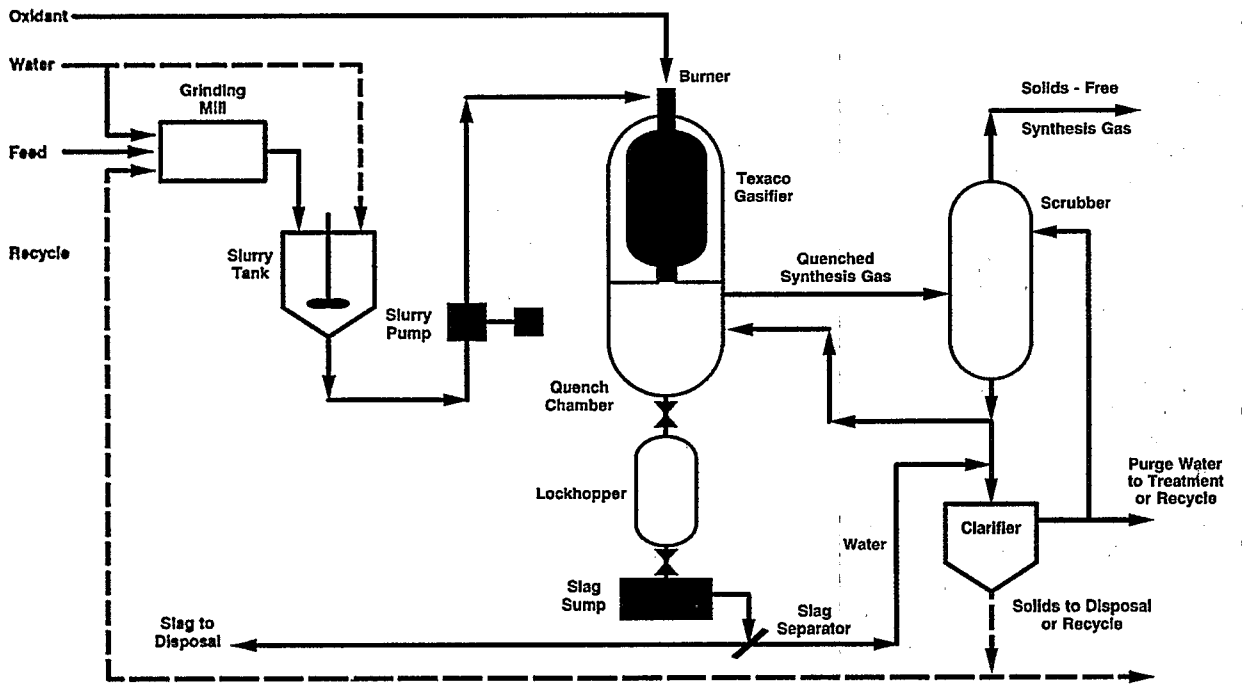
TEXACO SYNGAS, INC.
(Entrained-Bed Gasification)

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 to produce a gas containing mainly carbon monoxide and hydrogen. This product, called synthesis gas, can be used (1) to produce other chemicals or (2) to be burned as fuel. Ash in the feed melts and is removed as a glass-like slag. The treatment of hazardous waste materials in a gasifier is an extension of Texaco's conventional gasification technology, which has been operated commercially for over 30 years, using widely varying 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 degrees Fahrenheit.

Wastes are pumped in a 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, flow downward through the gasifier to a quench chamber that collects the slag for removal through a lock hopper. The synthesis gas is then further cooled and cleaned by a waste scrubbing system; a sulfur recovery



Schematic diagram of the entrained-bed gasification process

system may be added. Fine particulate matter removed by the scrubber may be recycled back to the gasifier.

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

The capacity of a system suitable for on-site waste destruction is based on a wet synthesis gas production rate of 3 million standard cubic feet per day. Depending on the heat content and proximate analysis, approximately 12 to 24 tons per day of hazardous waste can potentially be treated.

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 form containing 40 to 70 percent solids by weight and 60 to 30 percent liquid, usually water.

STATUS:

This technology was accepted into the SITE Demonstration program in July 1991. A demonstration with Superfund hazardous waste is planned for 1992 at Texaco's Montebello Research Laboratory. In December 1988, under a grant from the California Department of Health Services, Texaco demonstrated the gasification of low heating-value petroleum tank bottoms to produce synthesis gas and nonhazardous effluents. During a 40-hour pilot run, this hazardous material was 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 determined to be nonhazardous, based on California Assessment Manual limits for total and leachable materials. Both wastewater and solid residue were determined to be free of trace organics and EPA priority pollutants.

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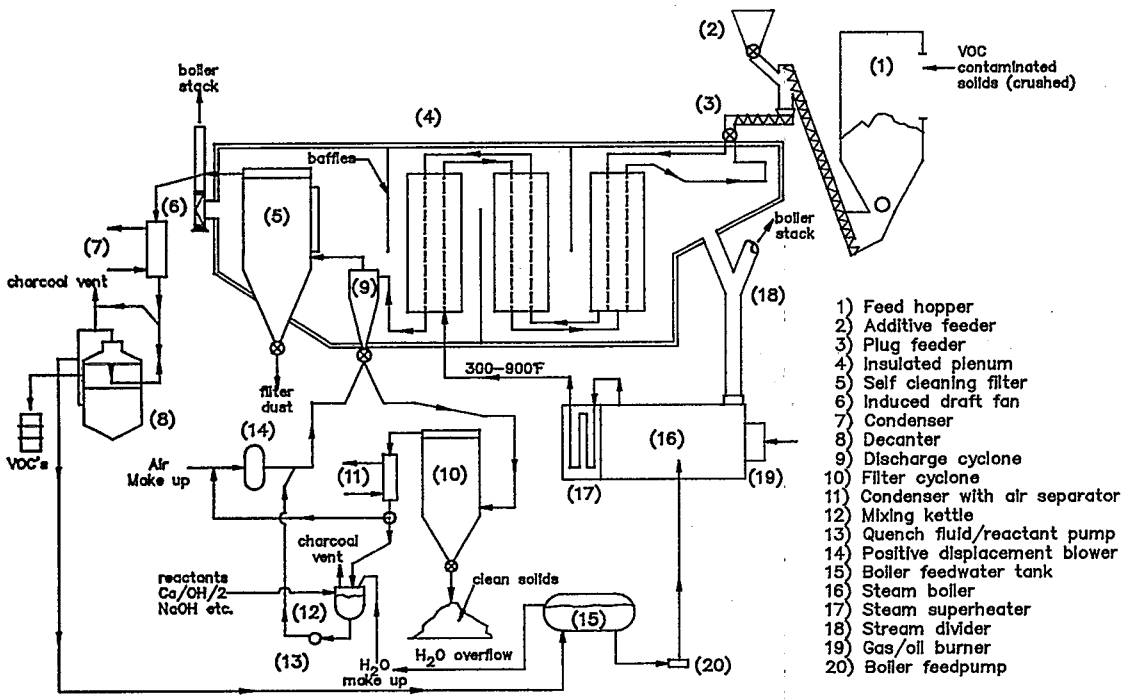
TEXAROME, INC.
(Solid Waste Desorption)

TECHNOLOGY DESCRIPTION:

The solid waste desorption process uses superheated steam (up to 900 degrees Fahrenheit [°F]) as a continuous conveying and stripping gas in a pneumatic system to treat contaminated solids. The counter-current flow of the gas (steam) and the solid phase (contaminated solids) provides a highly compact and efficient mass transfer separation. While the word pneumatic typically refers to air as a carrier gas, the carrier gas in this case is superheated steam, which is quite suitable for pneumatic conveying. However, unlike air at ambient temperatures, superheated steam as a carrier gas vaporizes the volatile and semivolatile substances present in the solids. The system (see figure below) uses a proprietary piping arrangement within the conveying system, which allows for a true counter-current flow and a multi-stage dispersion and separation (desorption) of the gases from the solids. This makes the efficient mass transfer task possible.

After desorption of virtually all volatile substances from the solid substrate, the last stage of the apparatus is used for quenching and as a reactor loop to provide a final chemical breakdown of the minute traces of volatiles left in the solid, if necessary. Nonvolatile inorganic contaminants (such as metals) are not separated but do not inhibit the process. In certain instances they may be treated by adding stabilization agents or reactants in the stripping stages or in the reactor loop.



Schematic diagram of the solid waste desorption process

A portable desorption plant consists of four trailer- or skid-mounted units. Up to four additional units may be required for the preconditioning of the contaminated solids, such as debris sifters and crushers. The final feed consistency required by this desorption process depends on the type of solid material to be processed and may have to be reduced to particle size of 20 mesh and under. The milled material is stored in a storage bin of a capacity equal to 2/3 of the daily throughput, allowing for retrieval at a constant flow rate, around the clock. During the discharge of the system, the clean solids are separated from the gas by cyclonic action and subsequent 1 to 5 micron filtration. The dust-free gas consisting of a mixture of superheated steam and volatile organic compound (VOC) vapors exits and passes through a heat exchanger for complete condensation and recovery of the liquid product. VOCs, most of which are lipophylic and not miscible with water, are removed continuously in a coalescing decanter and packaged in drums (or used as boiler fuel). The water phase is treated to further remove traces of VOCs or recycled in a closed loop as boiler feedwater.

WASTE APPLICABILITY:

The process can separate and recover organic volatiles, semivolatiles, polychlorinated biphenyls (PCB), pentachlorophenol (PCP), creosote, volatile inorganics, and organic fungicides and pesticides from inorganic solids (such as soils) as well as organic solids (such as wood wastes mop-up materials). Sludges and sediments can be preconditioned (for dry flow characteristics) to accommodate the feed consistency requirements. Treatable concentrations of light and heavy VOCs in the solid wastes can range from traces to near (dripping) saturation of the solids.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. Although no mobile field unit is ready for the SITE demonstration, the plant will be improved and modified to operate at 25 tons of solids per day. The SITE demonstration is tentatively scheduled for late fall 1991.

In 1982, a 4 ton per day pilot plant was set up in the Texas Hill Country to extract cedarwood oil from native Texas cedar. The project was moved to Leakey, Texas, in 1984, and the plant was scaled up to 12 tons per day. To date, this plant has been successfully operating around the clock.

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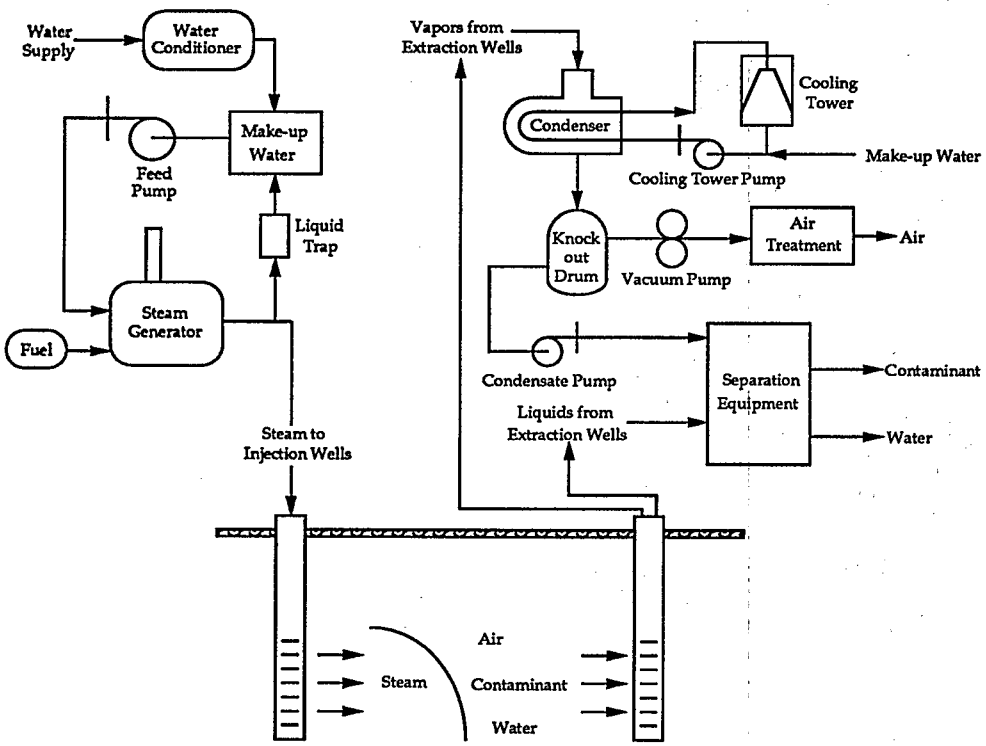
UDELL TECHNOLOGIES, INC.
(In Situ Steam Enhanced Extraction)

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 ground water or trapped by gas-phase activated carbon filters. The technology uses readily available components, such as injection and extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

WASTE APPLICABILITY:

The process is used to extract VOCs and SVOCs from contaminated soils and groundwater. The primary applicable compounds are hydrocarbons such as gasoline, diesel, and jet fuel, solvents such as trichloroethylene (TCE), trichloroethane (TCA), and dichlorobenzene (DCB), or a mixture of these compounds. The process may be applied to contaminants below the water table. After application of this process, the



In situ Steam Enhanced Extraction process schematic

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 geologic barrier exists to prevent downward percolation of a separate phase.

STATUS:

In August 1988, a successful pilot-scale demonstration of the process was completed at a site contaminated by a mixture of solvents; 764 pounds of contaminants were removed from the 10-foot-diameter, 12-foot-deep test region.

The technology is scheduled to be demonstrated under the SITE Demonstration Program at a burn pit with soil contaminated by waste oil mixed with VOCs, SVOCs, and metals at McClellan Air Force Base in Sacramento, California. The treatability studies on the McClellan contaminated wastes and soils were performed in fall 1991.

Also, a case study will be performed to remediate a gasoline spill both above and below the water table to depths of 137 feet at the Lawrence Livermore National Laboratory in Livermore, California.

An interagency agreement between the Naval Civil Engineering Laboratory (NCEL) in Port Hueneme, California and the Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio has been reached. NCEL and RREL are considering a demonstration of this process at the LeMoore Naval Air Station.

For more information regarding this technology, see the Hughes Environmental Systems, Inc., profile in the Demonstration Program section of this document.

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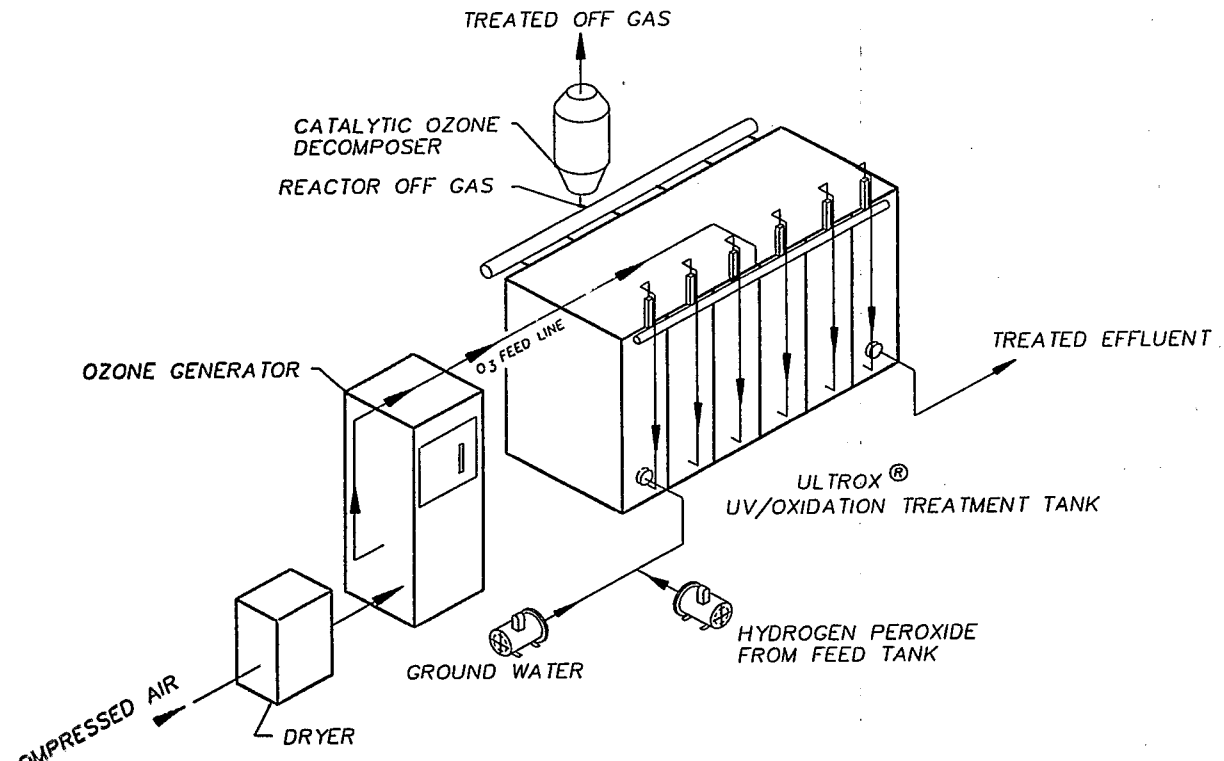
ULTROX INTERNATIONAL
(Ultraviolet Radiation and Oxidation)

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 wastewaters, groundwaters,and leachate. The treatment tank size is determined from the expected wastewater flow rate and the necessary hydraulic retention time to treat the contaminated water. The approximate UV intensity, and ozone and hydrogen peroxide doses, are determined from 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.



Isometric view of the Ultrox system

WASTE APPLICABILITY:

Contaminated groundwater, industrial wastewaters, and leachates containing halogenated solvents, phenol, pentachlorophenol, pesticides, polychlorinated biphenyls (PCB), 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).

DEMONSTRATION RESULTS:

Contaminated groundwater treated by the Ultrox system met regulatory standards at the appropriate parameter levels. Out of 44 VOCs in the wastewater, three were chosen to be used as indicator parameters. They are trichloroethylene (TCE), 1,1 dichloroethane (1,1-DCA), and 1,1,1 trichloroethane (1,1,1-TCA), all relatively refractory to conventional oxidation.

Removal efficiencies for TCE were about 99 percent. Removal efficiencies for 1,1-DCA and 1,1,1-TCA were about 58 percent and 85 percent, respectively. Removal efficiencies for total VOCs were about 90 percent.

For some compounds, removal from the water phase resulted from both chemical oxidation and stripping. Stripping accounted for 12 to 75 percent of the total removal for 1,1,1-TCA, and 5 to 44 percent for 1,1-DCA. Stripping was less than 10 percent for TCE and vinyl chloride, and was negligible for other VOCs present.

The Decompozon unit reduced ozone to less than 0.1 ppm Occupational Safety and Health Act (OSHA) standards, 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. There were no harmful air emissions to the atmosphere from the Ultrox system.

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

The technology is fully commercial, with over 20 commercial systems installed. Flow rates ranging from 5.0 gallons per minute to 1,050 gallons per minute are presently being used in various industries and site clean-up activities, including aerospace, Department of Energy (DOE), petroleum, pharmaceutical, automotive, woodtreating and municipal.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
(Excavation Techniques and Foam Suppression Methods)

TECHNOLOGY DESCRIPTION:

This project was the result of a joint EPA effort involving the Risk Reduction Engineering Laboratory (Cincinnati, Ohio), Air and Energy Engineering Research Laboratory (Research Triangle Park, North Carolina), and Region 9 to evaluate control technologies during excavation operations. In general, excavating soil contaminated with volatile organic compounds (VOCs) results in fugitive air emissions.

The area to be excavated was surrounded by a temporary enclosure (see figure below). Air from the enclosure was 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. An additional emission control method, a vapor suppressant foam, was applied to the soil before and after excavation.

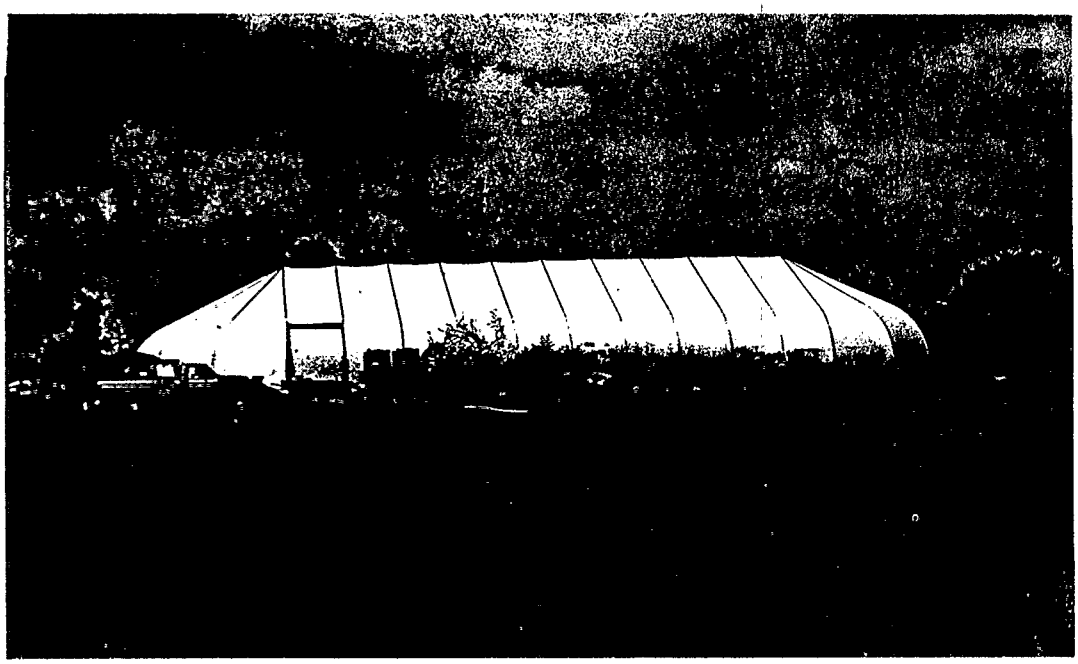
To control these emissions, containment and treatment technologies were combined during a SITE demonstration at the McColl Superfund site in Fullerton, California.

WASTE APPLICABILITY:

These technologies are suitable for controlling VOC emissions during the excavation of contaminated soil.

STATUS:

This technique was observed at the McColl Superfund site in Fullerton, California in June and July 1990. Results from the application are currently being prepared and will be available in early 1992.



Excavation area enclosure

DEMONSTRATION RESULTS:

An enclosure 60 feet wide, 160 feet long, and 26 feet high was erected over an area contaminated with VOCs and sulfur dioxide. Removal of the overburden and excavation of underlying waste was performed with a backhoe. There were three distinct layers of segregated waste: 3 feet of oily mud, 4 feet of tar, and a hard coal-like char layer. During excavation, 5-minute average air concentrations within the enclosed area were up to 1000 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 50 percent of the THC.

The concentrations of contaminants in the air inside the enclosure were higher than expected due in part to the vapor-suppressant foam's inability to form an impermeable membrane over the exposed wastes. The foams reacted with the highly acidic waste, causing degradation of the foam. Furthermore, purge water from foaming activities impacted operations by making 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 with fly ash, cement, and water in a pug mill. The char wastes did not require further processing.

FOR FURTHER INFORMATION:

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John Blevins
U.S. EPA, Region 9
Mail Code H-6-1
75 Hawthorne Avenue
San Francisco, CA 94105
415-744-2241
FTS: 484-2241

WASTECH, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

This solidification and stabilization technology applies proprietary bonding agents to soils, sludge, and liquid wastes with organic and inorganic contaminants to treat the pollutants within the wastes. The waste and reagent mixture is then mixed with cementitious materials, which form a stabilizing matrix. The specific reagents used are selected based on the particular waste to be treated. The resultant material is a nonleaching, high-strength monolith.

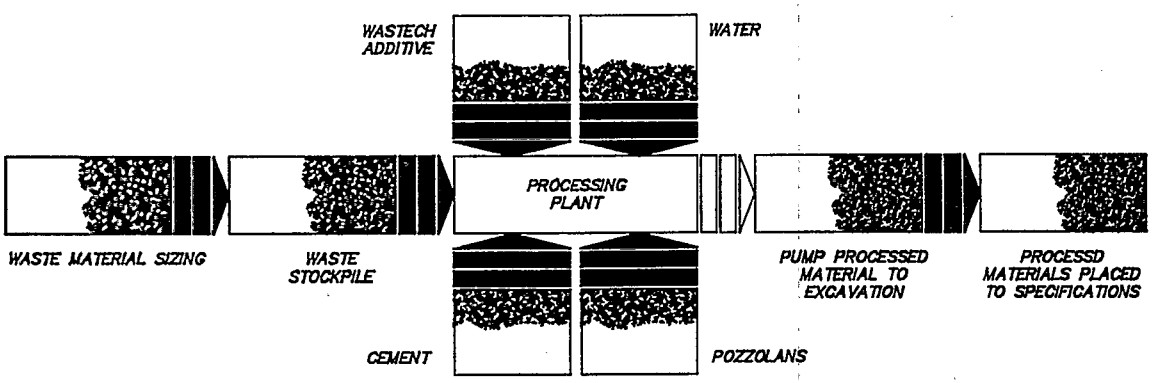
The process uses standard engineering and construction equipment. Since the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula.

The process begins with excavation of the waste. Materials containing large pieces of debris must be prescreened. The waste is then placed into a high shear mixer (see figure below), along with premeasured quantities of water and SuperSet®, WASTECH's proprietary reagent.

Next, cementitious materials are added to the waste-reagent mixture, stabilizing the waste and completing the treatment process. WASTECH's treatment technology does not generate waste by-products. The process can 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



On-site Remediation Project Flow Diagram

bottoms, chelating agents, and ion exchange resins, with contaminant concentrations ranging from part per million levels to 40 percent by volume. The technology can also treat wastes generated by the petroleum, chemical, pesticide, and wood-preserving industries, as well as wastes generated by many other manufacturing and industrial processes. WASTECH's technology can also be applied to mixed wastes containing radioactive materials, along with organic and inorganic contaminants.

STATUS:

This technology was accepted into the SITE Demonstration Program in Spring 1991. Bench-scale evaluation of the process is complete. A field demonstration at Robins Air Force Base in Macon, Georgia, was completed in August 1991. The WASTECH technology was used to treat high level organic and inorganic wastes at an industrial sludge pit. The technology is now being commercially applied to treat hazardous wastes contaminated with various organics, inorganics, and mixed wastes.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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WASTECH, Inc.
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114 Tulsa Road
Oak Ridge, TN 37830
615-483-6515

WESTERN RESEARCH INSTITUTE
(Contained Recovery of Oily Wastes)

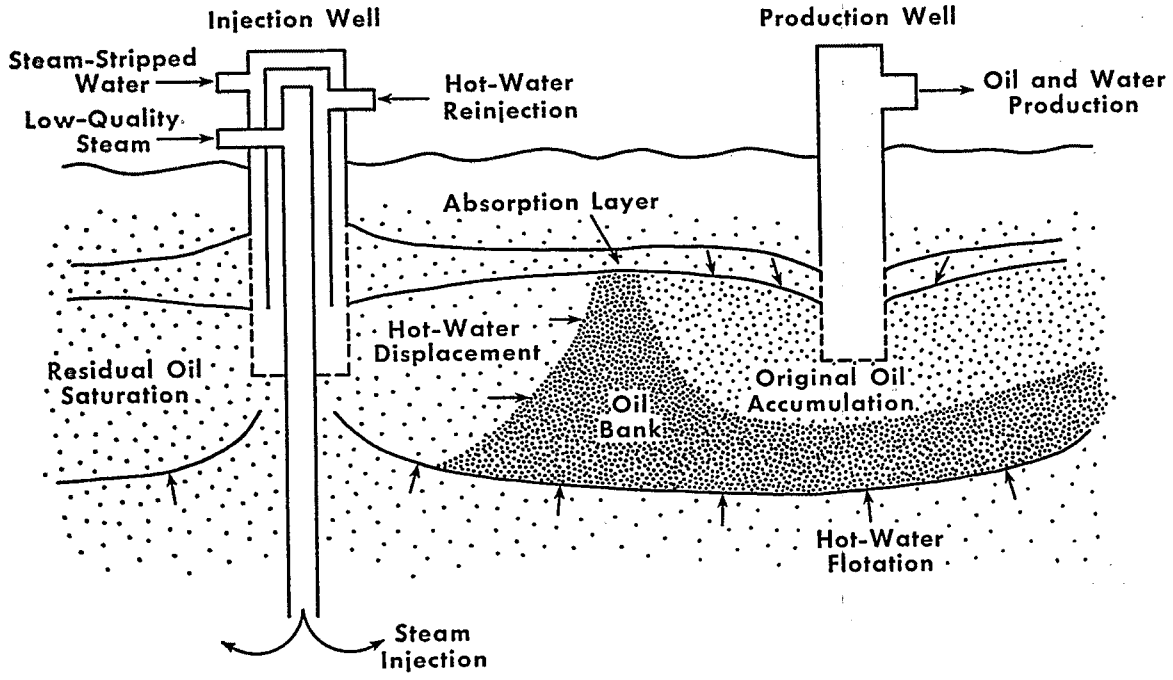
TECHNOLOGY DESCRIPTION:

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 and hot-water displacement are used to move accumulated oily wastes and water to production wells for above ground 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 deepest penetration of organic liquids. The steam condenses, causing rising hot water to dislodge and sweep buoyant organic liquids upward into the more permeable soil regions. Hot water is injected above the impermeable soil egions to heat and mobilize the oil waste accumulations, which are recovered by hot-water displacement.

When the oily wastes are displaced, the organic liquid saturations in the subsurface pore space increase, forming an oil bank. The hot water injection displaces the oil bank to the production well. Behind the oil bank, the oil saturation is reduced to an immobile residual saturation in the subsurface pore space. The oil 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 any water samples from the site. During treatment, all mobilized organic liquids and water-soluble contaminants are contained within the original boundaries of oily waste accumulations. Hazardous materials are contained laterally by



CROW™ subsurface development

groundwater isolation, and vertically by organic liquid flotation. Excess water is treated in compliance with discharge regulations.

The process (1) removes large portions of oily waste accumulations, (2) stops the downward migration of organic contaminants, (3) immobilizes any residual saturation of oily wastes, and (4) reduces the volume, mobility, and toxicity of oily wastes. It can be used for shallow and deep contaminated areas, and uses the same mobile equipment required by conventional petroleum production technology.

WASTE APPLICABILITY:

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

STATUS:

Based on results of this project in the Emerging Technology Program, this technology was invited to participate in the SITE Demonstration Program.

This technology was tested both at the laboratory and pilot-scale under the SITE Emerging Technology Program. The program showed the effectiveness of the hot-water displacement and displayed the benefits from the inclusion of chemicals with the hot water.

The technology will be demonstrated at the Pennsylvania Power and Light (PP&L) Brodhead Creek site at Stroudsburg, Pennsylvania. The site contains an area of high concentrations of by-products from a former operation. 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.

In addition to the SITE Program, this technology is now being demonstrated at a wood-treatment site in Minnesota. Other areas of activity include screening studies for other potential sites and an in-house project to advance the use of chemicals with the hot-water displacement.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Western Research Institute
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University Station
Laramie, WY 82071
307-721-2011

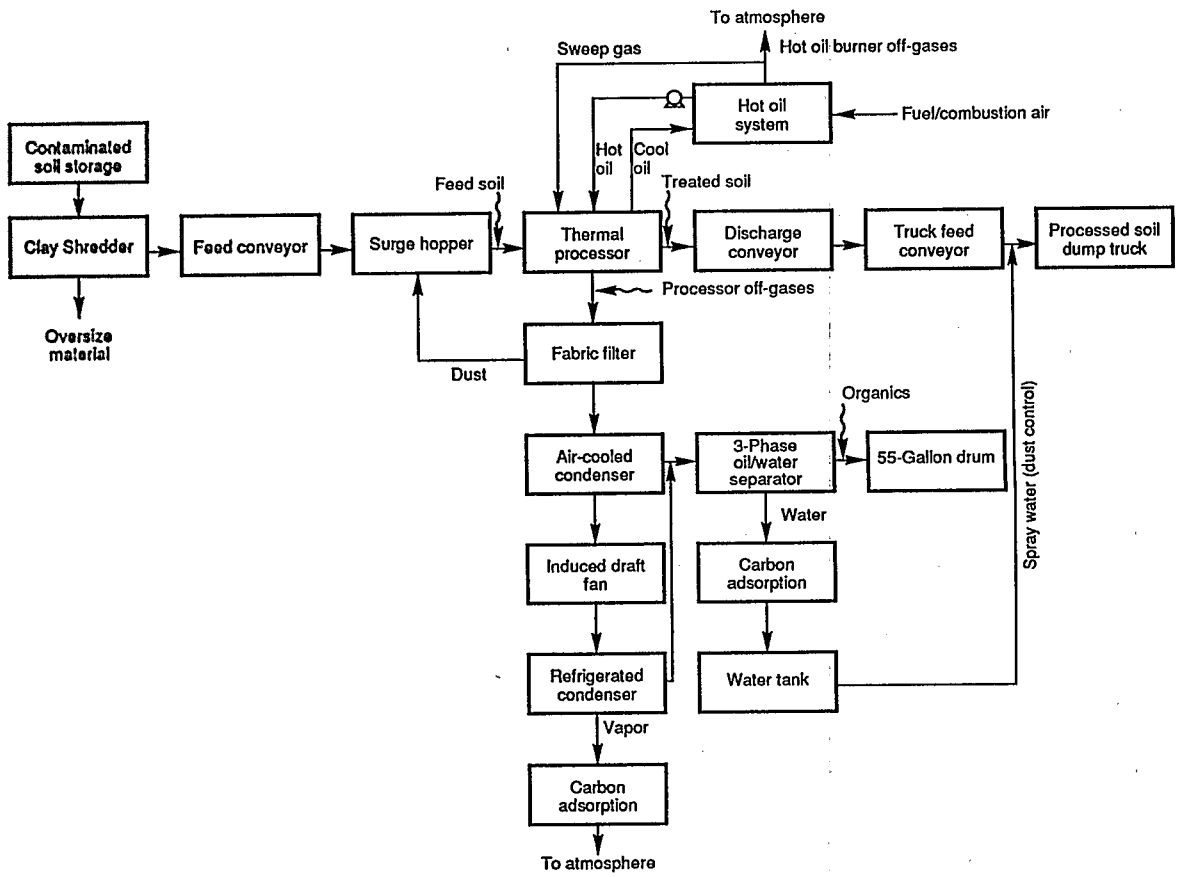
WESTON SERVICES, INC.
[Low Temperature Thermal Treatment (LT³®)]

TECHNOLOGY DESCRIPTION:

The basis of the LT³® technology is the thermal processor, an indirect heat exchanger used to dry and heat contaminated soils. The LT³® process includes three main steps: soil treatment, emissions control, and water treatment (see figure below). Equipment used in the LT³® process is mounted on three tractor trailer beds for transport and operation.

Excavated soil is processed through a shredder to increase the surface area of the soil. (This step may not be needed for sludges or similar matrices.) The conveyor and surge hopper, which are enclosed to reduce emissions, then feed the soil into the thermal processor. The thermal processor consists of two covered troughs that house four intermeshed screw conveyors. The covered troughs and screws are hollow to allow circulation of hot oil, providing indirect heating of the soils. Each screw moves the soil through the processor and thoroughly mixes the material.

The heating of the soil to 400 to 500 degrees Fahrenheit evaporates contaminants from the soil. (Temperatures may vary depending on the



Schematic diagram of the LT³® system

specific contaminants of concern.) The vapor stream is then processed through a baghouse dust collector, two condensers in series, and is subsequentially treated by carbon adsorption to remove about 99 percent of the organic contaminants and any particulate emissions. Remaining exhaust gas is continuously monitored to ensure that it contains total organic concentrations not greater than 3 parts per million (ppm) by volume.

The condensate from the LT³® system is separated into light and heavy organic compounds and water. The water is treated by carbon adsorption until it is free of contaminants, at which time it can be recycled to the LT³® fresh water system to be sprayed on the treated soil for dust control. The spraying occurs in the system before the soil is released. No water is discharged from the LT³® process.

WASTE APPLICABILITY:

This technology can be applied to soils contaminated with volatile and semivolatile organic compounds (VOC and SVOC).

STATUS:

This technology was accepted into the SITE Demonstration Program in September 1991. A site demonstration is scheduled for October 1991 at the Anderson Development Company (ADC) Superfund site, Adrian, Michigan. ADC manufactures specialty organic chemicals. The demonstration of the LT³® process will determine (1) how effectively the technology removes VOCs and SVOCs, from the site soil; (2) whether treated soil and sludge meet established cleanup goals; and (3) whether treated exhaust gas meets air permit requirements.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
Mike Cosmos
Weston Services, Inc.
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215-430-7423

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

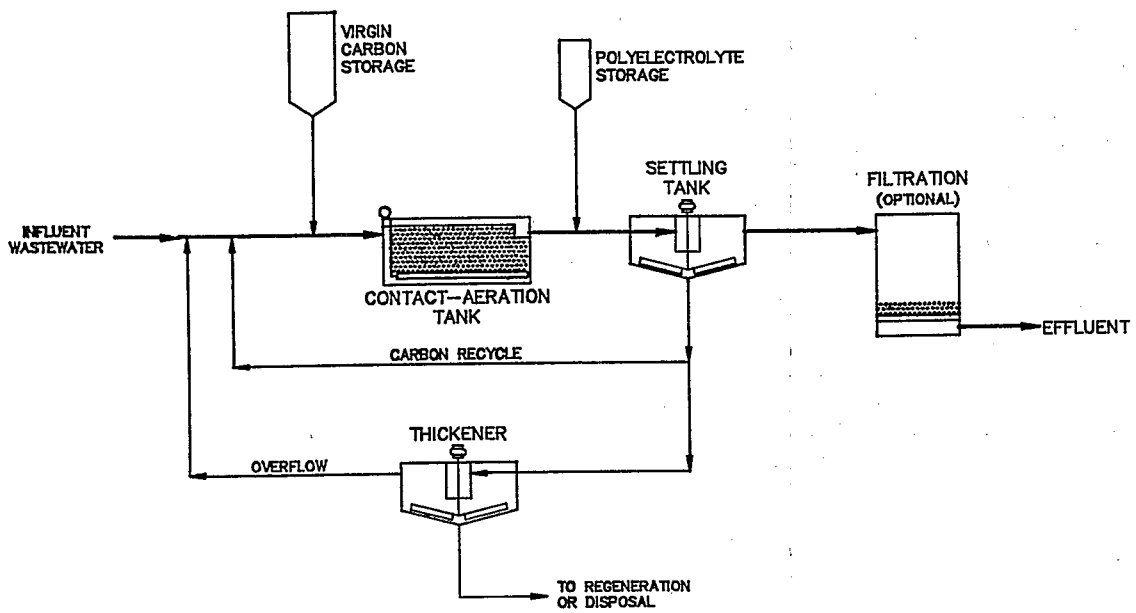
TECHNOLOGY DESCRIPTION:

Zimpro/Passavant Environmental Systems, Inc., has adapted the PACT® wastewater treatment system to the treatment of 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 with conventional technologies. A 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. With this technology, organic contaminants are removed 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 biological treatment by 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 treatment achieved by the system depends on the influent waste characteristics and the system's operating parameters. Important characteristics include biodegradability, absorbability, 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, by



PACT® Wastewater Treatment System General Process Daigram

varying the concentration of PAC in the system, and by adjusting the retention time of the mixed liquid, and volume ratio of the waste to biomass. 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. The overflow from the thickener is returned to the aeration tank and the concentrated solids are removed. Dewatered solids may be regenerated to recover PAC. The process is shown in the figure.

A two-stage 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.

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 (COD) 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. Site-specific conditions have prevented demonstration testing. Additional sites are now being evaluated for full demonstration of the PACT® system.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Zimpro/Passavant Environmental Systems, Inc.
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Rothschild, WI 54474
715-359-7211

EMERGING TECHNOLOGY PROGRAM

The Emerging Technology Program provides a framework to encourage the bench-and pilot-scale testing and evaluation of technologies that have already been proven at the conceptual stage. The goal is to promote the development of viable alternatives available for use in Superfund site remediations.

Technologies are solicited for the Emerging Technology Program through Requests for Pre-Proposals. After a technical review of the pre-proposals submitted, selected candidates are invited to submit a cooperative agreement application and detailed project proposal that undergoes another full technical review. A 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, emerging technologies may be considered for the SITE Demonstration Program.

Five solicitations have been issued to date -- in November 1987 (E01), July 1988 (E02), July 1989 (E03), July 1990 (E04), and July 1991 (E05). The selection of E05 projects from solicitations received in September will occur in early 1992.

Currently, six of the seven developers accepted under the November 1987 solicitation (E01), have completed their projects. Of these six, three technologies, Bio-Recovery System's biological sorption, the Colorado School of Mines' wetlands project, and the Western Research Institute's oil recovery technology, have been invited to participate in the Demonstration Program. Other emerging technologies that have promising results may also advance to the Demonstration Program.

Both completed and ongoing Emerging Technology Program participants are presented in alphabetical order in Table 3 and in the technology profiles that follow.

TABLE 3
SITE Emerging Technology Program Participants

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	Sam Fogel 617-245-6606	Ronald Lewis 513-569-7856 FTS: 684-7856	Solids, Liquids	Not Applicable	Chlorinated and Nonchlorinated Solvents
Alcoa Separations, Warrendale, PA (E03)	Bioscrubber	Paul Liu 412-772-1332	Naomi Barkley 513-569-7854 FTS: 684-78541	Soil, Water, Air	Not Applicable	Most Organics
Allis Mineral Systems, Inc., [formerly Boliden Allis, Inc.,] Milwaukee, WI (E03)	Pyrokiln Thermal Encapsulation Process	John Lees 414-475-3862	Marta Richards 513-569-7783 FTS: 684-7783	Soil, Sludge	Most Metallic Compounds	Most Organics
Atomic Energy of Canada, Ltd., Chalk River, Ontario (E01)	Chemical Treatment and Ultrafiltration	Leo Buckley 613-584-3311	John Martin 513-569-7758 FTS: 684-7758	Groundwater	Heavy Metals	Not Applicable
Babcock & Wilcox Co., Alliance, OH (E02)	Cyclone Furnace	Lawrence King 216-829-7576	Laurel Staley 513-569-7863 FTS: 684-7863	Solids, Soil	Non-Specific Inorganics	Non-Specific Organics
Battelle Memorial Institute, Columbus, OH (E01) [Project completed]	In Situ Electroacoustic Decontamination	Satya Chauhan 614-424-4812	Jonathan Herrman 513-569-7839 FTS: 684-7839	Soil	Heavy Metals	Not Applicable
BioTrol, Inc., Chaska, MN (E03)	Methanotrophic Bioreactor System	Jeffery Petola 612-448-2515	David Smith 513-569-7856 FTS: 684-7856	Water	Not Applicable	Halogenated Hydrocarbons
Bio-Recovery Systems, Inc.[1], Las Cruces, NM (E01) [Project completed]	Biological Sorption	Dennis Darnall 505-646-5018	Naomi Barkley 513-569-7854 FTS: 684-7854	Groundwater, Leachate, Wastewater	Heavy Metals	Not Applicable
Center for Hazardous Materials Research, Pittsburgh, PA (E03)	Acid Extraction Treatment System	Stephen Paff 412-826-5320	Kim Lisa Kreiton 513-569-7328 FTS: 684-7328	Soil	Heavy Metals	Not Applicable

* Solicitation number

1 Graduate of Emerging Technology Program

TABLE 3 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Center for Hazardous Materials Research, Pittsburgh, PA (E04)	Lead Smelting	Roger Price/ Steven Paff 412-826-5320	Patrick Augustin 908-321-6992 FTS: 340-6992	Battery Waste	Lead	Not Applicable
Colorado School of Mines,[2] Golden, CO (E01) [Project completed]	Wetlands-Based Treatment	Rick Brown 303-331-4404	Edward Bates 513-569-7774 FTS: 684-7774	Acid Mine Drainage	Metals	Not Applicable
Davy Research and Development Ltd., Cleveland, England (E04)	Chemical Treatment	Richard Hunter-Smith 04-44-642-607108	Kim Lisa Kreiton 513-569-7328 FTS: 684-7328	Soils, Sediments	Heavy Metals, Cyanides	Chlorinated phenols, Chlorinated solvents, Pesticides, PCBs
Electro-Pure Systems, Inc., Amherst, NY (E02)	Alternating Current Electrocoagulation Process	Clifton Farrell 716-691-2610	Naomi Barkley 513-569-7854 FTS: 684-7854	Groundwater, Wastewater, Leachate	Heavy Metals	Petroleum Byproducts, Coal-Tar Derivitaves
Electrokinetics, Baton Rouge, LA (E03)	Electro-Osmosis	Yalcin Acar 504-388-3992	Randy Parker 513-569-7271 FTS: 684-7271	Soil	Heavy Metals and Other Organics	Not Applicable
Electron Beam Research Facility, Florida International University, and University of Miami, Miami, FL (E03)	High-Energy Electron Irradiation	William Cooper 305-348-3049	Frank Alvarez 513-569-7631 FTS: 684-7631	Aqueous Solutions and Sludges	Not Applicable	Most Organics
Energy and Environmental Engineering, Inc., East Cambridge, MA (E01) [Project completed]	Laser-Induced Photochemical Oxidative Destruction	James Porter/ Gopi Vungarala 617-666-5500	Ronald Lewis 513-569-7856 FTS: 684-7856	Groundwater, Wastewater	Not Applicable	Non-Specific Organics
Energy and Environmental Research Corporation, Irvine, CA (E03)	Hybrid Fluidized Bed System	Gene Taylor 714-859-8851	Teri Shearer 513-569-7949 FTS: 684-7949	Solids, Sludges	Volatile Inorganics	Most Organics
Enviro-Sciences, Inc./ ART International, Inc., Randolph, NJ (E03)	Low-Energy Solvent Extraction Process	Werner Steiner 201-361-8840	S. Jackson Hubbard 513-569-7507 FTS: 684-7507	Soils, Sediments, Sludges	Most Inorganics	PCBs, Petroleum Hydrocarbons

2 Graduate of Emerging Technology Program

TABLE 3 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Ferro Corporation, Independence, OH (E03)	Waste Vitrification through Electric Melting	Emilio Spinosa 216-641-8580	Randy Parker 513-569-7271 FTS: 684-7271	Soils, Sediments, Sludges	Non-Specific Inorganics	Non-Specific Organics
Groundwater Technology, Inc., Concord, CA (E04)	Below Grade Bioremediation Cell	Ronald Hicks 415-671-2387	Ronald Lewis 513-569-7856 FTS: 684-7856	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	William Librizzi 201-596-2457	Uwe Frank 908-321-6626 FTS: 340-6626	Soil	Not Applicable	Biodegradable Organics
Institute of Gas Technology, Chicago, IL (E04)	Chemical and Biological Treatment	Robert Kelley 312-567-3809	Naomi Barkley 513-569-7854 FTS: 684-7854	Soil, Sludge, Groundwater, Surface water	Not Applicable	Most Organics
Institute of Gas Technology, Chicago, IL (E03)	Fluid Extraction-Biological Degradation Process	David Rue 312-567-3711	Annette Gatchett 513-569-7697 FTS: 684-7697	Soil	Not Applicable	Most Organics
Institute of Gas Technology, Chicago, IL (E03)	Fluidized-Bed Cyclonic Agglomerating Incinerator	Amir Rehmat 312-567-5899	Teri Shearer 513-569-7949 FTS: 684-7949	Solid, Liquid, Gas	Not Applicable	Most Organics
IT Corporation, Knoxville, TN (E02)	Batch Steam Distillation and Metal Extraction	Robert Fox 615-690-3211	Ronald Lewis 513-569-7856 FTS: 684-7856	Soil, Sludge	Heavy Metals	Non-Specific Organics
IT Corporation, Knoxville, TN (E04)	Mixed Waste Treatment Process	Ed Alperin 615-690-3211	Doug Grosse 513-569-7844 FTS: 684-7844	Soil	Non-Specific Inorganics	Non-Specific Organics
IT Corporation, Knoxville, TN (E02)	Photolytic and Biological Soil Detoxification	Robert Fox 615-690-3211	Randy Parker 513-569-7271 FTS: 684-7271	Soil	Not Applicable	PCBs, Other Non-Specific Organics
Membrane Technology and Research, Inc., Menlo Park, CA (E02)	VaporSep Membrane Process	Hans Wijmans/ Vicki Simmons 415-328-2228	Paul dePercin 513-569-7797 FTS: 684-7797	Gaseous Waste Streams	Not Applicable	Halogenated and Nonhalogenated Compounds

TABLE 3 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Montana College of Mineral Science & Technology, Butte, MT (E03)	Air-Sparged Hydrocyclone	Theodore Jordan 406-496-4112	Eugene Harris 513-569-7862 FTS: 684-7862	Aqueous Solutions	Low-Concentration Metals	Not Applicable
New Jersey Institute of Technology, Newark, NJ (E03)	Ghea Associates Process	Itzhak Gotlieb 201-596-5862	Annette Gatchett 513-569-7697 FTS: 684-7697	Mixtures	Most Inorganics	Most Organics
Nutech Environmental, London, Ontario (E04)	Photocatalytic Oxidation	Brian Butters 519-457-1676	John Ireland 513-569-7413 FTS: 684-7413	Wastewater, Groundwater, Air-streams	Cyanide, Sulphite, Nitrite Ions	PCBs, PCDDs, PCDFs, Chlorinated alkenes, Chlorinated phenols,
PSI Technology Company, Andover, MA (E04)	Metals Immobilization and Decontamination of Aggregate Solids	Srivats Srinvasachar 508-689-0003	Mark Meckes 513-569-7384 FTS: 684-7384	Soils, Sediments, Sludges	Heavy Metals	Most Organics
Pulse Sciences, Inc., Agouora Hills, CA (E04)	X-Ray Treatment	John Bayless/ Randy Curry 818-707-0095/ 415-632-5100	Esperanza Renard 513-569-7328 FTS: 684-7328	Soil, Water	Not Applicable	PCBs, TCE, TCA, Benzene
Purus, Inc., San Jose, CA (E04)	Photolytic Oxidation Process	Paul Blystone 408-453-7804	Norma Lewis 513-569-7665 FTS: 684-7665	Soil, Groundwater	Not Applicable	VOCs
J.R. Simplot Company, Boise, ID (E03)	Anaerobic Biological Process	Douglas Sell 208-389-7265	Wendy Davis-Hoover 513-569-7206 FTS: 684-7206	Soil, Sludge	Not Applicable	Nitroaromatics
Trinity Environmental Technologies, Inc., Mound Valley, KS (E03)	Ultrasonically Assisted Detoxification of Hazardous Materials	Duane Koszalka 316-328-3222	Kim Lisa Kreiton 513-569-7328 FTS: 684-7328	Solids	Not Applicable	PCBs and Other Chlorinated Compounds
University of South Carolina, Columbia, SC (E03)	In Situ Mitigation of Acid Water	Frank Caruccio 803-777-4512	Roger Wilmoth 513-569-7509 FTS: 684-7509	Acid Drainage	Most Metals	Not Applicable
University of Washington, Seattle, WA (E02)	Adsorptive Filtration	Mark Benjamin 206-543-7645	Norma Lewis 513-569-7665 FTS: 684-7665	Groundwater, Leachate, Wastewater	Metals	Not Applicable

TABLE 3 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Vortec Corporation, Collegeville, PA (E04)	Oxidation and Vitrification Process	James Hnat 215-489-2255	Teri Shearer 513-569-7949 FTS: 684-7949	Soil, Sediments, Mill Tailings	Metals	Most Organics
Warren Spring Laboratory, Herts, England (E04)	Physical and Chemical Treatment	D. Neil Collins 01-44-438-741122 ext. 752	Mary Stinson 908-321-6683 FTS: 340-6683	Soil	Metals	Petroleum Hydrocarbons, PAHs
Wastewater Technical Centre, Burlington Ontario (E02)	Cross-Flow Pervaporation System	Rob Booth/ Pierre Côté 416-336-4689/ 416-639-6320	John Martin 513-569-7758 FTS: 684-7758	Groundwater, Leachate, Wastewater	Not Applicable	VOCs, Solvents, Petroleum Hydrocarbons
Western Product Recovery, Group, Inc. Houston, TX (E04)	CCBA Physical and Chemical Treatment	Donald Kelly 713-493-9321	Joseph Farrell 513-569-7645 FTS: 684-7645	Wastewater, Sludges, Sediments, Soil	Heavy Metals	Most Organics
Western Research Institute,[3] Laramie, WY (E01) [Project Completed]	Contained Recovery of Oily Wastes	James Speight 307-721-2011	Eugene Harris 513-569-7862 FTS: 684-7862	Soil	Not Applicable	Coal Tar Derivatives, Petroleum Byproducts

3 Graduate of Emerging Technology Program

ABB ENVIRONMENTAL SERVICES, INC.

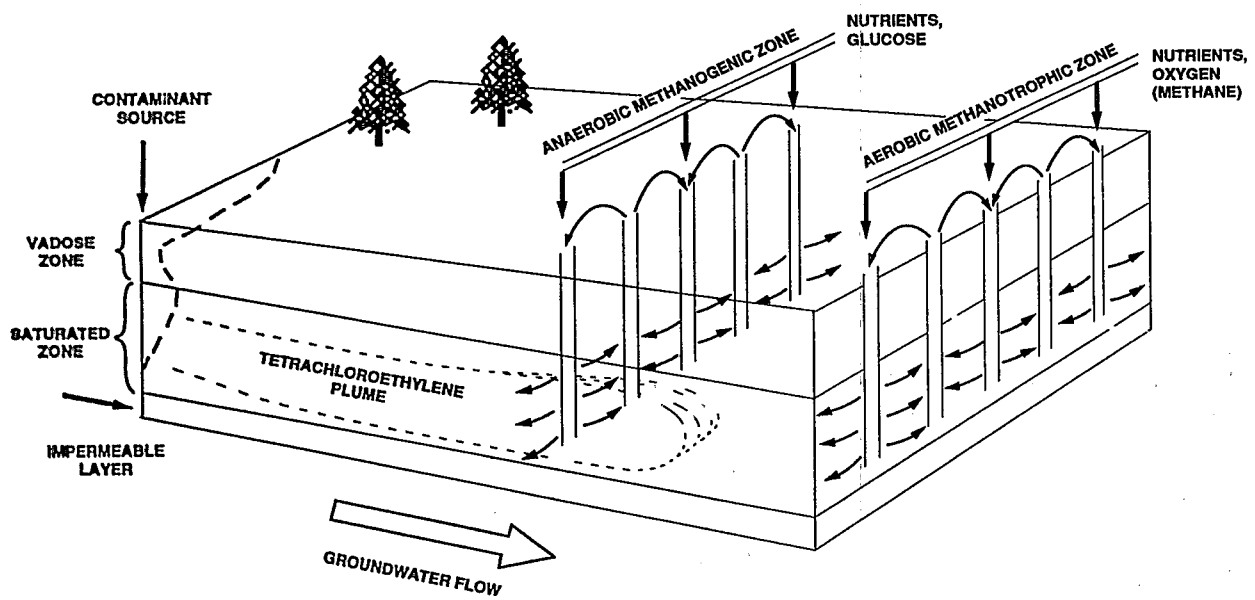
(Two-Zone Plume Interception In Situ Treatment Strategy)

TECHNOLOGY DESCRIPTION:

ABB Environmental Services, Inc. (ABB-ES), proposes to treat a mixture of chlorinated and nonchlorinated organic solvents in saturated soils and groundwater by applying its two-zone plume interception in situ treatment strategy. This treatment approach is being tested in a bench-scale demonstration project. The first zone is anaerobic and promotes the reductive dechlorination of highly chlorinated solvents, such as perchloroethylene. 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).

The first step of the treatment strategy for compounds such as perchloroethylene and trichloroethane is to encourage partial dechlorination by stimulating the growth of 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. Methanogenic bacteria are considered to be ubiquitously distributed in saturated soils.

At the completion of the (anaerobic) first step in the treatment process, all of the more highly chlorinated ethenes and ethanes (tetrachloroethylene [PCE], trichloroethylene [TCE], and trichloroethane [TCA]) in the contaminated plume are converted to less chlorinated forms (dichloroethylene [DCE], vinyl chloride [VC], and dichloroethane [DCA]) by methanogenic bacteria. At a point downgradient, oxygen is reintroduced into the groundwater. Following this, methanotrophic bacteria, growing on methane and oxygen, are expected to oxidize the DCE, VC, and DCA, as well as nonhalogenated solvents, to carbon dioxide and biomass.



Two-zone plume interception in situ treatment strategy

WASTE APPLICABILITY:

This in situ treatment technology can be applied to groundwater and industrial wastewater containing chlorinated and nonchlorinated solvents. Residuals would be carbon dioxide and biomass.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in July 1989. In preparation for eventual field testing, optimal treatment parameters are being determined by simulating the two-zone treatment in bench-scale soil aquifer simulators. Particular objectives of this testing are to (1) understand the factors that affect the development of the bioactive zones, (2) demonstrate the treatment of chlorinated and nonchlorinated solvent mixtures by using the two-zone process, and (3) develop a model for use in the design of field remediations. The bench-scale testing is 40 percent complete as of September 1991.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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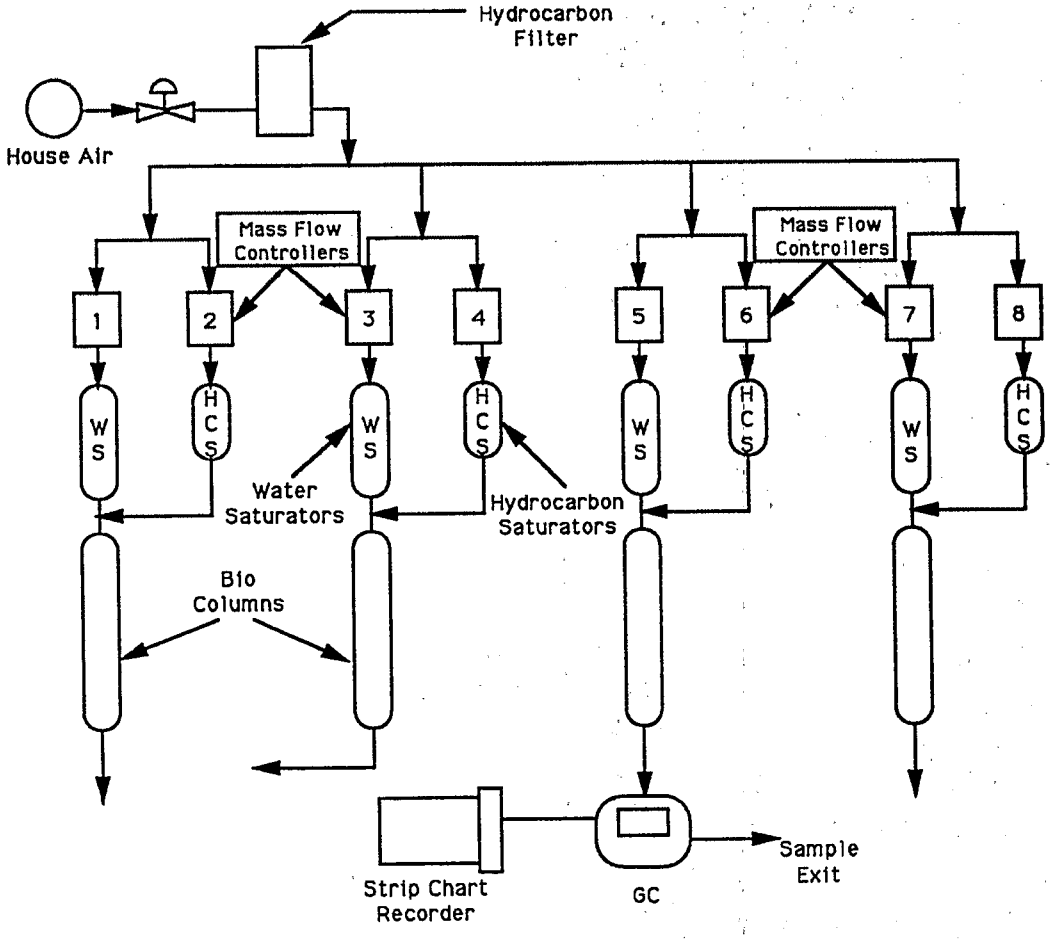
ALCOA SEPARATIONS TECHNOLOGY, INC.
(Bioscrubber)

TECHNOLOGY DESCRIPTION:

This bioscrubber technology digests hazardous organic emissions from soil, water, and air decontamination processes. The bioscrubber contains Alcoa's activated carbon medium as a support for microbial growth. This unique medium, with increased microbial population and enhanced bioactivity, provides effective conversion of diluted organics into carbon dioxide, water, and other nonhazardous compounds (see figure below).

The bioscrubber is designed for large volumes of air streams containing trace volatile organics. Almost complete removal of hazardous organics has been demonstrated in a lab-scale feasibility study.

The bioscrubber efficiency is attributed to the carbon medium having been tailored to balance macro- and micro-porosity. The macroporous volume provides sufficient internal porous surface area for microbial growth. The microporous surface provides sufficient



Schematic of bench-scale unit showing four bioscrubbers in parallel operation

adsorption sites on which to concentrate the dilute organic vapor for effective biological digestion.

WASTE APPLICABILITY:

The bioscrubber technology can be used to remove organic emissions from soil, water, or air decontamination processes. Alcoa is focusing on the treatment of streams containing trace aromatic solvents, such as benzene, toluene, and xylene. This technology could be adapted to halogenated hydrocarbons and other contaminants in the future.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. A bench-scale system has been assembled and is in full operation. The removal efficiency previously attained from a lab-scale feasibility study has been duplicated using this unit. Alcoa is presently evaluating the long-term stability and efficiency of the bioscrubber. The bench-scale study scheduled for completion in early 1992, will be followed by a pilot-scale demonstration.

FOR FURTHER INFORMATION:

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ALLIS MINERAL SYSTEMS
[formerly Boliden Allis, Inc.]
(PYROKILN THERMAL ENCAPSULATION Process)

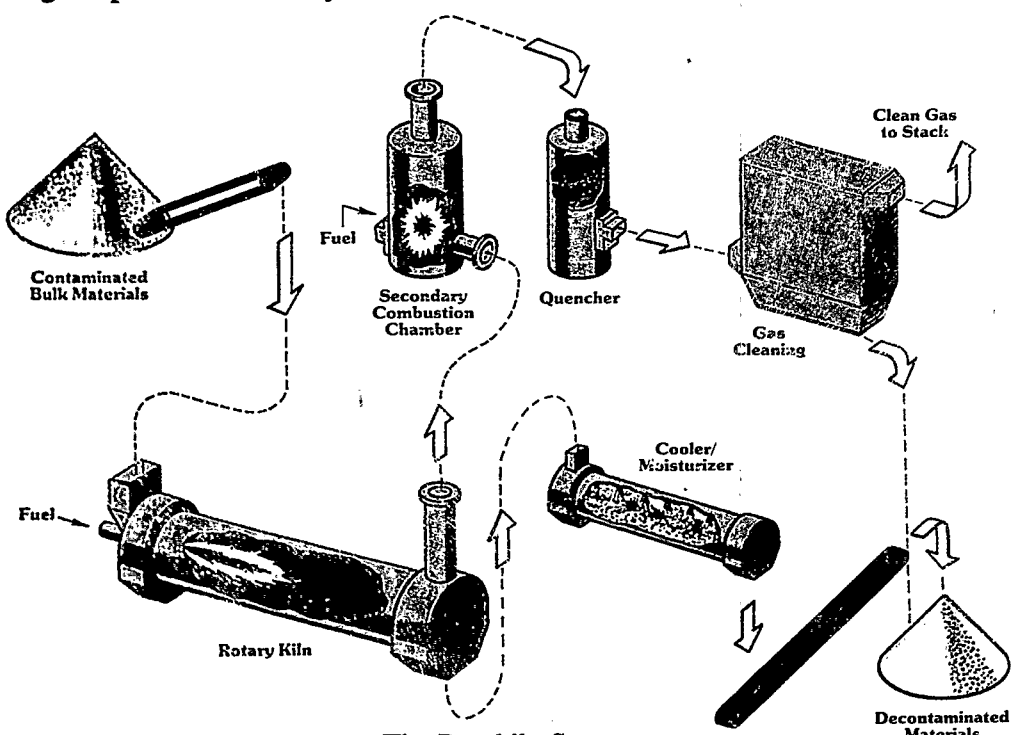
TECHNOLOGY DESCRIPTION:

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 thermally treats soils and sludges contaminated with both organics and metals. The advantages of this process include (1) immobilizing the metals remaining in the 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 heart of this process is thermal encapsulation. It traps metals in a controlled melting process operating in the temperature range between slagging and non-slagging modes, producing nodules of ash that are 1/4–to 3/4–inch in diameter.

Organic waste is incinerated in a rotary kiln. Metallic wastes (in particular, metals with high melting points) are trapped in the bottom ash from the kiln by adding fluxing agents that promote agglomeration via "controlled nodulizing." As proved by extraction procedure toxicity characteristic and toxicity characteristic leaching procedure (TCLP) tests, this PYROKILN THERMAL ENCAPSULATION



The Pyrokiln System

process can reduce metals leaching to levels below EPA limits. Metals with low melting and vaporization temperatures, such as arsenic, lead, and zinc, are partitioned between the bottom ash and the fly ash. Those that are concentrated in the fly ash are stabilized, if necessary, by adding reagents to the kiln and to the air pollution control system to reduce metals leaching to below EPA limits. Another advantage of this process is that it reduces 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 will be 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 outlet of the kiln to function as an ash agglomerator. Good temperature control is required to keep the agglomerates at the correct particle size, yielding the desired 1/4- to 3/4-inch size nodules. The production of nodules, rather than a molten slag, potentially avoids a multitude of operating problems, such as ash quenching, overheating, and premature failure of refractory. It also simplifies 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 applicable to soils and sludges. The process can destroy a broad range of organic species, including halogenated and nonhalogenated organics and petroleum products. Metallic compounds that may be encapsulated or stabilized include antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in March 1990. The process has been further investigated in batch tests during June and July 1991. A continuous flow, pilot-scale kiln test will be be conducted at Allis Mineral System's Process Research and Test Center in Oak Creek, Wisconsin, in spring 1992.

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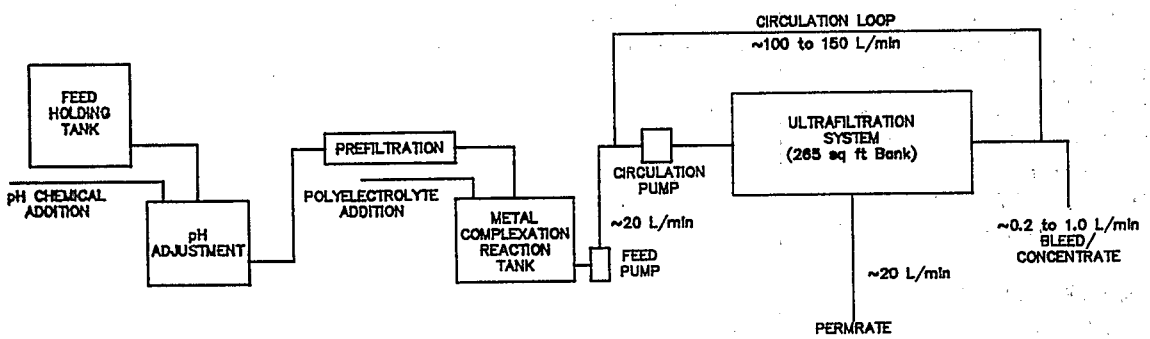
ATOMIC ENERGY OF CANADA, LTD.
(Chemical Treatment and Ultrafiltration)

TECHNOLOGY DESCRIPTION:

The Atomic Energy of Canada Limited (AECL) process uses chemical pretreatment and subsequent ultrafiltration to remove trace concentrations of dissolved metals from wastewater, contaminated groundwater, and leachate. The process provides both selective removal of metal contaminants and a volume-reduced water stream amenable to further treatment and disposal.

The process involves addition of water-soluble macromolecular compounds to the wastewater to form complexes with heavy metal ions. In addition, 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 conditions. Without the polyelectrolyte being present, and depending on the pH conditions, metal ions present in the waste solution either (1) precipitate, (2) remain completely in solution, or (3) remain in a state where metal precipitates and metal ion solutions coexist. Enlarged metal-polyelectrolyte complexes are found in the waste solution. The polyelectrolyte quantities needed to achieve the desired size enlargement are dependent on the concentration of metal ions; therefore the separated metal ions generally should be in the parts-per-million (ppm) range. After the desired size for the metal complex is achieved, the solution containing the complex is processed through a cross-flow ultrafiltration membrane system that retains the complexes (retentate or concentrate), while allowing uncomplexed ions to pass through the membrane with the filtered water (permeate). The filtered water is recycled, or discharged, depending on the goal set for metal removal. The figure below is a schematic of the process.

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 chemicals for pH adjustment and polyelectrolytes, (3) two banks of hollow-fiber ultrafilters, (4) a backflush



Single-stage Chemical Treatment - Ultrafiltration process flowsheet

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 the metal-polyelectrolyte complexation is achieved.

The conditioned feed is fed to the ultrafilter assembly through a recirculation loop. The recirculation loop includes membranes that provide the necessary contact time and turbulence for the separation of metal-polyelectrolyte complexes and other suspended and colloidal particulates. The permeate stream, which can be discharged, is continuously withdrawn, while the concentrate stream, consisting of most of the contaminants, is recycled through the recirculation loop until the desired volume reduction is achieved. After the target concentration is reached, the concentrate stream is withdrawn for further treatment, such as solidification, after which it can be readily and safely disposed.

WASTE APPLICABILITY:

The process can be used to treat wastewater contaminated with trace levels of toxic heavy metals that arise from different sources, including groundwaters, leachates, and surface runoff water. The process can also be applied to treatment of effluents from (1) industrial processes, (2) production and processing of base metals, (3) smelters, (4) electrolysis operations, and (5) battery manufacturing. Specific potential applications include removal of metals such as cadmium, lead, mercury, uranium, manganese, nickel, chromium, and silver.

Influent-dissolved metal concentrations amenable to treatment range from a few ppm to tens of ppm. In addition to dissolved metals, other inorganic and organic materials present as suspended or colloidal solids can be removed. The sole residue generated by this process is the ultrafiltration concentrate. The concentrate generally constitutes 5 to 20 percent of the feed volume.

STATUS:

The initial bench-scale and pilot-scale tests have indicated successful removal of cadmium, lead, and mercury. Design and construction of the transportable unit was based on bench-scale and pilot-scale test results.

Initial testing of the transportable unit at the Chalk River Laboratories and at a uranium mine tailings site in Ontario has been completed. 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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Chalk River Laboratories
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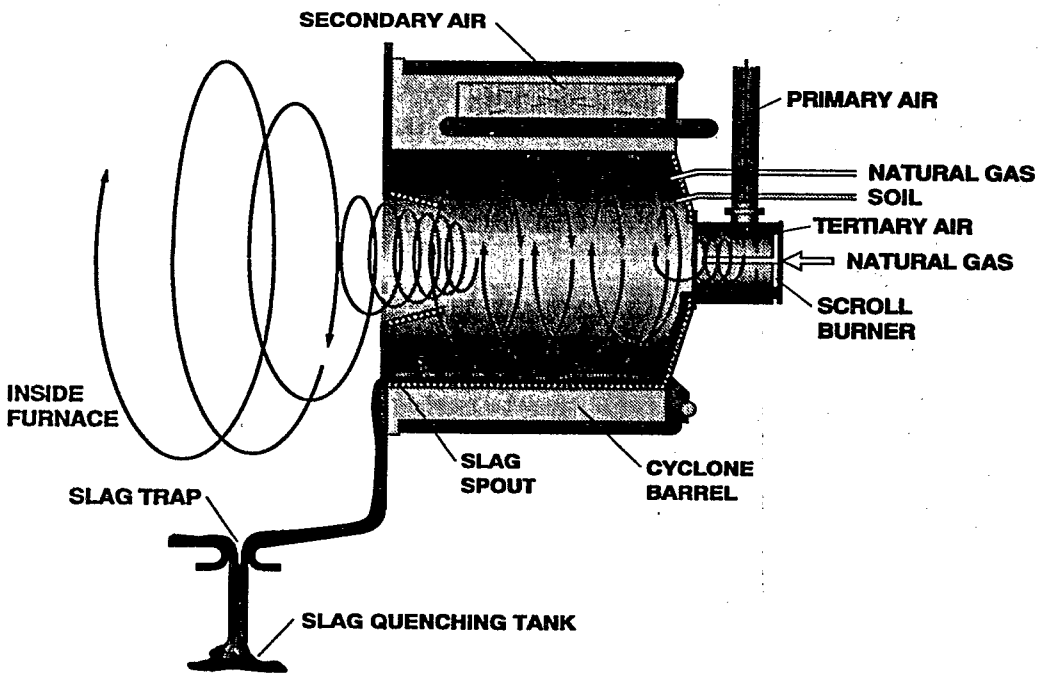
BABCOCK & WILCOX CO.
(Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

This furnace technology is designed to decontaminate wastes containing both organic and metal contaminants. The cyclone furnace retains heavy metals in a non-leachable slag and vaporizes and incinerates the organic materials in the wastes.

The treated soils resemble natural obsidian (volcanic glass), similar to the final product from vitrification.

The furnace is a horizontal cylinder (see figure below) and is designed for heat release rates greater than 450,000 British thermal units (Btu) per cubic foot (coal) and gas temperatures exceeding 3,000 degrees Fahrenheit (°F). Natural gas and preheated primary combustion air (820°F) enter the furnace tangentially. Secondary air (820°F), natural gas, and the synthetic soil matrix (SSM) enter tangentially along the cyclone barrel (secondary air inlet location). The resulting swirling action efficiently mixes air and fuel and increases combustion gas residence time. Dry SSM has been tested at pilot-scale feed rates of both 50 and 200 pounds per hour (lb/hr). The SSM is retained on the furnace wall by centrifugal action; it melts and captures a portion of the heavy metals. The organics are destroyed in the molten slag layer. The slag exits the cyclone furnace (slag temperature at this location is 2,400°F) and is dropped into a water-filled slag tank where it solidifies into a nonleachable vitrified material. A small quantity of the soil also exits as flyash from the furnace and is collected in a baghouse.



Cyclone furnace

WASTE APPLICABILITY:

This technology may be applied to high-ash solids (such as sludges and sediments) and soils containing volatile and nonvolatile organics and heavy metals. The less volatile metals are captured in the slag more readily. The technology would be well-suited to mixed waste soils contaminated with organics and nonvolatile radionuclides (such as plutonium, thorium, uranium). Because vitrification has been listed as Best Demonstrated Achievable Technology (BDAT) for arsenic and selenium wastes, the cyclone furnace may be applicable to these wastes.

STATUS:

The cyclone furnace was used to vitrify a dry synthetic soil matrix spiked with 7,000 parts per million (ppm) lead; 1,000 ppm cadmium; and 1,500 ppm chromium fed at nominal rates of 50 and 150 lb/hr. Concentrations of these contaminants in the vitrified (treated) SSM were 0.19, 0.12, and 0.08 milligrams per liter (mg/L), respectively. These levels are well below EPA limits. The capture of heavy metals in the slag was estimated at 8 to 17 percent for cadmium, 24 to 35 percent for lead, and 80 to 95 percent for chromium. The volume of the vitrified soil was reduced by 35 percent when compared to the dry SSM.

The cyclone furnace is now being modified to feed a wet synthetic soil. Further tests with SSM spiked with heavy metals will be performed in an attempt to optimize the capture of heavy metals in the slag.

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BATTELLE MEMORIAL INSTITUTE
(In Situ Electroacoustic Soil Decontamination)

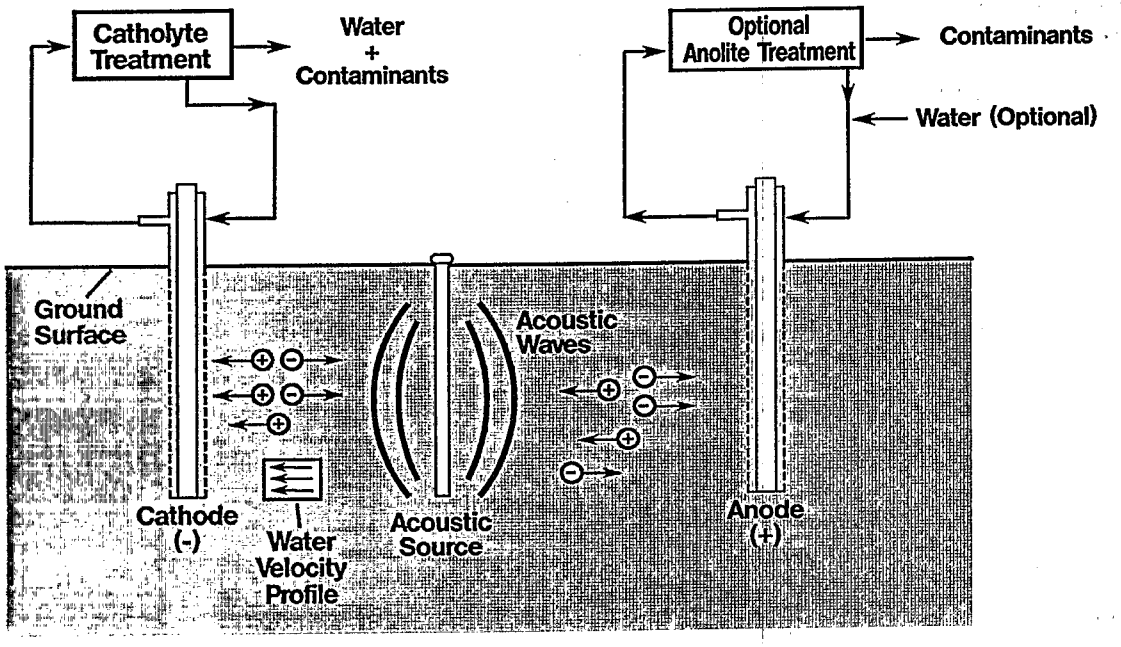
TECHNOLOGY DESCRIPTION:

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



Conceptual layout of electroacoustical soil decontamination (ESD) process

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 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 (NAPL) 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 electroacoustical 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. For more effective hydrocarbon removal, a modified ESD process has been developed but not tested. An EPA report (EPA/540/5-90/004) for the one-year investigation is available for purchase through the National Technical Information Service. The NTIS order no. is PB 90-204 728/AS. The phone number is 703-487-4650.

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BIO-RECOVERY SYSTEMS, INC.
(Biological Sorption)

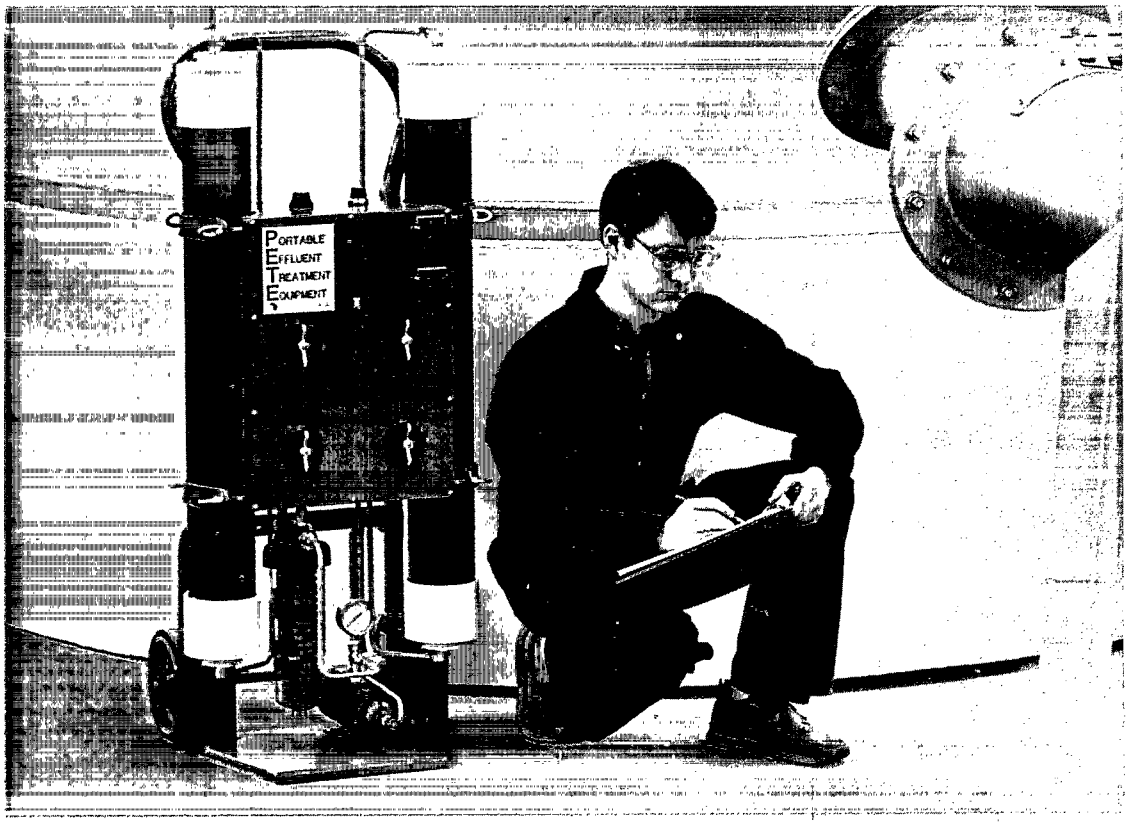
TECHNOLOGY DESCRIPTION:

The AlgaSORB™ sorption process is designed to remove heavy metal ions from aqueous solutions. The process is based on the natural affinity of the cell walls of algae for heavy metal ions.

The sorption medium is comprised 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 (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



PETE Unit

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 by using acids, bases, or other suitable reagents. This produces a small volume of solution containing highly concentrated metals that must undergo treatment.

The photograph 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 PETE unit is capable of treating flows of approximately 1 gallon per minute (gpm). Larger systems have been designed and manufactured to treat flow rates greater than 100 gpm.

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.

The system can remove heavy metals such as aluminum, cadmium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, uranium, vanadium, and zinc.

STATUS:

Under the Emerging Technology Program, the AlgaSORB™ sorption process was tested on mercury-contaminated groundwater at a hazardous waste site in Oakland, California, in fall 1989. Testing was designed to determine optimum flow rates, binding capacities, and the efficiency of stripping agents. The final report (EPA/540/5-90/005a) is now available. Based on the results from the Emerging Technology Program, Bio-Recovery Systems, Inc., has been invited to participate in the SITE Demonstration Program.

The process is being commercialized for groundwater treatment and industrial point source treatment. Treatability studies are required as the next stage in development.

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BIOTROL, INC.
(Methanotrophic Bioreactor System)

TECHNOLOGY DESCRIPTION:

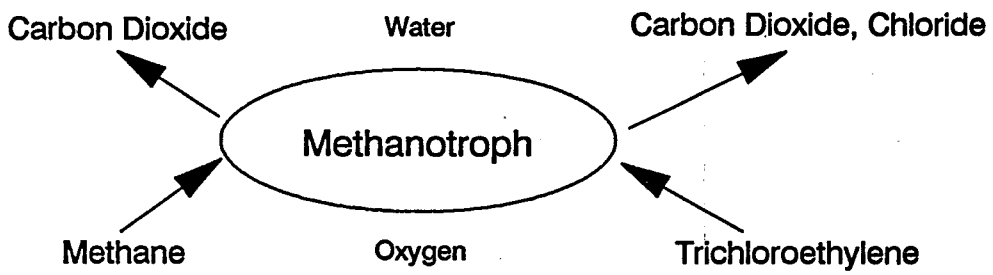
The methanotrophic bioreactor system is an aboveground remedial technology for water contaminated with halogenated hydrocarbons. trichloroethylene (TCE) and related compounds pose a new and difficult challenge to biological treatment. Unlike aromatic hydrocarbons, for example, TCE cannot be used as primary substrates for growth by bacteria. Their 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 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 form or a particulate (membrane-bound) form, BioTrol-sponsored research results have led to a patent pending on the discovery that the soluble form is responsible for extremely rapid rates of TCE degradation. BioTrol also has a patent pending on a colorimetric assay it uses to verify 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 TCE per gram cells (dry weight) per hour, which is 100 to 1,000 times faster than the rates for other systems.

WASTE APPLICABILITY:

The technology is applicable to water contaminated with halogenated aliphatic hydrocarbons, including TCE, dichloroethylene (DCE) isomers, vinyl chloride, dichloroethane



Cometabolism of TCE

(DCA) isomers, chloroform, dichloromethane (methylene chloride), and others.
In the case of groundwater treatment, bioreactor effluent can be reinjected or discharged either to a sanitary sewer or to a national pollutant discharge elimination system (NPDES) receiving water.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Bench-scale experiments were conducted during the first year on a continuous-flow, dispersed-growth system. Typical results obtained are shown in the table below. Pilot-scale field testing is planned for the second year. The pilot-scale test will provide data that could show the full-scale feasibility of the bioreactor technology.

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Typical lab continuous-flow results

CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Acid Extraction Treatment System)

TECHNOLOGY DESCRIPTION:

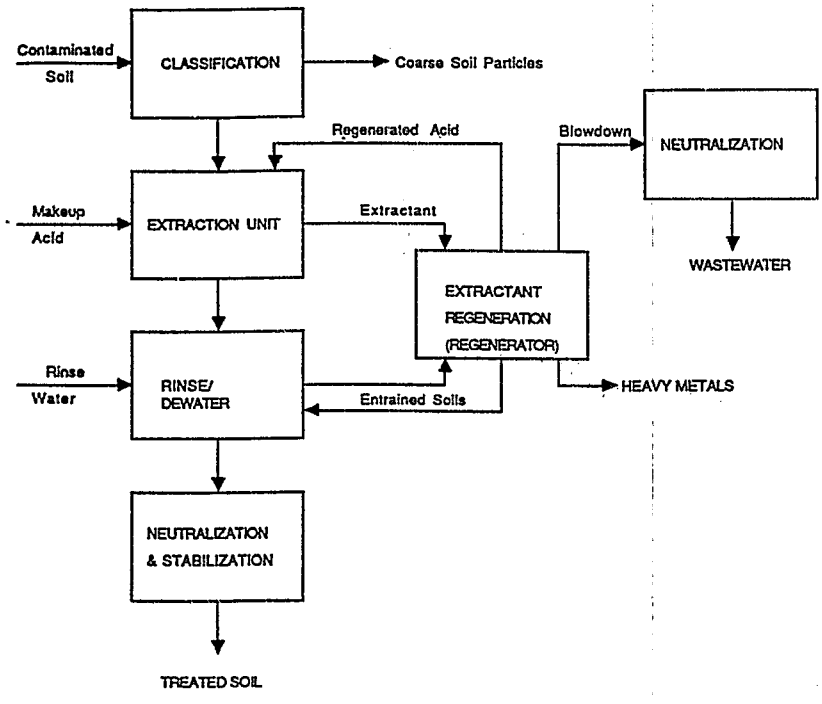
The acid extraction treatment system (AETS) is a soil washing process that uses hydrochloric acid to extract contaminants from soils. Following treatment, soil may be disposed of or used as fill material (see figure below).

The first step in the AETS is to separate large particles and gravel from the soil. The sand and clay-silt fractions (less than 4 mm) are retained for treatment. Hydrochloric acid is slowly added to a water and soil slurry to achieve and maintain a pH of 2. Precautions are taken to avoid lowering the pH below 2 and disrupting the soil matrix.

When the extraction is complete, the soil is rinsed, neutralized, and dewatered. The extraction solution and rinse water are regenerated. The regeneration process removes entrained soil, organics, and heavy metals from the extraction fluid. Heavy metals are concentrated in a form potentially suitable for economic recovery. Recovered acid is recycled to the extraction unit.

WASTE APPLICABILITY:

Although the AETS will extract organic contaminants from soil, its main application is to remove heavy metals, such as arsenic, cadmium, chromium, copper, lead, nickel and zinc. The



Flow diagram for AETS process

projected treatment capacity of the AETS is 20 tons per hour.

STATUS:

This technology has been tested in the laboratory on a limited, bench-scale basis. Similar extraction techniques have been applied to soils contaminated with organics. The developer has designed and is constructing a pilot-scale plant to test AETS on heavy metal-contaminated soils. Current plans include using the AETS on samples of contaminated soil from Superfund sites. Further experiments will be performed to establish optimal operating parameters for the extraction unit and to refine the regeneration and recovery process.

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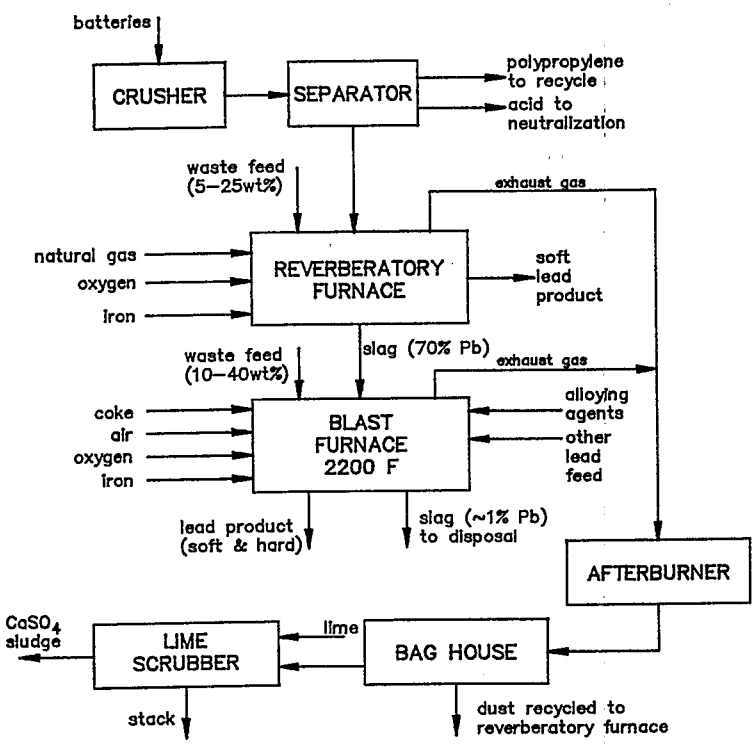
CENTER FOR HAZARDOUS MATERIALS RESEARCH
(Lead Smelting)

TECHNOLOGY DESCRIPTION:

Secondary lead smelting is a proven technology for reclaiming usable lead from many different sources containing between 30 and 65 percent lead, particularly lead-acid batteries (between 30 and 90 percent of which are currently reclaimed). This technology uses reverberatory and blast furnaces, which heat a mixture of lead and other materials and remove the lead by a combination of melting and reduction.

The Center for Hazardous Materials Research will use the secondary lead smelting technology to reclaim usable lead from waste materials such as lead-contaminated rubber battery casings, slags, and other wastes containing lower concentrations of lead (in the range of 1 to 10 percent), as compared with the current feedstock, which typically contains 30 to 65 percent lead. The process is intended to treat battery wastes present at the battery breaker Superfund sites, rather than soil. However, it is expected that the process may be able to handle a feedstock containing about 2 to 5 percent soil by weight. This percentage will be determined during testing. The net result will be the detoxification of these materials, while providing a viable product (such as reclaimed lead).



Lead smelting process schematic

This technology is based on existing reverberatory furnace design and basic pyrometallurgy. Feed materials are sized and screened to remove large debris. Next, grinding and crushing equipment reduce the size of the feed material, which is then charged to the gas-fired reverberatory furnace. The reverberatory furnace essentially operates as a melting furnace. The pure metallic lead portion of the feedstock (as opposed to any oxide content) is melted to produce molten lead, which accumulates and is removed periodically from the bottom of the furnace. The reverberatory furnace's operating conditions (relatively lower temperatures, short detention time, and oxidizing atmosphere, as compared with a blast furnace) cause any metal (lead) oxide portion of the feedstock to report to the furnace's slag waste stream. The feedstock, therefore, is not recovered in the reverberatory furnace.

In contrast, the high temperature, long detention time, and reducing conditions of the blast furnace serve to (1) melt metallic lead, and (2) metallurgically reduce lead oxides to produce pure molten lead. Slag waste from the reverberatory furnace, and other waste streams which contain predominantly lead oxide, are charged into a natural gas-fired blast furnace, along with coke, iron (a slag conditioner), and lime. The furnace operates at 2,200 degrees Fahrenheit (°F) to 2,400°F. Molten lead is removed from the furnace, further purified and refined, and reclaimed for reuse in the production of new lead acid batteries. The process will operate by substituting a fraction of the normal feed to the furnaces with the battery wastes from the Superfund sites. The figure on the previous page is an illustration of the lead recovery procedure.

WASTE APPLICABILITY:

This process treats waste materials such as discarded lead-contaminated rubber battery casings, slags, and other materials containing low concentrations of lead.

STATUS:

The project was accepted into the SITE Emerging Technology Program in March 1991. The developer is currently preparing the work plan and Quality Assurance Project Plan (QAPjP).

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COLORADO DEPARTMENT OF HEALTH
(Developed by COLORADO SCHOOL OF MINES)
(Wetlands-Based Treatment)

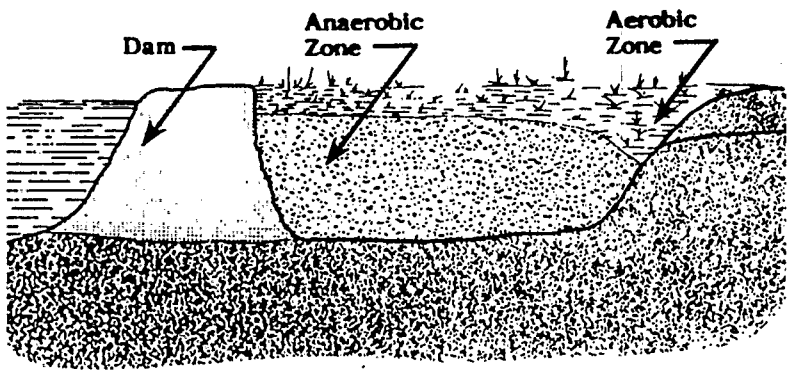
TECHNOLOGY DESCRIPTION:

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, which contain high metal concentrations and have a 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 come into contact with 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 in nature. Wetlands treatment has been applied with some success to wastewater in the eastern regions of the United States. The process may have to be adjusted to account for differences in



Typical wetland ecosystem

geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.

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 the discharge of acid mine drainage from the Big Five Tunnel near Idaho Springs, Colorado. Results of the study have shown that by optimizing design parameters, removal efficiency of heavy metals from the discharge can approach the removal efficiency of chemical precipitation treatment plants. An example of the optimum results from the three years of operation are given below.

- pH was raised from 2.9 to 6.5.
- Dissolved aluminum, cadmium, chromium, copper, zinc, concentrations were reduced by 98 percent or more.
- Iron was reduced by 84 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 Ceriodaphnia was reduced by factors of 4 to 20.

One of the final goals of this project will be the development of a manual that discusses design and operating criteria for construction of a full-scale wetland for treating acid mine discharges. This manual will be available in fall 1991.

As a result of the success of this technology 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. Construction of a full-scale wetland is the proposed remedial action for 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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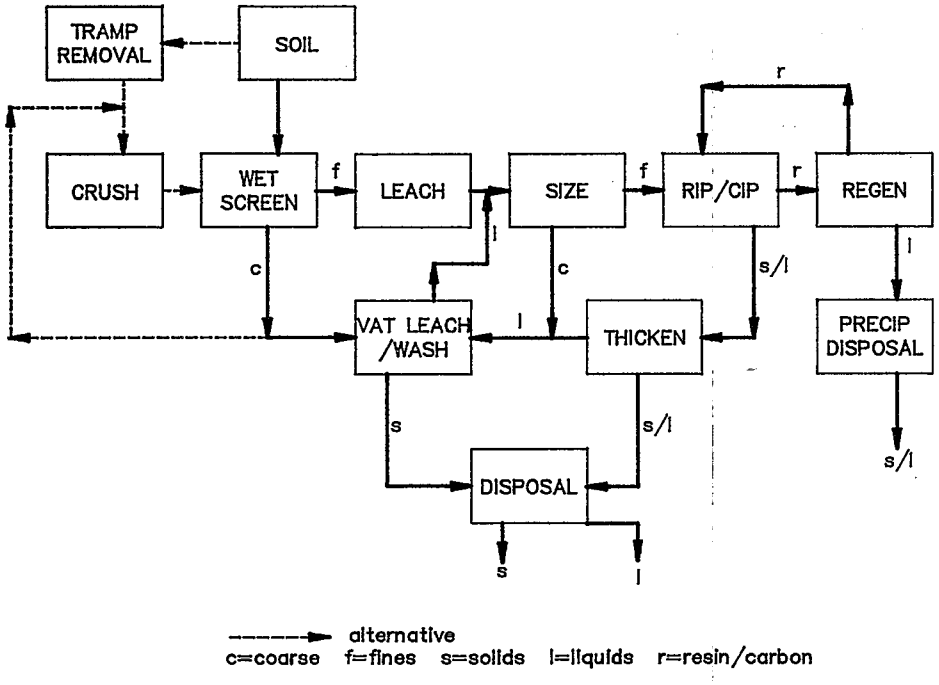
DAVY RESEARCH AND DEVELOPMENT, LTD.
(Chemical Treatment)

TECHNOLOGY DESCRIPTION:

This treatment employs resin-in-pulp (RIP) and carbon-in-pulp (CIP) technologies for treating soils, sediments, dredgings, and solid residues contaminated with organics and inorganics. The leach RIP and CIP technologies are based on the extraction, adsorption, and removal of contaminants from the slurry phase of a soil-water-extractant mixture.

In the past, the RIP and CIP processes have been successfully used for the recovery of metals from ores. The RIP process is well-established in the recovery of uranium, where anion exchange resins are used to adsorb the uranium that is leached as uranyl anion. The CIP process is commonly used in recovering precious metals, where activated carbon is used to adsorb gold and silver leached as cyanide complexes. This treatment technology uses both RIP and CIP processes in multi-stage continuous countercurrent contactors in horizontal arrangement.

The figure below presents a schematic of the process. Incoming contaminated material is either passed through wet screens or subject to tramp (debris) removal and crushing before reaching the wet screens. Fine material passing the wet screen is sent to the agitated leach tank, where the contaminants are extracted. Coarse material is sent to a vat leach and washing stage or returned to the crushing step. The leached fines and vat leach liquor are combined and passed to the cyclones which separate sands from the clays. When the contaminant concentrations exceed 10,000 to 25,000 milligrams per kilogram of soil, the liquid passes directly to precipitation and disposal, and the



Schematic diagram of the chemical treatment process

fine solids are reslurried before passing to the cyclone. The clays and leach liquor then pass to the RIP or CIP contactor where the contaminants are adsorbed onto ion-exchange resins or activated carbons. The thickened, treated solids are collected from the thickener and the vat leach and washing step for disposal or post-treatment. The resins and carbons are regenerated and recycled; the concentrated contaminants are then subjected to further treatment, disposal, or recovery.

WASTE APPLICABILITY:

RIP and CIP technologies are suitable for treating a wide range of materials contaminated by both inorganic and organic wastes. Inorganics treated to date include heavy metals and cyanide-containing wastes. This process also applies to treatment of chlorinated phenols, chlorinated solvents, pesticides, polychlorinated biphenyls, and other organics and inorganics by the choice of appropriate extractant reagents and sorbent materials.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. Laboratory studies have been underway since January 1991. A small pilot plant (treating approximately 2 tons per day) is expected to be in operation by early 1992. A suitable location for pilot-scale test work under the SITE Program is being sought in the United States for late 1992 or early 1993.

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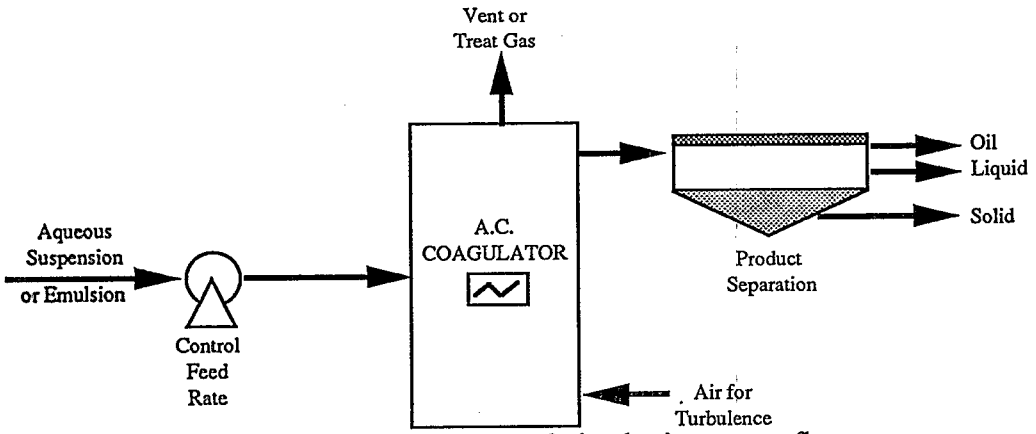
ELECTRO-PURE SYSTEMS, INC.
(Alternating Current Electrocoagulation Technology)

TECHNOLOGY DESCRIPTION:

Alternating current electrocoagulation (ACE) technology (ACE technology) offers an alternative to metal salts or polymer and polyelectrolyte addition for breaking stable emulsions and suspensions. The technology is also effective at removing certain metals and other soluble pollutants in the polishing step of effluent treatment. For example, the approximate maximum efficiency removal rates in percent are: lead-56, copper-96, zinc-91, phosphate-97, and flouride-56. Electrocoagulation introduces highly-charged polyhydroxide aluminum species into aqueous media that prompt the flocculation of colloidal particles and destabilization of oil-in-water emulsions. Liquid/liquid, and solid/liquid phase separations are achieved with production of sludges that can be filtered and dewatered more readily than those formed through chemical flocculant addition. The technology can be used to 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 is performed in either 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, 2) or an upright box containing aluminum plate electrodes spaced at nominal distances of 1/2 to 2 inches. Both ACE Separator™ units are small; 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. They have no moving parts, and can be easily integrated into a process treatment train either for effluent, pretreatment, or polishing.

Coagulation and flocculation occur simultaneously within the ACE Separator™ and continue within the product separation step. Charge neutralization and the onset of coagulation occur 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 occurs rapidly (often within 30 seconds) for most aqueous suspensions. After charge neutralization and the onset of coagulation, treatment is complete and the suspension and emulsion may be transferred by gravity flow to the product separation step.



Alternating current electrocoagulation basic process flow

Product separation is accomplished in conventional gravity-separation, decant vessels or by means of pressure or vacuum filtration. Coagulation and flocculation continue until complete phase separation is achieved. Waste is removed by using surface skimming, bottom scraping, and decanting.

After the product separation step, each phase (oil, water, and solid) is removed for reuse, recycling, further treatment, or disposal. The technology can be employed in conjunction 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, after dewatering, would be shipped off-site for disposal, and the dewatering filtrate would be recycled. Any floatable material would be reclaimed, refined, otherwise recycled or disposed of.

WASTE APPLICABILITY:

The ACE technology can be applied to various aqueous-based suspensions and emulsions typically generated by 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.

Reductions exceeding 90 percent in the loadings of aqueous clay, latex and titanium dioxide suspensions have been routinely achieved. Reductions exceeding 80 percent in the Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) contents of diesel fuel-spiked slurries have been achieved.

ACE technology has also been used to enable recovery of fine-grained product (latex, titanium dioxide, and edible oil solids) from industrial process streams that would otherwise have been lost to sewer discharge.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1988. The second year of laboratory-scale testing and development of the technology has been completed. Extensive experimentation on end-member metals and complex synthetic soil slurries has enabled definition of the major operating parameters for broad classes of effluents. Optimization of the treatment procedure to both minimize electric power consumption and maximize effluent throughput rates has been successful. Results indicate that electrocoagulation can affect aqueous and solid separations comparable to chemical flocculant addition, but with reduced filtration times and sludge volumes.

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ELECTROKINETICS, INC.
(Electro-Osmosis)

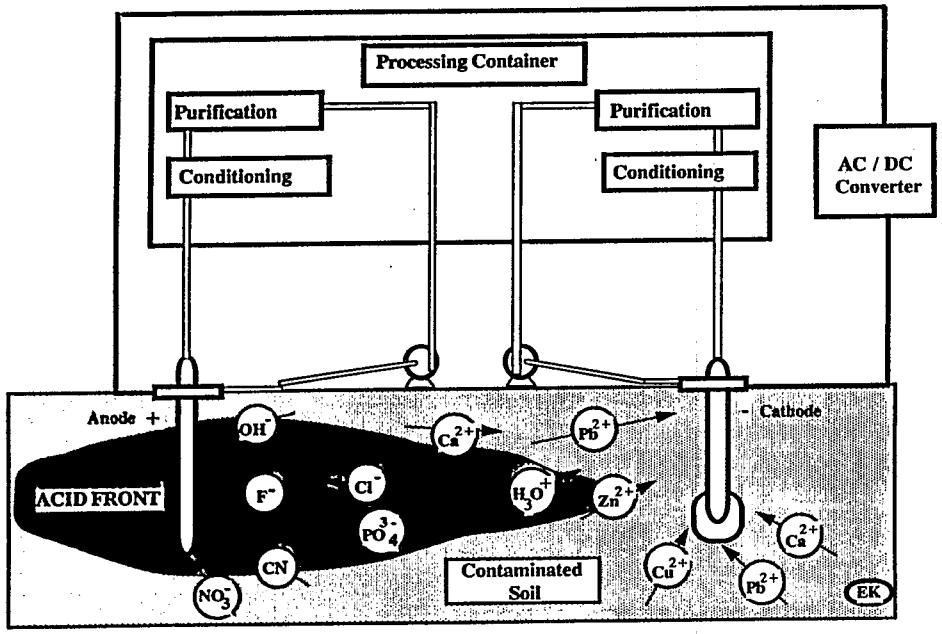
TECHNOLOGY DESCRIPTION:

Electrokinetic soil processing is an in situ separation and removal technique for extracting heavy metals and organic contaminants from soils. The technology uses electricity to affect chemical concentrations and groundwater flow. In electro-osmosis (EO), the fluid between the soil particles moves, because a constant, low direct current is applied through electrodes inserted into a soil mass..

The figure below presents a schematic diagram of the process and the ion flow. A comparison of flow with and without EO in clays is also depicted. The efficiency of electro-osmotic water transport under EO varies with the type of soil. The figure below also shows that EO can be an efficient process for pumping contaminants from fine-grained, low permeability soils.

Studies of the electrochemistry associated with the process indicate that an acid front is generated at the anode. This acid front eventually migrates from the anode to the cathode. Movement of the acid front by migration and advection results in desorption of contaminants from the soil. The concurrent mobility of the ions and pore fluid under the electrical gradients decontaminates the soil mass. These phenomena provide an added advantage over conventional pumping techniques for in situ treatment of contaminated fine-grained soils.

Recent bench-scale data indicate that the process may be applied to both saturated and partially saturated soils. The process will lead to temporary acidification of the treated soil. However, equilibrium conditions will be rapidly reestablished by diffusion when the electrical potential is removed.



Schematic diagram of electro-osmosis

Studies have indicated that metallic electrodes may dissolve as a result of electrolysis, and introduce corrosion products into the soil mass. However, if the electrodes are made of carbon or graphite, no residue will be introduced into the treated soil mass as a result of the process.

WASTE APPLICABILITY:

This is an in situ separation technique for extracting heavy metals, radionuclides, and other inorganic contaminants. Bench-scale laboratory data demonstrate the feasibility of removing arsenic, benzene, cadmium, chromium, copper, ethylbenzene, lead, nickel, phenol, trichloroethylene, toluene, xylene, and zinc from soils. Recent bench-scale tests demonstrated the feasibility of removing uranium and thorium from kaolinite. Limited field tests demonstrated that the method removed zinc and arsenic from both clays and saturated and unsaturated sandy clay deposits. Lead and copper were also removed from dredged sediments. The treatment efficiency was dependent upon the specific chemicals and concentrations. The technique proved 85 percent efficient in the removal of 500 parts per million (ppm) phenol from saturated kaolinite. In addition, the removal efficiency of lead, chromium, cadmium, and uranium, at levels up to 1000 ppm ranged between 75 and 95 percent.

STATUS:

Under the SITE Program, bench-scale laboratory studies investigating the removal of heavy metals precipitates, radionuclides, and organic contaminants will be completed by the end of 1991. Pilot-scale studies investigating removal of radionuclides will begin in January 1992. The pilot-scale study will be completed by the end of 1992. The technology will be available for full-scale implementation upon completion of the pilot-scale studies. Treatability studies, removal enhancement studies, and cost-effective electrode design and manufacture are currently in progress.

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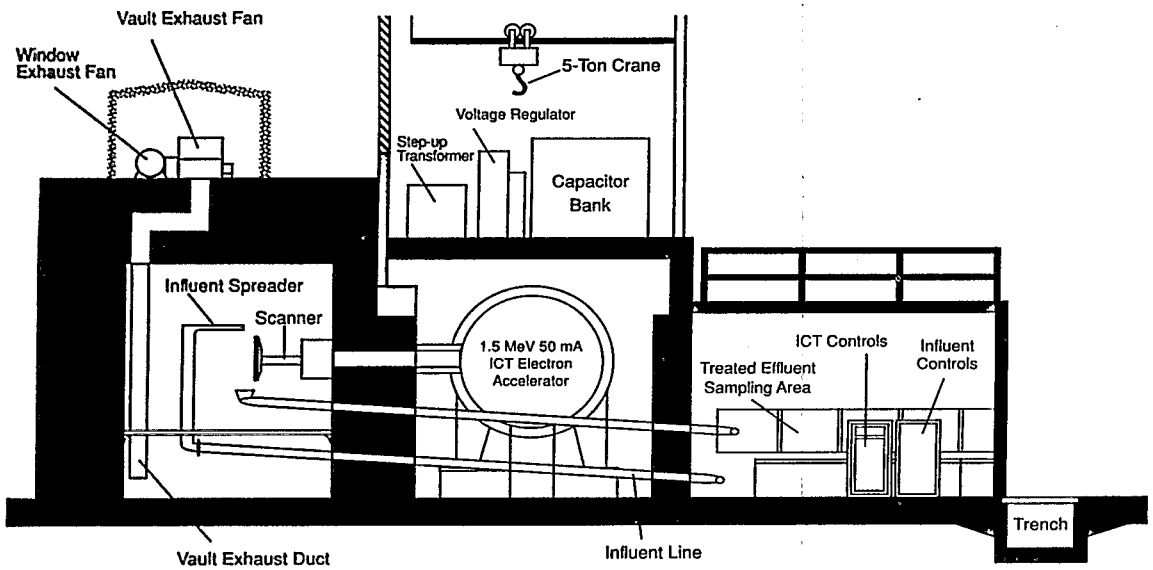
ELECTRON BEAM RESEARCH FACILITY
FLORIDA INTERNATIONAL UNIVERSITY and UNIVERSITY OF MIAMI
(High-Energy Electron Irradiation)

TECHNOLOGY DESCRIPTION:

High-energy electron irradiation of water solutions and sludges produces a large number of very reactive chemical species, including hydrogen peroxide. The reactive species that are formed are the aqueous electron (e^-_{aq}), the hydrogen radical (H•), and the hydroxyl radical (OH•). These short-lived intermediates react with organic contaminants, transforming them to nontoxic 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, the chemicals are mineralized to carbon dioxide and 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 shot into a thin stream of water or sludge as it falls through the beam. All reactions are complete in less than 1/10 of a second.



Electron Beam Research Facility

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 for treatability studies. 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 effective in treating 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, trichloroethylene, tetrachloroethylene, 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) the persistent pesticide, dieldrin.

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. The major research thrust of the first year has been to determine reaction by-products following high energy irradiation of solutions and sludges containing trichloroethylene (TCE), tetrachloroethylene (PCE), chloroform ($CHCl_3$), benzene, tolulene and *m*- and *o*-xylene. It appears, for the most part, that these compounds are mineralized. Trace quantities (a few micrograms per liter) of formaldehyde and other low molecular weight aldehydes have been detected; however, these compounds are not toxic at these concentrations.

The organic solutes of interest are currently being solubilized directly in aqueous solutions by using 6,000-gallon tank trucks to eliminate the solvent effects of the methanol.

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ENERGY AND ENVIRONMENTAL ENGINEERING, INC.
(Laser–Induced Photochemical Oxidative Destruction)

TECHNOLOGY DESCRIPTION:

This technology is designed to photochemically oxidize organic compounds in wastewater by adding a chemical oxident and applying ultraviolet (UV) radiation with an Excimer laser. The photochemical reactor can destroy low concentrations of organics in water. The energy is sufficient to fragment the bonds of organic compounds, and the radiation is not absorbed to any significant extent by the water molecules in the solution. The process is envisioned as a final treatment step to reduce organic contamination in groundwater and industrial wastewaters to acceptable discharge limits.

The overall reaction uses hydrogen peroxide as the oxidant in the reaction:

$$C_aH_bX + [2a + 0.5(b - 1)]H_2O_2 \xrightarrow{h\nu} aCO_2 + [2a+(b-1)]\ H_2O + HX$$

C_aH_bX = a halogenated toxic component in the aqueous phase. The reaction products are carbon dioxide, water, and the appropriate halogen acid.

The existing process equipment has a capacity of 1 gallon per minute when treating a solution containing 32 parts per million (ppm) of total organic carbon. It consists of a photochemical reactor, where oxidation is initiated, and an effluent storage tank to contain reaction products.

The skid-mounted system can be used in the field and stationed at a site. The exact makeup of the process will depend on the chemical composition of the groundwater or wastewater being treated.

Typically, contaminated groundwater is pumped from a feed well through a filter unit to remove suspended particles. The filtrate is then fed to the photochemical reactor and irradiated. The chemical oxidant, hydrogen peroxide (H_2O_2), is introduced to the solution to provide hydroxyl radicals required for oxidation.

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 formed when treating fluids contaminated with halogenated hydrocarbons.

The reaction kinetics depend on (1) toxicant concentration, (2) peroxide concentration, (3) irradiation dose, and (4) irradiation frequency.

Table 1 presents typical reaction times for specific levels of destruction for several toxicants of concern.

TABLE 1
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 can be applied to groundwater and industrial wastewater containing organics.

Typical target compounds tested, in which greater than 95 percent destruction removal efficiency (DRE) was obtained include benzene, chlorobenzene, chlorophenol, dichloroethene, and phenol.

Table 2 lists the compounds destroyed by ultraviolet ozonation processes that can be treated successfully by laser-induced photochemical oxidative destruction.

TABLE 2
COMPOUNDS TREATED WITH UV/OXIDATION

Ethers	Pesticides
Aromatic Amines	Benzene
Toluene	Ethylbenzene
Xylene	Citric Acid
Complexed Cyanides	Phenol
Trichloroethane	Trinitrotoluene
Polycyclic Aromatics	Trichloloethylene
Dichloroethane	Dioxins
Perchloroethylene	Methylene Chloride
Hydrazine	Dichloroethylene
Cresols	Cyclonite
Polynitrophenols	Polychlorinated Biphenyls
1,4-Dioxane	Ketones
Pentachlorophenol	Vinyl Chloride
Ethylenediaminetetraacetic Acid	

STATUS:

The process is entering the SITE Demonstration Program. The company is offering to conduct treatability studies for prospective clients. Funding is also being sought to construct a full-scale pilot facility. Preliminary cost evaluation shows the process to be very competitive compared to other UV/oxidation processes and carbon adsorption.

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ENERGY & ENVIRONMENTAL RESEARCH CORPORATION
(Hybrid Fluidized Bed System)

TECHNOLOGY DESCRIPTION:

The Hybrid Fluidized Bed (HFB) system treats contaminated solids and sludges by (1) incinerating all 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, a spouted bed rapidly heats solids and sludges to extract volatile organic and inorganic compounds. The bed's design retains larger soil clumps until they are reduced in size, but allows fine material to quickly pass through the primary stage. 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 abrasion and grinding action, resulting in the rapid size reduction of the feed materials through attrition. The spouted bed operates between 1500 degrees Fahrenheit (°F) and 1700°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 (FBA). 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.

The third stage is the high temperature particulate soil extraction system where clean processed soil is removed from the effluent gas stream with one or two hot cyclones. The clean soil is extracted hot to preclude the condensation of any unreacted volatile metal species. 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 soils 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 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. Non-volatile 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 Spouted Bed Incinerator (SBI) is complete. The second year of research is proceeding.

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ENVIRO-SCIENCES, INC., and ART INTERNATIONAL, INC.

(Low-Energy Solvent Extraction Process)

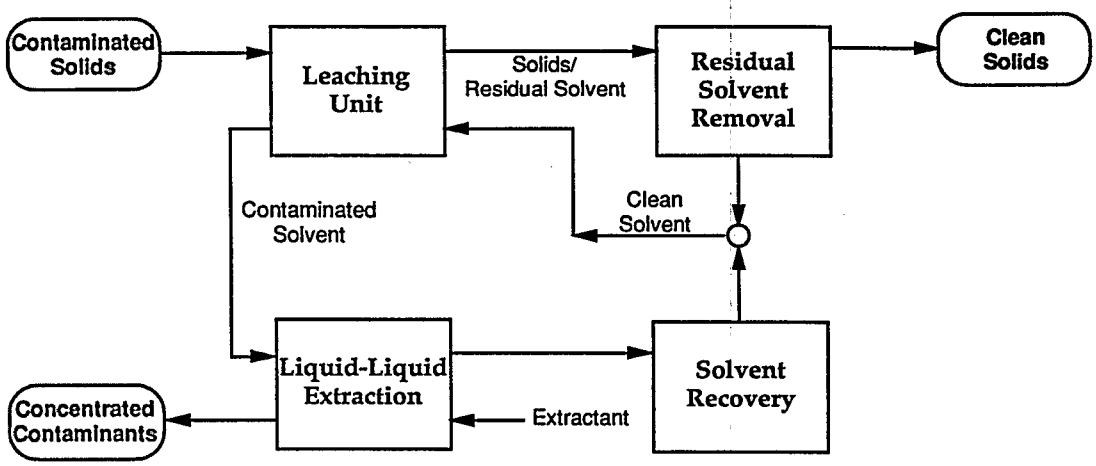
TECHNOLOGY DESCRIPTION:

The low-energy solvent extraction process (LEEP) uses common organic solvents to extract and concentrate organic pollutants from soils, sediments, and sludges (see figure below). The contaminants are leached from the solids with a hydrophilic (water-miscible) leaching solvent using a counter current contactor and are then concentrated in a hydrophobic (water-immiscible) stripping solvent. While the leaching solvent is recycled internally, the hydrophobic stripping solvent containing all of the contaminants is removed from the process for off-site disposal. Decontaminated solids are then returned to the environment.

The selected solvents are readily available, and inexpensive, and are applicable to almost every type of organic contaminant. Most organic contaminants of interest have a very high solubility, and particles of earth materials, such as soils and sediments, have fast settling rates in the selected solvents. The hydrophilic solvent is able to remove the otherwise impermeable water film surrounding the solid particles. These characteristics allow high leaching efficiencies at high leaching rates. Due to the favorable physical properties of the leaching solvent, it can be recycled at a low energy cost.

The LEEP technology is capable of operating at ambient conditions and involves simple-to-use, heavy-duty equipment. The LEEP design generally allows for a wide range of processing conditions, enabling the process to achieve required cleanup levels for virtually every organic contaminant.

The projected system capacity of the LEEP is 10 to 15 tons per hour. The number of stages depends on operating conditions, which can be adjusted to match site-specific parameters. The required cleanup levels can thus be achieved without multiple passes of the same material. Also, the design of the leaching unit allows the simultaneous use of different leaching solvents.



LEEP™ Technology Schematic

WASTE APPLICABILITY:

The process was originally designed to remove polychlorinated biphenyls (PCB) from sediments. However, it has been shown to have much broader application, including petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pesticides, wood preserving chlorophenol formulations, and tars.

LEEP has been used in bench-scale treatability studies to successfully decontaminate the following wastes:

- PCB contaminated solids
  - Sediments from the Hudson River and Waukegan Harbor contaminated with PCBs (Aroclors 1242 and 1254) and mineral oil
  - Topsoil contaminated with PCBs (Aroclor 1260)
  - Surface cover from an electric utility containing PCBs (Aroclor 1260) and mineral oil
  - Subsoil consisting of silt and clay contaminated with PCBs (Aroclor 1260)

- Refinery sludges
  - Rainwater impoundment sludge
  - Slop oil emulsion solids

- Oil contaminated solids
  - Subsoil contaminated with cutting oil used in metal machining
  - Fill material contaminated with fuel oil No. 6

- Manufactured gas plant sites
  - Soil contaminated with tar

STATUS:

The process concept was developed in 1987 under a EPA research grant. The technology was accepted into the SITE Emerging Technology Program in July 1989. Bench-scale process optimization and engineering and construction of a pilot plant have been completed. ART International Inc., offers bench-scale and pilot plant treatability studies for a fee. Several such studies have been completed. The first trailer-mounted commercial unit is scheduled to be available by the end of 1992.

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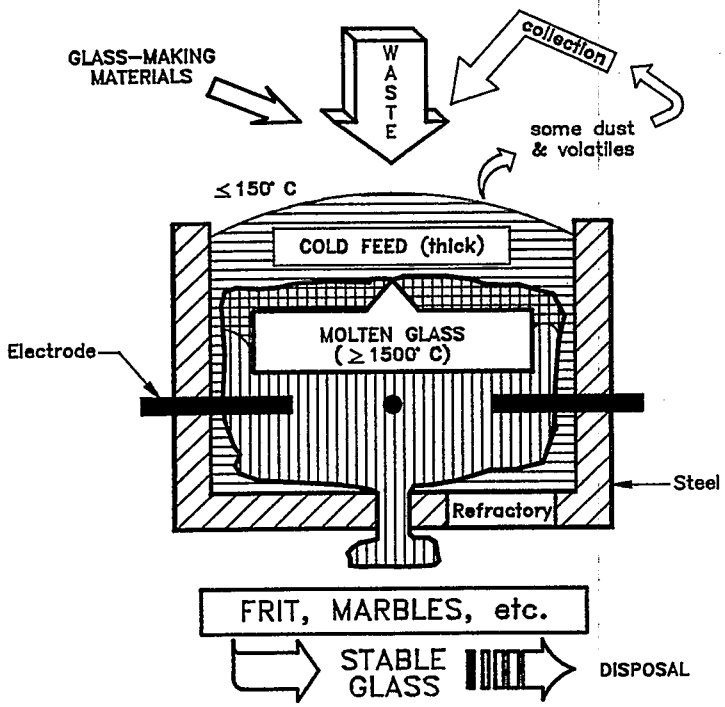
FERRO CORPORATION
(Waste Vitrification Through Electric Melting)

TECHNOLOGY DESCRIPTION:

Vitrification technology converts contaminated soils, sediments, and sludges into oxide glasses, rendering them nontoxic and suitable for landfilling as a nonhazardous material. Inorganic and toxic species are chemically bonded into an oxide glass and are changed chemically to a nontoxic form.

Two requirements for successfully vitrifying soils, sediments, and sludges are: (1) the development of glass compositions tailored to the waste being treated, and (2) the development of a glass melting technology that can convert the waste and additives into a stable glass without producing toxic emissions. Because of a low toxic emission rate, an electric melter may be more beneficial than a fossil fuel melter for vitrifying toxic wastes.

In an electric melter, molten glass -- an ionic conductor of relatively high electrical resistivity -- can be kept molten through joule heating. Consequently, electric melters process waste under a relatively thick blanket of feed material, which limits the emission of hot gases (see figure below). This blanket essentially forms a counter-flow scrubber for volatile emissions. In contrast, fossil fuel melters have large, exposed molten glass surface areas from which hazardous constituents can volatilize. Typical experience with commercial electric melters has shown that the loss of inorganic volatile constituents such as boric anhydride (B_2O_3) or lead oxide (PbO), which are both high in fossil fuel melters, is significantly reduced. Because of its low emission rate and small volume of exhaust gases, electric melting is a promising technology for incorporating high-level nuclear waste into a stable glass.



Electric furnace vitrification

WASTE APPLICABILITY:

Vitrification is a viable option for stabilizing inorganic components found in hazardous waste. In addition, the high temperature involved in glass production (approximately 1,500 degrees Celsius [°C]) will decompose organic material in the waste to relatively harmless components, which can be removed easily from the low volume of melter off-gas.

STATUS:

Initial testing is focused on developing a glass chemistry suitable for synthetic soil matrix (SSM) IV as defined by EPA's Risk Reduction Engineering Laboratory (RREL) Risk Control Branch. A synthetic soil has been chosen to alleviate permitting complications that would arise with the excavation and transport of a Superfund site waste. Extraction procedure (EP) toxicity and toxicity characteristic leachate procedure (TCLP) protocols will be used to define glass compositions that would render the former hazardous waste a nonhazardous waste. Glass properties required for melter operation will also be measured.

Initial trials are being conducted in a laboratory melter. SSM IV has been melted between 1,500°C and 1,600°C to produce a glass. Initial results indicate that the hazardous metallic elements have been chemically incorporated. Additional trials will establish initial operating conditions and provide operational experience that will be used to scale the technology to a pilot melter capable of producing glass at a rate of 100 to 200 pounds per hour. Drying, comminution, and mixing experiments are expected to be completed in fall 1991. Final evaluations of the product glass and the emission rate will be obtained from these pilot melter trials.

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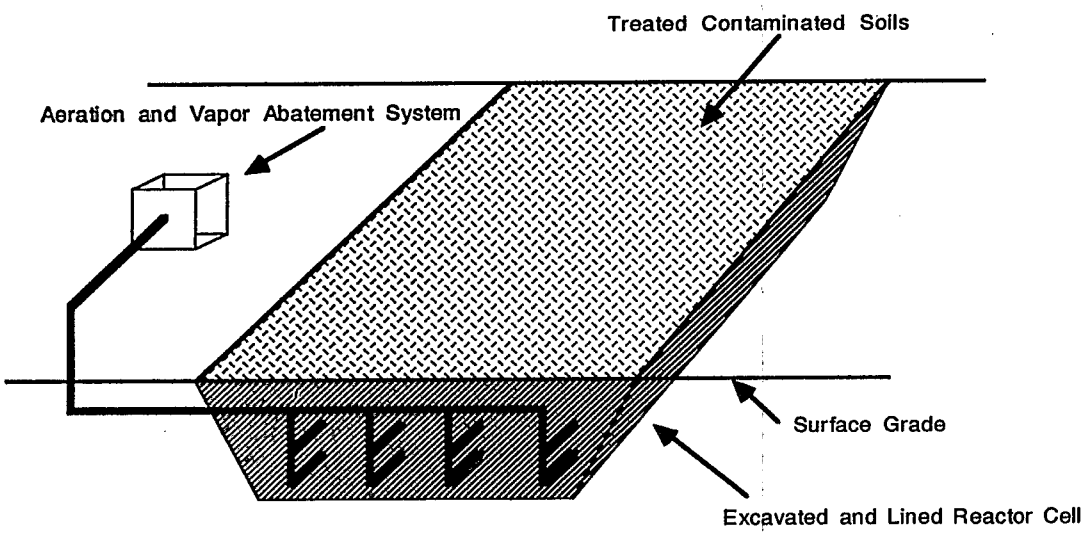
GROUNDWATER TECHNOLOGY GOVERNMENT SERVICES, INC.
(Below Grade Bioremediation Cell)

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 Groundwater Technology, Inc., 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 any 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/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. The figure below is a schematic of the technology.



Below grade bioremediation reactor

WASTE APPLICABILITY:

Applicable waste media include soil, sludge, and sediments. This technology is specifically being developed for cyclodiene insecticides; however, the process is applicable for all biodegradable organic compounds. The industry this technology is targeting is the pest control industry. Residuals expected following treatment include carbon dioxide and inorganic chloride salts.

STATUS:

Initial treatability studies were concluded in spring 1991. The results of these studies indicated that degradation of chlordane and heptachlor can be accelerated by the process and that treatment times will 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 the incorporation of white-rot fungi or chemical oxidation during the soil conditioning phase of the project. Field trials are scheduled to begin in fall 1991. Approximately 500 cubic yards of contaminated soil will be treated by the process.

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HAZARDOUS SUBSTANCE MANAGEMENT RESEARCH CENTER at NEW JERSEY INSTITUTE OF TECHNOLOGY

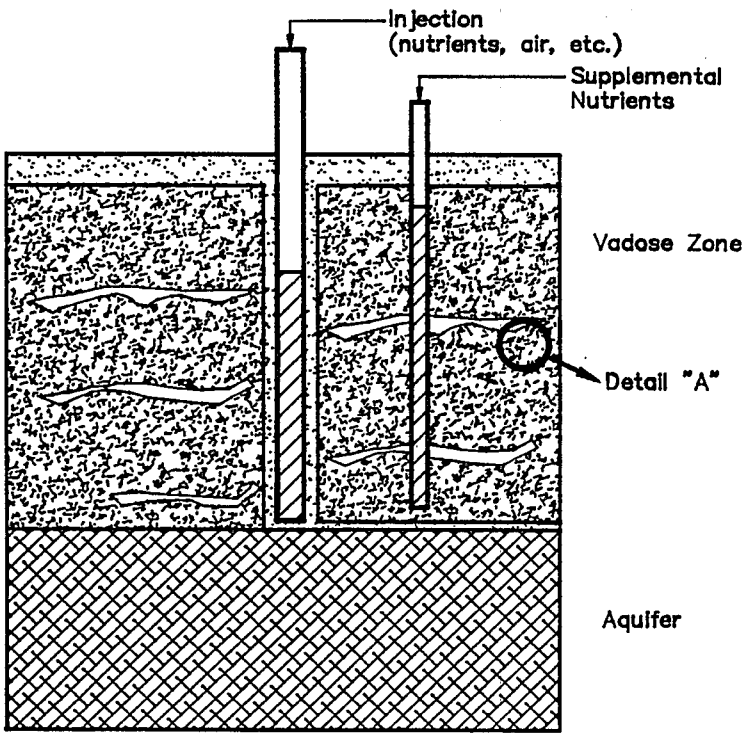
(Pneumatic Fracturing/Bioremediation)

TECHNOLOGY DESCRIPTION:

This technology uses two innovative techniques -- pneumatic fracturing and bioremediation -- as an integrated process to enhance in situ remediation of soils contaminated with organic constituents.

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, thereby 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 figures below). 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 the formation of methanogenic populations at greater distances away from the fractures. Contaminant diffusion processes are toward the



Vadose zone biodegradation with fracturing and vapor stripping

fracture, serving as a substrate for various microbial populations. This stacking arrangement results in enhanced growth of aerobic population through the reduction in substrate concentrations in the denitrifying and methanogenic zones.

WASTE APPLICABILITY:

This technology combines pneumatic fracturing and biodegradation for the remediation of soil contaminated with petroleum hydrocarbons, benzene, toluene, and xylene.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. This project combines effort between the Hazardous Substance Management Research Center at New Jersey Institute of Technology and BP America, Inc. A candidate site in Philadelphia, Pennsylvania, has been tentatively identified to demonstrate this technology. Site characterization is underway. Studies are underway to develop data needed for optimal design of the pilot-scale testing apparatus and testing protocols. Field pilot-scale testing is planned to begin in spring 1992.

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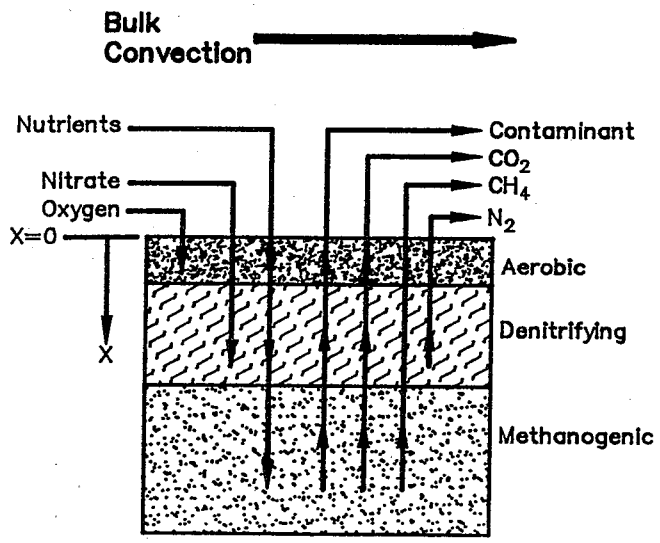


Detail "A". Contaminant, oxygen, nutrient, and reaction product fluxes

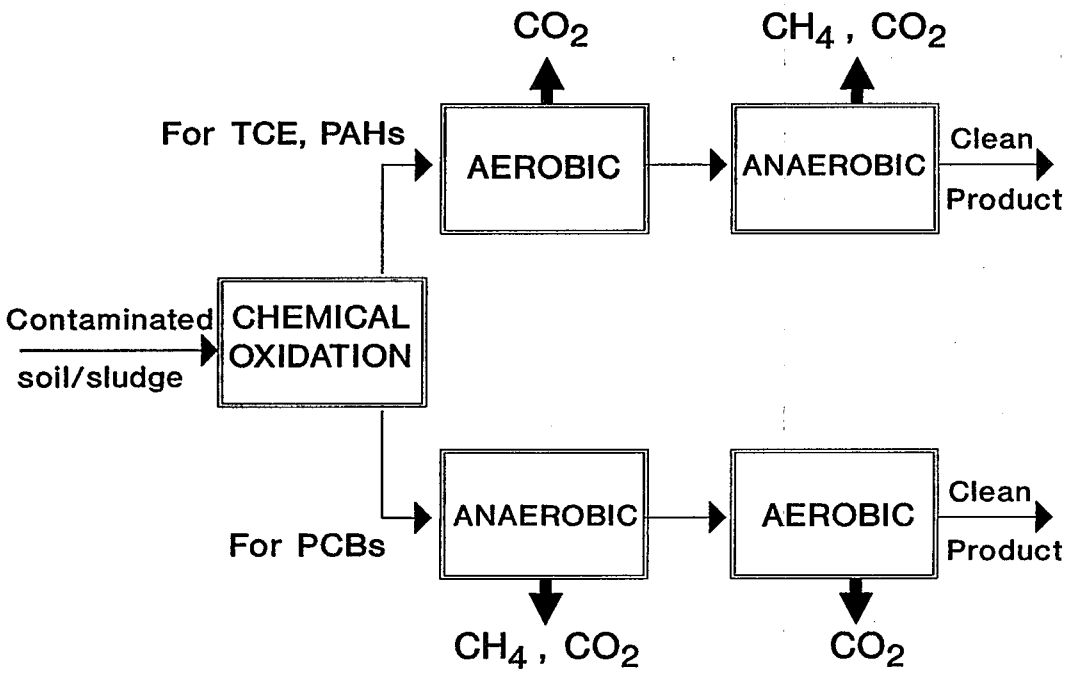
INSTITUTE OF GAS TECHNOLOGY
(Chemical and Biological Treatment)

TECHNOLOGY DESCRIPTION:

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 the pre-treatment, 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 the more severe process.

In chemical treatment/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 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 in which a slurry consisting of water and a carbonaceous material is heated to



CBT process schematic

temperatures ranging from 250 to 650 degrees Fahrenheit and under pressure of air or oxygen. Depending on the temperature, residence time, and the type of compounds being oxidized, carbonaceous material will either be 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. Special pressure vessels, which can withstand high temperatures and pressures, will be used in these studies.

The figure on the previous page shows some of the options that are available for application. The contaminated material is treated chemically by a chemical reagent degrading the organopollutants to carbon dioxide, water, and more biodegradable, partially oxidized intermediates. Additional treatment with ozone 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, as well as 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 remediation of soils containing low, as well as high, waste concentrations in sediments and sludges 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 be either (1) bioaccumulate in the biomass, (2) complex with organic or inorganic material in the soil slurries, or (3) 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. The developer is currently preparing the Work Plan and Quality Assurance Project Plan (QAPjP).

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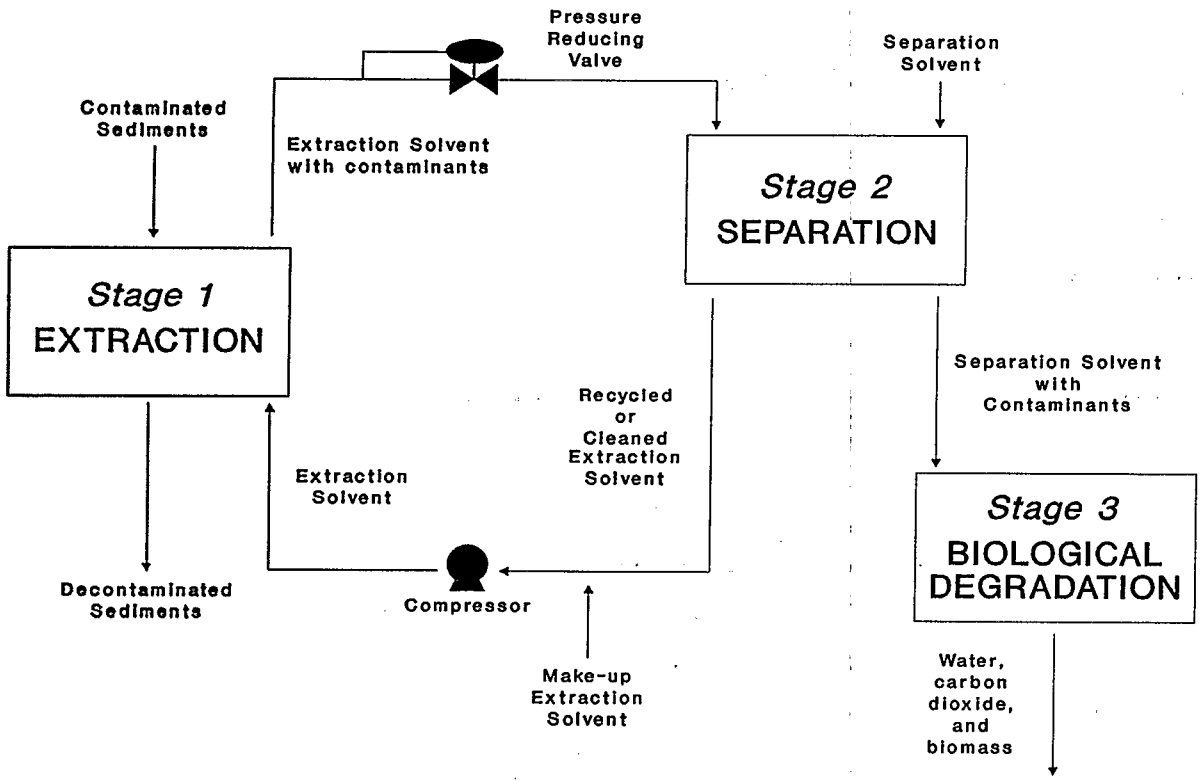
INSTITUTE OF GAS TECHNOLOGY
(Fluid Extraction–Biological Degradation Process)

TECHNOLOGY DESCRIPTION:

The fluid extraction–biological degradation (FEBD) process is a three–step process for the effective remediation of organic contaminants from soil (see figure below). It combines three distinct technologies: (1) fluid extraction, which removes organics from contaminated solids; (2) separation, which transfers pollutants from the extract to a biologically–compatible solvent; and (3) biological treatment, which degrades organic pollutants to innocuous end–products.

Contaminants first must be extracted from the soil. 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 can improve the removal of many contaminants.

Following extraction, organic contaminants are collected in a biologically–compatible separation solvent. Clean extraction solvent is recycled to the extraction stage. The separation solvent containing the contaminants is sent to the final



Overview of the fluid extraction–biodegradation process

stage of the process, where bacteria are used to degrade the waste to carbon dioxide and water.

Biodegradation is achieved in above ground aerobic bioreactors, using mixtures of bacterial cultures capable of degrading the contaminants. Selection of cultures is based on site characteristics. For example, if a site is contaminated mainly with polycyclic aromatic hydrocarbons (PAH), such as naphthalene, phenanthrene, fluorene, pyrene, and others, cultures able to grow at the expense of these hydrocarbons are used in the biological treatment stage.

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 (PCB). The process has been shown to be quite effective in treating nonhalogenated aliphatic and polycyclic aromatic hydrocarbons.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. The developer has conducted tests evaluating the extraction, separation, and biodegradation stages of the technology by using a soil obtained from a Superfund site that was contaminated with two-to-six ring PAH compounds. Extraction and degradation of these compounds has been successfully achieved. The developer is preparing the final report.

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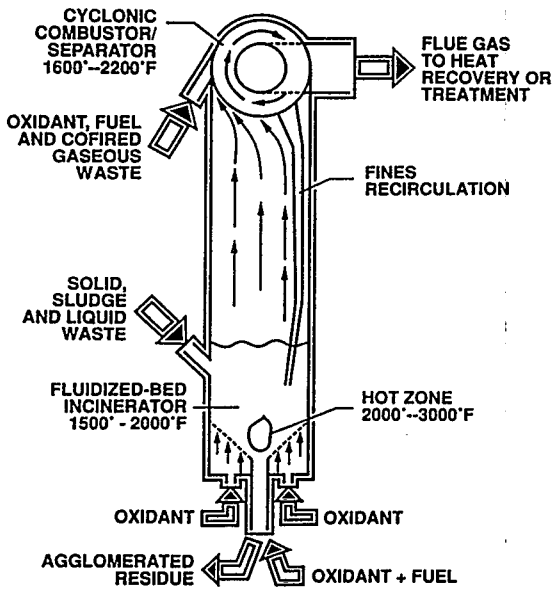
INSTITUTE OF GAS TECHNOLOGY
(Fluidized-Bed Cyclonic Agglomerating Incinerator)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology (IGT) has developed a two-stage, fluidized-bed cyclonic agglomerating incinerator (see figure below) based on a combination of technologies developed at IGT over many years. In the combined system, solid, liquid, and gaseous organic waste can be efficiently destroyed, while solid, nonvolatile, inorganic contaminants are combined within a glassy matrix suitable for disposal in an ordinary landfill.

The first stage of the incinerator is an agglomerating fluidized-bed reactor, which can operate either under substoichiometric conditions or with excess air. The system can operate over a wide range of conditions, from low temperature (desorption) to high temperature (agglomeration), including the gasification of high British thermal unit (Btu) wastes (such as natural gas). With a unique distribution of fuel and air, the bulk of the fluidized-bed is maintained at 1,500 to 2,000 degrees Fahrenheit (°F), while the central spout temperature can be varied between 2,000 and 3,000.

When the contaminated soils and sludges are fed into the fluidized-bed, the combustible fraction of the waste undergoes a rapid gasification and combustion, producing gaseous components. The solid fraction, containing metal 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 leachate procedure (TCLP).



Schematic of the two-stage fluidized-bed/cyclonic agglomerating incinerator

The gaseous products leaving the fluidized-bed may contain unburned hydrocarbons, furans, 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 incinerator, where it is further combusted at a temperature of 1,600 to 2,200 degrees Fahrenheit. The second stage is a cyclonic combustor and separator that provides sufficient residence time (2 1/2 seconds) to oxidize carbon monoxide and organic compounds to carbon dioxide and water vapor, with a combined destruction removal efficiency greater than 99.99 percent. Volatilized metals are collected downstream in the flue gas scrubber condensate.

IGT's two-stage fluidized-bed and cyclonic agglomerating incinerator is not an entirely new concept, but rather an improvement based on experience with other fluidized-bed and cyclonic combustion systems. The patented sloped-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 incinerator 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 to support fluidized-bed operation. Wastes such as municipal solid wastes, aluminum pot liners, or auto fluff will likely require comminution prior to incineration.

Because the solid components in the waste are heated above their fusion temperature during the agglomeration process, metals and other inorganic materials are encapsulated and immobilized within the glassy matrix.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Since then, tests conducted in the batch 6-inch diameter fluidized-bed unit 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 are inconclusive. Additional testing is required to demonstrate the operation of the bench-scale unit with the elutriated fines recycled to the hot zone.

The design of a pilot-plant incinerator with a capacity of 6 tons per day has been completed. Construction of the pilot plant will begin when negotiations with the engineering and construction firm have been completed.

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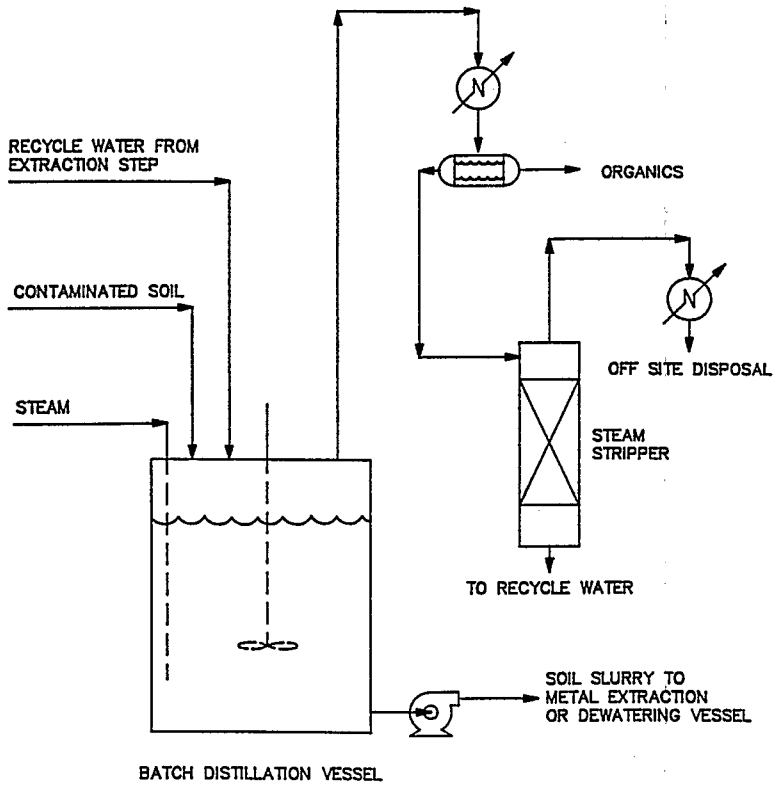
IT CORPORATION
(Batch Steam Distillation and Metal Extraction)

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. After treatment, the soil is decontaminated and may be returned to the site.

By mixing the waste soil with steam for a retention time of approximately one hour volatile organics are separated from the feed waste (soil) (see figure below). The resulting vapors are condensed and decanted to separate organic liquids from the aqueous phase. The soil is then transferred as a slurry to the metals extraction step. Condensed water from the step can be recycled through the system after further



Batch steam distillation step

treatment to remove soluble organics.

After the volatile organics are separated, heavy metals are removed from the soil slurry by hydrochloric acid. After contact with the acid, the solids and the acid solution containing the metals is pumped out through the use of gravimetric separation. Most heavy metals are converted to chloride salts in this step. This stream is then charged to a batch distillation system, where hydrochloric acid is recovered. The bottoms from the still, containing the 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 process is targeted for smaller sites that contain less than 5,000 tons of soil requiring treatment. Processing depends on the size of equipment used and batch cycle times. A process rate of 20 tons of soil per day per unit is standard.

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 Porgram in January 1988. Under the program three pilot-scale tests have been completed on three soils. Removal of benzene, toluene, ethylbenzene, and xylene (BTEX) was greater than 99 percent at 5 and 10 percent overhead steam condensate. Removal of chlorinated solvents ranged from 97 percent to 99 percent. One acid extraction and two water washes resulted in 95 percent removal of heavy metals, verified by 80 percent of the sample analyses. Toxicity characteristic leaching procedure (TCLP) tests on the treated soils showed that soils from eight of the nine tests met leachate criteria. Data was also collected on recovery of excess acid and collection of the heavy metals in a concentrate by precipitation.

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IT CORPORATION
(Mixed Waste Treatment Process)

TECHNOLOGY DESCRIPTION:

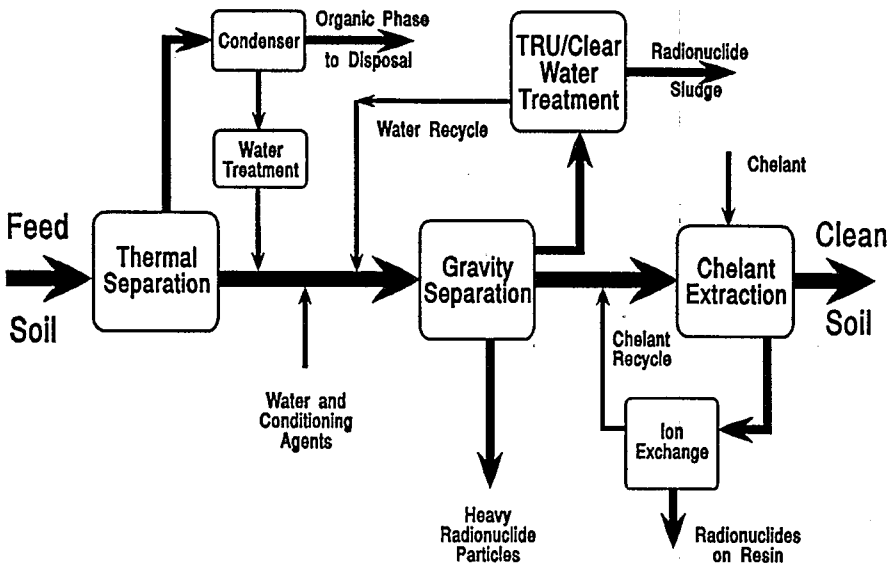
The mixed waste treatment process has been designed to address one of the more difficult waste treatment problems -- soils contaminated with both hazardous and radioactive constituents. The objective of the process is to separate the hazardous and radioactive contaminants into distinct organic and inorganic phases. The separated streams can then be further minimized, recycled, or destroyed at commercial disposal facilities with the decontaminated soil safely returned to the site.

The process combines thermal desorption, gravity separation, water treatment, and chelant extraction to treat various contaminants in soil. 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 associated with treatment of mixed waste streams. The individual unit operations will be run continuously during pilot-scale tests.

The initial treatment step is to prepare the bulk contaminated soil for processing by physical reduction of oversized material via crushing and grinding.

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 present in the soil. The soil passes through the chamber and is collected as a dry solid. Condensing of the volatilized organics and water generates separate liquid phases. The organic phase is decanted and removed for disposal. The contaminated aqueous phase is treated by passing it through activated carbon, removing soluble organics before combining with the thermally treated soil.

Inorganic contaminants are removed by three physical and chemical separation techniques: (1) gravity separation of high density particles, (2) chemical precipitation of soluble metals, and (3) chelant extraction of chemically bound metals.



Mixed waste treatment process flow diagram

Gravity separation will be 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 -- is based on the distribution of contaminants and physical properties of the thermally treated soil.

Many of the radionuclide 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, during the process cycle.

Some of the radionuclides that are not in soluble form remain with the soil through the gravity separation process. These radionuclides are removed from the soil via extraction with a chelant. The chelant solution then passes through an ion exchange resin to remove the radionuclides. The chelant solution is recycled back 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 can be applied to soils contaminated with both organic and inorganic contaminants, and radioactive material.

STATUS:

The mixed waste treatment process selected for the SITE Emerging Technology Program in October 1991. Pilot-scale testing under the program is planned for early 1992. Individual components of the treatment process have been demonstrated for various wastes from Department of Energy (DOE), Department of Defense (DOD), and commercial sites. Thermal separation of polychlorinated biphenyls (PCB) has been used to remove and recover PCBs from soil contaminated with uranium and technetium. The soils used in this pilot demonstration were from two separate DOE gaseous diffusion plants. Gravity separation of radionuclides has been demonstrated at pilot-scale at Johnston Atoll in the South Pacific. Gravity separation was successfully used to remove 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. Cadmium, copper, lead, nickel, plutonium, silver, uranium, and zinc have all been removed to dischargeable levels by using this chemistry. Chelant extraction has been successfully applied to surface contamination in the nuclear industry for more than 20 years. Application of this chemistry using soil washing equipment is expected to achieve similar results on subsurface contamination.

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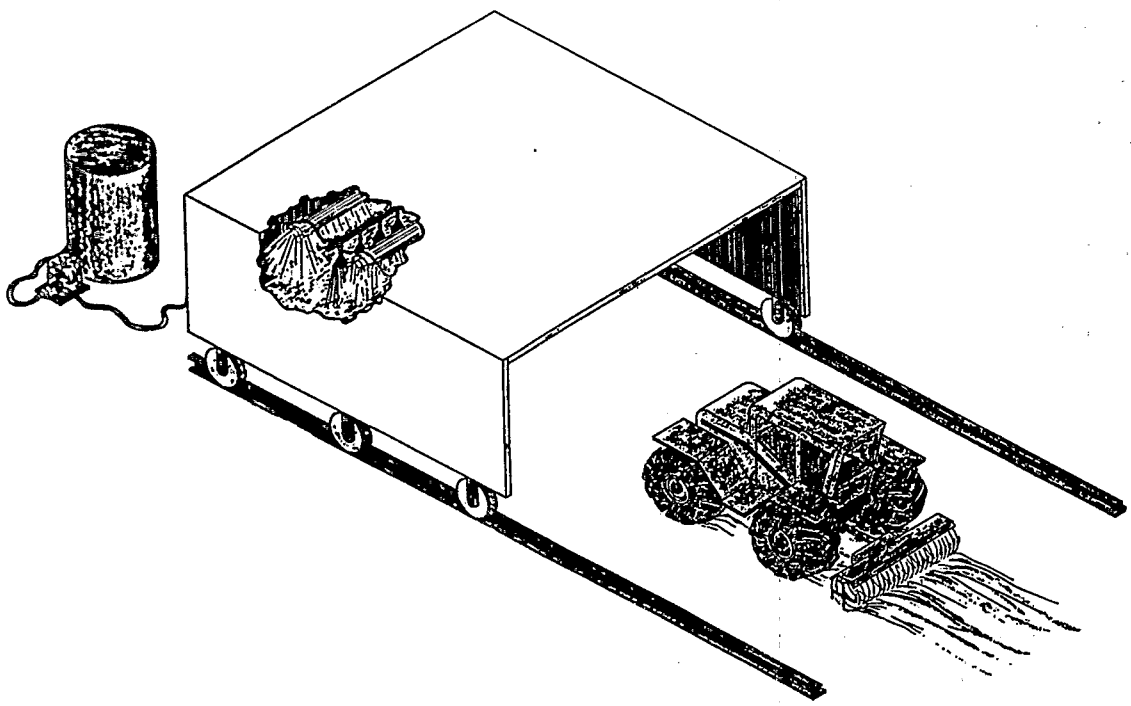
IT CORPORATION
(Photolytic and Biological Soil Detoxification)

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 by using ultraviolet (UV) radiation. Degradation is enhanced by adding detergent-like chemicals (surfactants) to mobilize the contaminants. Photolysis of the original contaminants is expected to convert them to less-resistant compounds. Biological degradation, the second step, is then used to further destroy the organic contamination and detoxify the soil. The rate of photolytic degradation is several times faster with artificial UV light than with natural sunlight.

When using sunlight for soil with shallow contamination, the soil is tilled with a power tiller and sprayed with surfactant (see figure below). Tilling and spraying are repeated frequently to expose new surfaces. Water may also be added to maintain soil moisture. UV lights with parabolic reflectors are suspended over the soil to irradiate it. 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, the excavated soil is treated in a specially constructed shallow treatment basin, which meets the requirements of the Resource Conservation and Recovery Act.



Photolytic degradation process using sunlight

The only residue from this combination of technologies is soil contaminated with both the end metabolites of the biodegradation processes and the surfactants that are used. The surfactants are common materials used in agricultural formulations.

WASTE APPLICABILITY:

This technology destroys organics, particularly dioxins, polychlorinated biphenyls (PCB), and other polychlorinated aromatics, as well as polycyclic aromatic hydrocarbons (PAH).

STATUS:

Bench-scale tests to optimize the processing conditions have been completed and the data are being evaluated to select the optimum conditions for pilot testing. Two contaminated soils will be tested -- one with PCBs and one with dioxin. A Toxic Substances Control Act (TSCA) permit has been received for the PCB pilot-scale test on soil brought into IT Corporation's Environmental Technology Development Center in Oak Ridge, Tennessee. A RCRA Research Development and Demonstration (RD&D) permit for the pilot test on soil contaminated with tetrachlorodibenzo-p-dioxin (TCDD) is in process. Pilot tests are scheduled to begin in September, 1991.

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MEMBRANE TECHNOLOGY AND RESEARCH, INC.
(VaporSep Membrane Process)

TECHNOLOGY DESCRIPTION:

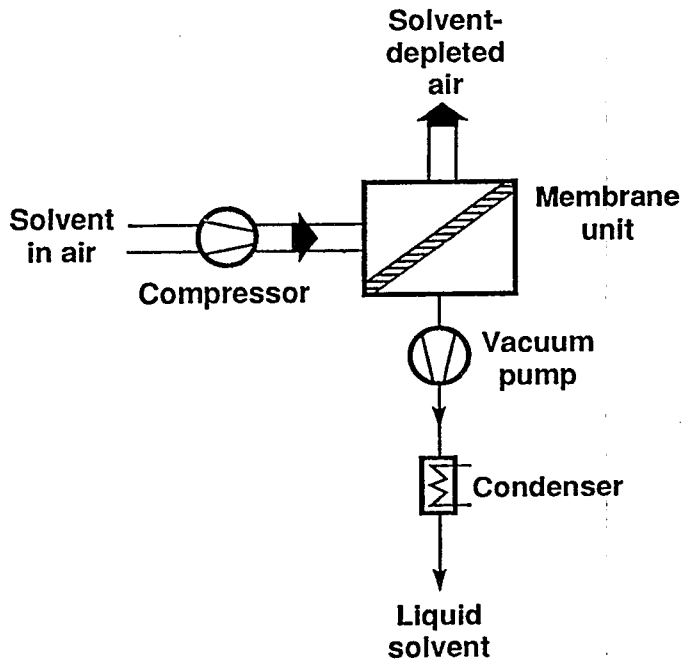
This technology uses synthetic polymer membranes to remove organic contaminants from gaseous waste streams. Organic contaminants are recovered in liquid form for recycling or disposal off-site.

Solvent-laden contaminated air at atmospheric pressure contacts one side of a membrane that is permeable to the organic material but impermeable to air (see figure below). A partial vacuum on the other side of the membrane draws the organic vapor through the membrane. The organic vapor is then cooled and condensed. The small volume of air that permeates the membrane is recycled through the system.

The treated stream may be vented, recycled for further use at the site, or passed to an additional treatment step. For more dilute waste streams, a two-stage process is required. Organic vapor is concentrated tenfold in the first stage and an additional tenfold in the second stage.

The system is transportable and is significantly smaller than a carbon adsorption system of similar capacity. The process generates a clean air stream and a pure liquid product stream that can be reused or incinerated.

Seventeen VaporSep systems have been built or are under construction. The capacities of these systems range from 1 to 100 standard cubic feet per minute (scfm). Twelve systems are pilot



Schematic of simple one-stage solvent vapor separation and recovery process

systems for demonstration purposes. Five are commercial installations that have been designed to meet removal specifications for specific applications.

WASTE APPLICABILITY:

Membrane systems can be applied to most airstreams containing halogenated and nonhalogenated contaminants. Typical applications are (1) the treatment of air stripper exhaust before discharge to the atmosphere, (2) reduction of process vent emissions such as those now regulated by EPA's source performance standards for the synthetic organic chemical manufacturing industry, and (3) recovery of chlorofluorocarbons (CFC) and hydrochlorofluorocarbons (HCFC). Effectiveness depends on the class of organic compound.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. The process has been tested on both the bench- and pilot-scale, and has achieved removal efficiencies of greater than 90 percent for selected organics.

This technology has been successfully field demonstrated in numerous industrial processes, including CFC and halocarbon recovery from process vents and transfer operations, and vinyl chloride monomer recovery from a polyvinyl chloride (PVC) manufacturing plant. The technology has been tested on air streams contaminated with a wide range of organics, in concentrations of 100 to over 100,000 parts per million.

The final report is in preparation and will be available in spring 1992.

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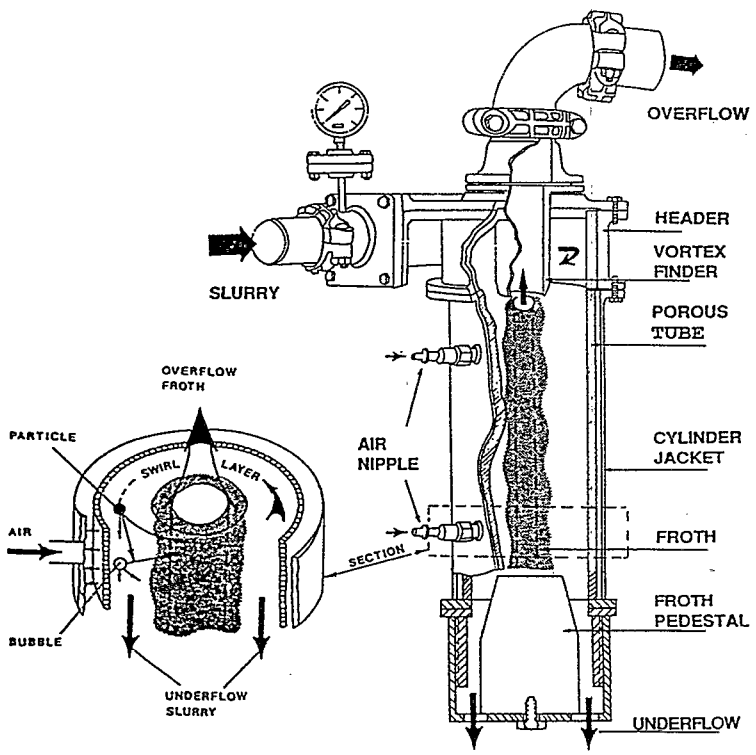
MONTANA COLLEGE OF MINERAL SCIENCE & TECHNOLOGY
(Air-Sparged Hydrocyclone)

TECHNOLOGY DESCRIPTION:

The air-sparged hydrocyclone (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 provide for even distribution of 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, moves 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



Air-sparged hydrocyclone

technology in the United States and elsewhere, leading to a number of industrial installations. Nevertheless, for both mechanical and column 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 will have 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. The ASH was developed under Dr. Jan Miller's research group at the University of Utah during the early 1980s to achieve fast flotation of fine particles in a centrifugal field.

WASTE APPLICABILITY:

This technology may be applied to removing 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 built and is presently evaluating the recovery of lead and zinc minerals from a tailing generated in the 1950s. Results to date are marginally successful, but the tailing was generated in a flotation operation and is not an ideal candidate for this technology. The investigators are seeking permission from the potentially responsible party (PRP) of a different tailing produced by gravity concentration to test their equipment.

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NEW JERSEY INSTITUTE OF TECHNOLOGY
(GHEA Associates Process)

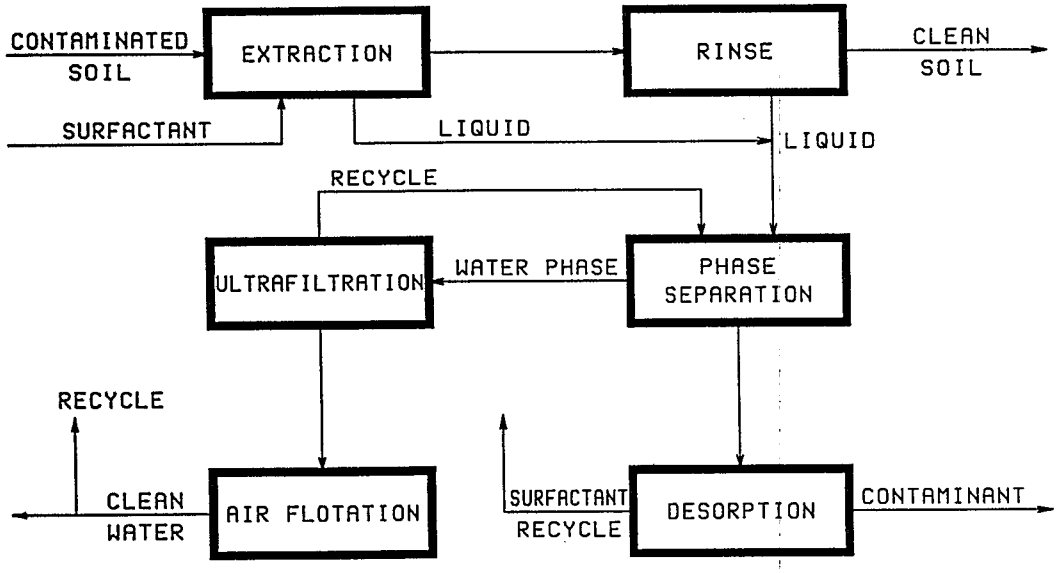
TECHNOLOGY DESCRIPTION:

In the Ghea Associates process, surfactants and additives, which can be applied to soil washing and wastewater treatment, are used to solubilize both organic and metal contaminants. In soil washing, soil extraction is followed by a water rinse to produce clean soil. The wash and rinse liquids are combined and treated to separate a surfactant and contaminant from the water in a sequence of steps consisting of phase separation, ultrafiltration, and air flotation. The purified water meets all of the National Pollutant Discharge Elimination System (NPDES) ground water discharge criteria, allowing it to (1) be discharged without further treatment and (2) to be reused in the process itself or as a source of high quality water for other users. The contaminants are separated from the surfactants by desorption and isolated as a concentrate. The desorption step regenerates the surfactants for repeated use in the process.

In wastewater treatment applications, surfactants are added to the wastewater to effect adsorption of 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. In balance, the process produces clean soil, clean water, and a highly concentrated contaminants fraction. No other residues, effluents, or emissions are produced. The figure below is a schematic diagram if the GHEA process

WASTE APPLICABILITY:

This technology can be applied to soil, sludges, sediments, slurries, groundwater, surface water,



Process for soil washing

end-of-pipe industrial effluents,and in situ soil flushing. The scope of contaminants is broad, including both organics and heavy metals, nonvolatile and volatile compounds, and highly toxic refractory compounds.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in January 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 twenty-fold enhancement of the contaminants removal rates. Tests using a 25-gallon pilot-plant are being conducted. The final report is in preparation and will be available in June 1992.

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TABLE 1
SUMMARY OF TREATABILITY TEST RESULTS

MATRIX	UNTREATED SAMPLE	TREATED SAMPLE	PERCENT REMOVAL
Volatile Organic Compounds (VOCs):			
Soil, ppm	20.13	0.05	99.7%
Water, ppb	109	2.5	97.8%
Total Petroleum Hydrocarbons (TPH):			
Soil, ppm	13,600	80	99.4%
Polychlorinated Biphenyls (PCB):			
Soil, ppm	380.00	.57	99.8%
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%
Flourene	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:	30.80	.3	99.0%

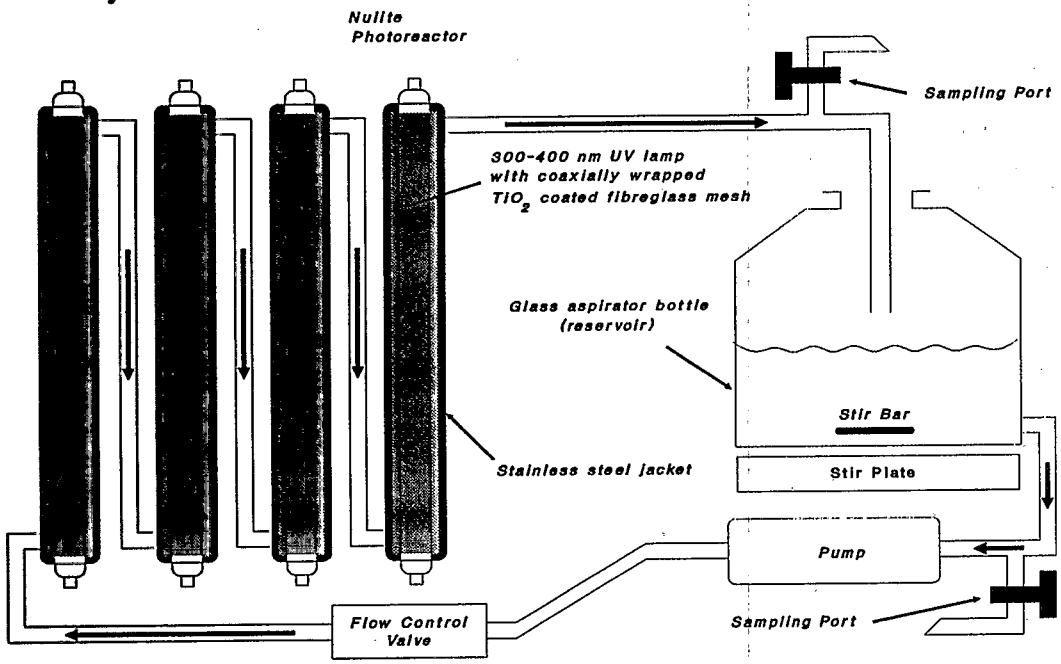
NUTECH ENVIRONMENTAL
a Division of NUTECH ENERGY SYSTEMS, INC.
(Photocatalytic Oxidation)

TECHNOLOGY DESCRIPTION:

Nulite™ Technology uses illuminated titanium dioxide to destroy organic pollutants and detoxify inorganic pollutants in water. The illumination of titanium dioxide in water generates excess electrons in the conduction band (e^-_{CB}) and positive "holes" (h^+_{VB}) in the valence band. At the surface, the photogenerated "holes" react either with adsorbed water or surface hydroxide groups to form hydroxide radicals. The hydroxide radicals are extremely reactive and readily attack organic molecules, eventually oxidizing them to carbon dioxide and water (and halide ions when the organic molecule contains halogen atoms).

Nutech Environmental has recently developed a strategy that drastically improves the efficiency of the technology. This strategy is based on adding efficient (preferably irreversible) electron acceptors to the system. These additives should (1) readily accept electrons from the conduction band, (2) rapidly dissociate into harmless products, and (3) if possible, provide additional routes for the formation of hydroxide radicals or other powerful oxidizing agents. Additives such as oxygen, hydrogen peroxide, ozone, and ammonium persulphate have been found to significantly improve the efficiency of the process.

The center of the Nulite™ Technology is a photoreactor. The photoreactor comprises a stainless steel jacket, a lamp and a photocatalytic sleeve (see figure below). The lamp emits ultraviolet (UV) light in the 300 to 400 nanometer range and is coaxially mounted within the jacket. Around the lamp is a Fiberglass mesh sleeve coated with titanium dioxide (anatase). Contaminated water flows through the photocatalytic sleeve. Because of its open pore configuration and large surface area,



Liquid phase test photoreactor configuration

the mesh creates turbulent mixing. The photoreactors can be linked in series or in parallel or both. The process can be operated both in continuous flow and batch operational modes. The figure shows the multipass operation. After passing through the photoreactors, water returns to the reservoir.

There are no known limits to the technology that would prevent the reactors from being scaled-up significantly. Furthermore, the titanium dioxide catalyst has no limits to its lifetime. Low concentrations of chemical intermediates may be formed; however, since the intermediates are produced as a result of the hydroxide attack on the organic compounds, their concentrations can be reduced to whatever level is desired by simply ensuring that contact or residence time is long enough to achieve target discharge criteria.

WASTE APPLICABILITY:

The Nulite™ Technology was initially designed to destroy organic pollutants and to detoxify inorganic pollutants in water. Recent developments, however, have clearly shown that this technology can also be applied to the destruction of organic pollutants in air streams.

Organic pollutants such as polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones, aldehydes, and amines can be destroyed by this technology. Inorganic pollutants such as, but not limited to, cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion (OCN^-), sulphate ion (SO_4^{2-}) and nitrate ions (NO_3^-) respectively.

The technology can be applied to 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. Groundwater remediation is another field to which this technology can be applied.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in May 1991. The efficiency of the process has significantly improved by adding irreversible electron acceptors to the system. With this improvement, the technology is not only capable of treating low concentrations, but high concentrations of organics can also be remediated. Further efficiency improvement, as well as the engineering and testing of a pilot reactor system for water treatment, are the company's current focus.

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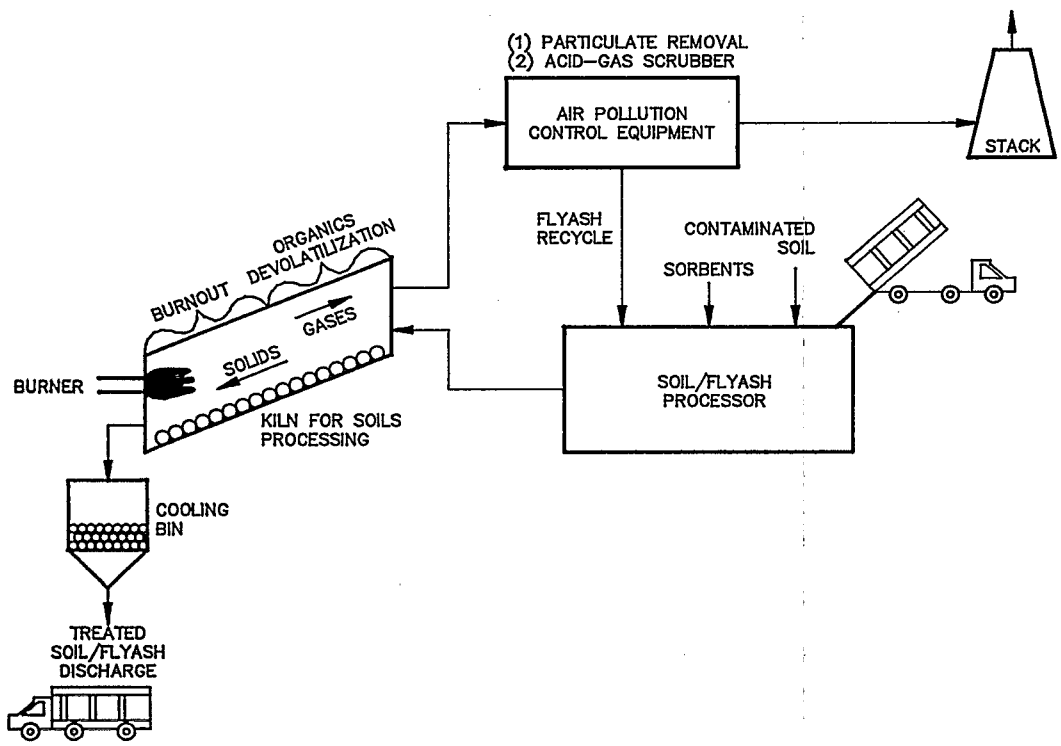
PSI TECHNOLOGY COMPANY

(Metals Immobilization and Decontamination of Aggregate Solids)

TECHNOLOGY DESCRIPTION:

PSI Technology Company's metals immobilization and decontamination of aggregate solids (MeIDAS) process (see figure below) is a modified incineration process for the destruction of organics and treatment of metals in contaminated soils. In this process, the contaminated soil is treated in a typical incinerator, in conjunction with sorbents. The high temperatures present during the processing destroys the organics, while simultaneously encapsulating the metals in the soil into a form that is nonleachable (as determined by toxicity characteristic leaching procedure analysis). With a one-to-one soil to sorbent ratio, the metals present in the soil can be effectively treated.

Standard air pollution control devices are used to clean the effluent gas stream. Hydrogen chloride and sulfur dioxide, formed from the oxidation of chlorinated organics and sulfur compounds present 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 solids, which are decontaminated with respect to organics and also will not leach toxic metal species.



MEIDAS process

WASTE APPLICABILITY:

The MeIDAS process treats organics and heavy metals including arsenic, cadmium, chromium, lead, nickel, and zinc in soils, sediments and sludges.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. The developer is currently preparing a quality assurance plan. Initial testing, conducted under an EPA Small Business Innovative Research program, has shown the feasibility of treating wastes containing arsenic, cadmium, lead, and zinc. A complete feasibility testing schedule is planned for the first year of the program. Pilot-scale evaluation will be completed in July 1993.

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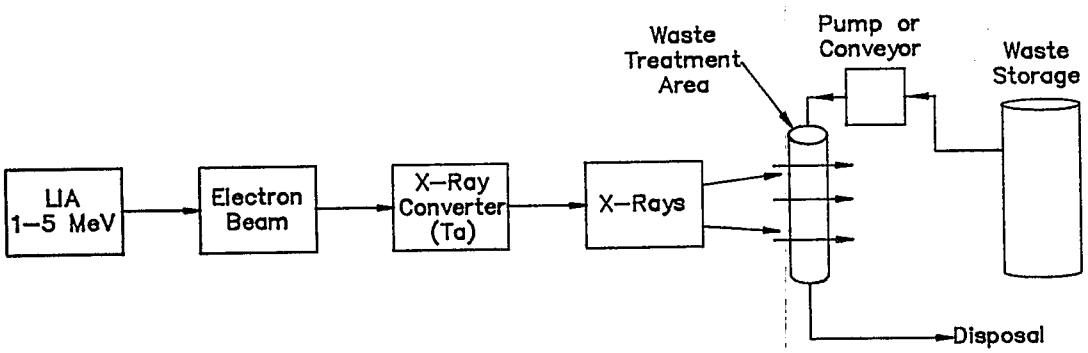
PULSE SCIENCES, INC.
(X-Ray Treatment)

TECHNOLOGY DESCRIPTION:

X-ray treatment of organically contaminated soil and water products is based on the in-depth deposition of ionizing radiation. The collision of energetic photons with matter generates a shower of energetic secondary electrons within the contaminated waste material. The electrons break up the complex molecules and form radicals that react with contaminant materials to form compounds such as water, carbon dioxide, and oxygen. Direct electron beam processing has been established as highly effective for the destruction of organic compounds in aqueous solutions, with residual organic contaminant levels in the μg/liter range. However, the electrons do not penetrate deeply and, thus, material handling can be a problem. X-ray treatment does nôt have this problem.

The physical mechanism by which volatile organic compounds (VOC) and semivolatile organic compound (SVOC) contaminants are removed is primarily dependent on the substrate. For example, in oxygenated water the primary reactant is the hydroxyl (OH) radical. This kinetic mechanism is also expected to play an important role in nonaqueous matrices, because of the presence of moisture in contaminated soil, sludge, and sediments. It is expected that the complete mineralization of contaminants at sufficiently high dose levels can be achieved with the elimination of undesirable air emissions and waste residuals.

A linear induction accelerator (LIA) is used, as shown on the figure below, to generate the x-rays used in the treatment process. The LIA can accelerate electron beams to energies of 1 to 5 million electron volts (MeV). (A prototype 1.2 MeV, 0.7 kilo-ampere (kA) accelerator will be used for the proposed tests.) A pulse of electrons, 55 nanoseconds in duration, is directed onto a converter to generate x-rays. The x-rays penetrate the waste material. The penetration depth of the x-rays is tens of centimeters long. 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 disposal barrels can be treated. No additives are required for the process; therefore, sealed containers can also be accommodated. The cost of x-ray processing is estimated to be competitive with alternative processes. Moreover, electron accelerators offer



Proposed schematic diagram for the X-Ray Treatment Process

a high level of safety; the x-ray output of the LIA is easily turned off by disconnecting the electrical power.

WASTE APPLICABILITY:

X-ray processing is uniquely capable of treating a large number of contaminants without expensive extraction or preparation of the waste. Organic wastes that may be treated include (1) benzene, (2) trichloroethane, (3) trichloroethylene, and (4) polychlorinated biphenyls (PCB). The large penetration depth of the x-rays combined with the high flux of the x-rays generated by the LIA, allows either disposable containers or flow systems to be treated.

STATUS:

This technology was accepted into the the SITE Emerging Technology Program in May 1991. Initial testing of the x-ray treatment process is scheduled for late 1991. Small scale samples will be exposed to x-ray dose levels of 100 kilorads to 5 megarads. Over 14 VOC and SVOC contaminants will be evaluated in soil and water mixtures. The treated samples will be analyzed at EPA-approved laboratories by using standard chemical analysis techniques (such as gas chromatography).

From these tests a database will be generated to provide the basis for construction of a processing pilot plant. The cost to build a 5-MeV facility will be based on the x-ray dose required to chemically decompose the various organic compounds. Operational costs, as well as the throughput capability of the plant, will also be estimated. Conceptual x-ray treatment plant designs based on this analysis will be submitted to EPA for review.

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PURUS, INC.
(Photolytic Oxidation Process)

TECHNOLOGY DESCRIPTION:

This process is based on photolytic oxidation for the destruction of volatile organic compounds (VOC) in soil and groundwater. The treatment system design embodies the use of 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 does not involve the formation of the hydroxyl radical. Direct photolysis occurs when sufficient UV light energy is absorbed by the organic contaminant, transforming electrons to higher energy states and causing molecular bonds to break (see figure below). The process depends entirely on the ability of the UV light source to emit wavelengths in the regions absorbed by the contaminant. An innovative feature of the Purus, Inc. technology is the ability to shift the UV spectral output to better optimize the photolysis.

The process uses vacuum extraction or air stripping to volatilize organic compounds from soils or groundwater, respectively. VOCs enter the photolysis reactor, where UV light is generated by a xenon flashlamp. The plasma is produced by pulse discharge of electrical energy across two electrodes contained in the lamp. Required exposure time for 99 percent destruction is on the order of seconds, allowing for continuous operation or air flow process. An advantage is that less energy is required to destroy the contaminant, than would be required for the water phase treatment.

WASTE APPLICABILITY:

The Purus photolytic oxidation process is designed for the destruction of VOCs, including dichloroethylene (DCE), tetrachloroethylene

Purus advanced UV photolysis

(PCE), trichloroethylene (TCE), and vinyl chloride volatilized from soil or groundwater. Other VOCs, such as benzene, carbon tetrachloride, and 1,1,1-trichloroethane, are being investigated.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in March 1991. Field testing of a full-scale prototype is scheduled to begin in October 1991. The test will be conducted at the Lawrence Livermore National Laboratory, a Superfund site under the auspices of EPA Region 9, located in Livermore, California. The site contains soil zones highly contaminated with TCE. A vacuum extraction system (VES) has been installed and will deliver contaminated air to the Purus, Inc. unit at air flows of up to 500 cubic feet per minute (CFM). The initial concentrations of TCE in the air will be approximately 250 parts per million by volume. The contaminant removal goal for the treatment has been set at 99 percent. Vapor phase carbon filters will be placed downstream of the Purus unit to satisfy California Air Quality emission control during the field test.

Initial laboratory testing of the system in batch mode has demonstrated the destruction of TCE. Exposure times of 3 seconds were required to achieve 99 percent destruction. Construction of a full-scale continuous flow prototype was based on these results. Treatment costs will be measured during the field test and will be compared against two alternative treatment technologies -- vapor phase carbon and catalytic oxidation. Photolysis products will also be measured to verify that no hazardous by-products are generated in the process.

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J.R. SIMPLOT COMPANY
(Anaerobic Biological Process)

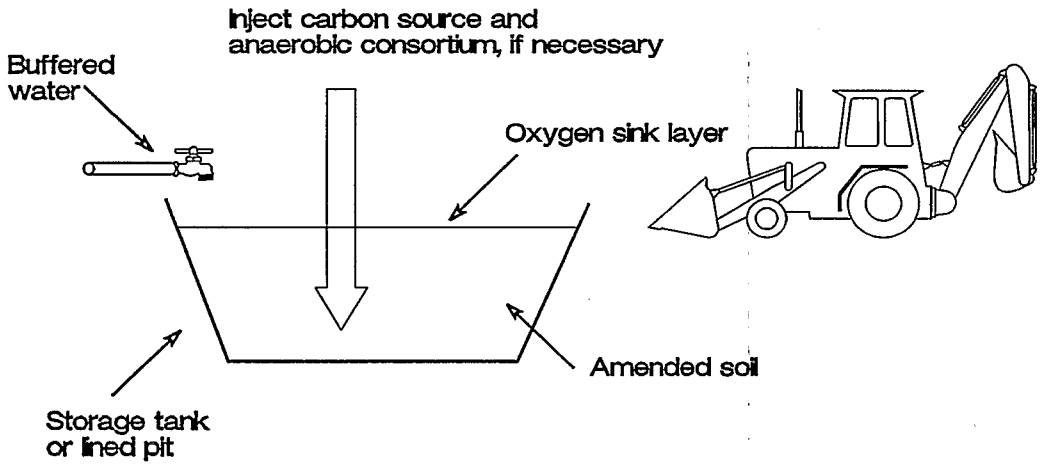
TECHNOLOGY DESCRIPTION:

This technology involves the bioremediation of soils and sludges contaminated with nitroaromatics. Nitroaromatics, particularly nitrotoluenes used as explosives, have become serious environmental contaminants at military locations nationwide. Pesticides are also examples of nitroaromatic environmental contaminants.

Considerable work during the 1970s indicated that complete biodegradation of 2,4,6-trinitrotoluene (TNT) and similar highly nitrated compounds did not occur. Biological reductions ($R-NO_2 \rightarrow R-NO \rightarrow R-NHOH \rightarrow R-NH_2$) and polymerization reactions appeared to occur, but actual degradations of aromatic nuclei were not generally observed.

Recently, it was discovered that anaerobic microbial mixtures can completely destroy many recalcitrant chemicals, such as chloroform, benzene, and chlorophenols, that had been considered essentially nonbiodegradable under such conditions. Extensive work with such microbes indicates that these systems are capable of complete mineralization of nitroaromatic pollutants.

Anaerobic microbial mixtures have been developed for both the pesticide dinoseb (2-sec-butyl-4,6-dinitrophenol) and TNT. These mixtures completely degrade their target molecules to simple nonaromatic products over a period of a few days. Transient formation of reduced intermediates (such as aminonitrotoluenes) and hydroxylated intermediates (such as methylphlorglucinol and



Schematic view of pilot-treatment

p-cresol) is observed. The consortia of microbes function at Eh's of -200 mV or more negative.

Pilot-scale treatment units (see figure) involve simple plastic or Fiberglass vessels that contain static soil slurries (50:50 w/v, soil:water). They are scaled in steps up to approximately 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 mV), a nitroaromatic-degrading anaerobic microbial consortium will be injected to initiate nitroaromatic-pollutant destruction. In some soils, inoculations are not necessary, because native consortia develop quickly.

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. Bench-scale processes have been developed for both dinoseb and TNT under the SITE Emerging Technology Program.

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

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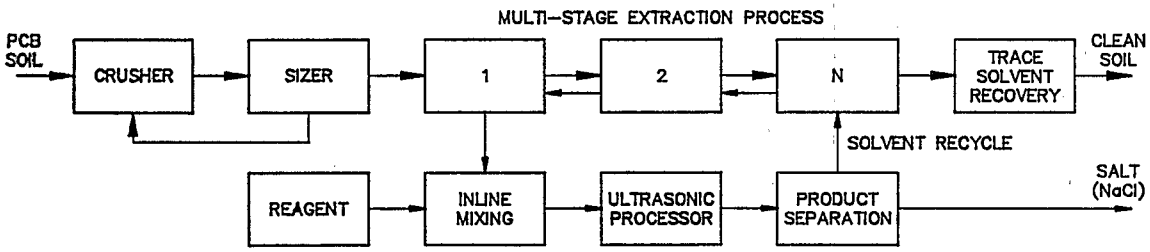
TRINITY ENVIRONMENTAL TECHNOLOGIES, INC.
(Ultrasonically Assisted Detoxification of Hazardous Materials)

TECHNOLOGY DESCRIPTION:

Trinity Environmental Technologies, Inc., has been chemically destroying polychlorinated biphenyls (PCB) in mineral oils under a Region 7 EPA permit since 1986. Trinity is now developing an ultrasonically assisted PCB destruction chemical process for PCB-contaminated soils. The technology uses an aprotic solvent and other reagents in the presence of ultrasonic irradiation to dehalogenate the PCBs to inert biphenyl and chloride. Gas chromatograph/mass spectrograph (GCMS) analysis of processed PCB materials shows that the process has no toxic or hazardous by-products. The commercial process is expected to be less costly than incineration but more costly than land disposal. There are no stack emissions associated with this process.

The process (see figure below) begins by sizing the solid material to allow better contact between the solvents and the PCBs. The PCBs are extracted from the contaminated material in a multiple-stage counter-current extraction process. The extraction solvent of choice is not aqueous. Therefore, the process avoids separation problems typically associated with water and clay soils. The solvent can be completely removed from the soil by using various unit operations, but solvent residue should not pose an environmental problem. The solvent has a high boiling point and is recyclable.

After the solvent is separated from the treated solids, it is pumped to an ultrasonic flow reactor. Reagent is added to the PCB-laden solvent prior to ultrasonic irradiation. During ultrasonic treatment, the PCBs are dehalogenated, and chlorine is completely stripped from the biphenyl structure. After treatment, the reaction products can be removed from the solvent, and the solvent is recycled to the extractor.



Process flow diagram

WASTE APPLICABILITY:

To date, only PCB aroclors and specific PCB cogeners have been treated using this process. However, other chlorinated hydrocarbons such as pesticides, herbicides, pentachlorophenol (PCP), polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) could also be treated by this technology. The process will be capable of treating many different solids 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 samples containing from 25 to 100 parts per million (ppm) PCB were treated by this technology. Initial results show that more than 80 percent destruction efficiency. Further laboratory experimentation is being conducted to isolate the mechanism of the reaction and enhance the destruction of PCBs. Through additional experimentation, the developer expects to reduce the ultrasonic irradiation time to less than 30 seconds.

A modular pilot-scale processor is being planned that will consist of a multistage extraction process for removing PCBs from the soil and a continuous ultrasonic reactor to destroy the PCBs. Initially the pilot process would be capable of processing one ton per hour. Additional modules could be added to increase the capacity of the process as needed. Contaminated soils would be used for these tests instead of the synthetically contaminated soils used in bench-scale testing. The modular plant is scheduled for construction in mid-1992 and to be completed by late-1992.

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UNIVERSITY OF SOUTH CAROLINA
(In Situ Mitigation of Acid Water)

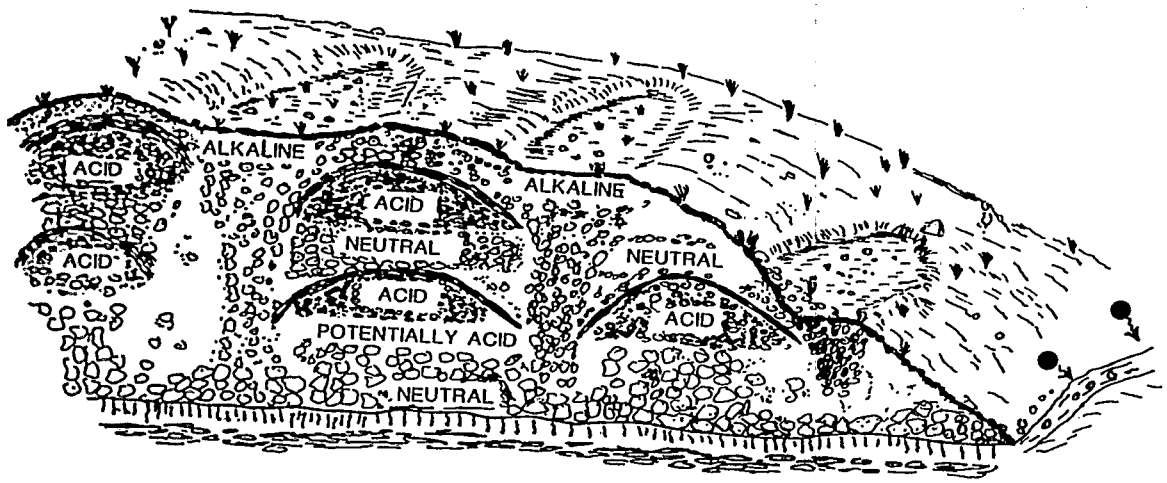
TECHNOLOGY DESCRIPTION:

This technology addresses the acid drainage problem associated with exposed sulfide-bearing minerals (such as mine waste rock and abandoned metallic mines) and is an innovative technique for the in situ mitigation of acid water. Acid drainage forms under natural conditions when iron disulfides (such as fool's gold) are exposed to the atmosphere and water, and spontaneously oxidize to produce a complex of highly soluble iron sulfates. These salts readily hydrolyze to produce an acid-, iron-, and sulfate-enriched drainage that adversely affects the environment.

The in situ mitigation strategy works by modifying the hydrology and geochemistry of the site. This is accomplished through land surface reconstruction and selective placement of limestone.

The technique can be applied to any site located in a humid area where limestone is available as a neutralizing medium. 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 be located in an area of rainfall sufficient to produce seeps or drainages that continually contact the limestone. Rainfall, therefore, helps to remediate the site, rather than increasing the acid drainage.

The overall conceptual model is presented in the figure below and is applicable primarily to mine construction. Surface depressions are constructed to collect surface runoff and funnel the water into the waste rock dump through chimneys constructed of alkaline material. Acidic material is capped with impermeable material to divert water from the acid cores. Through this design, some acid production can



MANIPULATION of ACID and ALKALINE STRATA and HYDROLOGY

Conceptual model for the abatement of acid drainages.

be tolerated, but the net acid load will be lower than the alkaline load, resulting in benign, nonacid drainage.

WASTE APPLICABILITY:

The technology is designed to neutralize acid drainage from abandoned waste dumps and mines.

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 (PVC) plastic. The lysimeters can be drained through an outlet pipe into 55-gallon collection barrels. Within the floor of the lysimeters, piezometers have been installed to 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 chemistry of the effluent draining from each lysimeter is currently being monitored. Leachate will be monitored for about 6 months to establish a baseline of quality, at which time selected lysimeters will be topically treated by maintaining two lysimeters as controls. By comparison, the efficacy of the acid abatement strategy will be evaluated. In addition, a rain gauge has been installed at the site for mass balance measurements, and an ancillary study has been implemented to correlate laboratory and field results.

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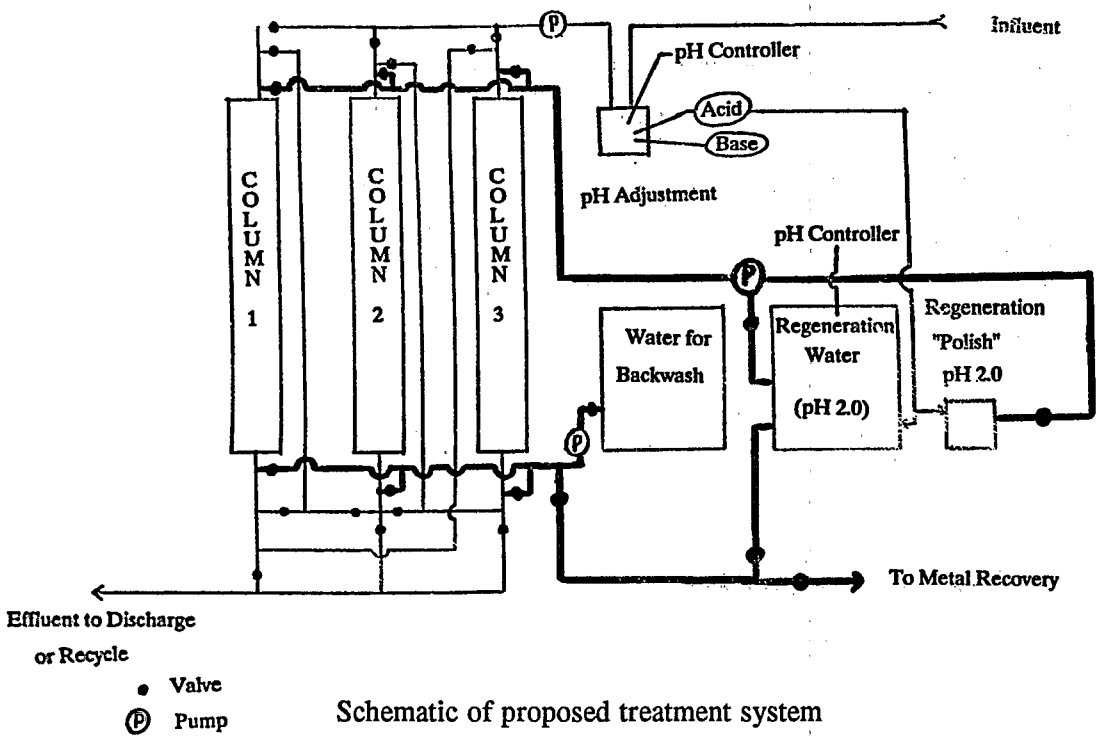
UNIVERSITY OF WASHINGTON
(Adsorptive Filtration)

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 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 by using a pH-induced desorption process.

The sand can be coated by a few different procedures. All involve 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, so acidic solutions can be used in the regeneration step to ensure complete metal recovery. There has been no apparent loss of treatment efficiency after tens of regeneration cycles. Anionic metals (such as arsenate, chromate, and selenite) can be removed from solution by treatment at pH near 4 and regeneration at high pH.

The substantial advantages of this technology over conventional treatment technologies for metals 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 the presence of



Schematic of proposed treatment system

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 0.5 parts per million (ppm) of cadmium, copper, or lead have been treated in packed columns with retention times of 2 minutes. 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 at this point, although the metals were still being removed; in other experiments, the capacity of the media to adsorb copper was about 7,000 milligrams per liter (mg/L) of packed bed.

When the columns were regenerated, the first batch of regenerant solutions contained about 500 ppm of metal each in the case of cadmium or lead, representing a concentration factor of about 1,000 to 1. The copper data have not been analyzed yet. At a flow rate yielding a 2-minute retention time, it would have taken 10,000 minutes, or about 7 days of continuous flow operation, to treat the 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 circuitboard 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 is being treated from Western Processing site a Superfund site near Seattle, Washington.

The project will be completed by December 1991 and data from the groundwater will be included in the final report.

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VORTEC CORPORATION
(Oxidation and Vitrification Process)

TECHNOLOGY DESCRIPTION:

Vortec has created an oxidation and vitrification process for remediation of soils, sludges, and sediments that have organic, inorganic, and heavy metal contamination. The system has the ability to oxidize and vitrify materials introduced as slurries, thus providing the capability of mixing waste oils, along with the hazardous soils.

The figure below is a block diagram of 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, which is the primary thermal processing system, consists of three major assemblies: a precombustor, an in-flight suspension preheater, and a cyclone melter chamber. Contaminated soil (waste in slurry or dry form) is introduced into the precombustor as the first step in the process, where heating and oxidation of the waste materials are initiated. The precombustor is a vertical vortex combustor designed to provide sufficient residence time to vaporize water and to initiate oxidation of organics in the waste materials before melting of the material. The suspension preheater is a counter rotating vortex (CRV) combustor designed to provide suspension preheating of the materials, as well as secondary combustion of volatiles emitting from the precombustor and combustion of auxiliary fuel introduced directly into the CRV combustor. The average temperature of materials leaving the CRV

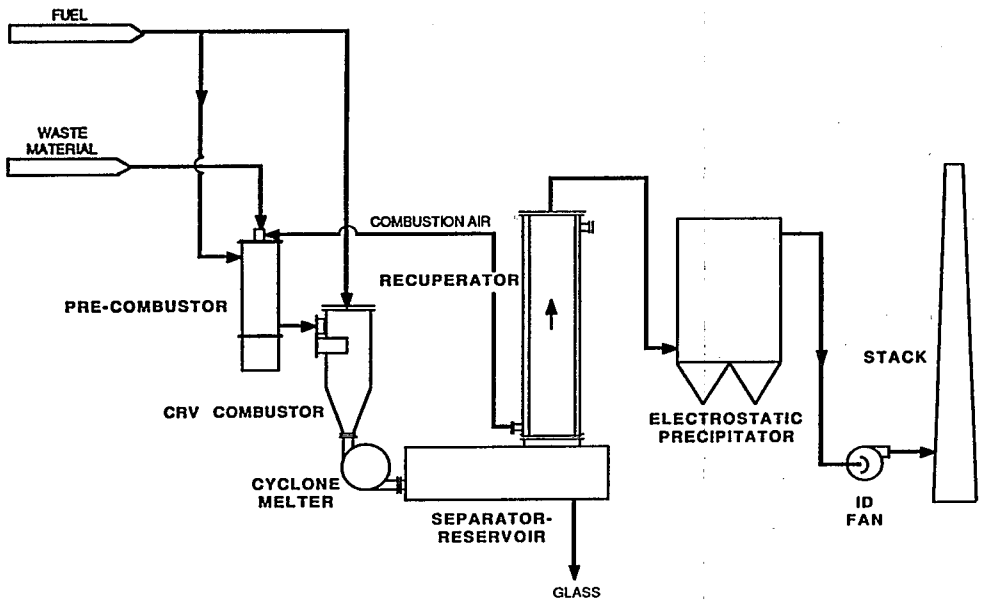

Diagram of the Vortec oxidation and vitrification process.

combustion chamber is typically between 2,200 and 2,700 degrees Fahrenheit.

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 layer. The vitrified glass product and the exhaust gases exit the cyclone melter through a tangential exit channel and enter a glass and gas separation chamber assembly. 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 cleanup. 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.

Some of the unique features of the Vortec oxidation and vitrification process include the following:

- processes solid waste with both organic and heavy metal contaminants
- uses various fuels, especially economical fuels and, possibly, waste fuels
- can handle waste quantities ranging from 5 tons/day to greater than 300 tons/day
- can recycle toxic materials collected in the air pollution control system
- produces a product that immobilizes heavy metals and has long-term stability
- produces a vitrified product that is nontoxic according to EPA's toxicity characteristic leaching procedure (TCLP) standards.

WASTE APPLICABILITY:

The Vortec oxidation and vitrification system treats soils, sediments, sludges, and mill tailings containing organic, metallic, and radioactive components. Organic materials included with the waste are successfully oxidized at the high temperatures achieved in the combustor. The chemical composition of the organic constituents of the waste material will determine the amount and type of glass-forming additives required to produce a vitrified product. The glass cullet produced by the process can be made to consistently pass TCLP requirements.

STATUS:

The Vortec technology was accepted into the SITE Emerging Technology Program in May 1991. The technology has been under development by the Department of Energy and others since 1985. A 20 tons/day pilot scale test facility has been processing nonhazardous industrial waste material for 2 years on an experimental and developmental basis. The vitrified product generated in these tests have passed TCLP. Preliminary system designs of up to 300 tons/day have been developed. The developer is currently developing the work plan and Quality Assurance Project Plan (QAPjP).

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WARREN SPRING LABORATORY
(Physical and Chemical Treatment)

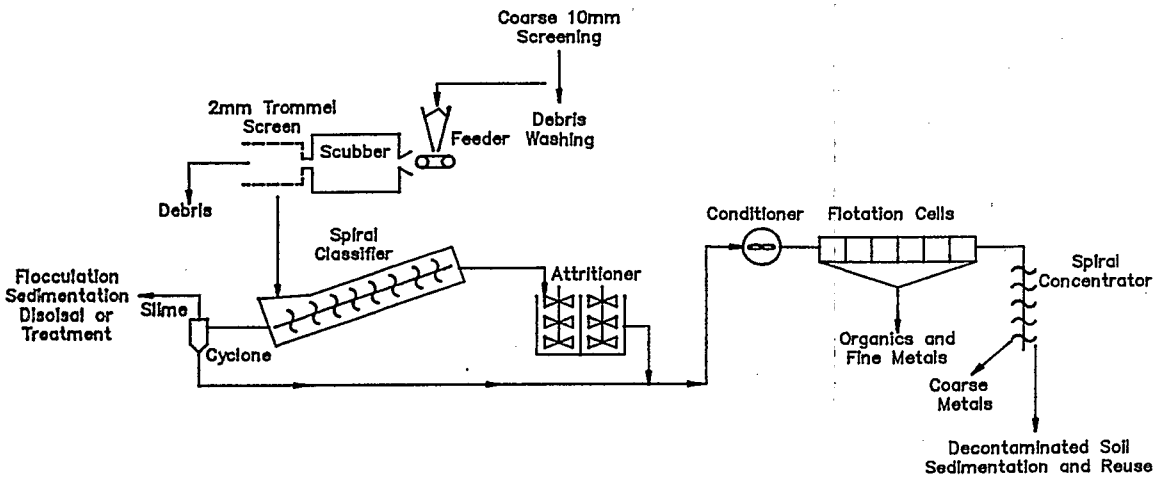
TECHNOLOGY DESCRIPTION:

Warren Spring Laboratory will investigate the application of feed preparation and mineral processing techniques for treatment of soil contaminated with metals, petroleum hydrocarbons, and polycyclic aromatic hydrocarbons.

Feed preparation processes to be evaluated include scrubbing, classifying, and cycloning. Mineral processing techniques including flotation, flocculation, high- and low-intensity magnetic separation, and gravity techniques will also be investigated. The processes will be taken to pilot-scale, culminating in an integrated system for the treatment of contaminated soil.

A typical flowsheet for the physical treatment of contaminated soil is shown in the figure. Feed samples will be subjected to scrubbing and attritioning procedures, by simple tumble scrubbers and attritioning scrubbers, with associated size fractionation and chemical analysis to evaluate the deployment of metals and organics. After feed preparation, samples will be subjected to magnetic separation by using high gradient and high intensity matrices for metals separation.

Flotation procedures for organics will use a range of frother types (alcohols, polyglycols, and cresols) to be evaluated over a range of pH values ranging from 5 to 10 to maximize organics recovery and increase selectivity with respect to solids. Metals flotation will be based on the comparison of different sulfydric collectors including xanthates, thiophosphates, thiocarbamates, and xanthogen formates. The separation of organic and metal phases will be examined by using selective flocculation techniques. Tailing samples will be subjected to



Typical flowsheet for the physical treatment of contaminated soils

heavy liquid centrifuge techniques to assess the presence of liberated metal phases and the potential of subsequent gravity separation.

Expected capacities for an operating plant using these procedures would be from 20 to 60 tons per hour.

WASTE APPLICABILITY:

The pilot-scale treatment system will treat contaminated soil for removal of metals, petroleum hydrocarbons, and polycyclic aromatic hydrocarbons.

The industrial origins of these wastes will include gas works, petrochemical plants, pickling plants, industrial chemical plants, coke factories, scrapyards, ship repair yards, and smelters.

STATUS:

The initial testing scheduled for late 1991 will focus on identifying and collecting suitable feed materials for the main research program. Characterization tests will then be conducted to establish the amenability of the soils to the methods under investigation so that a selection can be made of the soil to be studied at pilot-plant scale.

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WASTEWATER TECHNOLOGY CENTRE
(Cross-Flow Pervaporation System)

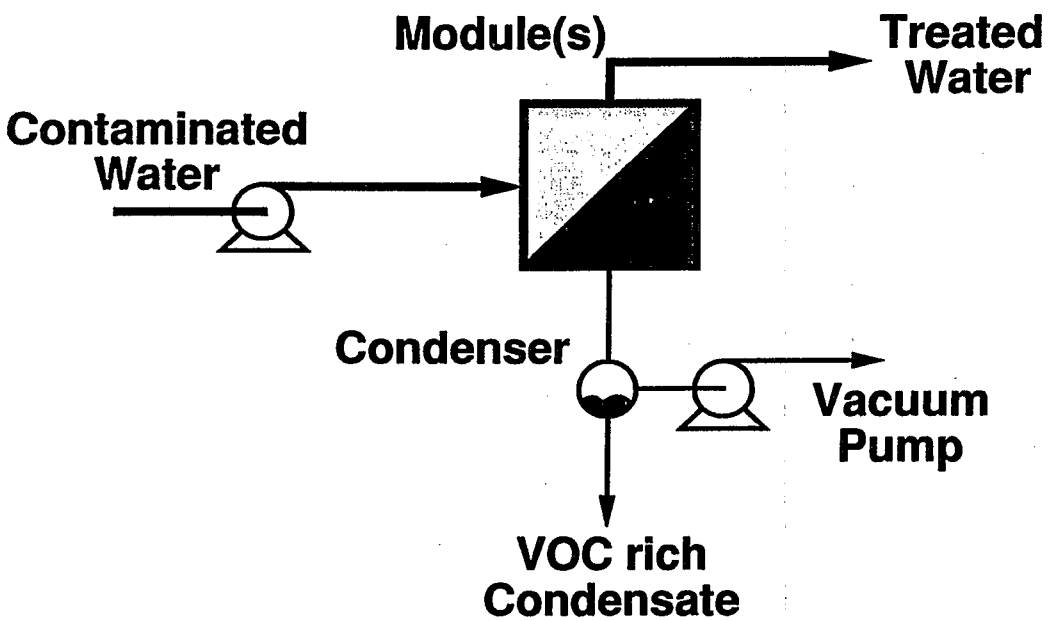
TECHNOLOGY DESCRIPTION:

Pervaporation is a process for removing volatile organic compounds (VOC) from contaminated water. The performance of the cross-flow pervaporation system increases with temperature, with an equipment limitation of 35 degrees Celsius. Permeable membranes that preferentially adsorb VOCs are used to partition VOCs from the contaminated water. The VOCs diffuse from the membrane and water interface through the membrane and are drawn off by a vacuum pump. Upstream of the vacuum pump, a condenser traps and contains the permeating vapors, condensing all the vapor, therefore, allowing no discharge to the atmosphere (see figure below). The condensed organic vapors represent only a fraction of the initial wastewater volume and may be sent for disposal at significant cost savings. Industrial waste streams may also be treated with this process, and solvents may be recovered for reuse.

A modular three liters per minute separation unit in which wastewater flows across the outside of a hollow fiber membrane has been tested at the Wastewater Technology Centre. The system's treatment capacity is limited to three liters per minute. In this configuration, the vacuum pump is applied to the inside of the fiber. This design provides very high packing densities and low pressure losses on both the feed and permeate sides.

WASTE APPLICABILITY:

Pervaporation can be applied to aqueous waste streams (groundwater, lagoons, leachate, and rinse water) contaminated with VOCs, such as solvents, degreasers, and gasoline. The



Pervaporation Process

technology is applicable to the types of wastes currently treated by carbon adsorption, air stripping, and reverse osmosis separation.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1989. A cost comparison, generated by Wastewater Technology Centre, showed that pervaporation can be competitive with air stripping and activated carbon to treat low concentrations of VOCs.

A pilot plant with a maximum removal efficiency of 99 percent was built and evaluated in-house with model compounds (toluene and trichlorethylene). A unit suitable for field demonstration should be available in 1992.

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WESTERN PRODUCT RECOVERY GROUP, INC.
(CCBA Physical and Chemical Treatment)

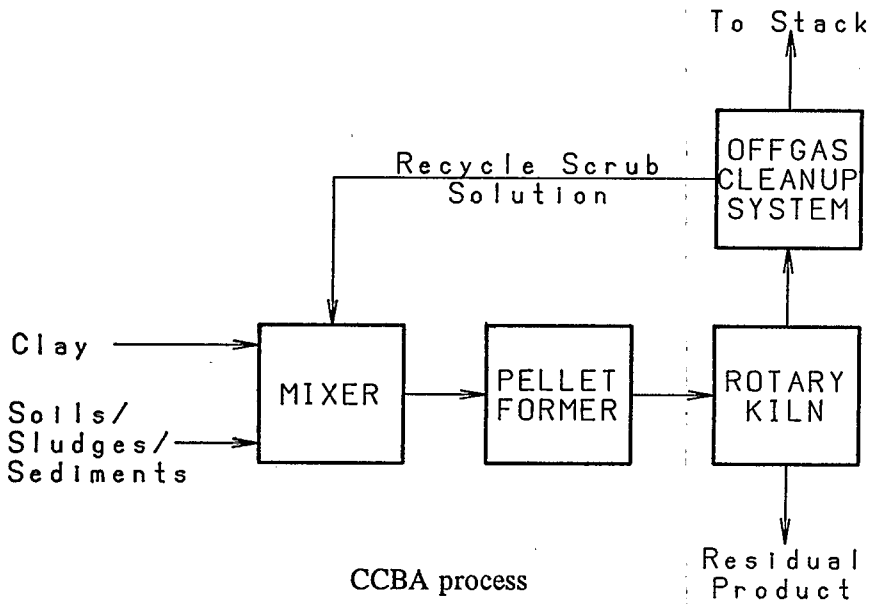
TECHNOLOGY DESCRIPTION:

The coordinate, chemical bonding, and adsorption (CCBA) process converts heavy metals in soils, sediments, and sludges to nonleaching silicates. The process (see figure below) is also capable of oxidizing organics in the waste stream and incorporating 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 residues 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 the necessary structure to provide sites for physical and chemical bonding of heavy metals to the clay.

The process is designed for continuous flow for the entering and outgoing streams. 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 degrees Fahrenheit 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. The pellets reach a temperature inside the kiln, where 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 system before release to the atmosphere. Excess scrub solution is recycled back to the front-end mixing process.



CCBA process

WASTE APPLICABILITY:

The CCBA process has been demonstrated commercially on metal hydroxide sludges at a sludge throughput of 70 wet tons per month, based on an 8 hour day, at 25 percent by weight solids. This process can be used on wastewater sludges, sediments, and soils contaminated with mixed organic and heavy metal wastes.

STATUS:

This technology was accepted into the SITE Emerging Technology Program January 1991. The SITE project is designed to extend the CCBA technology 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.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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Western Product Recovery Group, Inc.
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WESTERN RESEARCH INSTITUTE
(Contained Recovery of Oily Wastes)

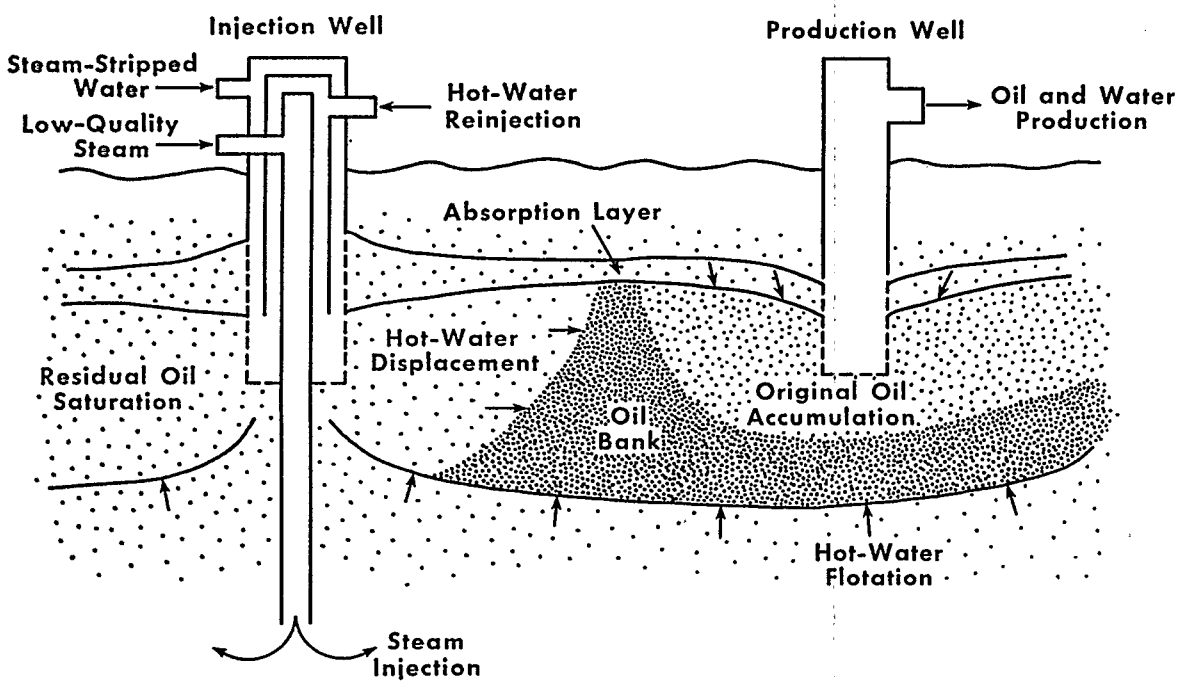
TECHNOLOGY DESCRIPTION:

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 and hot-water displacement are used to move accumulated oily wastes and water to production wells for above ground 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 deepest penetration of organic liquids. The steam condenses, causing rising hot water to dislodge and sweep buoyant organic liquids upward into the more permeable soil regions. Hot water is injected above the impermeable soil egions to heat and mobilize the oil waste accumulations, which are recovered by hot-water displacement.

When the oily wastes are displaced, the organic liquid saturations in the subsurface pore space increase, forming an oil bank. The hot water injection displaces the oil bank to the production well. Behind the oil bank, the oil saturation is reduced to an immobile residual saturation in the subsurface pore space. The oil 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 any water samples from the site. During treatment, all mobilized organic liquids and water-soluble contaminants are contained within the original boundaries of oily waste accumulations. Hazardous materials are contained laterally by



CROW™ subsurface development

groundwater isolation, and vertically by organic liquid flotation. Excess water is treated in compliance with discharge regulations.

The process (1) removes large portions of oily waste accumulations, (2) stops the downward migration of organic contaminants, (3) immobilizes any residual saturation of oily wastes, (4) and reduces the volume, mobility, and toxicity of oily wastes. It can be used for shallow and deep contaminated areas, and uses the same mobile equipment required by conventional petroleum production technology.

WASTE APPLICABILITY:

This technology can be applied to manufactured gas plant sites, wood-treating sites, and other sites with soils containing 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. The program showed the effectiveness of the hot-water displacement and displayed the benefits from the inclusion of chemicals with the hot water. Evaluation under the Emerging Technology program has been completed, 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 at Stroudsburg, Pennsylvania. The site contains an area of high concentrations of by-products from a former operation. 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.

In addition to the SITE program, this technology is now being demonstrated at a wood-treatment site in Minnesota. Other areas of activity include screening studies for other potential sites and an in-house project to advance the use of chemicals with the hot-water displacement.

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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 Program places high priority on those technologies that provide cost-effective and faster, safer, and better 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. The types of technologies of interest to EPA include: chemical sensors for in situ measurements; ground-water 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 an ongoing process in the MMTP; therefore, technology developers are encouraged to submit new and updated information at any time or as it becomes available. The information submitted is reviewed, cataloged, and incorporated into a technology matrix, from which EPA can make a preliminary determination of the types of innovative technologies that may be candidates for participation.

Currently, there are 14 active participants in the MMTP. These technologies are presented in alphabetical order in Table 4 and in the technology profiles that follow.

TABLE 4

SITE Monitoring and Measurement Technologies Program Participants

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	Eric Koglin/ Stephen Billets 702-798-2432	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	Volatile PAHs
Bruker Instruments,* Billerica, MA	Bruker Mobile Environmental Monitor	John Wronka 506-667-9580	Eric Koglin/ Stephen Billets 702-798-2432	Air Streams, Water, Soil, Sludge, Sediment	Not Applicable	VOCs and SVOCs
CMS Research Corporation, Birmingham, AL	MINICAMS	H. Ashley Page 205-733-6911	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Not Applicable	VOCs
EnSys, Inc.* [developed by Westinghouse Bio-Analytic Systems], Research Triangle Park, NC	ELISA	Stephen Friedman 914-941-5509	Jeanette Van Emon 702-798-2154	Water	Not Applicable	PCPs
Graseby Ionics, Ltd., Watford, Herts, England and PCP, Inc.,* West Palm Beach, FL	Ion Mobility Spectrometry	John Brokenshire/ Martin Cohen 01-44-923-816166/ 407-683-0507	Eric Koglin 702-798-2432	Air Streams, Vapor, Soil, Water	Not Applicable	VOCs, Chloroform, Ethylbenzene
HNU Systems, Incorporated, Newtown, MA	Portable Gas Chromatograph	Clayton Wood 617-964-6690	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Not Applicable	VOCs, Aromatic Compounds, Halocarbons
MDA Scientific, Incorporated, Norcross, GA	Infrared Spectrometer	Orman Simpson 404-242-0977	William McClenny 919-541-3158 FTS: 629-3158	Air Streams	Non-Specific Inorganics	Non-Specific Organics
Microsensor Systems, Incorporated, Springfield, IL	Portable Gas Chromatograph	N. L. Jarvis 703-642-6919	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Not Applicable	VOCs

* Demonstration or Evaluation complete

TABLE 4 (continued)

SITE Monitoring and Measurement Technologies Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Microsensor Technology, Incorporated,* Fremont, CA	Portable Gas Chromatograph	Gary Lee 415-490-0900	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Non-Specific Inorganics	Non-Specific Organics
Photovac International, Incorporated, Deer Park, NY	Photovac 10S PLUS	Mark Collins 516-254-4199	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Not Applicable	VOCs, Volatile Aromatic Compounds, Chlorinated Olefin Compounds
Sentex Sensing Technology, Incorporated, Ridgefield, NJ	Portable Gas Chromatograph	Amos Linenberg 201-945-3694	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams, Water, Soil	Not Applicable	VOCs
SRI Instruments, Torrance, CA	Gas Chromatograph	Dave Quinn 213-214-5092	Richard Berkley 919-541-2439 FTS: 629-2439	Air Streams	Not Applicable	VOCs
XonTech, Incorporated,* Van Nuys, CA	XonTech Sector Sampler	Matt Young 818-787-7380	Joachim Pleil 919-541-4680 FTS: 629-4680	Air Streams	Not Applicable	VOCs

* Demonstration or Evaluation complete

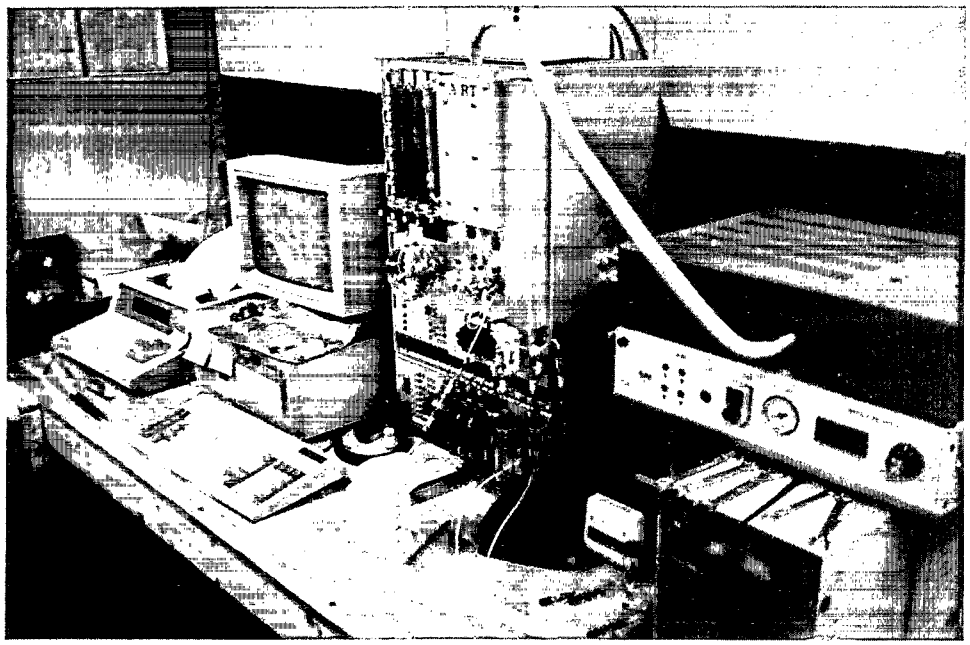
ANALYTICAL AND REMEDIAL TECHNOLOGY, INC.
(Automated Volatile Organic Analytical System)

TECHNOLOGY DESCRIPTION:

The automated volatile organic analytical system (AVOAS)(see photograph below) permits the continuous monitoring of a water stream. The instrument 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 can offer high sensitivity or specificity depending on the application or date 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 provide real-time analytical data during the remediation and long-term monitoring phases at a Superfund site.



Automated volatile organic analytical system

STATUS:

The demonstration was conducted in May 1991 at the Wells G and H Superfund site in EPA's 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 to measure the efficiency of the technique under study. For this evaluation, 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 is being prepared and is scheduled for completion in December 1991. A presentation of results is planned for 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 presented in the final report.

FOR FURTHER INFORMATION:

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TECHNOLOGY DEVELOPER CONTACT:
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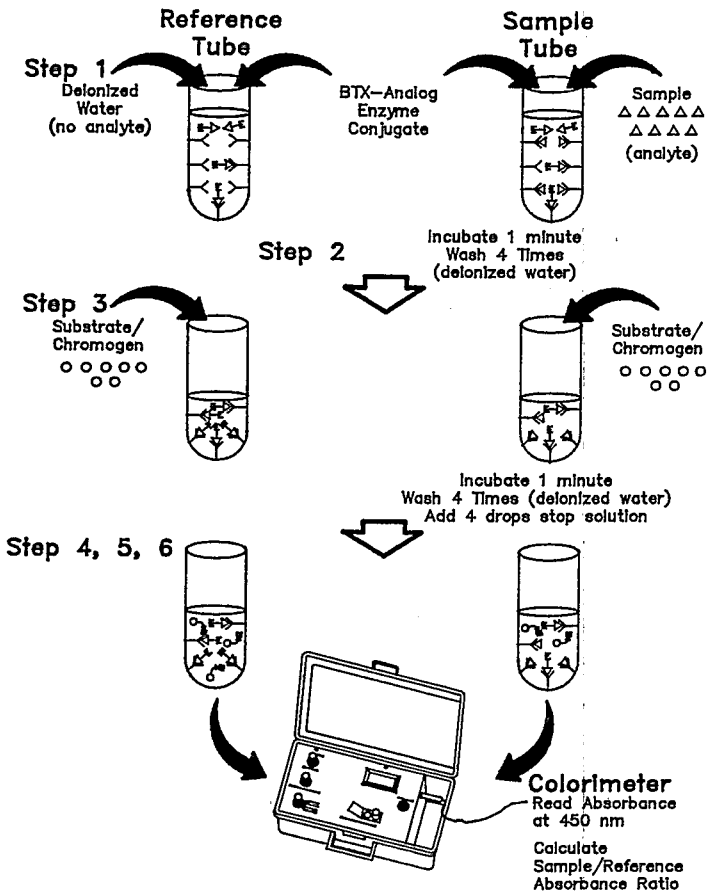
BINAX CORPORATION
Antox Division
(Equate® Immunoassay)

TECHNOLOGY DESCRIPTION:

The Equate® immunoassay test uses an anti-BTX (benzene, toluene, and xylene) 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 colorized enzymatic reaction product is formed. The enzymatic reaction is stopped by the addition of a few drops of sulfuric acid, which changes the color to yellow. As with other competitive enzyme-linked immunosorbent assays (ELISA), the color intensity of the enzymatic product is inversely proportional to the sample analyte concentration. Each sample



Antox BTX assay principle

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 ppm range. The test is sensitive to about 1 part per million and requires 5 to 10 minutes per analysis.

WASTE APPLICABILITY:

The immunoassay is designed to measure volatile polycyclic aromatic hydrocarbons in water.

STATUS:

The Environmental Monitoring System Laboratory – Las Vegas (EMSL-LV) conducted a performance evaluation of several successfully developed versions of the immunoassay test. Laboratory performance evaluation of the test focused on cross-reactivity and interference testing and on analysis of BTX, BTEX (benzene, toluene, ethylbenzene, and xylene), and gasoline standard curves.

As a preliminary field evaluation, five well samples and a creek sample were assayed in duplicate, both in the field and the laboratory, by the test. For confirmation, samples were also analyzed by purge-and-trap gas chromatography (GC) with an electron capture detector, in parallel with a photoionization detector.

A SITE demonstration of the Equate® test is planned for 1992.

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207-772-3544
FAX: 207-761-2074

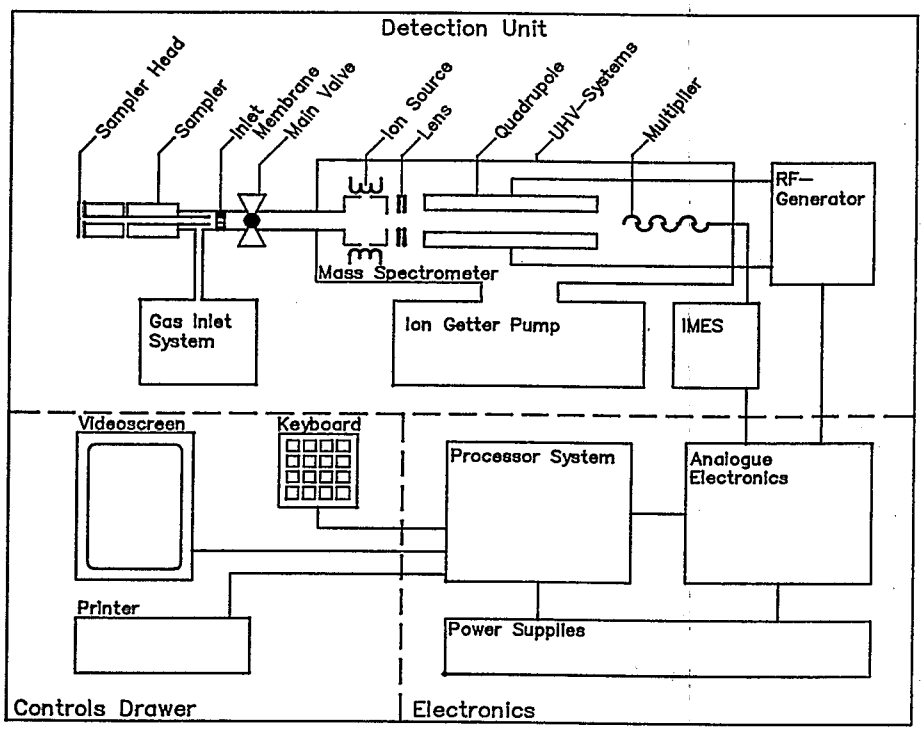
BRUKER INSTRUMENTS
(Bruker Mobile Environmental Monitor)

TECHNOLOGY DESCRIPTION:

This mobile environmental monitor (see figure below) is a field transportable analytical instrument 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 for the Bruker instrument have been specially modified 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 for use in detecting and monitoring chemical warfare agents. Environmental samples may be introduced to the mass analyzer through the direct air sampler or the gas chromatograph. Results are collected and stored in a computer, where data reduction and analysis



Schematic diagram of the mobile mass spectrometer

are carried out. The computer system is capable of providing reports within minutes of final data acquisition.

WASTE APPLICABILITY:

This instrument is designed to detect the full range of volatile and semivolatile organic compounds directly in air and in extracts of water, soil, sediment, sludge, and hazardous waste. For purposes of this demonstration, the instrument was used to determine the presence and concentration of polychlorinated biphenyls (PCB) in soil, polynuclear aromatics (PNA) in soil, and the full range of Superfund targeted volatile organic compounds (VOC) in water. This demonstration was conducted by using samples collected and analyzed at the Resolve and Westborough Superfund sites in EPA Region 1. The Bruker mobile environmental monitor can be used to provide in-field, real-time support during the characterization and remediation phases of cleanup at a hazardous waste site. The demonstration was conducted at Superfund sites known to contain the target compounds of interest. The intent of the study was to validate the technology by using a variety of quality control and environmental samples. The experimental design required that all of the samples analyzed in the field be shipped to a laboratory and analyzed by using standard Superfund analytical methods, as would be obtained under the Contract Laboratory Program.

STATUS:

The SITE demonstration was completed in September 1990 and a Project Report was provided to the Superfund Program Office. Presentations on the results of this study were made 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. Additional demonstrations under the Technology Support program are planned.

Environmental Monitoring Systems Laboratory - Las Vegas (EMSL/LV) has proposed purchase of a field portable gas chromatograph/mass spectrograph (GC/MS) system in fiscal year 1992 to pursue other applications and to expand the scope of the project as conducted under this SITE demonstration.

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TECHNOLOGY DEVELOPER CONTACT:
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CMS RESEARCH CORPORATION
(MINICAMS)

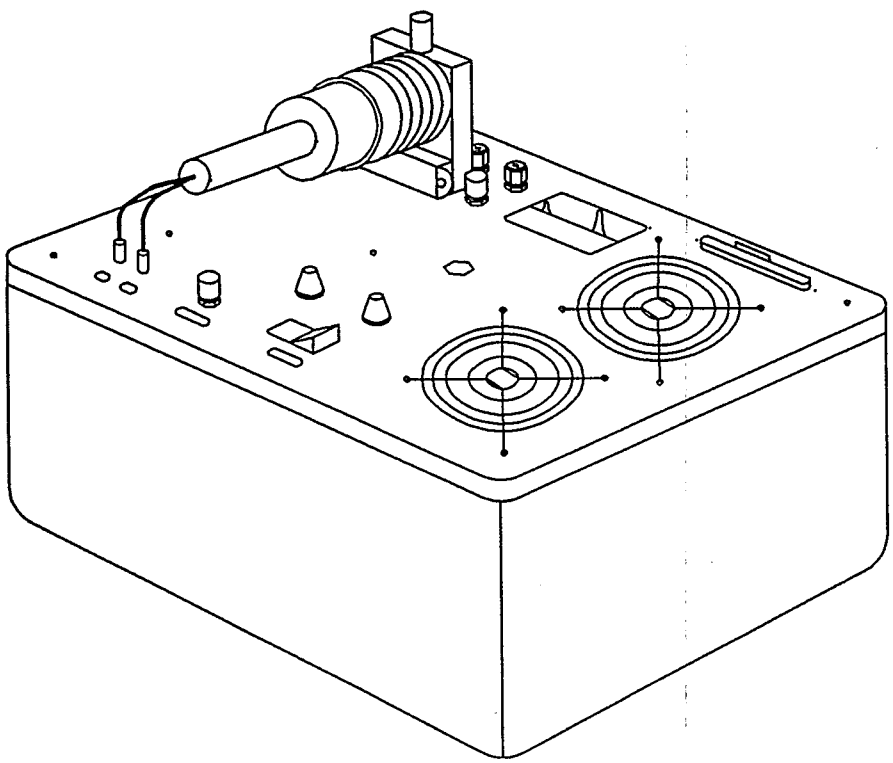
TECHNOLOGY DESCRIPTION:

The CMS Research Corporation's MINICAMS (see figure below) is an analytical and alarm system based on (1) collection of volatile organic compounds (VOC) on solid sorbents, (2) separation using capillary column gas chromatography, and (3) detection using either a flame-photometric detector, or a flame-ionization detector, or both. In addition to sounding an alarm when VOC concentration exceeds a preset level, the MINICAMS reports concentrations accurately over a range of up to eight orders of magnitude.

Cycle time can be varied from 2 minutes to more than 15 minutes.

WASTE APPLICABILITY:

The CMS MINICAMS can be used to monitor VOC emissions from hazardous waste sites and other emission sources before and during remediation. It is potentially applicable to many



CMS Research Corporation MINICAMS

kinds of vapor phase pollutants, but its performance characteristics in field operation have not yet been evaluated.

STATUS:

Laboratory evaluation of the CMS MINICAMS will be conducted during fall 1991. Field evaluation at a Superfund site under remediation is scheduled for January 1992.

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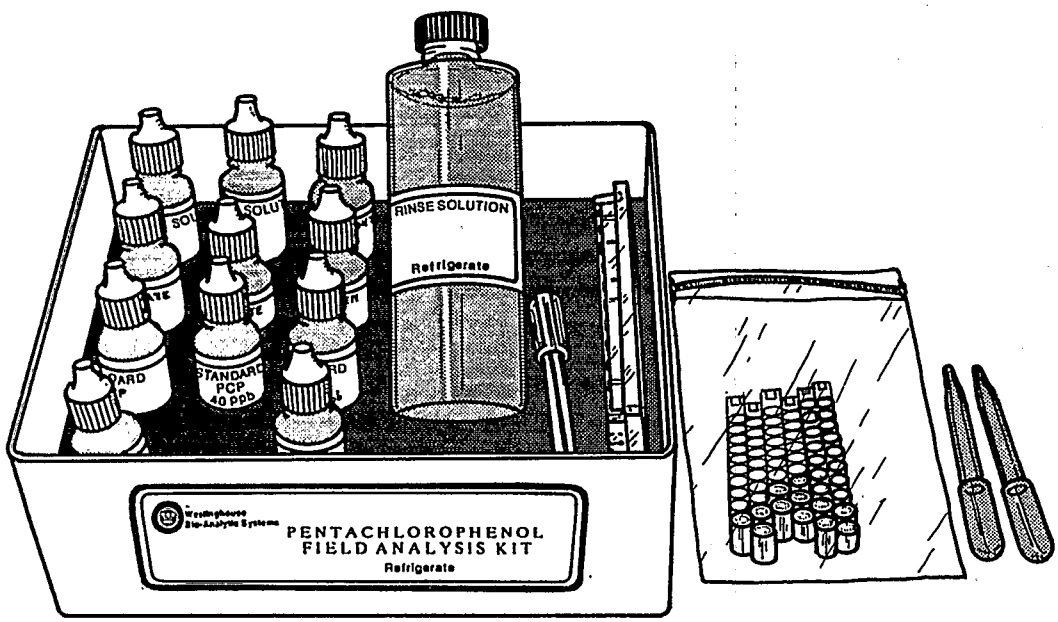
ENSYS, INC.
[Developed by WESTINGHOUSE BIO-ANALYTIC SYSTEMS] (ELISA)

TECHNOLOGY DESCRIPTION:

Westinghouse Bio-Analytic Systems (WBAS) developed two different immunoassays for determination of pentachlorophenol (PCP) in water samples. One is a quantitative 96-well microtiter plate enzyme-linked immunosorbent assay (ELISA); the other is a rapid, portable, semi-quantitative, microwell strip ELISA. A monoclonal antibody was used to develop the quantitative plate ELISA; a polyclonal antibody was used for the rapid strip ELISA. The antibodies had similar, but not identical, cross-reactivity profiles. For the purpose of clarity, these will be referred to as plate and strip immunoassays, respectively.

The plate ELISA requires about 3 hours of hands-on time. Although it has an overnight incubation step, sample throughput is extremely high. The test is sensitive to about 30 parts per billion and has a linear dynamic range of approximately 30 to 400 ppb. The plate method is a competitive inhibition ELISA and it has a different format than the strip ELISA. The 96-well microtiter plate is coated with a hapten (dichlorophenol) protein conjugate. In the first step, a colorimetric substrate (paranitrophenyl phosphate) is added, and the bound enzyme acts on it to produce a colored product. The intensity of the color, which is inversely proportional to the analyte concentration, is read spectrophotometrically. Typically, each plate contains a set of known standards that are run along with the unknown. A standard curve (concentration or log concentration) is plotted, fitted (by hand or computer), and used to quantify the unknowns.

The strip ELISA takes about 30 minutes to run,



WBAS field kit immunoassay

has a detection limit of 3 ppb, and has a linear dynamic range of 3 to 40 ppb. The microwell strips are coated with an anti-PCP polyclonal antibody. In the first step of the procedure, a sample (or standard containing analyte) is incubated with an enzyme-labeled (horseradish peroxidase) dichlorophenol conjugate in the antibody-coated wells. Free analyte in the sample competes with the hapten-conjugate for binding to the bound antibody. After washing the strip to remove unbound material, a substrate chromogen mixture is added to produce a colored product. Finally, the reaction is stopped by the addition of a few drops of 2N sulfuric acid. The intensity of color, which is inversely proportional to the sample (or standard) analyte's concentrate, is read on a battery-operated portable digital colorimeter.

WASTE APPLICABILITY:

These two ELISAs are used to analyze pentachlorophenol (PCP) in water samples.

STATUS:

From July through early September 1989, a field demonstration of the plate and strip ELISAs was conducted as a part of the SITE Program at the McGillis and Gibbs Superfund site in New Brighton, Minnesota. The immunoassay demonstration ran concurrently with the demonstration of a bioreactor. In conjunction with the bioreactor demonstration, groundwater influent and effluent samples from within the bioreactor process cycle were analyzed by gas chromatography/mass spectrometer (GC/MS) (EPA Method 8270), following EPA Method 3510 extraction, and by the two ELISAs.

The objective of the immunoassay SITE demonstration was to evaluate the ruggedness and utility of the immunoassay kits. This was accomplished by collecting grab samples and splits of composite field samples taken for GC/MS analysis as part of the bioreactor demonstration. These samples, along with splits of field blanks, field duplicates, and quality assurance samples, were analyzed by the ELISA on-site and by the strip and plate ELISA at the Environmental Monitoring Systems Laboratory - Las Vegas (EMSL-LV) and WBAS laboratories. All field samples selected for on-site analysis were analyzed by the plate ELISA at both laboratories. During the first and third weeks of the demonstration, selected field samples were analyzed by the strip ELISA in both laboratories (as well as on-site). This was designed to provide laboratory versus on-site and laboratory versus laboratory comparison data. The performance of the immunoassay strip assay was evaluated and compared with the GC/MS results and the plate immunoassay results. A SITE Project Summary report will be published in December 1991.

FOR FURTHER INFORMATION:

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Research Triangle Park, NC 27709
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GRASEBY IONICS, LTD. and PCP, INC.
(Ion Mobility Spectrometry)

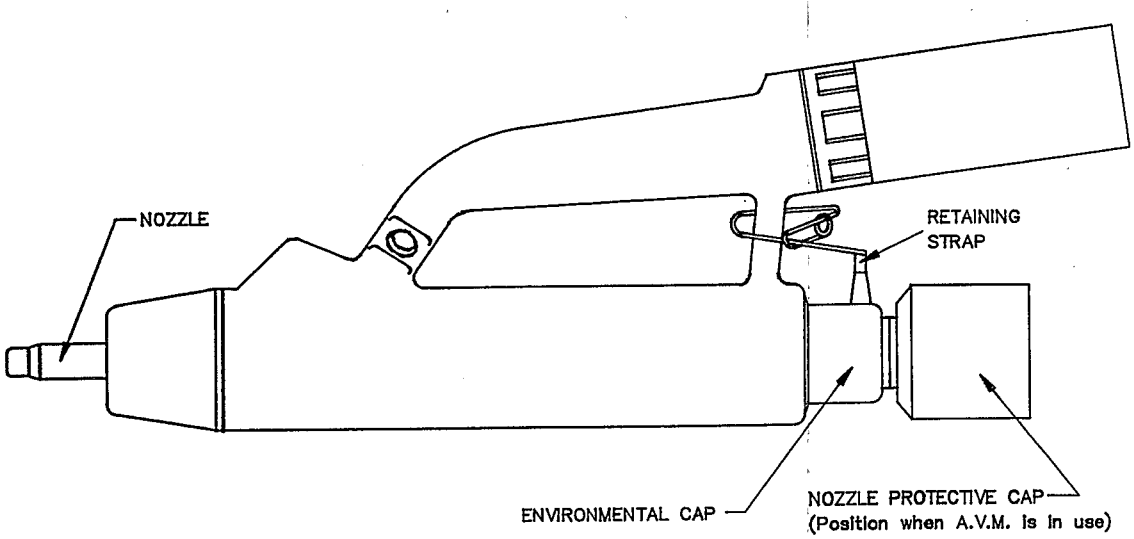
TECHNOLOGY DESCRIPTION:

Ion mobility spectrometry (IMS) is a technique used to detect and characterize organic vapors in air. The principles of IMS involve 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, less power, less weight, and simplicity.

Two technology developers participated in the laboratory demonstration that was conducted in summer and fall 1990. One developer, Graseby Ionics Ltd., used a commercially available, self-contained instrument that weighs about 2 kilograms (see figure below). The other developer, PCP, Inc., used a larger (12 kg) transportable IMS. This laboratory demonstration was the first opportunity for these developers to test their instruments by using environmental samples.

WASTE APPLICABILITY:

The IMS units, which are intended to be used in a preprogrammed fashion, are capable of monitoring one of several chemicals, such as chlororform, 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 the analysis of solid materials, the contaminants must be introduced to the instrument in the gas phase, therefore requiring some sample preparation.



Airborne vapor monitor

STATUS:

The laboratory SITE demonstration of IMS was valuable. Though the potential of IMS for environmental measurements has been mentioned for a long time, the results of this demonstration highlighted, for the first time, the limitations of the technology. Two main needs must be met before IMS will be field-ready for environmental 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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Las Vegas, NV 89193-3478
702-798-2432

TECHNOLOGY DEVELOPER CONTACTS:
John Brokenshire
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Analytical Division
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011-44-923-816166

Martin Cohen
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2155 Indian Road
West Palm Beach, FL 33409-3287
407-683-0507

HNU SYSTEMS, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

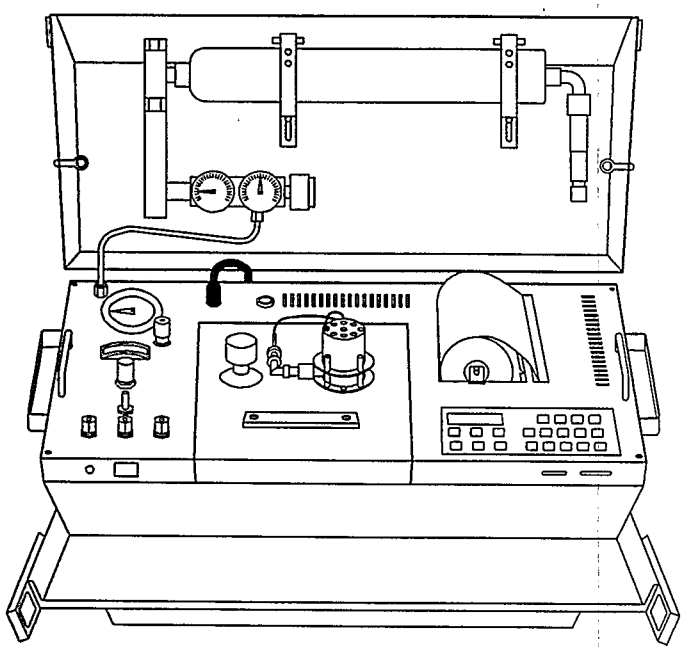
The HNU GC 311 portable gas chromatograph (see figure below) is specially designed to be field-deployable. It has an internal carrier gas supply, operates on 110-volt line power, and is microprocessor-controlled. Chromatograms are plotted, and data are printed on an internal printer plotter. Data can 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 potentially be used to monitor volatile organic compound (VOC) 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 performance characteristics in field operation have not yet been evaluated. The photoionization detector is sensitive to compounds that ionize below 10.4 electron volts (eV), such as aromatic compounds and unsaturated halocarbons. The electron-capture detector is sensitive to material with a high affinity for electrons, such as halocarbons.

STATUS:

Laboratory evaluation of the HNU GC 311 will be conducted during fall 1991. Field evaluation at a Superfund site under remediation is scheduled for January 1992.



HNU Systems GC 311

FOR FURTHER INFORMATION:

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Atmospheric Research and Exposure Assessment Laboratory
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TECHNOLOGY DEVELOPER CONTACT:
Clayton Wood
HNU Systems, Incorporated
160 Charlemont Street
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617-964-6690

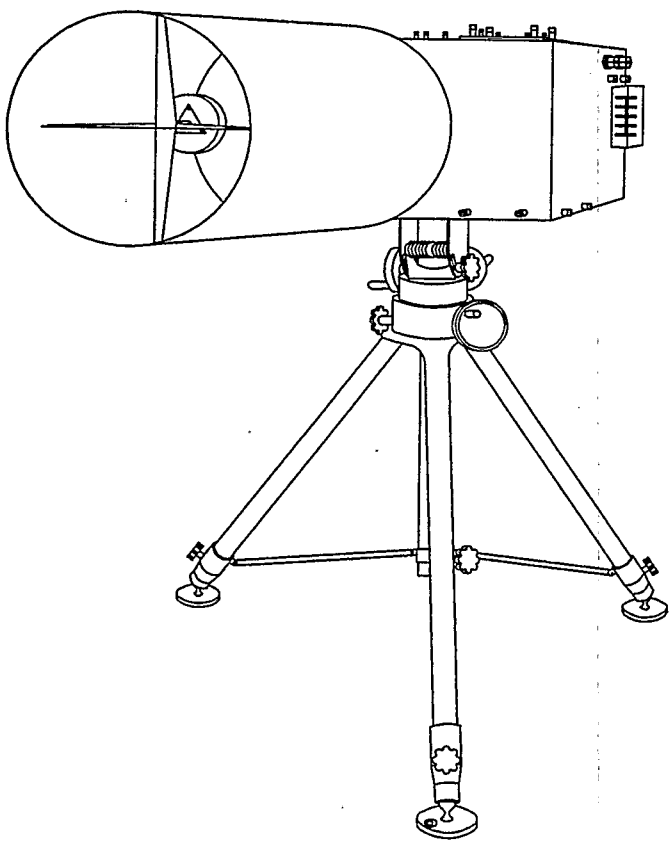
MDA SCIENTIFIC, INCORPORATED
(Infrared Spectrometer)

TECHNOLOGY DESCRIPTION:

This long-path monitoring system (see figure below) is a field-deployable long-path Fourier transform infrared spectrometer that measures the absorption caused 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 facilitating 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



Fourier transform infrared spectrometer

inorganic compounds, especially those that are too volatile to be collected by preconcentration methods. It can be used to monitor emissions 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 for identification and quantification of compounds in the presence of background interference is under development. Current efforts include the establishment of field operating procedures and quality control procedures. A field evaluation of this instrument will be conducted at a Superfund site in January 1992.

FOR FURTHER INFORMATION:

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TECHNOLOGY CONTACT:
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MDA Scientific, Incorporated
3000 Northwoods Parkway
Norcross, GA 30071
404-242-0977

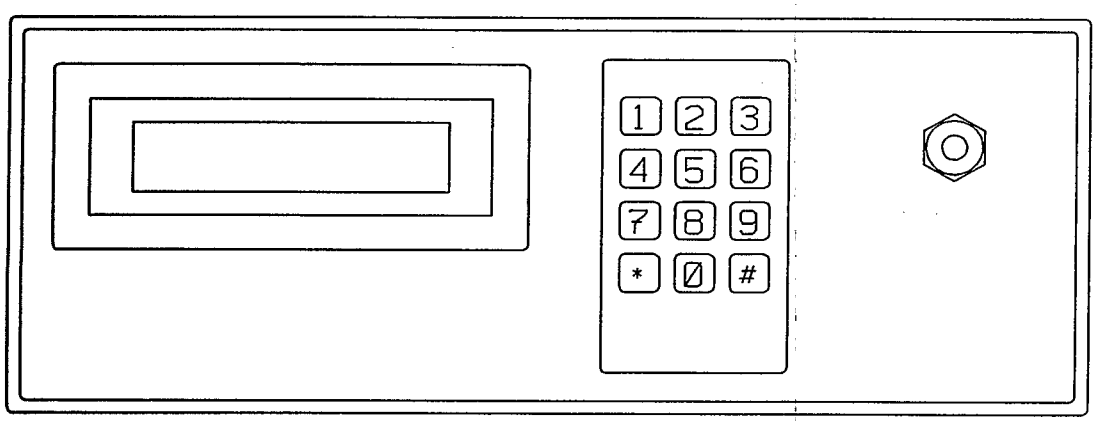
MICROSENSOR SYSTEMS, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The MSI-301A (see figure below) vapor monitor 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 potentially be used to monitor volatile organic compound (VOC) 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 field operation have not yet been evaluated.



MSI-301A Vapor Monitor

STATUS:

Laboratory evaluation of the MSI-301A gas chromatograph will be conducted during the fall of 1991. The sensitivity of the instrument was not adequate for field operation without preconcentration. In January 1992, the instrument will be evaluated in the field at a superfund site using a preconcentrator.

FOR FURTHER INFORMATION:

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TECHNOLOGY CONTACT:
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Microsensor Systems, Incorporated
6800 Versar Center
Springfield, IL 22151
703-642-6919

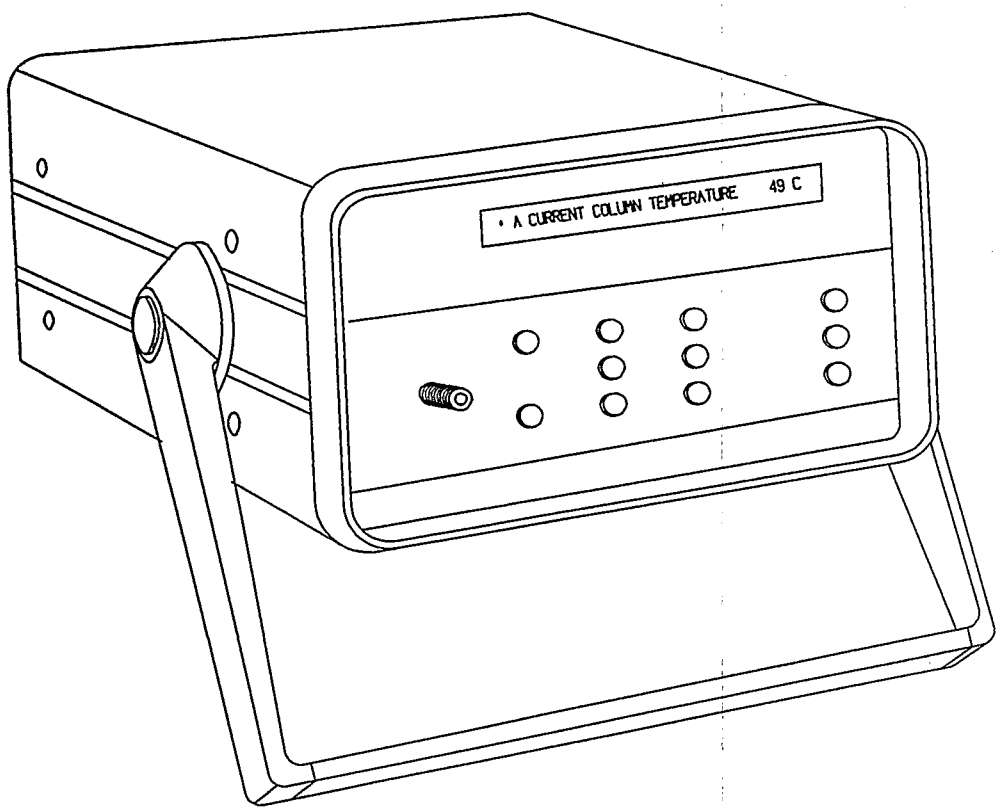
MICROSENSOR TECHNOLOGY, INCORPORATED
(Portable Gas Chromatograph)

TECHNOLOGY DESCRIPTION:

The Microsensor Technology M200 gas analyzer (see figure below) is a dual-channel portable gas chromatograph. The inlet system and thermal conductivity detector are micromachined on a silicon wafer and connected by a short length of microbore column. Samples are drawn through a loop, which is then placed in line with the carrier stream. Concentrations as low as 1 part per million 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 Microsensor Technology M200 can potentially be used to monitor VOC emissions from hazardous waste sites before and during remediation. Analysis of concentrations below 1 part per million (ppm) requires the use of a preconcentrator. Because of the universal sensitivity of its thermal conductivity detector, it is potentially applicable to all kinds of vapor-phase compounds, both organic and inorganic. However, its performance characteristics in field operation have not yet been evaluated.



M200 gas analyzer

STATUS:

Laboratory evaluation of this instrument was conducted during 1990 and 1991. The sensitivity of the instrument was not adequate for field operation without preconcentration. In January 1992, the instrument will be evaluated in the field at a Superfund site using a preconcentrator.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
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TECHNOLOGY CONTACT:
Gary Lee
Microsensor Technology, Incorporated
41762 Christy Street
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PHOTOVAC INTERNATIONAL, INCORPORATED
(Photovac 10S PLUS)

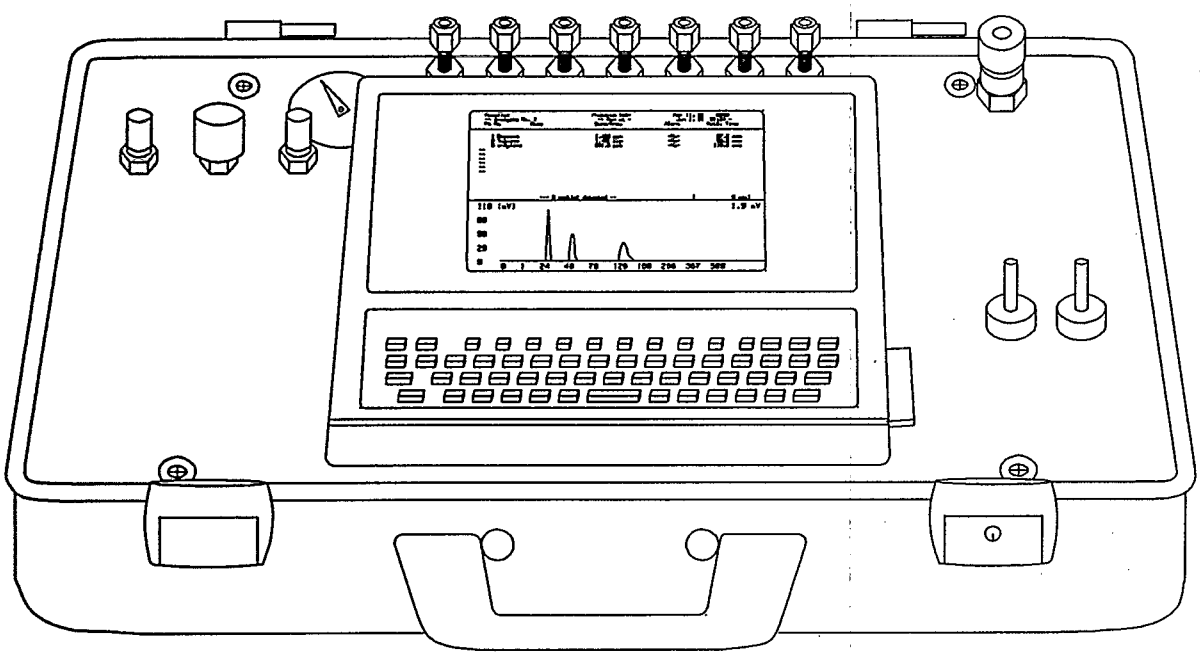
TECHNOLOGY DESCRIPTION:

The Photovac 10S PLUS (see figure below) is a redesigned version of the Photovac 10S70. The Photovac 10S70 is a battery-powered portable gas chromatograph which has already been evaluated. Many of its design problems have been addressed. The 10S PLUS 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° 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 preconcentration, at concentrations well below 1 part per billion.

WASTE APPLICABILITY:

The Photovac 10S PLUS can potentially 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, has been shown to be an effective -- though somewhat



Photovac 10S PLUS

temperamental -- monitor for volatile aromatic and chlorinated olefin compounds at ambient background levels.

STATUS:

Laboratory evaluation of the Photovac 10S PLUS will be conducted during fall 1991. Field evaluation at a Superfund site under remediation is scheduled for January 1992. The evaluations will determine the extent to which problems with the 10S70 have been solved.

FOR FURTHER INFORMATION:

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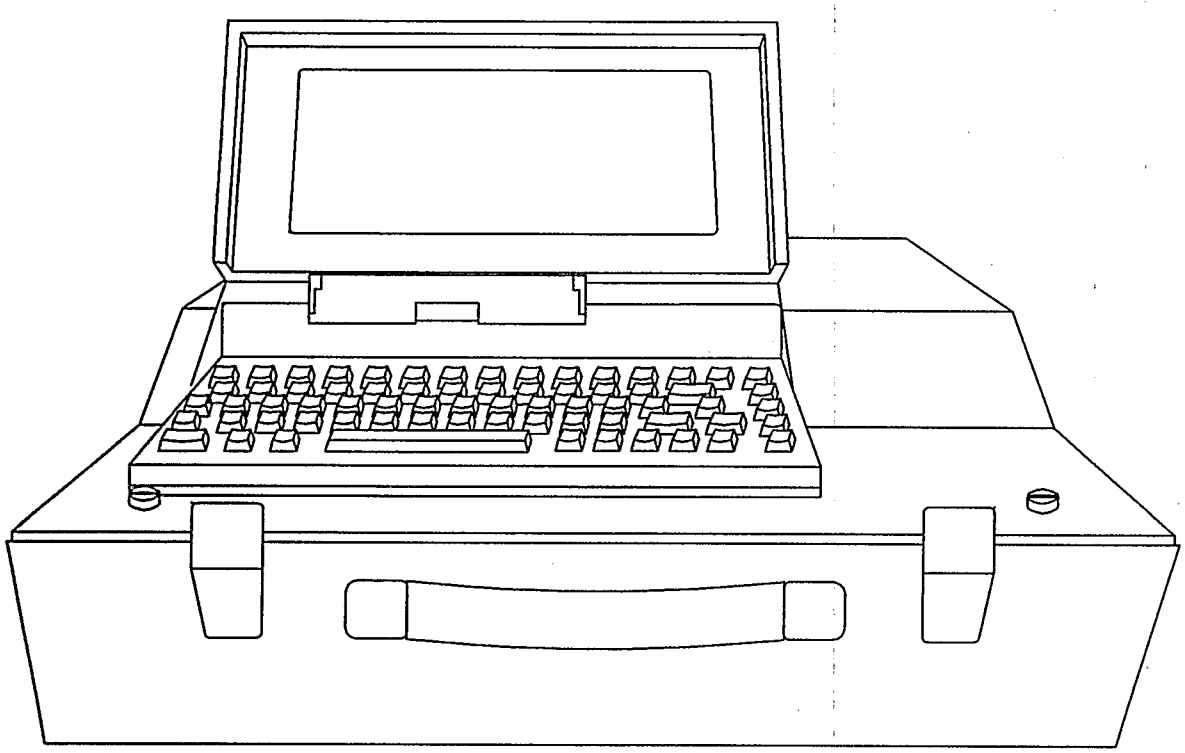
SENTEX SENSING TECHNOLOGY, INCORPORATED
(Portable Gas Chromatograph)

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 one 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 (VOC) emissions from hazardous waste sites and other emission sources before and during remediation. It has been used for several years in water and soil analyses and can be applied to analysis of all kinds of vapor phase pollutants.



Portable gas chromatograph

STATUS:

Laboratory evaluation of the scentograph will be conducted during fall 1991. Field evaluation at a Superfund site under remediation is scheduled for January 1992.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
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TECHNOLOGY CONTACT:
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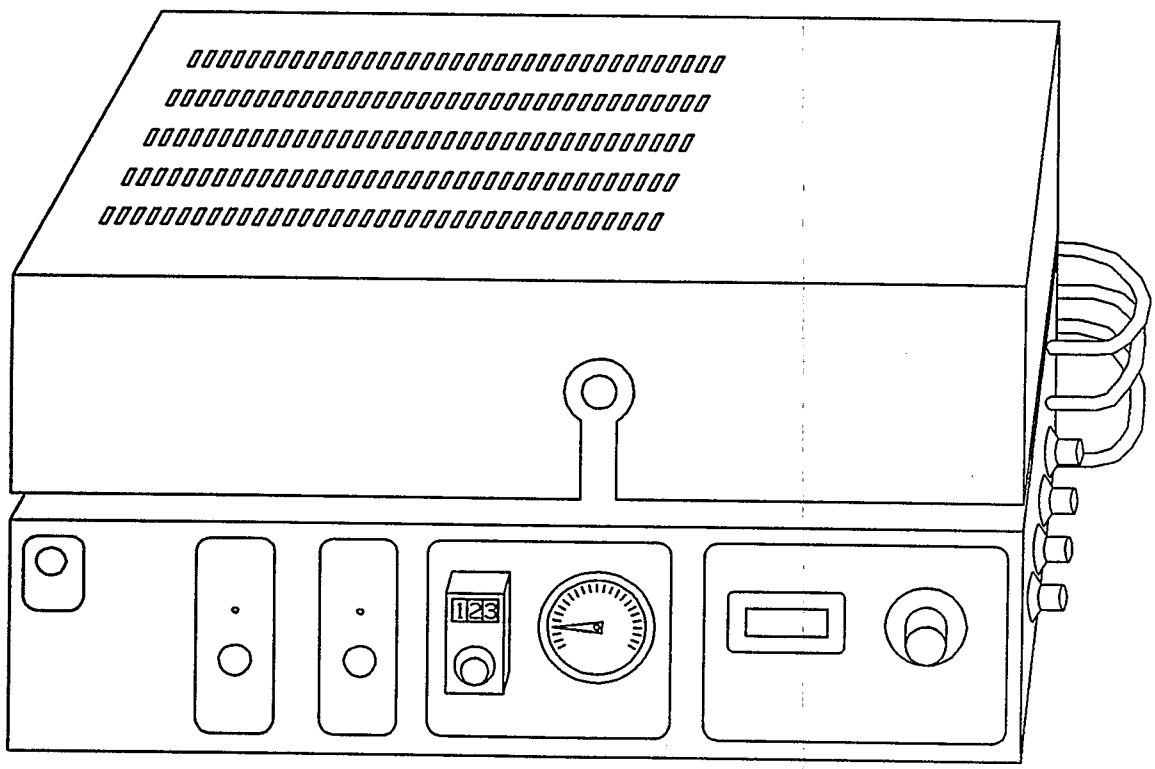
SRI INSTRUMENTS
(Gas Chromatograph)

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. Available detectors include thermal conductivity, flame ionization, nitrogen-phosphorus, thermionic ionization, photoionization, electron capture, Hall, and flame photometric. 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 and during remediation. It can be applied to



8610 gas chromatograph

volatile organic compounds (VOC), but its performance characteristics in field operation have not yet been evaluated.

STATUS:

Laboratory evaluation of the SRI 8610 gas chromatograph will be conducted during fall 1991. Field evaluation at a Superfund site under remediation is scheduled for January 1992.

FOR FURTHER INFORMATION:

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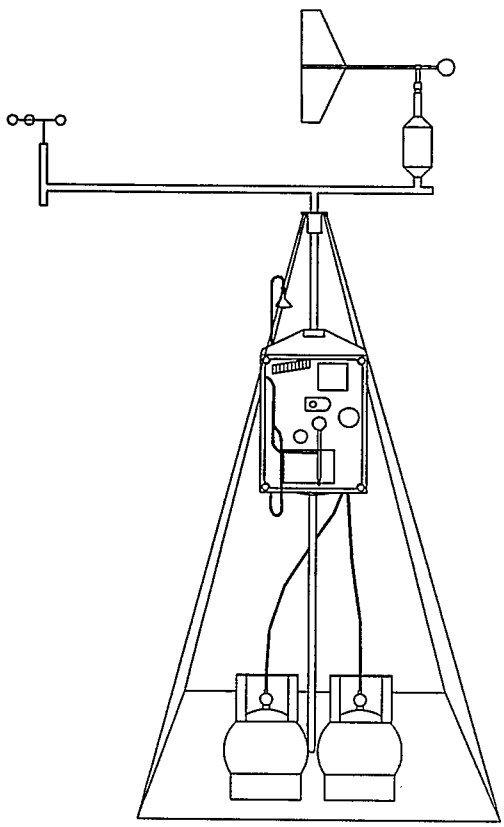
XONTECH INCORPORATED
(XonTech Sector Sampler)

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 which is not part of the "in" territory. When wind velocity exceeds 0.37 meters 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. At other times, neither canister is filled. Over an extended period of time, a target sample and a background sample are produced.

WASTE APPLICABILITY:

The Xontech sector sampler can potentially be used to monitor volatile organic compound (VOC) emissions from hazardous waste sites and



Sector sampler

other emission sources before and during remediation. Short-term sampling can determine which compounds are emitted from a site in high concentrations. Long-term monitoring can be used to assess effects of an emission source on the local population.

STATUS:

This method has been shown to be useful in two short-term field demonstration studies. Mathematical methods for processing data have been developed and shown to be appropriate. Issues remaining to be studied in more detail 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:

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TECHNOLOGY CONTACT:
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XonTech Incorporated
6862 Hayvenhurst Avenue
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ACRONYMS

BTEX	Benzene, Toluene, Ethylbenzene, Xylene
DCA	Dichloroethane
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated Dibenzodioxin
PCDF	Polychlorinated Dibenzofuran
PCP	Pentachlorophenol
SVOC	Semivolatile Organic Compound
TCA	Trichloroethane
TCE	Trichloroethene
VOC	Volatile Organic Compound

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INFORMATION REQUEST FORM

The EPA's Risk Reduction Engineering Laboratory is responsible for testing and evaluating technologies used at Superfund site cleanups. To receive publications about these activities, indicate your area of interest by checking the appropriate box(es) below and mail the top half of this sheet to the following address:

U.S. Environmental Protection Agency
Center for Environmental Research Information
26 West Martin Luther King Drive
Cincinnati, Ohio 45268
Attention: ORD Publications Unit (MS-G72)

(A9) ☐ Superfund
(A8) ☐ Superfund Innovative Technology Evaluation (SITE) Program

Name _____
Firm _____
Address _____
City, State, Zip Code _____

EPA plans to issue two requests for proposals during the coming year; one in January 1992 for the Demonstration Program (SITE 007), and the other in July 1992 for the Emerging Technology Program (E06). 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)

(007) ☐ Demonstration Program RFP
(E06) ☐ Emerging Technology Program RFP

Name _____
Firm _____
Address _____
City, State, Zip Code _____