EPA-542-R-95-001
March 1995

Abstracts of Remediation Case Studies

Federal Remediation Technologies Roundtable

Prepared by the

Member Agencies of the Federal Remediation Technologies Roundtable

Abstracts of Remediation Case Studies

Volume 1

Prepared by Member Agencies of the
Federal Remediation Technologies Roundtable

Environmental Protection Agency
Department of Defense
- U.S. Air Force
- U.S. Army
- U.S. Navy

Department of Energy
Department of Interior
National Aeronautics and Space Administration
Tennessee Valley Authority
Coast Guard

March 1995

NOTICE

This document has been subjected to administrative review by Agencies participating in the Federal Remediation Technologies Roundtable, and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Further information on the Roundtable may be obtained from the Chairman at EPA's Technology Innovation Office at (703) 308-8800.

FOREWORD

This report is a collection of abstracts summarizing 37 case studies of site remediation projects prepared by Federal agencies. The case studies were undertaken to document the results and lessons learned from early technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of cleanup technologies. The case studies were collected under the auspices of the Federal Remediation Technologies Roundtable as part of a larger effort to improve future project documentation and information transfer.

The Roundtable was created to exchange information on site remediation technologies, and to consider cooperative efforts that could lead to a greater application of innovative technologies. Roundtable member agencies, including the U.S. Environmental Protection Agency, U.S. Department of Defense, and U.S. Department of Energy, expect to complete many site remediation projects in the near future. These agencies recognize the importance of documenting the results of these efforts, and the benefits to be realized from greater coordination.

The case study reports themselves are organized by technology in a four-volume set listed below. In the future, the set will grow through periodic supplements tracking additional progress with site remediation.

Remediation Case Studies: Bioremediation (PB95-182911);
Remediation Case Studies: Groundwater Treatment (PB95-182929);
Remediation Case Studies: Soil Vapor Extraction (PB95-182937); and
Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification (PB95-182945).

Four Volume Set: Remediation Case Studies (PB95-182903).

To order, call the National Technical Information Service at (703) 487-4650 or write them at the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161.

Walter W. Kovalick, Jr., Ph.D.
Chairman
Federal Remediation Technologies Roundtable

This page intentionally left blank.

TABLE OF CONTENTS

This page intentionally left blank.

1.0 INTRODUCTION

The purpose of this report is to provide summary information for site remediation projects, and to serve as a reference for identifying case study reports, available under separate cover (see Foreword). The case studies are the first in a series of studies being prepared by Federal agencies to improve future remedy selection at contaminated sites and to allow a comparison of technologies in support of broader analyses, such as the consideration of presumptive remedies.

Case Studies

The case studies were developed by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). The studies present cost and performance information for full-scale remediation efforts and several large-scale demonstration projects and were prepared retrospectively, based on available information and interviews with project personnel. The case studies are meant to serve as primary reference sources, and contain information on the site, contaminants and media treated, technology, technology vendor, a summary of cost and performance data, and points of contact for the technology application. The case studies contain varying levels of detail, reflecting the differences in the availability of data and information on cost and performance. Also, full-scale cleanup efforts are not conducted primarily for the purpose of technology evaluation; therefore, data collection is usually limited to establishing compliance with contractual requirements or regulatory levels.

EPA has documented 17 completed full-scale remediation efforts using innovative technologies. DoD and DOE have prepared 20 case studies of both innovative technologies and conventional groundwater pump-and-treat technologies. Twenty-two projects are completed. For projects that are ongoing, interim findings will be updated in future publications, when the final data are available.

Guide to Documenting Cost and Performance for Remediation Projects

During the preparation of the case studies, a work group of the Federal Remediation Technologies Roundtable met to coordinate documentation of future site remediation efforts. The resulting Guide to Documenting Cost and Performance for Remediation Projects presents recommended procedures for documenting site matrix characteristics and technology operation, performance, and cost. Recommendations include specific parameters to measure and report for 13 conventional and innovative cleanup technologies.

Abstracts Contained in This Report

The abstracts summarize key project information in a consistent format, to allow the reader to easily assess potential interest in specific case studies. If the reader

desires more information, the complete copies of the case studies may be obtained under separate cover. The abstracts are based on recommended terminology and procedures from the Guide to Documenting Cost and Performance for Remediation Projects. Roundtable agencies are investigating strategies for future electronic search and distribution.

The 37 case studies in this series are grouped by technology, and summarized in Tables 1 through 4, listed below:

- **Table 1. Summary of Remediation Case Studies: Bioremediation;**
- **Table 2. Summary of Remediation Case Studies: Groundwater Treatment;**
- **Table 3. Summary of Remediation Case Studies: Soil Vapor Extraction; and**
- **Table 4. Summary of Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification.**

These tables include information on technology used, contaminants and media treated, and project duration. The tables also note highlights of the technology applications.

The *bioremediation* volume contains reports on nine projects that include bioventing and land treatment technologies, as well as a unique, large-scale slurry-phase project. In these projects, petroleum hydrocarbons are the most frequent contaminants of concern. Two land treatment projects in this volume are completed cleanups at creosote sites.

The *groundwater treatment* volume describes 11 groundwater treatment projects, eight of which are still ongoing. Most of the projects address petroleum hydrocarbons and chlorinated aliphatics, such as trichloroethylene (TCE). The eight ongoing projects are using pump-and-treat technologies, while two of the three completed efforts utilized air sparging. One report in this volume describes a project that used in situ steam injection/electrical heating of subsurface soils (referred to as dynamic underground stripping).

The *soil vapor extraction* report describes 10 projects. Various chlorinated aliphatic contaminants were treated at eight of the locations. One report in this volume describes a project that used soil vapor extraction (SVE) followed by bioventing. (Note: this one project, completed at Hill Air Force Base, Site 914, is described in both the SVE and Bioremediation case study volumes.) One of the projects described in the SVE volume used horizontal wells with remote monitoring of equipment.

The last volume primarily describes projects using *thermal desorption*, including six completed applications at sites contaminated with PCBs, pesticides, or chlorinated aliphatics. Two projects in this volume used *soil washing* and *in situ vitrification* technologies, respectively.

Cost Analysis

Table 5 summarizes cost data for 35 of the 37 case studies, including information on quantity of media treated and contaminant removed. In addition, Table 5 shows a calculated unit cost for some projects, and identifies key factors potentially affecting project cost. While a summary of project costs is useful, it is difficult to compare costs for different projects because of site-specific factors and differences in level of detail.

Cost data are shown on Table 5 as reported in the case studies, and have not been adjusted for inflation to a common year basis. The dollar values shown in Table 5 should be assumed to be dollars for the time period that the project was in progress (shown on Tables 1 through 4 as project duration).

The project costs shown in the second column of the table were compiled consistently. However, the case studies themselves vary in terms of the level of detail and format of the available cost data. Where possible, project costs were categorized according to an interagency Work Breakdown Structure (WBS). The WBS specifies costs as 1) before-treatment costs, 2) after-treatment costs, or 3) treatment costs. (Table 5 provides information on which activities fall under each category.) In many cases, however, the available information was not sufficiently detailed to be broken down in this way.

The column for the calculated cost for treatment provides a dollar value per unit of soil or groundwater treated and, if possible, per pound of contaminant removed. Note that comparisons using the information in this column are complicated by the fact that calculated costs may only be available on a per cubic yard or per ton basis, and cannot be converted back-and-forth due to limited availability of soil bulk density data.

Key factors that potentially affect project costs include economies of scale, concentration levels in contaminated media, required cleanup levels, completion schedules, and hydrogeological conditions. It is important to note that several projects in the case study series represent early applications, and that the costs of these technologies are likely to decrease in the future as firms gain experience with design and operation.

On-Line Access

The case study abstracts contained in this report are available on-line through EPA's Cleanup Information Bulletin Board System (CLU-IN). To access CLU-IN by modem, call (301) 589-8366, or to contact the CLU-IN help desk, call (301) 589-8368. CLU-IN is available on the Internet; the telnet address is clu-in.epa.gov or 134.67.99.13.

This page intentionally left blank.

Table 1. Summary of Remediation Case Studies: Bioremediation

Site Name, State (Technology)	Contaminants Treated					Media (Quantity)	Project Duration	Highlights
	BTEX and/or TPH	Chlorinated Aliphatics	Explosives	Polynuclear Aromatic Hydrocarbons	Source of Contamination (Principal Contaminants)			
Brown Wood Preserving Superfund Site, FL (Land Treatment)				●	Lagoon (creosote)	Soil (8,100 yd^3)	12/89 - 7/90	Sum of 6 carcinogenic PAHs reduced from 100-280 mg/kg to 23-92 mg/kg
Eielson Air Force Base, AK (Bioventing)	●				Spills and leaks (JP-4 fuel)	Soil (not available)	Operational since 7/91	Use of various soil warming techniques to demonstrate technology effectiveness in a subarctic environment
French Ltd. Superfund Site, TX (Slurry-Phase Bioremediation)		●		●	Disposal pit, spills and leaks (benzene, vinyl chloride, benzo(a)-pyrene)	Soil and sludge (300,000 tons)	1/92 - 11/93	Large-scale treatment of a lagoon in place; novel air injection system used to minimize air emissions
Hill Air Force Base, Site 280, UT (Bioventing)	●				Spills and releases (JP-4 fuel)	Soil (not available)	Operational since 12/90	Optimized air flow rates to maximize bioremediation while minimizing volatilization
Hill Air Force Base, Site 914, UT (Bioventing Preceded by SVE)	●				Spill (JP-4 fuel)	Soil (5,000 yd^3)	10/88 - 12/90	System converted from SVE to bioventing after one year of operation
Lowry Air Force Base, CO (Bioventing)	●				UST (heating oil)	Soil (not available)	Operational since 8/92	Bioventing used to treat residual petroleum contamination in an excavated area
Lowry Air Force Base, CO (Land Treatment)	●				UST (heating oil)	Soil (not available)	Operational since 7/92	Soil contaminated with high levels of TPH (>11,000 mg/kg) and relatively low levels of BTEX (<100 mg/kg)
Scott Lumber Company Superfund Site, MO (Land Treatment)				●	Lagoon and spills (creosote)	Soil (15,916 tons)	12/89 - 9/91	Sum of 16 PAHs reduced from 560-700 mg/kg to 130-155 mg/kg; over 70% reduction in PAH concentrations
Umatilla Army Depot Activity, OR (Composting)			●		Lagoon (TNT/RDX/HMX)	Soil (224 yd^3)	5/92 - 11/92	Field demonstration project using windrows

Key:

SVE - Soil Vapor Extraction
BTEX - Benzene, Toluene, Ethylbenzene, and Xylene
TPH - Total Petroleum Hydrocarbons

Table 2. Summary of Remediation Case Studies: Groundwater Treatment

Site Name, State (Technology)	Contaminants Treated					Media (Quantity)	Project Duration	Highlights
	BTEX and/or TPH	Chlorinated Aliphatics	Non-chlorinated Aliphatics	Polychlorinated Biphenyls	Source of Contamination (Principal Contaminants)			
Amcor Precast, UT (Density Driven Sparging)	●				UST (diesel and gasoline)	Soil (not available) Groundwater (not available)	3/92 - 9/93	Treatment process combines aerobic biodegradation and in situ air sparging
Amoco Petroleum Pipeline, MI (Extraction followed by GAC)	●		●		Petroleum pipeline (BTEX and MTBE)	Groundwater (775 million gallons in 5 years)	Operational since 10/88	Large-scale voluntary cleanup of groundwater and free product; 118,000 gallons of free product recovered in 6 years; cleanup included air sparging pilot testing
Ft. Drum, Fuel Dispensing Area 1595, NY (Extraction followed by air stripping and GAC)	●				UST (gasoline and No. 2 fuel)	Groundwater (not available)	Operational since 2/92	Free product recovery where precise source of contamination could not be found
Langley Air Force Base, IRP Site 4, VA (Extraction followed by air stripping)	●				UST (JP-4 fuel)	Groundwater (not available)	Operational since 7/92	Vacuum-assisted well point extraction system to remove groundwater and free product
Lawrence Livermore National Laboratory, GSA, CA (Dynamic underground stripping)	●				UST (leaded gasoline)	Soil and groundwater (not available)	11/92 - 12/93	Field demonstration of steam injection, electrical heating, and underground imaging
McClellan Air Force Base, Operable Unit B/C, CA (Extraction followed by air stripping)		●			UST, landfill (TCE)	Groundwater (660 million gallons in 7 years)	Operational since 1988	Large-scale cleanup; 7 extraction wells; waste sources included landfill, UST, disposal pit, burn area
McClellan Air Force Base, Operable Unit D, CA (Extraction followed by air stripping)		●			Disposal pit, open burning (TCE)	Groundwater (not available)	Operational since 1987	Large-scale cleanup; 6 extraction wells; waste sources included disposal and burn pits
Twin Cities Army Ammunition Plant, MN (Extraction followed by air stripping)		●			Discharges to sewer, dumping and burning (TCE)	Groundwater (1.4 billion gallons 10/91 - 9/92)	Operational since 10/87	Large cleanup effort; complex hydrogeology; estimated time for remediation 50 to 70 years
U.S. Department of Energy Kansas City Plant, MO (Extraction followed by advanced oxidation processes)	●	●		●	Manufacturing (TCE)	Groundwater (11.2 million gallons in 1993)	Operational since 1983	Extracted groundwater treated using low and high intensity ultraviolet, ozone, and peroxide; presence of DNAPLs suspected
U.S. Department of Energy Savannah River Site, A/M Area, SC (Extraction followed by air stripping)		●			Surface impoundment (TCE)	Groundwater (198 million gallons per year)	Operational since 9/85	Groundwater contamination covers 1,200 acres at a thickness of 150 feet with presence of DNAPLs confirmed
U.S. Department of Energy Savannah River Site, A/M Area, SC (In situ air stripping)		●			Surface impoundment (TCE)	Groundwater (not available) Soil (not available)	Operational since 7/90	Field demonstration of air sparging using horizontal wells; report discusses experience with installation of horizontal wells

Key:

GAC - Granular Activated Carbon
SVE - Soil Vapor Extraction
BTEX - Benzene, Toluene, Ethylbenzene, and Xylene
TPH - Total Petroleum Hydrocarbons

Table 3. Summary of Remediation Case Studies: Soil Vapor Extraction

Site Name, State (Technology)	Contaminants Treated				Media (Quantity)	Project Duration	Highlights
	BTEX and/or TPH	Chlorinated Aliphatics	Non-chlorinated Aliphatics	Source of Contamination (Principal Contaminants)			
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA (SVE w/product recovery)		●		Storage drums (PCA)	Soil (98,203 yd^3)	Operational since 8/92	Demonstration project - discusses experience with on-site solvent recovery for off-gasses
Fairchild Semiconductor Corporation Superfund Site, CA (SVE)		●	●	UST (TCA, xylenes)	Soil (42,000 yd^3)	1/89 - 4/90	Early application of SVE at a site with complex hydrogeology; included aquifer dewatering and slurry wall installed prior to treatment
Hastings Groundwater Contamination Superfund Site, Well Number 3 Subsite, NE (SVE w/GAC)		●		Spill of grain fumigants (CCl_4)	Soil (185,000 yd^3)	6/92 - 7/93	Relatively large quantity of soil treated using SVE
Hill Air Force Base, Site 914, UT (SVE with catalytic oxidation followed by bioventing)	●			Spill (JP-4 fuel)	Soil (5,000 yd^3)	10/88 - 12/90	SVE used to reduce higher concentrations of hydrocarbons; system converted from SVE to bioventing after one year of operation
Luke Air Force Base, North Fire Training Area, AZ (SVE w/thermal oxidizer)	●		●	Fire training area (petroleum, oil, lubricant wastes)	Soil (not available)	10/90 - 12/92	Estimated 14,200 pounds of contaminants removed and destroyed using thermal oxidation; report discusses experience with operation of thermal oxidizer
McClellan Air Force Base, Operable Unit D, Site S, CA (SVE w/catalytic oxidizer & scrubber)		●		Disposal pit (PCE, TCE, 1,1-DCA, Freon-113)	Soil (not available)	Operational since 1993	Demonstration project of SVE with catalytic oxidation and scrubbing of extracted vapors
Rocky Mountain Arsenal Superfund Site (Motor Pool Area-Operable Unit #18), CA (SVE w/product recovery and GAC)		●		Motor vehicle maintenance (TCE)	Soil (34,000 yd^3)	7/91 - 12/91	Application demonstrated that a pilot-scale system removed sufficient vapor contaminants from the vadose zone, and that expansion of the system beyond a pilot-scale was not necessary
Sacramento Army Depot Superfund Site, Tank 2 (Operable Unit #3), CA (SVE w/GAC)		●	●	UST (PCE, ethyl-benzene, xylenes)	Soil (650 yd^3)	8/92 - 1/93	Small quantity of soil treated using SVE; unexpected recovery of Freon-113 began part way through operation
SMS Instruments Superfund Site, NY (SVE w/catalytic incineration and scrubbing)		●	●	UST (chlorobenzene, 1,2-dichlorobenzene, xylenes)	Soil (1,250 yd^3)	5/92 - 10/93	SVE using horizontal wells and remote monitoring of system performance; relatively small quantity of soil treated
Verona Well Field Superfund Site (Thomas Solvent Raymond Road - Operable Unit #1), MI (SVE w/catalytic oxidation and GAC)		●	●	UST (PCE, TCA, acetone, toluene)	Soil (26,700 yd^3)	3/88 - 5/92	First Superfund application of SVE; catalytic oxidation replaced activated carbon due to higher than expected recoveries

Key:

GAC - Granular Activated Carbon
SVE - Soil Vapor Extraction
BTEX - Benzene, toluene, Ethylbenzene, and Xylene
TPH - Total Petroleum Hydrocarbons

Table 4. Summary of Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification

Site Name, State (Technology)	Contaminants Treated							Media (Quantity)	Project Duration	Highlights
	BTEX and/or TPH	Chlorinated Aliphatics	Pesticides	Polynuclear Aromatic	Polychlorinated	Metals	Source of Contamination (Principal Contaminants)			
Anderson Development Company Superfund Site, MI (Thermal desorption)		●		●			**Manufacturing process (MBOCA, phenol, phthalates)**	**Soil (5,100 tons)**	**1/92 - 6/93**	**Treatment using a thermal auger system with hollow-screw conveyors**
King of Prussia Technical Corporation Superfund Site, NJ (Soil washing)						●	**Surface impoundment (Cr, Cu, Ni)**	**Soil and sludge (19,200 tons)**	**6/93 - 10/93**	**Innovative on-site monitoring technique, including use of X-ray fluorescence; early full-scale soil washing application at a Superfund site**
McKin Superfund Site, ME (Thermal desorption)	●	●		●			**Disposal Pit (TCE)**	**Soil (11,500 yd^3)**	**7/86 - 4/87**	**Early full-scale application of thermal desorption**
Outboard Marine Corporation Superfund Site, OH (Thermal desorption)					●		**Surface water & sewer discharges**	**Soil and sediment (12,755 tons)**	**1/92 - 6/92**	**Achieved PCB mass removal efficiency of 99.98%--much higher than the 97% requirement**
Parsons Chemical/ETM Enterprises Superfund Site, MI (In situ vitrification)			●	●		●	**Surface water & sewer discharges (DDT, mercury, dioxins)**	**Soil (3,000 yd^3)**	**5/93 - 5/94**	**First application at a Superfund site; melt requires one year to cool, and final results expected after May 1995**
Pristine, Inc. Superfund Site (Thermal desorption)		●	●	●			**Spills and on-site disposal (aldrin, DDT, dieldrin, dioxin)**	**Soil (12,800 tons)**	**11/93 - 3/94**	**Contaminated soils exhibited a wide range of pH and moisture conditions, and contained greater than 2% elemental sulfur**
T H Agriculture & Nutrition Company Superfund Site, GA (Thermal desorption)			●				**Spills and leaks (DDT, toxaphene, BHC)**	**Soil (4,300 tons)**	**7/93 - 10/93**	**Soils contaminated with a mixture of organochlorine pesticides; interlock process control system monitored 9 process parameters**
Wide Beach Development Superfund Site, NY (Thermal desorption w/dehalogenation)					●		**Road oiling (PCB 1254)**	**Soil (42,000 tons)**	**10/90 - 9/91**	**Thermal desorption combined with APEG dechlorination**

Key:

BTEX - Benzene, Toluene, Ethylbenzene, and Xylene
TPH - Total Petroleum Hydrocarbons

Table 5. Remediation Case Studies - Summary of Cost Data

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Bioremediation					
Brown Wood Preserving Superfund Site, FL (Land Treatment)	T - 565,406 B - 58,000 A - 9,800	8,100 cubic yards of soil	--	$70/cubic yard of soil treated	Treatment using 3 lifts; system constructed using a clay liner and underdrain system; cleanup completed 6 months ahead of schedule
Eielson Air Force Base, AK (Bioventing)	C - 758,077 (includes design and engr.) O - 177,160	Not available	--	Ongoing field demonstration	Includes costs for floating fuel collection and groundwater monitoring not associated with bioventing
French Ltd. Superfund Site, TX (Slurry-Phase Bioremediation)	T - 26,900,000 B - 16,500,000 A - 5,600,000	300,000 tons of soil and sludge	--	$90/ton of soil and sludge treated	Excavation not required for treatment; relatively large quantity treated resulted in economies of scale
Hill Air Force Base, Site 280, UT (Bioventing)	C - 115,000 O - 24,000	Not available	--	Ongoing full-scale cleanup	One injection well, relatively small project
Hill Air Force Base, Site 914, UT (Bioventing)	T - 599,000	5,000 cubic yards of soil	--	$120/cubic yard of soil treated	Four injection wells, relatively high concentrations of contaminants
Lowry Air Force Base, CO (Bioventing)	C - 28,650 (includes design and engr.) O - 32,875	Not available	--	Ongoing full-scale cleanup	Relatively shallow bioventing system
Lowry Air Force Base, CO (Land Treatment)	C - 104,257 (includes design and engr.) O - 18,460 (estimated operating costs)	Not available	--	$19/ton estimated cost; assumes 3.5 years to complete treatment	Treatment using one lift; non-RCRA liner

Project Cost*
T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance
B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis
A = Costs for after-treatment activities, including disposal of residuals and site restoration
C = Capital costs
O = Annual operating costs

Calculated Cost for Treatment**
**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Bioremediation (Continued)					
Scott Lumber Company Superfund Site, MO (Land Treatment)	T - 1,292,000 (1989-1991) 254,000 for laboratory analyses	15,961 tons of soil	--	$81/ton of soil treated	Treatment using 2 lifts; system constructed using a clay liner and underdrain system
Umatilla Army Depot Activity, OR (Composting)	T - 1,840,000 B - 2,000,000 (projected for full-scale operation)	Projected costs based on treatment of 20,000 tons of soil	--	$92/ton projected based on 5 years treatment, and compliance with RCRA Waste Pile Facility Standards	Costs estimated based on results of 40-day demonstration
Groundwater Treatment					
Amcor Precast, UT (Density-Driven Sparging)	C - 156,950 O - 62,750	Not available	Not available	--	Cleanup completed in approximately 18 months
Amoco Petroleum Pipeline, MI (Extraction followed by GAC)	C - 297,000 (for groundwater recovery and treatment system) (includes design and engr.) C - 375,000 (for air sparging system) O - 475,000	775 million gallons of groundwater in 5 years	118,000 gallons free product recovered	Ongoing full-scale cleanup; O&M to date approximately $0.003 per 1,000 gallons of groundwater treated	--
Ft. Drum, Fuel Dispensing Area 1595, NY (Extraction followed by air stripping and GAC)	C - 958,780 (includes design and engr.) O - 129,440 (estimated)	Not available	Not available	Ongoing full-scale cleanup	--

Project Cost*

T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance

B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis

A = Costs for after-treatment activities, including disposal of residuals and site restoration

C = Capital costs

O = Annual operating costs

Calculated Cost for Treatment**

**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Groundwater Treatment (Continued)					
Langley Air Force Base, IRP Site 4, VA (Extraction followed by air stripping)	C - 569,739 O - 216,561 (1993) O - 143,047 (1994)	Not available	Not available	Ongoing full-scale cleanup	16 extraction wells; low hydraulic conductivity
Lawrence Livermore National Laboratory, CA (Dynamic underground stripping)	T - 5,400,000 (includes design and engr.) B - 1,700,000	Not available	7,600 gallons of gasoline	Field demonstration project	Complex hydrogeology and wide range of hydraulic conductivity; demonstration completed in approximately one year
McClellan Air Force Base, Operable Unit B/C, CA (Extraction followed by air stripping)	C - 4,000,000 O - 1,240,000	660 million gallons of groundwater in 7 years	Approximately 44,000 pounds VOCs removed in 7 years	Ongoing full-scale cleanup; $80 in operating costs per lb of VOC removed (first year of operation data only)	10 extraction wells
McClellan Air Force Base, Operable Unit D, CA (Extraction followed by air stripping)	C - 4,000,000 O - 1,240,000	660 million gallons of groundwater in 7 years	Approximately 44,000 pounds VOCs removed in 7 years	Ongoing full-scale cleanup; $80 in operating costs per lb of VOC removed (first year of operation data only)	10 extraction wells (includes 4 extraction wells in OU C)
Twin Cities Army Ammunition Plant, MN (Extraction followed by air stripping)	C - 8,034,454 (includes design and engr.) O - 588,599	Not available	Not available	Ongoing full-scale cleanup; O&M to date calculated as $0.12 per 1,000 gallons treated	Complex hydrogeology and wide range of hydraulic conductivity at site

Project Cost*

T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance

B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis

A = Costs for after-treatment activities, including disposal of residuals and site restoration

C = Capital costs

O = Annual operating costs

Calculated Cost for Treatment**

**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
U.S. Department of Energy Kansas City Plant, MO (Extraction followed by advanced oxidation processes)	C - 1,383,400 O - 355,200 (actual costs for FY 1987 to 1994)	11.2 million gallons groundwater treated (1993)	Not available	Ongoing full-scale cleanup; AOP operating costs for second generation system projected as $13.80/1,000 gallons	Presence of DNAPLs suspected; use of AOP more expensive than air stripping
Groundwater Treatment (Continued)					
U.S. Department of Energy Savannah River Site, SC (Extraction followed by air stripping)	C - 4,103,000 O - 149,200 (1985 to 1990)	198 million gallons of groundwater per year	273,300 pounds VOC removed (1985-1993)	Ongoing full-scale cleanup; O&M to date approximately $0.75 per 1,000 gallons treated	Complex hydrogeology; recent discovery of DNAPLs prompted a reevaluation of pump and treat
U.S. Department of Energy Savannah River Site, A/M Area, SC (In situ air stripping)	Projected costs - equipment 253,525 (includes system design and engr.); site work - 5,000; labor - 62,620; and consumables - 157,761	Not available	16,000 pounds VOCs removed in demonstration	Field demonstration; projected costs of $15.60/lb of VOC removed	This demonstration project quantified cost advantage of air sparging over pump and treat; installation costs for horizontal wells greater than for vertical wells
Soil Vapor Extraction (SVE)					
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA (SVE w/product recovery)	C - 5,313,973 O - 100,000	98,203 cubic yards of soil	Not available	Ongoing full-scale cleanup	22 extraction wells and on-site solvent recovery systems used in demonstration phase; no information available on components of total capital cost or annual operating costs

Project Cost*

T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance

B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis

A = Costs for after-treatment activities, including disposal of residuals and site restoration

C = Capital costs

O = Annual operating costs

Calculated Cost for Treatment**

**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Fairchild Semiconductor Corporation Superfund Site, CA (SVE)	**C - 2,100,000 Total Operating Costs - 1,800,000 (16 months)**	**42,000 cubic yards of soil**	**16,000 pounds contaminants removed (16 months)**	**$93/cubic yard of soil treated $240/pound of contaminant removed**	**39 extraction wells; complex hydrogeology; cleanup completed in 16 months**
Hastings Groundwater Contamination Superfund Site, Well Number 3 Subsite, NE (SVE w/GAC)	**T - 370,000**	**185,000 cubic yards of soil**	**600 pounds carbon tetrachloride removed**	**$2/cubic yard of soil treated $620/pound of carbon tetrachloride removed**	**10 extraction wells; large-scale project benefits from economies-of-scale; low levels of contaminants**
Soil Vapor Extraction (SVE) (Continued)					
Hill Air Force Base, Site 914, UT (SVE)	**T - 599,000**	**5,000 cubic yards of soil**	**211,000 pounds TPH removed**	**$120/cubic yard of soil treated $2.80/pound of TPH removed**	**Two years of system operation; costs include both SVE and bioventing**
Luke Air Force Base, North Fire Training Area, AZ (SVE w/thermal oxidizer)	**C - 297,017 (includes design and engr.) O - 210,168**	**Not available**	**12,000 pounds contaminants removed**	**$42/lb of contaminant removed**	**2 extraction wells and permeable soil; cleanup completed in 14 months**
McClellan Air Force Base, Operable Unit D, Site S, CA (SVE w/catalytic oxidizer and scrubber)	**3,800,000 (budget for 1993-1994) (includes design and engr.)**	**Not available**	**113,000 pounds VOC removed (15 weeks operation)**	**Ongoing field demonstration**	**17 extraction wells and 3 zones of contamination; total cost includes site characterization**

Project Cost*
T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance
B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis
A = Costs for after-treatment activities, including disposal of residuals and site restoration
C = Capital costs
O = Annual operating costs

Calculated Cost for Treatment**
**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Rocky Mountain Arsenal Superfund Site (Motor Pool Area - Operable Unit #18), CO (SVE w/product recovery and GAC)	T - 74,600 B - 88,490 A - 19,650	34,000 cubic yards of soil	70 pounds contaminants removed	$2.20/cubic yard of soil treated $1,100/pound of contaminant removed	2 extraction wells; large volume of soil treated contained relatively low levels of contaminants; pilot-scale, costs do not include disposal of carbon
Sacramento Army Depot Superfund Site, Tank 2 (Operable Unit #3), CA (SVE w/GAC)	T - 290,000 (cost estimate adjusted to account for Freon; assumed operation costs equivalent for Freon and non-Freon contaminants)	650 cubic yards of soil	500 pounds VOC removed (non-Freon)	$450/cubic yard of soil treated $580/lb of non-Freon contaminant removed	8 extraction wells; small project limited economies-of-scale; unexpected presence of Freon-113 significantly increased carbon usage; complex hydrogeology; low permeability
SMS Instruments Superfund Site, NY (SVE w/catalytic incineration and scrubbing)	T - 450,521	1,250 cubic yards of soil	Not available	$360/cubic yard of soil treated	2 extraction wells; small project limited economies-of-scale; cleanup completed in 17 months
Soil Vapor Extraction (SVE) (Continued)					
Verona Well Field Superfund Site, (Thomas Solvent Raymond Road - Operable Unit #1), IL (SVE w/catalytic oxidation and GAC)	T - 1,600,000 B - 480,000 A - 5,000	26,700 cubic yards of soil	45,000 pounds VOCs removed	$60/cubic yard of soil treated $36/pound of VOC removed	23 extraction wells; extensive sampling and analysis required; cleanup completed in 4 years
Thermal Desorption, In Situ Vitrification, and Soil Washing					

Project Cost*

T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance
B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis
A = Costs for after-treatment activities, including disposal of residuals and site restoration
C = Capital costs
O = Annual operating costs

Calculated Cost for Treatment**

**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Anderson Development Company Superfund Site, MI (Thermal desorption)	Not available	5,100 tons of soil	--	Projected costs range from $230 to $340/ton of soil treated (SITE program cost estimates based on demonstration project)	Projected costs affected by soil moisture content
King of Prussia Technical Corporation Superfund Site, NJ (Soil washing)	7,700,000	19,200 tons of soil and sludge	--	Not Calculated	No information available on components of total cost
McKin Superfund Site, ME (Thermal desorption)	2,900,000	11,500 cubic yards of soil	--	Not Calculated	Limited information available on components of total cost
Outboard Marine Corporation Superfund Site, OH (Thermal desorption)	T - 2,474,000 B - 900,000	12,755 tons of soil and sediment	--	$190/ton of soil and sediment treated	--
Parsons Chemical/ETM Enterprises Superfund Site, MI (In situ vitrification)	T - 800,000 B - 800,000 A - 90,000	3,000 cubic yards of soil	--	$270/cubic yard of soil treated	Application involved excavation and staging of wastes

Project Cost*
T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance
B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis
A = Costs for after-treatment activities, including disposal of residuals and site restoration
C = Capital costs
O = Annual operating costs

Calculated Cost for Treatment**
**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

Table 5. Remediation Case Studies - Summary of Cost Data (Continued)

Site Name, State (Technology)	Project Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Project Costs
Thermal Desorption, In Situ Vitrification, and Soil Washing (Continued)					
Pristine, Inc. Superfund Site, OH (Thermal desorption)	**Not available**	**12,800 tons of soil**	--	--	--
T H Agriculture & Nutrition Company Superfund Site, GA (Thermal desorption)	**T - 849,996 B - 252,582**	**4,300 tons of soil (2,500 cubic yards)**	--	**$200/ton of soil treated $340/cubic yard of soil treated**	**Small project limited economies-of-scale; cleanup completed in 4 months**
Wide Beach Development Superfund Site, NY (Thermal desorption/dehalogenation)	**T - 11,600,000 B - 908,000 A - 3,400,000**	**42,000 tons of soil**	--	**$280/ton of soil treated**	**Lack of structural integrity of treated soil led to need for off-site disposal**

Project Cost*

T = Costs for treatment activities, including preprocessing, capital equipment, operation, and maintenance
B = Costs for before-treatment activities, including site preparation, excavation, and sampling and analysis
A = Costs for after-treatment activities, including disposal of residuals and site restoration
C = Capital costs
O = Annual operating costs

Calculated Cost for Treatment**

**Calculated based on costs for treatment activities (T): excludes costs for before- (B) and after- (A)treatment activities. Calculated costs shown as "Not Calculated" if an estimate of treatment costs unavailable.

This page intentionally left blank.

2.0 REMEDIATION CASE STUDIES: BIOREMEDIATION

Land Treatment at the Brown Wood Preserving Superfund Site Live Oak, Florida

<table>
<tr><td>Site Name:
Brown Wood Preserving Superfund Site</td><td rowspan="2">Contaminants:
Polynuclear Aromatic Hydrocarbons (PAHs)
- Primary constituents in creosote
- Total PAH concentrations in stockpiled soil ranged from 100 to 208 mg/kg</td><td>Period of Operation:
January 1989 to July 1990</td></tr>
<tr><td>Location:
Live Oak, Florida</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
John Ryan
Remediation Technologies, Inc. (ReTeC)
1011 Southwest Klickitat Way, Suite 207
Seattle, WA 98134
(206) 624-9349</td><td rowspan="2">Technology:
Land Treatment
- Construction of the land treatment area (LTA) included installation of a clay liner, berm, run-on swales, and a subsurface drainage system
- Retention pond for run-off control; portable irrigation system
- Treatment performed using three lifts of soil; first lift inoculated with PAH - degrading microorganisms
- Lifts cultivated once every two weeks; soil moisture content maintained at 10%</td><td>Cleanup Authority:
CERCLA
- ROD Date: 4/8/88
- PRP Lead</td></tr>
<tr><td>SIC Code:
2491B (Wood Preserving using Creosote)</td><td>Point of Contact:
Martha Berry
Remedial Project Manager
U.S. EPA Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-3016</td></tr>
<tr><td>Waste Source:
Manufacturing Process; Lagoon</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 8,100 cubic yards of soil treated in three lifts
- Mixture of lagoon contents; lagoon had a clay bottom and sandy contents, which ranged from silty clay to fine sand</td></tr>
<tr><td>Purpose/Significance of Application:
This was one of the early applications of land treatment of creosote-contaminated soil at a Superfund site.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- ROD specified cleanup goals for PAHs in terms of Total Carcinogenic Indicator Chemicals (TCICs)
- TCICs defined as the sum of the concentrations of six constituents: benzo(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; chrysene; dibenzo(a,h)anthracene; and indeno(1,2,3-cd)pyrene
- ROD required reduction of TCIC concentration to 100 mg/kg within two years of initial seeding</td></tr>
<tr><td colspan="3">Results:
- The cleanup goal was achieved within 18 months
- TCIC concentrations at 18 months ranged from 23 to 92 mg/kg</td></tr>
</table>

Land Treatment at the Brown Wood Preserving Superfund Site Live Oak, Florida (Continued)

Cost Factors:

- **Total costs for treatment activities at this site were approximately $565,400 (including solids preparation and handling; mobilization/setup; and short-term (up to 3 years) and long-term (over 3 years) operation costs)**
- **Over half of total costs (about $312,000) were for short-term operation**
- **Before treatment costs were approximately $58,000 (including mobilization and preparatory work, site work, and solids collection and containment)**
- **After treatment costs were approximately $9,800 for demobilization**

Description:

From 1948 to 1978, the Brown Wood Preserving site was used to pressure treat lumber products with creosote. While pentachlorophenol was occasionally used, creosote was the primary wood preservative. Lumber was pressure treated in two cylinders and wastewaters from these cylinders were discharged to a lagoon. The lagoon and soils at the site were determined to be contaminated with high levels of organics (primarily polynuclear aromatic hydrocarbons (PAHs) found in creosote) and the site was placed on the NPL in December 1982. In April 1988, following the completion of several interim removal activities, a Record of Decision (ROD) was signed specifying land treatment for contaminated soils stockpiled during the interim removal activities.

Land treatment of the PAH-contaminated soils was performed from January 1989 to July 1990. Approximately 8,100 cubic yards of stockpiled soil were treated in three lifts. The cleanup goal specified in the ROD was 100 mg/kg for Total Carcinogenic Indicator Chemicals (TCICs - the sum of the concentrations of six PAHs selected by EPA based on the results of a risk assessment) to be achieved within two years of operation. The cleanup goal was achieved within 18 months using land treatment, 6 months ahead of the 2-year timeframe specified in the ROD. The concentrations of TCICs measured during verification sampling (July 1990) ranged from 23 to 92 mg/kg. The LTA was revegetated in October 1991 and approximately 90% of the former LTA was covered with native grasses by March 1992.

The total treatment cost for this application at the Brown Wood site was approximately $565,400. The treatment costs included solids preparation and handling, mobilization and setup, and operation costs. In addition, there were before-treatment costs (mobilization and preparatory work, site work, and solids collection and containment) of approximately $58,000 and after-treatment costs (demobilization) of approximately $9,800. This application is notable for being one of the early applications of land treatment of creosote-contaminated soil at a Superfund site.

Refueling Loop E-7, Source Area ST20
Bioventing Treatment at
Eielson Air Force Base
Alaska

<table>
<tr><td>Site Name:
Eielson Air Force Base Source Area ST20</td><td rowspan="2">Contaminants:
Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
- Soil TPH levels averaged 1,500 mg/kg
- Contamination is concentrated in areas greater than 5.25 feet below ground surface</td><td>Period of Operation:
Status - Ongoing
Report covers - 7/91 to 7/94</td></tr>
<tr><td>Location:
Fairbanks, Alaska</td><td>Cleanup Type:
Field Demonstration</td></tr>
<tr><td>Vendor:
Ronald M. Smith
Battelle-Pacific Northwest Labs
Richland, WA</td><td rowspan="2">Technology:
Bioventing
- Bioventing conducted in conjunction with several soil warming techniques
- Four experimental plots tested: passive warming, active warming, surface warming, and control</td><td>Cleanup Authority:
CERCLA and State: Alaska
- Federal Facilities Agreement
- ROD Date: 9/92</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Capt. Timothy Merrymon
354 CES/CEVR
2258 Central Ave., Suite 1
Eielson AFB, Alaska 99702</td></tr>
<tr><td>Waste Source:
Spills and Leaks of JP-4 Jet Fuel</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Thickness of contamination in saturated zone - 6.1 meters
- Soil consists of interbedded layers of loose to medium dense gravel and sands with varying amounts of silt to 6-9 feet
- Underlain by 600 feet of medium dense to dense sandy gravel
- No permafrost encountered at site</td></tr>
<tr><td>Purpose/Significance of Application:
Bioventing with various soil warming techniques to demonstrate technology effectiveness in a subarctic environment.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- TPH - 200 mg/kg in soil
- Benzene - 2 lbs/day in extracted soil gas
- Remedial activities to be conducted in accordance with a Federal Facilities Agreement between U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation</td></tr>
<tr><td colspan="3">Results:
- Bioventing project not complete at time of this report
- Preliminary results indicate that bioventing with soil warming stimulates in situ biodegradation year round in a subarctic environment
- Active warming achieved higher biodegradation rates than passive or surface warming
- Ambient air samples showed no detectable concentrations of benzene 4 feet and 6 feet above ground level</td></tr>
</table>

Refueling Loop E-7, Source Area ST20
Bioventing Treatment at
Eielson Air Force Base
Alaska (Continued)

Cost Factors:
- **Estimated Capital Costs - $758,077 (including floating fuel collection devices, soil bioventing equipment, composting site development, mobilization, groundwater remediation and engineering design)**
- **Estimated Annual Operations and Maintenance (O&M) Costs - $177,160 (O&M of three components - floating fuel (5 year duration), soil bioventing (10 year duration), groundwater monitoring (30 year duration), including sample analysis and monitoring of each component)**

Description:

As a result of spills and leaks of JP-4 jet fuel at a refueling complex at Eielson Air Force Base (AFB) in Fairbanks, Alaska, soil was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). In November 1989, Eielson AFB was added to the National Priorities List (NPL) with the fuel-saturated area within the Refueling Loop E-7, Source Area ST20 designated as CERCLA Operable Unit 1. A field demonstration of bioventing and three soil warming techniques began in July 1991 including active warming, passive warming, and surface warming. Specific cleanup goals include TPH (200 mg/kg in soil), and benzene (2 lbs/day in extracted soil gas).

The field demonstration of the bioventing system was on-going as of July 1994. Available respiration test data for oxygen consumption rates confirmed the occurrence of biological degradation processes. Preliminary results indicate that bioventing with soil warming achieves biodegradation year round in a subarctic environment. Active warming was found to achieve a higher biodegradation rate than passive or surface warming. It was noted that biodegradation is enhanced by adequate soil oxygen, moisture, and nutrient levels; that injection wells are impractical at source areas with a naturally high concentration of iron in the groundwater; and that high soil moisture content interferes with soil gas monitoring and reduces the number of soil gas monitoring points that can be sampled.

The estimated capital cost of this application was approximately $758,000 and the estimated annual operations and maintenance costs are $177,160. Full-scale remedial activities at the site will be conducted in accordance with a Federal Facilities Agreement between the U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation.

Slurry-Phase Bioremediation at the French Limited Superfund Site Crosby, Texas

<table>
<tr><td>Site Name:
French Limited Superfund Site</td><td rowspan="2">Contaminants:
Polynuclear Aromatic Hydrocarbons (PAHs) and Chlorinated Aliphatics;
- Primary constituents included benzene, vinyl chloride, and benzo(a)pyrene
- Site contaminants included volatile organics (up to 400 mg/kg); pentachlorophenol (up to 750 mg/kg); semivolatiles (up to 5,000 mg/kg); metals (up to 5,000 mg/kg); PCBs (up to 616 mg/kg) and arsenic</td><td>Period of Operation:
January 1992 to November 1993</td></tr>
<tr><td>Location:
Crosby, Texas</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendors:
Jonathan Greene
ENSR
3000 Richmond Avenue
Houston, TX 77098
(713) 520-9900
Gary Storms
Praxair, Inc.
39 Old Ridgebury Road
Danbury, CT 06810
(203) 837-2174</td><td rowspan="2">Technology:
Slurry-Phase Bioremediation
- Two treatment cells designed to hold 17 million gallons each
- Mixflo™ aeration system used to maintain dissolved oxygen concentration at 2.0 mg/L
- Tarry sludge dredged and treated separately from subsoil in lagoon</td><td>Cleanup Authority:
CERCLA
- ROD Date: 3/24/88
- PRP Lead</td></tr>
<tr><td>SIC Code:
4953E (Waste management-refuse systems; sand and gravel pit disposal)</td><td>Point of Contact:
Judith Black
Remedial Project Manager
U.S. EPA Region 6
1445 Ross Avenue
Dallas, TX 75202
(214) 665-6739</td></tr>
<tr><td>Waste Source:
Disposal pit</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil and Sludge
- Approximately 300,000 tons
- Soils varied from fine grained silts to coarse sand
- Sludges - tar-like consisting of a mixture of petrochemical sludges, kiln dust, and tars (styrene and oils)</td></tr>
<tr><td>Purpose/Significance of Application:
A large full-scale application of slurry-phase bioremediation of a lagoon at a Superfund site. An innovative system was used to minimize air emissions during the remediation.</td></tr>
</table>

Slurry-Phase Bioremediation at the French Limited Superfund Site Crosby, Texas (Continued)

Regulatory Requirements/Cleanup Goals:

- **The ROD specified maximum allowable concentrations in the lagoon subsoils and sludges for 5 contaminants: benzo(a)pyrene (9 mg/kg), total PCBs (23 mg/kg), vinyl chloride (43 mg/kg), arsenic (7 mg/kg), and benzene (14 mg/kg)**
- **The ROD specified an action level for total VOCs of 11 ppm for 5 minutes at the site boundary at any time during treatment**

Results:

- **The specified cleanup criteria were met within 10 months treatment for Cell E and 11 months treatment for Cell F**
- **There were no exceedances of the established criteria for VOC air emissions**

Cost Factors:

- **Total costs were approximately $49,000,000 (including project management, pilot studies, technology development, EPA oversight, and backfill of the lagoon)**
- **$26,900,000 of total costs were for activities directly attributed to treatment (including solids, liquid, and vapor/gas preparation and handling, pads/foundations/spill control, mobilization/setup, startup/testing/permits, training, and operation)**
- **$16,500,000 were for before-treatment activities (including mobilization and preparatory work, monitoring sampling, testing, and analysis, site work, surface water, groundwater, and air pollution/gas collection and control, solids and liquids/sediments/sludges collection and containment, and drums/tanks/structures/miscellaneous demolition and removal)**
- **$5,600,000 were for after-treatment activities (including decontamination and decommissioning, commercial and non-commercial disposal, site restoration, non-treatment unit demobilization, topsoil, and revegetation)**

Description:

The French Ltd. Superfund site in Crosby, Texas, is a former industrial waste disposal facility where an estimated 70 million gallons of petrochemical wastes were disposed in an unlined lagoon at the site between 1966 and 1971. The primary contaminants at the site included benzo(a)pyrene, vinyl chloride, and benzene, as well as arsenic and PCBs.

In 1983, the Potentially Responsible Parties (PRPs) formed the French Limited Task Group (FLTG) to lead the remediation at the site. The ROD, signed in March 1988, specified bioremediation of the lagoon. In addition, the ROD specified soil cleanup goals for five target contaminants (benzo(a)pyrene, total PCBs, vinyl chloride, arsenic, and benzene). Slurry-phase bioremediation of the lagoon was performed from January 1992 through November 1993. An innovative system (the MixFlo system) was used for aeration in this application that minimized air emissions while supplying oxygen to the biomass. This system used pure oxygen and a series of eductors to oxygenate the mixed liquor while minimizing air emissions. During this time, approximately 300,000 tons of contaminated sludge and soil in the lagoon were treated to levels below those specified in the ROD. In addition, air emission limits specified in the ROD were not exceeded during treatment. Total costs for the system were approximately $49,000,000, including approximately $26,000,000 for activities directly attributed to treatment.

This application is notable as being the first application of slurry-phase bioremediation at a Superfund site, and included approximately $12,000,000 in technology development and pilot-scale testing work. According to FLTG, the costs for future applications of slurry-phase bioremediation depend on site-specific chemical and physical conditions with oxygen and nutrient supply being key factors affecting the cost of bioremediation systems.

Low-Intensity Bioventing for Remediation of a JP-4 Fuel Spill at Site 280 Hill Air Force Base Ogden, Utah

Site Name:
Hill Air Force Base, Site 280

Location:
Ogden, Utah

Contaminants:
Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
- **Soil TPH concentrations measured as high as 5,040 mg/kg**
- **Soil gas TPH concentrations measured as high as 11,200 ppm**

Period of Operation:
Status - Ongoing
Report covers - 12/90 to 6/94

Cleanup Type:
Full-scale cleanup (interim results)

Vendor:
Not Available

Technology:
Bioventing
- **System consists of 1 injection well and 10 monitoring wells**
- **Air flow rate on blower discharge ranged from 20 to 117 acfm; operated since 11/93 at 20 acfm**
- **Blower discharge pressure of 2 in. of Hg**

Cleanup Authority:
State: Utah

SIC Code:
9711 (National Security)

Point of Contact:
William James
Remedial Project Manager
Hill Air Force Base
Ogden, Utah

Waste Source:
Spills and other releases of JP-4 jet fuel

Purpose/Significance of Application:
Bioventing to remediate soils contaminated with JP-4 jet fuel.

Type/Quantity of Media Treated:
Soil
- **Soil-gas permeability value - 0.057 darcy**
- **Porosity 30 to 50%; moisture content 1.4 to 18%; air conductivity 4.7 to 7.8 darcies; particle density 0.3 to 0.5 gm/cm^3 and particle diameter 0.8 to 10 mm; soil bulk density 0.37 to 0.48 gm/cm^3; soil organic content 0.08 to 0.86%**

Regulatory Requirements/Cleanup Goals:
- **No specific cleanup goals established at this time**
- **Cleanup assessment will be conducted subject to "Guidelines for Estimating Numeric Cleanup Levels for Petroleum Contaminated Soils at Underground Storage Tank Release Sites," which are established by Utah Department of Health**

Results:
- **Bioventing project was not complete at time of this report**
- **Respiration rate tests from 4/91 to 11/93 indicate hydrocarbon degradation is occurring**
- **As of 11/92, soil gas TPH concentration reduced to less than or equal to 2,600 ppm**
- **Estimates of the mass of contaminants removed have not yet been reported**

Cost Factors:
- **Total Capital Cost (estimated) - $115,000 (including construction of piping system, buildings, process equipment, and startup)**
- **Total Annual Operating Cost (estimated over 4 years) - $24,000 (including labor, electricity, lab charges, maintenance, and monitoring)**

Low-Intensity Bioventing for Remediation of a JP-4 Fuel Spill at Site 280 Hill Air Force Base Ogden, Utah (Continued)

Description:
As a result of spills and other releases of JP-4 jet fuel at the 280 Fuel Storage Lot at Hill Air Force Base in Ogden, Utah, soil was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). TPH concentrations were reported as high as 5,000 mg/kg in the soil and 11,200 ppm in the soil gas. A low-intensity bioventing system was installed at the site and has been in operation since December 1990. No specific cleanup goals have been established at this time. The final cleanup assessment will be conducted subject to "Guidelines for Estimating Numeric Cleanup Levels for Petroleum Contaminated Soils at Underground Storage Tank Release Sites", which are established by the Utah Department of Health.

The bioventing system includes one injection well (100 ft. depth) and 10 monitoring wells (varying depths). During the operation of this system, the air flow rate of the blower discharge had been varied between 20 and 117 acfm (at a discharge pressure of 2 in. of Hg) in order to optimize air flow rates while eliminating volatilization. Available data from respiration rate tests (4/91 to 11/93) indicate that hydrocarbon degradation is occurring. As of November, 1992, soil gas TPH concentrations had been reduced from 11,200 mg/kg to below 2,600 mg/kg. Estimates of the mass of contaminants removed have not yet been reported.

The estimated total capital cost for this application is $115,000. The total annual operating cost, estimated over 4 years, is $24,000 exclusive of final site characterization. During this application, it was noted that biodegradation is enhanced by maintaining adequate soil oxygen, moisture, and nutrient levels and that estimates of biodegradation are more accurate if oxygen depletion is used instead of carbon dioxide formation. In addition, it was noted that air flow rates can be optimized to low levels ranging from 40 to 67 acfm.

Soil Vapor Extraction and Bioventing for Remediation of a JP-4 Fuel Spill at Site 914, Hill Air Force Base, Ogden, Utah

<table>
<tr><td>Site Name:
Hill Air Force Base, Site 914</td><td rowspan="2">Contaminants:
Total Petroleum Hydrocarbons (TPH)
- TPH concentrations in untreated soil ranged from <20 to 10,200 mg/kg with average soil TPH concentration of 411 mg/kg</td><td>Period of Operation:
October 1988 - December 1990</td></tr>
<tr><td>Location:
Ogden, Utah</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="4">Technology: Bioventing Preceded by SVE
<u>Bioventing</u>
- 4 vent wells (Numbers 12-15) located on the southern perimeter of the spill area; 31 monitoring wells; 3 neutron access probes (for soil moisture monitoring)
- Vent wells approximately 50 feet deep with 4-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- Monitoring wells - ranged in depth from 6 to 55 feet with 1-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- No treatment of extracted vapors required (hydrocarbon concentrations <50 mg/L; use of catalytic incinerator not required)
- Air flow - 250 acfm
- Soil moisture - 6 to 12%
- Nutrients added - C:N:P ratio of 100:10:10
<u>SVE</u>
- 7 vent wells (Numbers 5-11 located in areas of highest contamination), 31 monitoring wells, 3 neutron access probes (soil moisture monitoring)
- Vent wells approximately 50 feet deep with 4-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- Plastic liner installed over part of spill area surface to prevent local air infiltration and bypassing of air flow to the vent well directly from the surface
- Monitoring wells - range in depth from 6 to 55 feet with 1-inch diameter PVC casing and a 2-foot screened interval to the bottom of the well
- Catalytic incinerator for extracted vapor
- Air flow - 1,500 acfm (maximum), 700 acfm (typical)</td><td>Cleanup Authority:
State: Utah</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td rowspan="3">Point of Contact:
Robert Elliot
OO-ACC/EMR
7274 Wardleigh Road
Hill AFB, Utah 84055</td></tr>
<tr><td>Waste Source:
Spill of JP-4 Jet Fuel</td></tr>
<tr><td>Purpose/Significance of Application:
One of the early applications involving sequential use of SVE and bioventing technology.</td></tr>
</table>

Soil Vapor Extraction and Bioventing for Remediation of a JP-4 Fuel Spill at Site 914, Hill Air Force Base, Ogden, Utah (Continued)

Type/Quantity of Media Treated:
Soil
- **5,000 yds^3 contaminated by spill (surface area of 13,500 ft^2)**
- **Approximate extent of 10,000 mg/kg JP-4 contour covered area 100 by 150 feet**
- **Formation consists of mixed sands and gravels with occasional clay lenses**
- **Air permeability ranged from 4.7 to 7.8 darcies**

Regulatory Requirements/Cleanup Goals:
- **38.1 mg/kg TPH**
- **Cleanup conducted under Utah Department of Health's "Guidelines for Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites"**

Results:
- **Achieved specified TPH levels**
- **Average TPH soil concentrations in treated soil reduced to less than 6 mg/kg;**
- **211,000 lbs of TPH removed in approximately 2 years of operation;**
- **Removal rate ranged from 20 to 400 lbs/day**

Cost Factors:
- **Total costs of $599,000, including capital and 2 years of operating costs**
- **Capital costs - $335,000 (including construction of piping and wells, other equipment, and startup costs)**
- **Annual operating costs - $132,000 (including electricity, fuel, labor, laboratory charges, and lease of equipment for 2 year operation)**

Description:
In January 1985, an estimated 27,000 gallons of JP-4 jet fuel were spilled at the Hill Air Force Base Site 914 when an automatic overflow device failed. Concentrations of total petroleum hydrocarbons (TPH) in the soil ranged from <20 mg/kg to over 10,000 mg/kg, with an average concentration of about 400 mg/kg. The spill area covered approximately 13,500 ft^2.

The remediation of this spill area was conducted from October 1988 to December 1990 in two phases: the soil vapor extraction (SVE) phase followed by the bioventing phase. The SVE system included 7 vent wells (Numbers 5-11) located in the areas of highest contamination, 31 monitoring wells, and a catalytic incinerator. The typical air flow rate through the vent wells was 700 acfm, with a maximum of 1,500 acfm. In addition, a plastic liner was installed over part of the spill area surface to prevent local air infiltration and bypassing of air flow to the vent well directly from the surface. Within a year, the SVE system removed hydrocarbons from the soil to levels ranging from 33 to 101 mg/kg. Further reduction of the hydrocarbon concentration in the soil, to levels below the specified TPH limit, was achieved by using bioventing for 15 months. The bioventing system included 4 vent wells (Numbers 12-15), located on the southern perimeter of the spill area, and the monitoring wells used for SVE system. Because hydrocarbon concentrations were <50 mg/L in the extracted vapors, the catalytic incinerator was not required for this phase. Biodegradation was enhanced by injecting oxygen, moisture, and nutrients to the soil. Average TPH concentrations in the treated soil were less than 6 mg/kg.

The total capital cost for this application was $335,000 and the total annual operating costs were $132,000. In monitoring biodegradation rates, oxygen depletion was found to be a more accurate estimator of biodegradation rate than carbon dioxide formation. Carbon dioxide sinks, such as biomass, solubility in water, and reaction with the soil, limited the usefulness of carbon dioxide formation as a process control parameter.

Underground Storage Tanks (USTs)
Bioventing Treatment at
Lowry Air Force Base (AFB)
Denver, Colorado

<table>
<tr><td>Site Name:
Lowry Air Force Base</td><td rowspan="2">Contaminants:
Total Petroleum Hydrocarbons (TPH)
- Total Recoverable Petroleum Hydrocarbons (TRPH) concentrations of 15 to 14,000 mg/kg were measured in soil samples below the area excavated for landfarming
- BTEX concentrations in soil samples were lower than cleanup criteria</td><td>Period of Operation:
Status - Ongoing
Report covers - 8/92 to 4/94</td></tr>
<tr><td>Location:
Denver, Colorado</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290</td><td rowspan="2">Technology:
Bioventing
- 6 piping manifolds (each consisting of two 10 ft, 2 in diameter screens)
- Placed in excavation at right angles (in a horizontal plane), surrounded with 1 to 2 ft layer of pea gravel
- Aerated to maintain an oxygen concentration greater than 14%
- Carbon dioxide concentration maintained at less than 4%</td><td>Cleanup Authority:
State: Colorado</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Lt. Tom Williams
3415 CES/DEV
Lowry AFB, CO 80230</td></tr>
<tr><td>Waste Source:
Underground Storage Tank</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- No estimates have been made of the quantity of soil treated or hydrocarbon product degraded at the time of this report
- Moist, firm sandy clay in top 10-15 ft
- Medium to coarse-grained sand in next 15-80 ft</td></tr>
<tr><td>Purpose/Significance of Application:
Bioventing to remediate soils contaminated with heating oil which contained relatively high concentrations of TPH and relatively low concentrations of soluble contaminants (e.g., benzene).</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Treated soil - TPH < 500 mg/kg; TRPH < 500 mg/kg; and BTEX < 100 mg/kg
- Cleanup conducted under EPA and State of Colorado Underground Storage Tank Regulations and the Colorado Department of Health's Remedial Action Category III (RAC III) action levels</td></tr>
<tr><td colspan="3">Results:
- Bioventing project was not complete at time of this report
- No TRPH, BTEX, or TPH data are available at this time
- Bioventing system maintained adequate O_2 levels in the contaminated soil and removed CO_2 from the soil</td></tr>
</table>

Underground Storage Tanks (USTs)
Bioventing Treatment at
Lowry Air Force Base (AFB)
Denver, Colorado (Continued)

Cost Factors:
- **Final cost data were not available**
- **Total Capital Cost - $28,650 (including equipment, site work, engineering, project management)**
- **Annual Operating Costs - $32,875 per year (including electricity, maintenance, laboratory charges)**

Description:

As a result of a leak of heating oil from an underground storage tank (UST) at Lowry Air Force Base in Denver, Colorado, soil was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). Following excavation of contaminated soil to a depth of 35 to 40 feet below ground level, soil sampling from the bottom of the excavation indicated that TRPH concentrations of 15 mg/kg to 14,000 mg/kg remained in the soils. A bioventing system, consisting of six bioventing piping manifolds, was installed at the bottom of the excavation and began operating in August 1992. The soil was aerated to maintain an oxygen concentration greater than 14% and a CO_2 concentration less than 4%.

The bioventing of the contaminated soil at this site was ongoing as of April 1994. The target cleanup levels for the soil were TPH to less than 500 mg/kg; Total Recoverable Petroleum Hydrocarbons (TRPH) to less than 500 mg/kg; and BTEX to less than 100 mg/kg. The cleanup is being conducted under the authority of the Colorado Department of Health Underground Storage Tank Program. While no TPH, TRPH, or BTEX data were available at the time of this report, the bioventing system was found to have maintained adequate O_2 and CO_2 levels in the soil.

The total capital cost for this application is $28,650 and the estimated annual operating costs are $32,875. It was noted during this application that key operating parameters for bioventing are soil moisture, oxygen content, and carbon dioxide content; and that more frequent and better reported respiration test results would provide a more complete picture of the progress of the bioventing process, and indicate when final soil samples should be collected.

Underground Storage Tanks (USTs)
Land Treatment at
Lowry Air Force Base (AFB)
Denver, Colorado

<table>
<tr><td>Site Name:
Lowry Air Force Base</td><td rowspan="2">Contaminants:
Benzene, toluene, ethylbenzene, and xylenes (BTEX) and Total Petroleum Hydrocarbons (TPH)
- Contaminated soil - BTEX < 100 mg/kg; Total Recoverable Petroleum Hydrocarbons (TRPH) up to 11,000 mg/kg; 3,100 mg/kg average
- Stockpiled soil - average TRPH of 3,983 mg/kg</td><td>Period of Operation:
Status - Ongoing
Report covers - 7/92 to 9/93</td></tr>
<tr><td>Location:
Denver, Colorado</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290</td><td rowspan="2">Technology:
Land Treatment
- Soil spread on plastic sheeting to thickness of 14 to 18 inches
- One-time addition of ammonium nitrate nutrients (C:N:P ratios of 200:10:1)
- Soil aerated twice a month (April-November)
- Soil moisture content 10%-15%</td><td>Cleanup Authority:
State: Colorado</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Lt. Tom Williams
3415 CES/DEV
Lowry AFB, CO 80230</td></tr>
<tr><td>Waste Source:
Underground Storage Tank</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Soil type firm sandy clay and medium to coarse-grained sand
- Soil moisture content ranged from 6% to 11%
- 5,400 yd^3 treated plus three additional truckloads of contaminated soil</td></tr>
<tr><td>Purpose/Significance of Application:
Land treatment to remediate soils contaminated with heating oil which contained relatively high concentrations of TPH and relatively low concentrations of soluble contaminants (e.g., benzene).</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Treated soil - TPH < 500 mg/kg; TRPH < 500 mg/kg; and BTEX < 100 mg/kg
- Cleanup conducted under EPA and State of Colorado Underground Storage Tank Regulations and the Colorado Department of Health's Remedial Action Category III (RAC III) action levels</td></tr>
<tr><td colspan="3">Results:
- Land treatment project was not complete at time of this report
- No TRPH, BTEX, or TPH data are available at this time
- Total Extractable Petroleum Hydrocarbon levels as of September 1993 ranged from 1,300-1,700 mg/kg</td></tr>
</table>

Underground Storage Tanks (USTs)
Land Treatment at
Lowry Air Force Base (AFB)
Denver, Colorado (Continued)

Cost Factors:
- **Total Capital Cost - $104,257 (including site work, permitting, construction/mobilization/demobilization, pilot testing, project management); pilot testing was $76,000 of the total capital costs**
- **Estimated Annual Operating Costs - $18,460 per year (including laboratory charges, maintenance, monitoring)**

Description:

As a result of a leak of heating oil from an underground storage tank (UST) at Lowry Air Force Base in Denver, Colorado, soil at the site was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). An estimated 10,500 gallons of fuel oil were released. The USTs in the area were removed and the contaminated soil was excavated. Land treatment was selected for the excavated soil; treatment of about 5,400 cubic yards began in July 1992 and is ongoing at the time of this report. For this land treatment application, nutrients (ammonium nitrate) were added in a one-time application, the soil is tilled twice a month, and soil moisture content is kept between 10 to 15% by weight. The target cleanup levels for the soil are TPH to less than 500 mg/kg; Total Recoverable Petroleum Hydrocarbons (TRPH) to less than 500 mg/kg, and BTEX to less than 100 mg/kg. The cleanup is being conducted under the authority of the Colorado Department of Health Underground Storage Tank Program.

The estimated completion time for the land treatment operation was two years. However, as of September 1993, the treatment had not been completed. While no TPH, TRPH, or BTEX data were available at the time of this report, levels of Total Extractable Petroleum Hydrocarbons (TEPH) sampled as of September 1993 showed levels in the range of 1,300 to 1,700 mg/kg. These data and the results of a pilot test, which showed a general decrease in TEPH over time, appear to indicate that land treatment will be effective, though no projections for a completion date are available at this time.

The total capital cost for this project is $104,257 including $76,000 for pilot testing, and the estimated annual operating costs are $18,640. Available information to date indicates that the credibility of the land treatment soil assessment would have been improved if an adequate, random sampling program had been used for sample collection. In addition, laboratory analysis should have been consistent throughout the pilot test or an explanation of inconsistencies provided.

Land Treatment at the Scott Lumber Company Superfund Site Alton, Missouri

Site Name:
Scott Lumber Company Superfund Site

Location:
Alton, Missouri

Contaminants:
Polynuclear Aromatic Hydrocarbons (PAHs)
- **PAH concentrations were measured as high as 0.326 mg/kg in lagoon water, 12,400 mg/kg in sludge, and 63,000 mg/kg in soils**
- **Benzo(a)pyrene ranged from 16 to 23 mg/kg at initiation of treatment**

Period of Operation:
December 1989 to September 1991

Cleanup Type:
Full-scale cleanup

Vendor:
Christina Consentini
Remediation Technologies, Inc. (ReTeC)
1001 S. 24th Street, W., Suite 105
Billings, MT 59102
(406) 652-7481

SIC Code:
2491B (Wood Preserving - using Creosote)

Technology:
Land Treatment
- **Construction of land treatment area included a clay liner and berms, run-on swales, and subsurface drainage system**
- **Retention pond and irrigation system**
- **Treatment performed using two lifts of soil**
- **Indigenous microorganisms used to support biodegradation**
- **Nutrients added to Lift No. 1; none added to Lift No. 2**
- **Cultivated once every two weeks**

Cleanup Authority:
CERCLA (removal action)
- **Action memorandum date: 7/10/87**
- **Fund Lead**

Point of Contact:
Bruce A. Morrison
Remedial Project Manager
U.S. EPA - Region 7
Emergency Planning and Response Branch
25 Funston Road
Kansas City, KS 66115
(913) 551-7755

Waste Source:
Surface Impoundment/Lagoon; Spill

Purpose/Significance of Application:
This was one of the early applications of land treatment at a Superfund site contaminated with creosote compounds.

Type/Quantity of Media Treated:
Soil
- **15,961 tons of soil treated in two lifts**
- **Classified as sand per USDA system**
- **Approximately 4% of soil passes a No. 200 sieve**

Regulatory Requirements/Cleanup Goals:
- **Action levels in soil were established for total PAHs at 500 mg/kg and for benzo(a)pyrene at 14 mg/kg**
- **Total PAHs was defined as the sum of 16 specific PAH constituents**

Results:
- **Land treatment achieved specified action levels for PAHs and benzo(a)pyrene**
- **Lift No. 1 - Total PAHs reduced from 560 to 130 mg/kg, and BAP from 16 to 8 mg/kg, in 6 months of treatment**
- **Lift No. 2 - Total PAHs reduced from 700 to 155 mg/kg and BAP from 23 to 10 mg/kg, in 3 months of treatment**

Cost Factors:
- **Total Costs for Removal Action - approximately $4,047,000 (including $1,292,000 for the land treatment contractor (over 3 years), $254,000 for laboratory analyses, EPA contractors and EPA oversight)**

Land Treatment at the Scott Lumber Company Superfund Site Alton, Missouri (Continued)

Description:
From 1973 to 1985, the Scott Lumber Company, located near Alton, Missouri, operated a wood treating facility used to preserve railroad ties with a creosote/diesel fuel mixture. As a result of these operations, soil at the site was found to have been contaminated with polynuclear aromatic hydrocarbons (PAHs) at concentrations as high as 63,000 mg/kg. An Action Memorandum was signed in July 1987, which specified the construction and operation of a land treatment unit (LTU) as a removal action for treatment of PAH-contaminated soils at the site. Cleanup activities were performed in three phases. The first two phases involved decontamination and removal of surface debris and sludge at the site and excavation and stockpiling of contaminated soil at the site. Phase III involved on-site land treatment of the contaminated stockpiled soil.

Land treatment was performed from December 1989 through September 1991, and 15,961 tons of soil were treated during this application. Stockpiled soil was placed in the LTU in two lifts. Approximately 200 lbs per acre of ammonium phosphate fertilizer were added to the first lift to adjust the nutrients in the soil. No nutrient adjustments were made to the second lift. Each lift was cultivated once or twice a week and irrigated, as necessary, to maintain a moisture content between 1% and 4%.

Action levels for the soil at the site, established by EPA, were 14 mg/kg for benzo(a)pyrene (BAP) and 500 mg/kg for total PAHs. Land treatment at the Scott Lumber site reduced levels of BAP and total PAHs to below action levels. In Lift 1, BAP concentrations were reduced from 16 mg/kg to 8 mg/kg and total PAH concentrations were reduced from 560 mg/kg to 130 mg/kg within 6 months. In Lift 2, concentrations were reduced from 23 mg/kg to 10 mg/kg for BAP and from 700 mg/kg to 155 mg/kg for total PAHs within 3 months. The total costs for this removal action were $4,047,000, including $1,292,000 for the land treatment contractor and $254,000 for laboratory analyses. Site demobilization was completed in September 1991.

Windrow Composting of Explosives Contaminated Soil at Umatilla Army Depot Activity Hermiston, Oregon

<table>
<tr><td>Site Name:
Umatilla Army Depot Activity (UMDA), Explosives Washout Lagoons, CERCLA Soils Operable Unit</td><td rowspan="2">Contaminants:
Explosives
- Primary soil contaminants include 2,4,6-trinitrotoluene (TNT); hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)
- Contaminant levels >100 ppm limited to soils in the first 2 to 4 feet below the surface of the lagoons</td><td>Period of Operation:
May 1992 to November 1992</td></tr>
<tr><td>Location:
Hermiston, Oregon</td><td>Cleanup Type:
Field Demonstration</td></tr>
<tr><td>Vendor:
Roy F. Weston, Inc.</td><td rowspan="2">Technology:
Composting
- Excavated soil screened and mixed with soil amendments
- Nonaerated and aerated windrows composted for 40 days
- Treated soil mixed with top soil and revegetated, redeposited in excavated area, or landfilled
- Windrows contained contaminated soil (30%), cow manure (21%), alfalfa (18%), sawdust (18%), potatoes (10%), and hen manure (3%)
- Mixed 3 to 7 times per week, temperature 15 to 60°C, oxygen up to 21%, moisture 30 to 40%, pH 5 to 9</td><td>Cleanup Authority:
CERCLA</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Remedial Project Manager
Umatilla Army Depot Activity
Hermiston, OR</td></tr>
<tr><td>Waste Source:
Surface Impoundment/Lagoon</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 244 cubic yards (8 windrows, 28 cubic yards each)
- Predominantly Quincy fine sand and Quincy loamy fine sand</td></tr>
<tr><td>Purpose/Significance of Application:
Field demonstration of windrow composting to biodegrade explosives-contaminated soils.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Concentrations of explosives in soil to be below 30 ppm; target compounds were TNT and RDX
- Top 5 feet of soil below the lagoons to be excavated, treated, and returned to the excavated area</td></tr>
<tr><td colspan="3">Results:
- Windrow composting performance after 40-day treatment generally reduced the levels of target explosives to below the cleanup goals
- TNT reduced from 1,600 to 4 ppm (aerated and nonaerated)
- RDX reduced from 1,000 to 7 ppm (aerated) and 2 ppm (nonaerated)
- HMX reduced from 200 to 47 ppm (aerated) and 5 ppm (nonaerated)</td></tr>
</table>

Windrow Composting of Explosives Contaminated Soil at Umatilla Army Depot Activity Hermiston, Oregon (Continued)

Cost Factors:
- **No costs were available for the field demonstration**

Projected cost for full-scale windrow composting:
- **Capital cost for treatment activities - $1,840,000 (including equipment, buildings, structures, mechanical/piping, and electrical)**
- **Five-year operating cost - $2,000,000 (including power, amendments, fuel, labor, and maintenance)**
- **Full-scale costs assume 20,000 tons of soil, 5-year project duration, nonaerated windrows, mixed daily, 30% soil loading, 30-day treatment periods, and compliance with RCRA Waste Pile Facility Standards**

Description:

From approximately 1955 to 1965, the Umatilla Army Depot Activity (UMDA) operated a munitions washout facility in Hermiston, Oregon, where hot water and steam were used to remove explosives from munitions bodies. About 85 million gallons of heavily-contaminated wash water were discharged to two settling lagoons at the site. The underlying soils and groundwater were determined to be contaminated with explosive compounds, primarily TNT, RDX, and HMX, and the site was placed on the NPL in 1987.

Windrow composting was used in a field demonstration at UMDA from May to November 1992 to treat 244 cubic yards of contaminated soil. Nonaerated and aerated windrows were treated for 40 days, using several soil amendments, and tested for residual contamination. TNT was reduced from 1600 to 4 ppm (aerated and nonaerated), RDX reduced from 1000 to 7 ppm (nonaerated) and 2 ppm (aerated), and HMX reduced from 200 to 47 ppm (aerated) and 5 ppm (nonaerated) in the 40 day treatment period. With the exception of HMX (aerated), these levels were below the targeted soil cleanup levels of 30 ppm.

Costs were not available for the field demonstration. The costs for a full-scale application of windrow composting at Umatilla were estimated assuming treatment of 20,000 tons of soil, 5-year project duration, nonaerated windrows, mixed daily, 30% soil loading, 30-day treatment periods, and RCRA Waste Pile facility standards. The capital cost for the full-scale application was estimated as $2,118,000, and the annual operating cost as $527,000.

This page intentionally left blank.

3.0 REMEDIATION CASE STUDIES: GROUNDWATER TREATMENT

Density-Driven Groundwater Sparging at Amcor Precast Ogden, Utah

<table>
<tr><td>Site Name:
Amcor Precast</td><td rowspan="2">Contaminants:
Benzene, Toluene, Ethylbenzene, Total Xylenes (BTEX), Naphthalene, and Total Petroleum Hydrocarbons (TPH)
<u>Groundwater</u>
- Average groundwater concentrations (mg/L) in plume area/site maximum - TPH (51/190), benzene (1.3/4.7), toluene (2.4/9.4), ethylbenzene (0.78/2.7), total xylenes (2.5/8.0), naphthalene (0.18/0.63)
<u>Soil</u>
- Average soil concentrations (mg/kg) in plume area/site maximum - TPH (555/1,600), benzene (2.0/7.8), toluene (1.4/2.5), ethylbenzene (5.7/19), total xylenes (37/110)</td><td>Period of Operation:
March 1992 to September 1993</td></tr>
<tr><td>Location:
Ogden, Utah</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Todd Schrauf
Wasatch Env., Inc.
2251B West California Ave.
Salt Lake City, UT 84104
(801) 972-8400</td><td rowspan="2">Technology:
In situ Density-Driven Groundwater Sparging and Soil Vapor Extraction
- System consists of three main components - groundwater sparging system; groundwater recirculation system; and soil vapor extraction system
- Groundwater sparging was principal method of remediation; SVE was used locally
<u>Sparging System</u>
- Density-driven groundwater sparging - removed petroleum hydrocarbons using (1) aerobic degradation and (2) in situ air stripping; water inside the wellbore was aerated directly by injecting air at the base of the wellbore
- 12 groundwater sparging wells installed to a depth of 18 feet
<u>Groundwater Recirculation</u>
- 3 downgradient extraction (pumping) wells installed to a depth of 20 feet and 1 upgradient injection galley (former tank excavation backfilled with pea gravel)
<u>SVE</u>
- 3 vertical extraction wells located adjacent to the pumping wells
- Vapor discharged to atmosphere</td><td>Cleanup Authority:
State: Utah Department of Environmental Quality, Division of Response and Remediation (DERR)</td></tr>
<tr><td>SIC Code:
Not Available</td><td>Point of Contact:
Shelly Quick
Utah DERR</td></tr>
<tr><td>Waste Source:
Underground Storage Tanks</td><td colspan="2">Type/Quantity of Media Treated:
Groundwater and Soil
- Site stratigraphy - interbedded silty sand and poorly graded fine gravel underlain by a silty clay aquitard at a depth of approximately 18 feet below ground surface
- Depth to groundwater - 5 to 11 feet; aquifer thickness (7-13 feet)
- Porosity (20-35%), hydraulic conductivity (190 ft/day)
- Aerial extent of the plume - approximately 30,000 ft^2; vertical extent of contamination - contaminants concentrated in vertical zone from approximately 5 to 11 feet below ground surface
- Estimated volume of contaminated soil - 7,000 yd^3</td></tr>
</table>

Density-Driven Groundwater Sparging at Amcor Precast Ogden, Utah (Continued)

Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with diesel and gasoline fuels using in situ density-driven groundwater sparging and soil vapor extraction.

Regulatory Requirements/Cleanup Goals:
- **Soil - DEQ Recommended Cleanup Levels (RCLs) - TPH - 30 mg/kg; Benzene - 0.2 mg/kg; Toluene - 100 mg/kg; Ethylbenzene - 70 mg/kg; Xylenes - 1,000 mg/kg; Naphthalene - 2.0 mg/kg**
- **Groundwater - BTEX and naphthalene to below MCLs; no cleanup goal for TPH in groundwater**
- **Air - no air discharge permit was required because air emissions were below de minimis standards of the Utah Division of Air Quality**

Results:
- **The cleanup goals were achieved for all contaminants of concern in both soil and groundwater**

Cost Factors:
- **Total Capital Cost: $156,950 (including drill/install wells and sparging system, start-up, project management)**
- **Total Annual Operating Cost: $62,750 (including electricity, maintenance, monitoring)**

Description:
Amcor Precast in Ogden, Utah, stored gasoline and diesel fuel in three underground storage tanks. A release was discovered in 1990. An investigation in 1991 indicated that the areal extent of groundwater contamination was approximately 30,000 ft^2 and that an estimated 6,700-7,000 yd^3 of soil had been contaminated. The primary contaminants of concern were benzene, toluene, ethylbenzene, and xylenes (BTEX), naphthalene, and total petroleum hydrocarbons (TPH). A density-driven groundwater sparging system and soil vapor extraction (SVE) system were installed in January/February 1992 and operated from March 1992 to September 1993. The sparging system was used as the primary remediation technology. SVE was used locally to treat volatilized hydrocarbons, created by the air stripping process, and prevent contaminants from migrating to nearby office buildings.

With the density-driven groundwater sparging system at Amcor, water inside the wellbore was aerated by injecting air into the base of the wellbore (rather than injected under pressure) with the resulting injection air bubbles stripping contaminants from the water while increasing the dissolved oxygen content. In addition, the aeration process acted to create groundwater circulation and transport. Therefore, with this system, petroleum hydrocarbons were removed from the subsurface by (1) aerobic biodegradation resulting from the supply of oxygen to the saturated zone; and (2) in situ air stripping. The air stripped vapors are transferred to the vadose zone and are biodegraded in place. The application of density-driven groundwater sparging and SVE achieved the specified cleanup goals for both soil and groundwater. The cleanup goals for soil and for all contaminants except naphthalene in groundwater were achieved within 11 months of system operation. The cleanup goal for naphthalene in groundwater was achieved within 18 months.

The total capital cost for this application was about $157,000 and total annual operating costs were $62,750. Air sparging is limited to contaminants that can be degraded by indigenous bacteria under aerobic conditions. Maximum sparging well air flow and groundwater wellbore circulation rates are dependent on well diameter, depth to groundwater, and the hydraulic conductivity of the formation. Therefore, longer remediation times or a greater number of sparging wells may be required in lower permeability formations.

Petroleum Product Recovery and Contaminated Groundwater Remediation Amoco Petroleum Pipeline Constantine, Michigan

<table>
<tr><td>Site Name:
Amoco Petroleum Pipeline</td><td rowspan="2">Contaminants:
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX), Methyl tert butyl ether (MTBE)
- An estimated 300,000 to 2 million gallons of gasoline, fuel oil, and kerosene released to subsurface
- Free product present in an approximate 6-acre area at an average apparent thickness of 2 feet</td><td>Period of Operation:
Status: Ongoing
Report covers - 10/88 to 6/94</td></tr>
<tr><td>Location:
Constantine, Michigan</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Residuals Management Technology, Inc.</td><td rowspan="3">Technology:
Groundwater Extraction followed by Granular Activated Carbon (GAC); In situ Air Sparging of saturated zone
<u>Groundwater Extraction With GAC</u>
- 4 extraction wells installed in two phases (1988 and 1992); depths up to 28 feet below ground surface (bgs) with extraction rates of 50 and 100 gpm
- Extracted water treated using two GAC vessels in series; recovered free product sent to storage in aboveground tanks
<u>In-situ Air Sparging</u>
- 30 two-inch diameter air sparging wells with 3-foot screens
- Installed to depths of 25-30 feet
- Two 300 scfm blowers</td><td>Cleanup Authority:
Other: Voluntary cleanup</td></tr>
<tr><td>SIC Code:
4612 (crude petroleum piping)</td><td rowspan="2">Point of Contact:
Paul Ressmeyer
Remedial Project Manager
Amoco Corporation</td></tr>
<tr><td>Waste Source:
Other: Petroleum pipeline leak</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale pump and treat of petroleum contaminated-groundwater using granular activated carbon to recover free product and treat groundwater. In situ air sparging was subsequently added to treat the saturated zone.</td><td colspan="2">Type/Quantity of Media Treated:
Groundwater
- 775 million gallons of groundwater between 1988 and 1993
- Sand and gravel
- Porosity 30-40%
- Hydraulic conductivity 0.0002 - 0.0004 cm/sec</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The remediation is being performed as a voluntary action by Amoco; final cleanup criteria will be established in the future with concurrence from the Michigan Department of Natural Resources
- Treated water required to meet SPDES permit requirements prior to discharge - benzene (5 μg/L), total BTEX (20 μg/L), MTBE (380 μg/L), pH (6.5-9.0)</td></tr>
</table>

Petroleum Product Recovery and Contaminated Groundwater Remediation Amoco Petroleum Pipeline Constantine, Michigan (Continued)

Results:

Groundwater Extraction with GAC

- **118,000 gallons of free product recovered (10/87-12/93); rate of free product recovery has decreased to 20 to 25 gallons per month as of late 1993**
- **Free product has been hydraulically contained and observed apparent thickness of free product has been reduced to <0.01 feet**
- **Concentrations of BTEX in extracted groundwater have remained relatively constant; MTBE concentrations have decreased**
- **Treated effluent from GAC have generally met SPDES discharge limits**

In-situ Air Sparging

- **Pilot testing indicated a radius of influence of 65-150 feet per single well**
- **No additional results were available at the time of this report**

Cost Factors:

- **Total Capital Costs: about $297,000 for groundwater recovery and treatment system (including well construction, pumps, system installation, engineering); $375,000 for the air sparging system (including 3 months of initial operations, and testing)**
- **Annual Operating Costs (approximate): about $475,000 for groundwater recovery and treatment system; not yet defined for air sparging system**
- **An estimated total cost for completing the cleanup is not available at this time**

Description:

The Amoco Corporation owns and operates a liquid petroleum product pipeline that transverses the Constantine site. As a result of a pipeline leak, discovered in June 1987, an estimated 350,000 to 2 million gallons of gasoline, fuel oil, and kerosene were released to the subsurface. Free product was present at an average apparent thickness of 2 feet. Beginning in October 1988, a groundwater pump and treat system, consisting of 4 extraction wells and granular activated carbon (GAC) vessels, was used to recover free product and treat the contaminated groundwater. In situ air sparging of the saturated zone was subsequently added and began operating in February 1994.

Through December 1993, groundwater extraction with GAC had recovered an estimated 118,000 lbs of free product and reduced the observed apparent thickness of the free product layer to <0.01 feet. MTBE concentrations were reduced; however, BTEX concentrations near the source of contamination remained relatively constant. No full-scale performance data were available for the air sparging system at the time of this report.

The groundwater extraction with GAC system operated > 95% of the time through December 1993. Periodic shutdowns of 1 to 3 days were required for carbon changeout and extraction well rehabilitation. Leasing the activated carbon system and carbon provided flexibility to modify the treatment system in response to changing operating conditions. However, GAC proved to be inefficient in removing MTBE when compared to BTEX.

Recovery of Free Petroleum Product
Fort Drum, Fuel Dispensing Area 1595
Watertown, New York

<table>
<tr><td>Site Name:
Fort Drum Fuel Dispensing Area 1595</td><td rowspan="2">Contaminants:
Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)
- Gasoline and #2 fuel oil
- Free product measured in two wells in 1990 and 1994
- Full extent of contamination not yet defined</td><td>Period of Operation:
Status: Ongoing
Report covers - 2/92 to 4/94</td></tr>
<tr><td>Location:
Watertown, New York</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="2">Technology:
Groundwater Extraction followed by Air Stripping and Granular Activated Carbon
- 2 recovery wells - approximately 25 ft. below ground surface; average rate of 5-6 gpm
- Oil/water separator - 575 gallon capacity
- Air stripper - 750 cfm
- GAC - 4 55-gallon steel drums; 200 lb GAC per drum; operated 2 in series</td><td>Cleanup Authority:
DoD</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Remedial Project Manager
Fort Drum Environmental Division
Watertown, NY</td></tr>
<tr><td>Waste Source:
Underground Storage Tank</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater and Free Product
- Hydraulic conductivity of aquifer 0.11 to 0.0012 cm/sec
- Transmissivity 11,787 to 32,518 using Jacob method</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale remediation to recover free-phase petroleum product using groundwater extraction and air stripping and granular activated carbon (GAC).</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Final cleanup criteria have not been established at this time; the project is being conducted as a Rapid Response Interim Remediation
- Treated water discharged to the POTW must meet the following criteria - benzene (3 μg/L), toluene (35 μg/L), xylenes (190 μg/L), ethylbenzene (8 μg/L)</td></tr>
<tr><td colspan="3">Results:
- Information on the total quantity of free product recovered is not available at this time
- The effluent from the treatment system met all discharge criteria</td></tr>
<tr><td colspan="3">Cost Factors:
- Total Capital Costs - $958,780 (including system design and construction including site work, equipment, and mobilization/demobilization)
- Total Annual Operating Costs - $129,440 (including carbon changeout/regeneration, maintenance, laboratory analysis, and project management)
- An estimated cost for completion of the cleanup is not available at this time</td></tr>
</table>

Recovery of Free Petroleum Product
Fort Drum, Fuel Dispensing Area 1595
Watertown, New York (Continued)

Description:
Fort Drum in Watertown, New York, established in 1906, serves as a combat skills training area and operations headquarters for light infantry troops. Motor vehicle and aircraft refueling activities are conducted in Area 1595 of the facility. Area 1595 includes an underground storage tank (UST) and 10 dispensing units for gasoline, diesel fuel, and jet fuel. In 1982, free petroleum product was observed in a spring near this area. Suspected contaminant sources include leaking USTs and wastewaters from vehicle washing operations located adjacent to Area 1595. The primary contaminants of concern are BTEX (benzene, toluene, ethylbenzene, and xylenes) and free petroleum product. The full extent of the contamination had not been defined at the time of this report. The site remediation is being performed as a Rapid Response Interim Remediation and final cleanup criteria have not been established at this time.

A pump and treat recovery, consisting of two recovery wells, an oil/water separator, an air stripper, and granular activated carbon vessels, was operated from March 1992 to mid-1993. The system was restarted in February 1994 and was operational at the time of this report. The first year of operation focused on troubleshooting and little data were collected during that time. As such, no information is available at this time on the total quantity of free product recovered or the rate of recovery. Data from the air stripper/GAC system indicated that the concentrations of contaminants in the effluent meet the POTW discharge criteria for BTEX. An air emissions certificate was issued by the State in October 1992; however, information on specific emission limits was not available at the time of this report.

The total capital costs for this remediation are $958,780 and the estimated total annual operating costs are $129,440. Based on operations to date, it has been observed that free product recovery pumps require frequent maintenance and that activated carbon efficiency was limited because of fouling by iron and biomass.

Pump & Treat of Contaminated Groundwater at Langley Air Force Base Virginia

<table>
<tr><td>Site Name:
Langley Air Force Base, IRP Site 4</td><td rowspan="2">Contaminants:
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) and Total Petroleum Hydrocarbons (TPH)
- Primary constituents of JP-4 fuel are alkanes, cycloalkanes, alkylbenzenes, indans/tetralins, naphthalenes
- Total Recoverable Petroleum Hydrocarbons - 25 to 4,100 ppb in groundwater; >100 ppm in soil
- Free product floating on groundwater has exceeded 1 ft. in thickness</td><td>Period of Operation:
Status: Ongoing
Report covers - 7/92 to 1/94</td></tr>
<tr><td>Location:
Langley, Virginia</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="3">Technology:
Groundwater Extraction using a Vacuum Assisted Well Point Extraction System and Aboveground Air Stripping
- Extraction - 16 vacuum extraction wells connected by a header pipe to a central vacuum system; wells extend to approximately 14 ft. below ground surface
- Extraction network has an average flow rate of 32 gpm (2 gpm per well); vacuum pump provides 24-25 in of Hg
- Separation - initial oil/water separation occurs in a vacuum decanter followed by a high efficiency oil/water separator; oil phase is sent to a storage tank
- Treatment of aqueous phase - 2 air stripping columns - Column 1 - air/water ratio of 180 and air flow of 1,440 cfm at 60 gpm; Column 2 - air/water ratio of 100 and air flow of 800 cfm at 60 gpm</td><td>Cleanup Authority:
UST Corrective Action and State: Virginia</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td rowspan="2">Point of Contact:
Vern Bartels
Remedial Project Manager
Langley AFB</td></tr>
<tr><td>Waste Source:
Underground Storage Tanks</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with fuel oil using a vacuum assisted well point extraction system and aboveground air stripping.</td><td colspan="2">Type/Quantity of Media Treated:
Groundwater and Free Product
- Area of free product - about 600 ft. x 300 ft.; estimated volume of free product is 12,000 to 31,000 gallons
- Area of groundwater contamination - about 1,000 ft. x 2,000 ft.
- Properties of aquifer include pH (6.4 - 7.2), hydraulic conductivity (0.00099 - 0.002 ft/day), transmissivity (0.99 - 2.2 ft^2/day)</td></tr>
</table>

Pump & Treat of Contaminated Groundwater at Langley Air Force Base Virginia (Continued)

Regulatory Requirements/Cleanup Goals:
- **Groundwater: BTEX - Benzene (1.4 ppb), Toluene (2 ppb), Ethylbenzene (1 ppb), Total Xylenes (3 ppb)**
- **Air Stripper Criteria for discharge: BTEX - Benzene (7 ppb), Toluene (50 ppb), Ethylbenzene (4.3 ppb), Total Xylenes (13 ppb), Lead (5.6 ppb) and TPH (1,000 ppb)**
- **Cleanup conducted under Virginia State Regulations and Federal Underground Storage Tank Regulations**

Results:
As of 1/94:
- **Floating product - appears to be largely unaffected at this time; no estimates of the amount of free product recovered are available at this time**
- **Air Stripper - average concentrations from air stripper are below discharge criteria**

Cost Factors:
- **Total Capital Costs - $569,739 (1992) (including demolition and excavation, system installation, startup, mobilization and site preparation)**
- **Annual Operating Costs - $216,561 (1993), $143,047 (1994) (including labor, materials, and equipment)**
- **An estimated total cost for completing the cleanup is not available at this time**

Description:
Langley AFB has operated since 1916 as an aviation research and development facility. JP-4 fuel was stored in underground storage tanks and, in 1981, twenty-four 25,000-gallon underground fuel tanks and a fuel pipeline located at IRP Site 4 were determined to be leaking. In 1987, the tanks were abandoned by cleaning and sand-cement backfilling. Subsequent remedial investigation activities detected fuel contamination in soil and groundwater, including free product floating on the groundwater table at up to 1 foot in thickness. Primary contaminants of concern at the site are BTEX (benzene, toluene, ethylbenzene, and xylenes) and total petroleum hydrocarbons (TPH).

A groundwater pump and treat system consisting of a vacuum assisted well point extraction system, oil/water separators, and air strippers, began operating in July 1992 and was operational at the time of this report. Results to date indicate that, on average, the effluent concentration of BTEX, TRPH, and lead from the air stripper are below the discharge criteria. However, the layer of free product floating on the groundwater appears to be largely unaffected at this time. In addition, an estimate of free product recovered to date cannot be made since a sample port was not installed because of vacuum inlet conditions. It was noted that such sampling points are necessary to allow quantification of system performance.

The total capital costs for this application were about $569,700 and the annual operating costs for years 1993 and 1994 were about $216,600 and $143,000, respectively. Operational difficulties including problems with scaling, oil/water separator icing, and delays in acquiring spare parts have caused the system to be down about 51% of the time. In early 1994, adjustments to the system were made, including the use of chemical additives to prevent fouling of the system. It was noted that a roof over the treatment plant would have prevented weather-related damage and downtime (i.e., icing of oil/water separator).

Dynamic Underground Stripping
Demonstrated at Lawrence Livermore National Laboratory
Gasoline Spill Site, Livermore, California

Site Name:
Lawrence Livermore National Laboratory, Gasoline Spill Site

Location:
Livermore, California

Technical Information:
Roger Aines, Principal Investigator, LLNL (510) 423-7184
Robin Newmark, LLNL (510) 423-3644
Kent Udell, UC Berkeley (510) 642-2928
John Mathur, US DOE (301) 903-7922

SIC Code:
5541 (Gasoline service station)

Waste Source:
Underground Storage Tanks

Contaminants:
Benzene, Toluene, Ethylbenzene, Total Xylenes (BTEX)
- **Concentrations of fuel hydrocarbons (FHC) in gasoline as high as 5,100 ppm in saturated sediments near center of vadose zone (indicates likely presence of free-phase gasoline)**
- **Benzene levels in groundwater greater than 1 ppb found within 300 feet of release point**
- **Benzene levels in soil greater than 50 ppm**

Technology:
Dynamic Underground Stripping (DUS)
- **Combination of three technologies: steam injection at periphery of contaminated area to drive contaminants to centrally-located vacuum extraction locations; electrical heating of less permeable soils; and underground imaging to delineate heated areas**
- **Six steam injection/electrical heating wells approximately 145 feet deep, 4-inch diameter, screened in upper and lower steam zones**
- **Three electrical heating wells approximately 120 feet deep, 2-inch diameter**
- **One groundwater and vapor extraction well, approximately 155 feet deep, 8-inch diameter**
- **Extracted water processed through an air-cooled heat exchanger, oil/water separators, filters, UV/H_2O_2 treatment unit, air stripping, and GAC**
- **Extracted vapors processed through heat exchanger, demister, and internal combustion (IC) engines**

Period of Operation:
November 1992 - December 1993

Cleanup Type:
Field demonstration (commercial-scale)

Cleanup Authority:
CERCLA and Other: Bay Area Air Quality Management District

Licensing Information:
Kathy Willis
University of California Office of Tech Transfer
1320 Harbor Bay Parkway, Suite 150
Alameda, CA 94501
(510) 748-6595

Kathy Kaufman
Tech. Transfer Init. Program, L-795
University of California
Lawrence Livermore Nat'l. Laboratory
7000 East Avenue
P.O. Box 808
Livermore, CA 94550
(510) 422-2646

Purpose/Significance of Application:
Commercial-scale demonstration of dynamic underground stripping. Results compared to pump and treat, and pump and treat with vacuum extraction technologies.

Dynamic Underground Stripping
Demonstrated at Lawrence Livermore National Laboratory
Gasoline Spill Site, Livermore, California (Continued)

Type/Quantity of Media Treated:
Soil and Groundwater
- **100,000 cubic yards heated to at least 200°F**
- **4 hydrogeologic units and 7 hydrostratigraphic layers identified near gas pad**
- **Hydraulic conductivity ranged from <5 gpd/ft^2 (low permeability) to 1,070 gpd/ft^2 (very high to high permeability)**
- **Low groundwater velocities kept contamination confined to a relatively small area**

Regulatory Requirements/Cleanup Goals:
- **Groundwater cleanup levels established based on California MCLs: benzene 1 ppb; ethylbenzene 680 ppb; and xylenes 1,750 ppb**
- **Remediation was required until soil contaminant concentrations were identified as not adversely impacting groundwater**
- **Air permits were issued by the BAAQMD for the air stripper, GAC, IC engine, and for site-wide benzene**

Results:
- **Over 7,600 gallons of gasoline removed during demonstration effort**
- **Most of the gasoline was recovered in the vapor stream and not from extracted groundwater**

Cost Factors:
- **Overall program costs for the field demonstration, including all research and development costs, were $1,700,000 for before-treatment costs (project management, characterization and compliance monitoring), and $5,400,000 for treatment activities (process monitoring, subsurface wells, steam generation and electrical heating surface equipment, aboveground treatment systems, utilities, and labor and material costs)**

Description:
The 800-acre Lawrence Livermore National Laboratory (LLNL) site was used as a flight training base and aircraft assembly and repair facility by the Navy beginning in 1942. In 1951, the Atomic Energy Commission converted the site into a weapons design and basic physics research laboratory. Initial releases of hazardous materials occurred in the mid- to late-1940s. Between 1952 and 1979, up to 17,000 gallons of leaded gasoline were released from underground storage tanks beneath a gasoline filling station in an area now designated as the Gasoline Spill Area (GSA). Soil and groundwater in the GSA were found to be contaminated with BTEX (benzene, toluene, ethylbenzene, and xylenes) and fuel hydrocarbons.

A commercial-scale field demonstration of Dynamic Underground Stripping (DUS) was completed at the GSA from November 1992 to December 1993. DUS is a combination of three technologies: steam injection at the periphery of a contaminated area to drive contaminants to a centrally-located vacuum extraction location; electrical heating of less permeable soils; and underground imaging (primarily Electrical Resistance Tomography) to delineate heated areas. The DUS system used at the GSA employed 6 steam injection/electrical heating wells, 3 electrical heating wells, and 1 vacuum extraction well, as well as above ground water and vapor treatment equipment.

Over 7,600 gallons of gasoline were removed by the DUS system in the demonstration effort. Most of the gasoline was recovered in the vapor stream and not from the extracted groundwater. Potential cost savings of $4,000,000 were identified for applying DUS at the same site in the future (taking into account the benefits of the lessons learned and without research-oriented activities).

Pump & Treat of Contaminated Groundwater at Operable Unit B/C McClellan Air Force Base California

<table>
<tr><td>Site Name:
McClellan Air Force Base, Operable Unit (OU) B/C</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Trichloroethene (TCE), cis-1,2-Dichloroethene (cis-1,2-DCE), Tetrachloroethene (PCE), 1,2-Dichloroethane (1,2-DCA)
- In an area of 7,800 million cubic feet, there is an estimated 33,000 kg of VOCs; percent of total mass for individual constituents is TCE (82.7%), cis-1,2-DCE (0.5%), PCE (16.7%), 1,2-DCA (0.1%)</td><td>Period of Operation:
Status: Ongoing
Report covers - 1988 to 1993</td></tr>
<tr><td>Location:
Sacramento, California</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="2">Technology:
Groundwater Extraction followed by Aboveground Air Stripping
- 7 extraction wells pump to a main treatment plant
- Air stripper - design capacity of 1,000 gpm; average flow rate of 250 gpm
- Supplemental Treatment - thermal oxidizer and caustic scrubber for offgases; two GAC units in series to polish liquid phase prior to discharge</td><td>Cleanup Authority:
DoD</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Remedial Project Manager
McClellan AFB
Sacramento, CA</td></tr>
<tr><td>Waste Source:
Landfill; Underground Storage Tank; Disposal Pit; Open Burn Area</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- As of 1/94: Over 660 million gallons of groundwater treated since startup in March 1987
- Groundwater subsurface consists of 5 distinct monitoring zones (A through E); evidence points to hydraulic link among 5 zones
- Hydraulic conductivity ranges from 2.8 to 30.7 ft/day
- Transmissivity ranges from 100-2,000 ft^2/day</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with VOCs using groundwater extraction and aboveground air stripping.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
Final cleanup criteria have not been established at this time
- Current target is <0.55 μg/L VOCs for groundwater
- NPDES permit - acetone, MEK, and MIK to <1 mg/L and VOCs to <0.5 μg/L</td></tr>
<tr><td colspan="3">Results:
- Influent VOC concentrations have decreased from about 60 ppm in 1987 to about 4 ppm in 1993
- The effluent from the treatment system has been below the permitted discharge levels since operation began
- As of 3/94, approximately 44,000 lbs of VOCs have been removed since startup</td></tr>
</table>

Pump & Treat of Contaminated Groundwater at Operable Unit B/C McClellan Air Force Base California (Continued)

Cost Factors:
- **Total Capital Cost in 1987 - $4,000,000 (including over $1,700,000 for the incinerator, air stripper, scrubber, wells, and GAC tanks, and about $1,000,000 for heat exchangers, blowers, pumps, and compressors; control center)**
- **Total Annual Operating Costs - $1,240,000 (including contractor operations, utilities, sampling and analysis, project management)**
- **An estimated total cost for completing the cleanup is not available at this time**

Description:

The McClellan Air Force Base in Sacramento, California was established in 1937. Operations at the 3,000-acre facility include aircraft, electronics, and communications equipment maintenance and repair, and a wide variety of hazardous materials have been used at the site. The site was added to the National Priorities List in 1987. Areas of contamination at the site include Operable Unit B (OU B) and Operable Unit C (OU C). Releases from OU B resulted from disposal/release of hazardous substances from landfills, underground storage tanks, storage lots, burial and burn pits. Releases from OU C were attributed to waste disposal activities. Extensive VOC contamination has been identified at the facility. The primary constituents of concern are TCE, cis-1,2-DCE, PCE, and 1,2-DCA.

A groundwater extraction and treatment system including air stripping was installed with operations beginning in 1988. Offgases from the air stripper are treated by thermal oxidation and caustic scrubbing. The effluent from the air stripper is treated using GAC prior to a NPDES-permitted discharge. The 1993 data on the influent to the air stripper show that the VOC concentrations have decreased to about 4 ppm from concentrations of 60 ppm (1987). An estimated 44,000 pounds of VOCs have been removed as of March 1994. The remediation was ongoing at the time of this report and final performance data are not yet available. In addition, the treatment system has been effective in treating groundwater to below the NPDES discharge limits.

The total capital costs for this system are $4,000,000 and the total annual operating costs are $1,240,000. The system has been on line 98% of the time. Problems of scaling and deposition in the air stripper from calcium and magnesium salt precipitation were remedied by changing to 2-inch packing from 1-inch packing in the air stripper. Corrosion was minimized through material changes to nickel-based commercial alloys and change in physical layout to improve flow.

Pump & Treat of Contaminated Groundwater at Operable Unit D McClellan Air Force Base California

<table>
<tr><td>Site Name:
McClellan Air Force Base
Superfund Site, Operable Unit D</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Trichloroethene (TCE), cis-1,2-Dichloroethene (cis-1,2-DCE), Tetrachloroethene (PCE), 1-2-Dichloroethane (1,2-DCA)
- In an area of 7,800 million cubic feet, there is an estimated 33,000 kg of VOCs; percent of total mass for individual constituents - TCE (82.7%), cis-1,2-DCE (0.5%), PCE (16.7%), 1,2-DCA (0.1%)</td><td>Period of Operation:
Status: Ongoing
Report covers - 1987 to 1993</td></tr>
<tr><td>Location:
Sacramento, California</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="2">Technology:
Groundwater Extraction followed by Aboveground Air Stripping
- 6 extraction wells pump to a main treatment plant
- Air Stripper - design capacity of 1,000 gpm; average flow rate of 250 gpm
- Supplemental Treatment - thermal oxidizer and caustic scrubber for offgases; two GAC units in series to polish liquid phase prior to discharge</td><td>Cleanup Authority:
DoD</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Remedial Project Manager
McClellan AFB
Sacramento, CA</td></tr>
<tr><td>Waste Source:
Disposal Pit; Open Burn Pits</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- As of 1/94: Over 660 million gallons of groundwater treated since startup in March 1987
- Groundwater subsurface consists of 5 distinct monitoring zones (A through E); evidence points to hydraulic link among 5 zones
- Hydraulic conductivity ranges from 2.8 to 30.7 ft/day
- Transmissivity ranges from 100-2,000 ft^2/day</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale remediation of groundwater contaminated with VOCs using groundwater extraction and aboveground air stripping.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
Final cleanup criteria have not been established at this time
- Current target is <0.55 μg/L VOCs in groundwater
- NPDES permit limits on acetone, MEK, MIK of 1 mg/L and VOCs of 0.5 μg/L</td></tr>
<tr><td colspan="3">Results:
- Influent VOC concentrations have decreased from about 60 ppm in 1987 to about 4 ppm in 1993
- The effluent from the treatment system has been below the permitted discharge levels since operation began
- Approximately 44,000 lbs of VOCs have been removed since startup</td></tr>
</table>

Pump & Treat of Contaminated Groundwater at Operable Unit D McClellan Air Force Base California (Continued)

Cost Factors:
- **Total Capital Costs - $4,000,000 (including over $1,700,000 for the incinerator, air stripper, scrubber, wells, and GAC tanks, and about $1,000,000 for heat exchangers, blowers, pumps, and compressors; control center)**
- **Total Annual Operating Costs - $1,240,000 (including contractor operations, utilities, sampling and analysis, project management)**
- **An estimated total cost for completing the cleanup is not available at this time**

Description:

The McClellan Air Force Base in Sacramento, California was established in 1937. Operations at the 3,000-acre facility include aircraft, electronics, and communications equipment maintenance and repair, and a wide variety of hazardous materials have been used at the site. Operable Unit D (OU D) was primarily a waste disposal area at McClellan from 1956 until the last 1970s. Numerous burial and burn pits which had received solid waste, oil, various chemicals, and industrial sludges were closed in the late 1970s and early 1980s. Extensive VOC contamination has been identified at the facility with the primary constituents of concern at OU D being TCE, cis-1,2-DCE, PCE, and 1,2-DCA.

A groundwater extraction and treatment system including air stripping was installed with operations beginning in 1988. Offgases from the air stripper are treated by thermal oxidation and caustic scrubbing. The effluent from the air stripper is treated using GAC prior to a NPDES-permitted discharge. The 1993 data on the influent to the air stripper show that the VOC concentrations have decreased to about 4 ppm from concentrations of 60 ppm (1987). An estimated 44,000 pounds of VOCs have been removed as of March 1994. The remediation was ongoing at the time of this report and final performance data are not yet available. In addition, the treatment system has been effective in treating groundwater to below the NPDES discharge limits.

The total capital costs for this system are $4,000,000 and the total annual operating costs are $1,240,000. The system has been on line 98% of the time. Problems of scaling and deposition in the air stripper from calcium and magnesium salt precipitation were remedied by changing to 2-inch packing from 1-inch packing in the air stripper. Corrosion was minimized through material changes to nickel-based commercial alloys and change in physical layout to improve flow.

Pump & Treat of Contaminated Groundwater at Twin Cities Army Ammunition Plant, New Brighton, Minnesota

<table>
<tr><td>Site Name:
Twin Cities Army Ammunition Plant (TCAAP)</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Contaminants of greatest concern in the groundwater are: 1,1-DCE, 1,1-DCA, 1,2-DCE, chloroform, 1,1,1-TCA, TCE, and PCE
- TCE is the most prevalent VOC on site, with concentrations greater than 10,000 ppb in groundwater</td><td>Period of Operation:
Status: Ongoing
Report covers - 10/87 to 9/92</td></tr>
<tr><td>Location:
New Brighton, Minnesota</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="2">Technology:
Groundwater Extraction followed by Air Stripping
- 12 boundary recovery wells and 5 source area recovery wells
- Air stripping plant designed to treat 2,900 gal/min; 4 towers - 2 @ 7 feet diameter and 2 @ 8 feet diameter; all 36 feet tall with propylene packing
- Treated water discharged to a sand and gravel pit, or, alternately to an elevated tank
- Designed for an operating life of 30 years</td><td>Cleanup Authority:
CERCLA
- ROD Date: 10/88</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Remedial Project Manager
Twin Cities Army Ammunition Plant
New Brighton, MN</td></tr>
<tr><td>Waste Source:
Other: Variety of Waste Disposal Practices, including Discharges to Sewer, Dumping, and Burning</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- Over 1.4 billion gallons of water pumped from 10/91 to 9/92
- Complex hydrogeology and heterogeneities in a multilayer aquifer system
- Fractured bedrock and discontinuous sand, clay, and till layers
- Hydraulic conductivity 0.001 to 137 ft/day; transmissivity 3,160 to 28,724 ft^2/day</td></tr>
<tr><td>Purpose/Significance of Application:
Pump and treat of large-volume of groundwater contaminated with VOCs.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Several RODs apply to overall TCAAP remedial program, including a ROD for groundwater remediation
- Target cleanup criteria focus on residual levels of contamination in groundwater and containment of existing plume
- Target cleanup levels in groundwater include: TCE - 5 ppb; PCE - 6.9 ppb; 1,2-DCE - 70 ppb; and 1,1,1-TCA - 200 ppb</td></tr>
<tr><td colspan="3">Results:
- Boundary Groundwater Recovery System (BGRS) recovered an average of 23 pounds of VOCs per day
- TCAAP Groundwater Recovery System (TGRS) recovered 19,510 pounds of VOCs in one year of operation
- Historical total of 92,700 pounds of VOCs recovered in 6 years of operation (BGRS and TGRS)
- Plume containment successful at site
- VOC plumes changed little after several years of treatment; estimate of remediation time increased to achieve a concentration of 17 ppb TCE in 50 to 70 years</td></tr>
</table>

Pump & Treat of Contaminated Groundwater at Twin Cities Army Ammunition Plant, New Brighton, Minnesota (Continued)

Cost Factors:
- **Capital costs - $8,034,454 (including construction of treatment plant, wells, force main and pump houses, startup, engineering, and project management)**
- **Annual operating costs - $588,599 (including power, labor, maintenance, laboratory charges, and replacement of tower packing)**
- **Total Life Cycle Costing estimated as $0.30 per 1,000 gallons of water treated**
- **Total cost of operation and maintenance calculated as $0.12 per 1,000 gallons of water treated**

Description:

The Twin Cities Army Ammunition Plant, established in 1941, has been used for the production and storage of munitions. The site includes 7 major production buildings and over 300 auxiliary buildings. A series of hydrogeological investigations beginning in 1981 revealed elevated levels of VOCs in groundwater; 14 separate source areas have been identified at the site. Trichloroethene (TCE) has been measured at concentrations over 10,000 ppb in the groundwater. Target groundwater cleanup levels were established for four constituents - TCE, PCE, 1,2-DCE, and 1,1,1-TCA.

Groundwater extraction followed by air stripping has been used at this site since October 1987 to treat contaminated groundwater. The groundwater extraction system includes 12 boundary recovery wells and 5 source area recovery wells. Extracted groundwater is treated using four 36-feet tall air stripping towers. An estimated 92,700 pounds of VOCs have been recovered in 6 years of system operation. Although plume containment has been successful at the site, the plumes have changed little after several years of treatment.

An estimate of the time required for remediation has been revised from 30 years to 50 to 70 years, based on a review of data collected to date. Capital costs for this application were $8,034,454, and annual operating costs are $588,599.

Pump and Treat of Contaminated Groundwater at U.S. Department of Energy Kansas City Plant Kansas City, Missouri

<table>
<tr><td>Site Name:
U.S. Department of Energy (DOE)
Kansas City Plant</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics; includes Tetrachloroethene (PCE), Trichloroethene (TCE), 1,2-Dichloroethenes (1,2-DCEs), and Vinyl Chloride
PCBs, Petroleum Hydrocarbons, and Metals
- TCE concentrations of > 10,000 μg/L in groundwater
- Presence of DNAPLs suspected</td><td>Period of Operation:
Status: Ongoing
Report covers - 5/88 to 2/94</td></tr>
<tr><td>Location:
Kansas City, Missouri</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Allied Signal, Inc.</td><td rowspan="2">Technology:
Groundwater Extraction with Advanced Oxidation Processes (AOPs)
- 14 extraction wells and one trench; screened intervals of wells ranged from 27 feet to approximately 47 feet below ground surface; flow rates ranged from 0.9 to 5 gallons per minute (gpm) based on a design flow rate of 2 gpm
- Interceptor trench of 250 ft. in length; ranged in depth from about 22 ft. to 31 ft.
- Treatment system - acidification to solubilize inorganic metals, bag filtration, UV/peroxide oxidation, and neutralization
- Initial AOP - UV/Ozone/Peroxide system replaced in May 1993 with a high intensity UV/Peroxide system</td><td>Cleanup Authority:
RCRA Corrective Action and Other: Kansas City Water and Pollution Control Department</td></tr>
<tr><td>SIC Code:
9711 (National Security)
3724 (aircraft-engine manufacturing)</td><td>Point of Contact:
G.P. Keary
Environmental Restoration Program Manager
DOE Kansas City Plant
Kansas City, MO</td></tr>
<tr><td>Waste Source:
Manufacturing Process</td><td colspan="2">Type/Quantity of Media Treated:
Groundwater
- 11.2 million gallons treated (1993)
- Horizontal/Vertical distribution of VOCs in groundwater - up to 4,000 ft. horizontal and over 40 ft. vertical
- Alluvial deposits underlain by bedrock consisting of sandstone and shale
- Shale is relatively impermeable
- Porosity of aquifer is 20%
- Horizontal Hydraulic Conductivity of aquifer is 1.1 to 2.3 ft/day; sandstone is 0.04 to 0.005 ft/day; underlying shale is impermeable in water</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
Full scale remediation of groundwater contaminated with VOCs using advanced oxidation processes (UV/peroxide).</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at U.S. Department of Energy Kansas City Plant Kansas City, Missouri (Continued)

Regulatory Requirements/Cleanup Goals:
- **Final cleanup goals for site have not been established at time of report; will be set subsequent to RFI/CMS activities**
- **Treated groundwater discharged to municipal sewer system must meet requirements of permit issued by the Kansas City Water and Pollution Control Department; for organics - total organic halogen 0.16 mg/L; metals - 0.69 to 100 mg/L**

Results:
As of February 1994:
- **Influent VOC concentrations to UV/Peroxide treatment system were 10.6 mg/L with an average influent concentration of 25 mg/L; effluent concentrations were 0.01 mg/L**
- **The UV/peroxide system destroyed > 99.95% VOCs**
- **PCBs were detected at levels up to 0.3 μg/L in influent to UV/peroxide unit; not detected in effluent**
- **VOC contaminant plume appears to be contained**
- **No significant change in VOC groundwater concentrations at this time**

Cost Factors:
- **Total Capital Costs: $1,383,400 (including equipment, site preparation, construction/engineering, startup)**
- **Annual Operating Costs: $355,200 (including maintenance, project management, laboratory analysis, supplies)**
- **An estimated total cost for completing the cleanup is not available at this time.**

Description:
The U.S. Department of Energy (DOE) Kansas City Plant, constructed in 1942, has been used for aircraft engine manufacturing, production of nuclear weapons components, and defense-related research and manufacturing operations. During the 1980s, hydrogeologic investigations identified soil and groundwater contamination at the site which had resulted from releases from the research and manufacturing operations. The primary contaminants detected included chlorinated VOCs, aromatic VOCs, PCBs, and metals. DNAPLs are suspected in the groundwater, but have not been detected at this time. Final cleanup goals have not been established at this time. Treated water from the system is discharged to the municipal sanitary sewer system under the provisions of a Kansas City Water and Pollution Control Department wastewater discharge permit (2/88).

Operation of a groundwater pump and treat system, which includes an Advanced Oxidation Process (AOP), began in May 1988 under RCRA corrective action. The initial system included 14 extraction wells followed by a low intensity Ultraviolet (UV)/Ozone/Peroxide treatment system. This system was replaced in May 1993 by a high intensity UV/Peroxide system to provide additional 30 GPM treatment capacity for groundwater and to correct operational problems with the initial unit (equipment malfunctions and downtime). While the cleanup is ongoing at this time and final performance data are not yet available, interim results indicate that the extraction system appears to be containing the VOC contaminant plume. However, the concentrations of VOC in the groundwater have not changed significantly.

The total capital costs for this application were $1,383,400 and the annual operating costs were $355,200. With respect to the AOP, the replacement of the low intensity UV/ozone/peroxide system with the high intensity UV/peroxide system resulted in both increased treatment capacity and cost savings while meeting the discharge limits for the treated water. The high intensity UV/peroxide system eliminated the need for GAC polishing and treatment of air emissions and reduced operation and maintenance costs. Although more expensive than alternatives such as air stripping, AOP was selected because it destroys the contaminants rather than transferring contaminants to other media.

Pump and Treat of Contaminated Groundwater at U.S. Department of Energy Savannah River Site, Aiken, South Carolina

<table>
<tr><td>Site Name:
U.S. Department of Energy (DOE)
Savannah River Site A/M Area</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Trichloroethene (TCE), Tetrachloroethene (PCE), and 1,1,1-Trichloroethane (TCA)
- Concentrations of volatile organic compounds (VOCs) in groundwater reported as high as 500 ppm
- Groundwater TCE concentrations over 48 ppm
- Groundwater contains 260,000-450,000 pounds of dissolved organic solvents in concentrations greater than 0.01 ppm, estimated to be 75% TCE
- Soil TCE concentrations over 10 ppm
- Dense nonaqueous phase liquids (DNAPLs) are present in groundwater</td><td>Period of Operation:
Status: Ongoing
Report covers - 9/85 to 12/93</td></tr>
<tr><td>Location:
Aiken, South Carolina</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
C.L. Bergen
Westinghouse Savannah River Company
Aiken, SC</td><td rowspan="2">Technology:
Groundwater Extraction Wells followed by Air Stripping
- 11 recovery wells at depths to over 200 feet below ground surface
- Production air stripper has a design capacity of 610 gpm; operated at 510 gpm
- 1993 average flow rate was 479 gpm; average air flow rate was 2,489 cfm
- In 1993, 19,500 lbs of VOCs removed; average air emission rate of 2 lbs/hr</td><td>Cleanup Authority:
RCRA Corrective Action and State: South Carolina Bureau of Air Quality Control</td></tr>
<tr><td>SIC Code:
9711 (National Security)
3355 (Aluminum forming)
3471 (Metal finishing)</td><td>Point of Contact:
G.E. Turner, DOE
Savannah River Oper. Office
Environmental Restoration Div.
Aiken, SC</td></tr>
<tr><td>Waste Source:
Surface Impoundment</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- VOC contaminated groundwater has an approximate thickness of 150 ft and covers about 1,200 acres
- Complex hydrogeology arising from heterogeneities in a multilayer aquifer system with discontinuous sand and clay layers
- Hydraulic conductivity 9 - 73 ft/day
- Transmissivity 175 - 12,500 gpd/day</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale pump and treat remediation of groundwater contaminated with VOCs using aboveground air stripping.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at U.S. Department of Energy Savannah River Site, Aiken, South Carolina (Continued)

Regulatory Requirements/Cleanup Goals:
Groundwater:
TCE - 5 ppb; PCE - 5 ppb; TCA - 200 ppb
- **Adopted in 1990, based on EPA MCLs**
- **During initial remediation efforts in 1985, the cleanup goal was 99% removal of VOCs over a 30-year period**

Air:
34 tons/yr VOCs or 7.9 lbs/hr
- **Based on South Carolina Bureau of Air Quality Control permit**

Results:
As of 1993:
- **Influent concentrations to air stripper decreased for TCE (from 25,000 ppb to about 6,000 ppb) and PCE (from 12,000 ppb to 4,000 ppb)**
- **The total quantity of VOCs removed from 1985 to 1993 is 273,300 lbs**
- **Average VOC removal efficiency for air stripper >99.9%**

Cost Factors:
- **Total Capital Costs (1990 dollars) - $4,103,000 (including design, construction and installation, engineering, site development)**
- **Total Annual Operating Costs (1990 dollars) - $149,200 (for years 1985 to 1990) (including electricity, maintenance, operation, well sampling and analysis)**
- **Total cost of operation and maintenance is $0.75 per 1,000 gallons treated (198 million gallons per year treated)**
- **An estimated total cost for completing the cleanup is not available at this time**

Description:
At the U.S. Department of Energy Savannah River Site, administrative buildings are located within the "A" area and aluminum forming and metal finishing operations have been performed within the "M" area. An estimated 3.5 million pounds of solvents were discharged from these operations between 1958 and 1985, with over 2 million pounds sent to an unlined settling basin. Groundwater contamination beneath the settling basin was discovered in 1981. The primary contaminants were volatile organic compounds (VOCs) at concentrations up to 500 ppm. A pilot groundwater remediation system was operated in 1983, with the full-scale groundwater treatment begun on September 1985. The full-scale technology included groundwater extraction wells and a production air stripper. The design of the production air stripper was based on pilot and prototype air strippers.

While the remediation was ongoing at the time of this report, reductions in concentrations of both TCE and PCE to the air stripper have been noted and the estimated total historical (1985 to 1993) removal of VOCs is over 273,000 lbs. In addition, the average VOC removal efficiency of the air stripper is greater than 99.9%. Contaminated groundwater in the source areas and the areas of the highest VOC concentrations appears to be contained at this time. However, the areas at the fringes of the plume are not as well contained, due to hydraulic factors.

The total capital cost for this application is $4,103,000 and the total annual operating costs are $149,200. DNAPLs were discovered in the groundwater in 1991 and pose a significant limitation to the long-term use of pump and treat, since pump and treat is effective for plume restoration only where DNAPL source areas have been contained or removed. A need for supplemental site characterization to fully define the DNAPL contamination and to redirect ongoing remediation activities has been identified.

In Situ Air Stripping of Contaminated Groundwater at U.S. Department of Energy Savannah River Site Aiken, South Carolina

<table>
<tr><td>Site Name:
U.S. Department of Energy (DOE), Savannah River Site A/M Area</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Trichloroethene (TCE), Tetrachloroethene (PCE), 1,1,1-Trichloroethane (TCA)
- Concentrations of volatile organic compounds (VOCs) in groundwater reported as high as 500 ppm
- Groundwater TCE concentrations over 48 ppm
- Groundwater contains 260,000-450,000 pounds of dissolved organic solvents in concentrations greater than 0.01 ppm, estimated to be 75% TCE
- Soil TCE concentrations over 10,000 μg/L (1991)
- Dense nonaqueous phase liquids (DNAPLs) are present in groundwater</td><td>Period of Operation:
July 1990 to September 1993</td></tr>
<tr><td>Location:
Aiken, South Carolina</td><td>Cleanup Type:
Field Demonstration</td></tr>
<tr><td>Vendor:
C.L. Bergen
Westinghouse Savannah River Co.
Aiken, SC</td><td rowspan="2">Technology:
In Situ Air Stripping
- 7 horizontal wells installed; only 2 wells used in field demonstration
- Demonstration wells: 1 installed in saturated zone; 1 installed in vadose zone; targeted contaminated sands
- Air injected through lower horizontal well, below the water table
- Demonstration focused on supplementing pump and treat efforts
- Demonstration did not include offgas treatment</td><td>Cleanup Authority:
RCRA Corrective Action and State: South Carolina Dept. of Health and Environmental Control, Air Quality Control, and Underground Injection Control</td></tr>
<tr><td>SIC Code:
9711 (National Security)
3355 (Aluminum forming)
3471 (Metal finishing)</td><td>Point of Contact:
G.E. Turner, DOE
Savannah River Oper. Office
Environmental Restoration Div.
Aiken, SC</td></tr>
<tr><td>Waste Source:
Surface Impoundment</td><td colspan="2">Type/Quantity of Media Treated:
Groundwater and Soil
- Area of VOC-contaminated groundwater has an approximate thickness of 150 feet and covers about 1,200 acres
- Aquifer units characterized to 180 feet below ground surface (9 separate units), showing complex hydrogeology and discontinuous sand and clay layers
- Hydraulic conductivity 9 - 73 ft/day
- Transmissivity 175 - 12,500 gpd/day</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
Field demonstration of in situ air stripping using horizontal wells to supplement groundwater pump and treat technology.</td></tr>
</table>

In Situ Air Stripping of Contaminated Groundwater at U.S. Department of Energy Savannah River Site Aiken, South Carolina (Continued)

Regulatory Requirements/Cleanup Goals:
- **No specific cleanup goals identified for the field demonstration**
- **Demonstrations permitted by the South Carolina Department of Health and Environmental Control (SCDHEC) Air Quality Control (AQC) and Underground Injection Control (UIC)**

Results:
- **Substantial changes in groundwater VOC concentrations measured during demonstration**
- **Increased microbial numbers and metabolic activity exhibited during air injection period**
- **139 day demonstration (July-December 1990) removed nearly 16,000 pounds of VOCs**
- **Vacuum extraction removed an estimated 109 lbs VOC/day while air injection resulted in an additional 20 lbs/day VOC removal**

Cost Factors:
- **Costs for conducting field demonstration not provided**

Cost study for in situ air stripping provided the following projected costs:
- **Total equipment costs - $253,525 (including design and engineering, well installation, air injection and extraction system, piping, and electrical)**
- **Site costs - $5,000 (setup and level area)**
- **Total Annual Labor Costs - $62,620 (including mobilization/demobilization, monitoring, and maintenance)**
- **Total Annual Consumable Costs $157,761 (including carbon recharge, fuel, and chemical additives)**

Description:

At the U.S. Department of Energy Savannah River Site, administrative buildings are located within the A area and aluminum forming and metal finishing operations have been performed within the "M" area. An estimated 3.5 million pounds of solvents were discharged from these operations between 1958 and 1985, with over 2 million pounds sent to an unlined settling basin. Groundwater contamination beneath the settling basin was discovered in 1981. A pump and treat program has been ongoing since 1985 for removal of VOCs from the groundwater.

A field demonstration using in situ air stripping with horizontal wells in the A/M Area was conducted from July 1990 to September 1993. The demonstration was part of a program at Savannah River to investigate the use of several technologies to enhance the pump and treat system. In the air stripping demonstration, air was injected into a lower horizontal well in the saturated zone and extracted through the horizontal well in the vadose zone. The demonstration did not include treatment of offgases. The in situ air stripping process increased VOC removal over conventional vacuum extraction from 109 pounds per day to 129 pounds per day. Nearly 16,000 pounds of VOCs were removed during the 139 day demonstration period.

A cost analysis performed as part of this demonstration showed that in situ air stripping can remove VOCs for approximately 69% of the cost for conventional methods. Installation costs for horizontal wells is greater than for vertical wells. For deeper horizontal wells (over 40-50 feet), costs range from $360 to $700 per foot. Several implementation concerns were identified for installing horizontal wells at Savannah River.

This page intentionally left blank.

4.0 REMEDIATION CASE STUDIES: SOIL VAPOR EXTRACTION

Soil Vapor Extraction System at Commencement Bay, South Tacoma Channel (Well 12A), Phase 2, Tacoma, Washington

<table>
<tr><td>Site Name:
Commencement Bay, South Tacoma Channel (Well 12A) Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
trans-1,2-Dichloroethene (DCE),
1,1,2,2-Tetrachloroethane (PCA),
1,1,2,2-Tetrachloroethene (PCE),
Trichloroethene (TCE)
- Average VOC concentrations in top 25 feet of soil ranged from 10 to 100 mg/kg
- Average PCA concentrations in soil borings ranged from 6,200 at 30 feet depth to over 19,000 mg/kg at 40 feet depth
- Approximately 571,000 lbs of VOCs present in unsaturated zone</td><td>Period of Operation:
Status: Ongoing
Report covers - 8/92 to 2/94</td></tr>
<tr><td>Location:
Tacoma, Washington</td><td>Cleanup Type:
Full-scale cleanup (Report documents demonstration phase)</td></tr>
<tr><td>Vendor:
Environmental Science & Engineering, Inc.</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 22 wells used for vapor extraction, air inlet, and observation
- Vapor-phase carbon adsorption (GAC) used for treatment of extracted VOCs
- GAC beds regenerated on site with low pressure steam
- Design flow rate for extraction system of 3,000 standard cubic feet per minute (scfm)</td><td>Cleanup Authority:
CERCLA, Local Requirements
- ROD Date: 3/85</td></tr>
<tr><td>SIC Code:
2851 (Paints, Varnishes, Lacquers, Enamels, and Allied Products)</td><td>Point of Contact:
Phil Stoa
Remedial Project Manager
U.S. Army Corps of Engineers
Seattle District</td></tr>
<tr><td>Waste Source:
Storage - Drums; Other: Pour off from Processing Tanks</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Volume of contaminated soil reported as 98,203 cubic yards, based on an area of 66,300 ft^2 and a depth of 40 ft
- Upper aquifer (50 ft thickness) consists of unconfined sand and gravel
- Surface soil permeability ranges from 2.8 to 3.6 x 10^{-3} cm/sec
- Separate liquid phases of VOCs in soil and groundwater suspected
- Tar-like compounds in soil suspected</td></tr>
<tr><td>Purpose/Significance of Application:
Application of soil vapor extraction with an on-site solvent recovery system; relatively large volume of contaminated soil; possible presence of separate liquid phases of VOCs and tar-like compounds in soil.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- No specific cleanup goals identified in Record of Decision
- Local permit required for air emissions
- Performance objective for air treatment system set at 99% removal
- Air discharge limits specified as follows:
PCA 0.149 lbs/hr
PCE 0.095 lbs/hr
TCE 0.344 lbs/hr</td></tr>
</table>

Soil Vapor Extraction System at Commencement Bay, South Tacoma Channel (Well 12A), Phase 2, Tacoma, Washington (Continued)

Results:
- **No results provided for quantity of contaminants removed during demonstration phase**
- **Computer modelling results show predicted removal rates for VOCs as a function of time**
- **Pilot-scale results indicated that 3 to 4 lbs/day/well of VOC could be removed from the upper 30 feet of soil**
- **No results provided for air emissions - treatment system removals or mass discharge rates**
- **Problems were experienced with the operation of the solvent recovery system**
- **Condensed mixed solvents formed an emulsion which did not readily separate from the water**

Cost Factors:
Total Capital Cost - $5,313,973 (as of 5/94) (no breakdown of costs available)
Annual Operating Costs - $100,000 (estimated) (no breakdown of costs available)

Description:
The Commencement Bay site was used from 1927 to 1964 for waste oil recycling, paint and lacquer thinner manufacturing, and solvent reclamation and hundreds of drums of material were stored at the site. Leaks from these drums, as well as the dumping of wastes directly on the ground and overflows from the solvent and waste oil recycling tanks, resulted in contamination of the soil and groundwater at the site. The primary contaminants of concern at the site included DCE (trans-1,2-dichloroethylene), PCA (1,1,2,2-tetrachloroethane), PCE (1,1,2,2-tetrachloroethylene), and TCE (trichloroethylene). VOC soil concentrations range from 10 to 100 mg/L.

A full-scale SVE system was constructed in 1992. Operation testing of this system began in August 1992 and this report covers the demonstration phase of the project. The SVE system includes 22 vapor extraction wells. Granular activated carbon (GAC), used to treat extracted vapors, is regenerated on site using low pressure steam, which was subsequently condensed. The on-site solvent recovery system is used to separate VOCs from the condensate.

As of May 1994, the total capital costs and annual operating costs for this application were $5,313,973 and $99,810, respectively. While no performance data are available at this time, it was noted that the SVE system seems to be performing adequately. Several problems were experienced in the operation of the solvent recovery system. Condensed mixed solvents formed an emulsion which did not readily separate from the water. The report identifies a need to perform pilot testing of the solvent recovery system to ensure that separation of VOCs and water can be performed.

Soil Vapor Extraction at the Fairchild Semiconductor Corporation Superfund Site San Jose, California

<table>
<tr><td>Site Name:
Fairchild Semiconductor Corporation Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated and Non-Chlorinated Aliphatics
- TCA (trichloroethane), DCE (1,1-dichloroethene), IPA (isopropyl alcohol), xylenes, acetone, Freon-113, and PCE (tetrachloroethene)
- Maximum concentration of total solvents in soil was 4,500 mg/kg
- TCA - measured as high as 3,530 mg/kg in soil; xylenes as high as 141 mg/kg in soil</td><td>Period of Operation:
January 1989 to April 1990</td></tr>
<tr><td>Location:
San Jose, California</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Dennis Curran
Canonie Environmental Services Corporation
441 N. Whisman Road, Building 23
Mountain View, CA 94043
(415) 960-1640</td><td rowspan="3">Technology:
Soil Vapor Extraction
- 39 extraction wells, 2 vacuum pumps (capacity of 4,500 ft^3/min at 20 inches of Hg)
- Vapor treatment system - dehumidification unit and vapor phase granular activated carbon</td><td>Cleanup Authority:
CERCLA and State: California
- ROD Date: 3/20/89
- PRP Lead</td></tr>
<tr><td>SIC Code:
3674 (Semiconductors and Related Devices)</td><td rowspan="2">Point of Contact:
Belinda Wei
U.S. EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2280</td></tr>
<tr><td>Waste Source:
Underground Storage Tank</td></tr>
<tr><td>Purpose/Significance of Application:
One of the early full-scale applications of SVE; used at a site with a complex hydrogeology.</td><td colspan="2">Type/Quantity of Media Treated:
Soil
- 42,000 yds^3
- Sands, silts, and clays; air permeability 0.12-0.83 cm/sec; transmissivity - 69,000 to 810,000 gpd/ft</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
Operation of SVE system until total chemical removal rate was less than 10 lbs/day and the chemical removal rate from individual wells decreased to 10% or less of the initial removal rate or until the chemical removal rate declined at a rate of less than 1% per day for 10 consecutive days</td></tr>
<tr><td colspan="3">Results:
- Achieved the cleanup goal for the 10 lbs/day total chemical removal rate in 8 months
- After 16 months of operation, the removal rate for total chemicals was less than 4 lbs/day</td></tr>
<tr><td colspan="3">Cost Factors:
- Actual capital costs - $2,100,000 (including installation of wells and vapor extraction system, and engineering services)
- Total operation and maintenance costs for 16 months - $1,800,000 (including water quality sampling and analysis, water level monitoring, equipment maintenance, engineering services, and carbon regeneration)</td></tr>
</table>

Soil Vapor Extraction at the Fairchild Semiconductor Corporation Superfund Site San Jose, California (Continued)

Description:
The Fairchild Semiconductor Corporation Superfund site (Fairchild) is a former semiconductor manufacturing facility which operated from 1977 to 1983. In late 1981, an underground storage tank used to store organic solvent was determined to be leaking. An estimated 60,000 gallons of solvents were released to the soil and groundwater. The primary contaminants of concern in the soil were 1,1,1-trichloroethane (TCA), 1,1-dichloroethene (DCE), tetrachloroethene (PCE), xylene, acetone, Freon-113, and isopropyl alcohol (IPA). Reported concentrations of total solvents in the soil were as high as 4,500 mg/kg, with maximum concentrations of TCA and xylenes in soil of 3,530 mg/kg and 941 mg/kg, respectively. As part of a multi-site cooperative agreement between EPA, the State of California, and Fairchild, Fairchild conducted site remediation activities at the San Jose site, including installing a soil vapor extraction (SVE) system. The California Regional Water Quality Control Board established a soil cleanup goal for this remediation of a total chemical rate of less than 10 lbs/day, along with specific performance goals for individual wells.

The SVE system, which consisted of 39 extraction wells, operated from January 1989 to April 1990. The most rapid reductions in contaminant concentrations occurred during the first 2 months of operation. After 8 months of operation, the SVE system achieved the cleanup goal of less than 10 lbs/day for total chemical removed. After 16 months of operation, the system achieved a chemical removal rate of less than 4 lbs/day, at which time the system was shut off.

The total costs for the SVE treatment system at Fairchild were approximately $3,900,000. The actual costs were about 7% less than the projected costs because the time required for the cleanup was less than originally estimated. This treatment application was part of a multi-faceted cleanup program which included the installation of a slurry wall and dewatering of the aquifer which accelerated contaminant removal from the soil.

Soil Vapor Extraction at the Hastings Groundwater Contamination Superfund Site Well Number 3 Subsite, Hastings, Nebraska

<table>
<tr><td>Site Name:
Hastings Groundwater Contamination Superfund Site, Well Number 3 Subsite</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Carbon tetrachloride, chloroform, trichloroethylene (TCE), 1,1-dichloroethane (DCA), 1,1,1-trichloroethane (TCA), and perchloroethylene (PCA)
- Highest carbon tetrachloride concentration measured in soil gas was 1,234 ppmv at 112 ft below ground surface</td><td>Period of Operation:
June 1992 to July 1993</td></tr>
<tr><td>Location:
Hastings, Nebraska</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Steve Roe
Morrison-Knudsen Corporation
7100 East Belleview Avenue
Suite 300
Englewood, CO 80111
(303) 793-5089</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 10 extraction wells (5 deep, 3 intermediate, 2 shallow)
- 5 monitoring well probes
- An air/water separator, vacuum pump, and vapor phase granular activated carbon unit</td><td>Cleanup Authority:
CERCLA
- ROD Date: 9/26/89
- Fund Lead</td></tr>
<tr><td>SIC Code:
0723A (Crop Preparation Services for Market, Except Cotton Ginning-Grain Fumigation)</td><td>Point of Contact:
Diane Easley (RPM)
U.S. EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7797</td></tr>
<tr><td>Waste Source:
Spill; Other: Contaminated Aquifer</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 185,000 yd^3
- Shallow zone: moisture content 26.3%, air permeability 1.9 x 10^{-10} cm^2, TOC - 270 mg/kg
- Deep zone: moisture content 5%, air permeability 6.2 x 10^{-8} cm^2, TOC - < 50 mg/kg</td></tr>
<tr><td>Purpose/Significance of Application:
Full-scale SVE application at a Superfund site to treat a large quantity of soil contaminated with carbon tetrachloride.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
Extraction rate for carbon tetrachloride of 0.001 lb/hr
- Established in 1992 by EPA and Nebraska Department of Environmental Quality</td></tr>
</table>

Soil Vapor Extraction at the Hastings Groundwater Contamination Superfund Site Well Number 3 Subsite, Hastings, Nebraska (Continued)

Results:
- **The SVE system achieved the cleanup goal of 0.001 lb/hr extraction rate for carbon tetrachloride within 9 months of operation**
- **Approximately 600 pounds of carbon tetrachloride extracted, about 45 pounds extracted within the first 2 months of operation**

Cost Factors:
- **Total cost of $369,628 (including project monitoring and control, procurement support, construction management (drilling, construction, system dismantlement, and grouting of wells), operations, maintenance, and reporting)**

Description:

Soil Vapor Extraction (SVE) was used at the Hastings Groundwater Contamination Superfund site to treat approximately 185,000 cubic yards of soil contaminated with carbon tetrachloride (CCl_4). The site had become contaminated through accidental spills of carbon tetrachloride which was used in the 1960s and 1970s as a fumigant at a grain storage facility. Concentrations of CCl_4 were measured in soil gas at the site at levels as high as 1,234 ppmv. A Record of Decision (ROD) was signed in September 1989, specifying SVE as an interim source control measure.

A pilot-scale treatability study (2 deep and 2 shallow extraction wells), conducted from April to May 1991, removed 45 pounds of CCl_4. The full-scale SVE system, based on the pilot-scale study, consisted of 10 extraction wells (5 deep, 3 intermediate, and 2 shallow) and was operated from June 1992 to July 1993. EPA and the Nebraska Department of Environmental Quality established an extraction rate for CCl_4 of 0.001 lb/hr as the cleanup goal with operation of the system required until field analytical results were verified through laboratory analysis and confirmation of no rebounding of CCl_4. The SVE system achieved the 0.001 lb/hr CCl_4 extraction rate within 6 months (January 1993) with the results verified and no rebounding confirmed by July 1993.

The total cost for this treatment application was approximately $370,000. Actual costs were 17% less than projected. Cost savings were attributed to the effectiveness of the SVE system (the cleanup required only 9 months rather than the estimated 2 years based on treatability study results), and use of local contractors.

Soil Vapor Extraction and Bioventing for Remediation of a JP-4 Fuel Spill at Site 914, Hill Air Force Base, Ogden, Utah

<table>
<tr><td>Site Name:
Hill Air Force Base, Site 914</td><td rowspan="2">Contaminants:
Total Petroleum Hydrocarbons (TPH)
- TPH concentrations in untreated soil ranged from <20 to 10,200 mg/kg with average soil TPH concentration of 411 mg/kg</td><td>Period of Operation:
October 1988 to December 1990</td></tr>
<tr><td>Location:
Ogden, Utah</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Not Available</td><td rowspan="4">Technology: Soil Vapor Extraction followed by Bioventing
<u>SVE</u>
- 7 vent wells (Numbers 5-11 located in areas of highest contamination), 31 monitoring wells, 3 neutron access probes (for soil moisture monitoring)
- Vent wells approximately 50 feet deep with 4-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- Plastic liner installed over part of spill area surface to prevent local air infiltration and bypassing of air flow to the vent well directly from the surface
- Monitoring wells - ranged in depth from 6 to 55 feet with 1-inch diameter PVC casing and a 2-foot screened interval to the bottom of the well
- Catalytic incinerator for extracted vapor
- Air flow - 1,500 acfm (maximum), 700 acfm (typical)
<u>Bioventing</u>
- 4 vent wells (Numbers 12-15) located on the southern perimeter of the spill area; 31 monitoring wells; 3 neutron access probes (soil moisture monitoring)
- Vent wells approximately 50 feet deep with 4-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- Monitoring wells - range in depth from 6 to 55 feet with 1-inch diameter PVC casings, screened from 10 to 50 feet below ground surface
- No treatment of extracted vapors required (hydrocarbon concentrations <50 mg/L; use of catalytic incinerator not required)
- Air flow - 250 acfm
- Soil moisture - 6 to 12%
- Nutrients added - C:N:P ratio of 100:10:10</td><td>Cleanup Authority:
State: Utah</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td rowspan="3">Point of Contact:
Robert Elliot
OO-ACC/EMR
7274 Wardleigh Road
Hill AFB, UT 84055</td></tr>
<tr><td>Waste Source:
Spill of JP-4 Jet Fuel</td></tr>
<tr><td>Purpose/Significance of Application:
One of the early applications involving sequential use of SVE and bioventing technology.</td></tr>
</table>

Soil Vapor Extraction and Bioventing for Remediation of a JP-4 Fuel Spill at Site 914, Hill Air Force Base, Ogden, Utah (Continued)

Type/Quantity of Media Treated:
Soil
- **5,000 yds^3 contaminated by spill (surface area of 13,500 ft^2)**
- **Approximate extent of 10,000 mg/kg JP-4 contour covered area 100 by 150 feet**
- **Formation consists of mixed sands and gravels with occasional clay lenses**
- **Air permeability ranged from 4.7 to 7.8 darcies**

Regulatory Requirements/Cleanup Goals:
- **38.1 mg/kg TPH**
- **Cleanup conducted under Utah Department of Health's "Guidelines for Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites"**

Results:
- **Achieved specified TPH levels**
- **Average TPH soil concentrations in treated soil reduced to less than 6 mg/kg**
- **211,000 lbs of TPH removed in approximately 2 years of operation**
- **Removal rate ranged from 20 to 400 lbs/day**

Cost Factors:
- **Total costs of $599,000, including capital and 2 years of operating costs**
- **Capital costs - $335,000 (including construction of piping and wells, other equipment, and startup costs)**
- **Annual operating costs - $132,000 (including electricity, fuel, labor, laboratory charges, and lease of equipment for 2 year operation)**

Description:
In January 1985, an estimated 27,000 gallons of JP-4 jet fuel were spilled at the Hill Air Force Base Site 914 when an automatic overflow device failed. Concentrations of total petroleum hydrocarbons (TPH) in the soil ranged from <20 mg/kg to over 10,000 mg/kg, with an average concentration of about 400 mg/kg. The spill area covered approximately 13,500 ft^2.

The remediation of this spill area was conducted from October 1988 to December 1990 in two phases: the soil vapor extraction (SVE) phase followed by the bioventing phase. The SVE system included 7 vent wells (Numbers 5-11) located in the areas of highest contamination, 31 monitoring wells, and a catalytic incinerator. The typical air flow rate through the vent wells was 700 acfm, with a maximum of 1,500 acfm. In addition, a plastic liner was installed over part of the spill area surface to prevent local air infiltration and bypassing of air flow to the vent well directly from the surface. Within a year, the SVE system removed hydrocarbons from the soil to levels ranging from 33 to 101 mg/kg. Further reduction of the hydrocarbon concentration in the soil, to levels below the specified TPH limit, was achieved by using bioventing for 15 months. The bioventing system included 4 vent wells (Numbers 12-15), located on the southern perimeter of the spill area, and the monitoring wells used for SVE system. Because hydrocarbon concentrations were <50 mg/L in the extracted vapors, the catalytic incinerator was not required for this phase. Biodegradation was enhanced by injecting oxygen, moisture, and nutrients to the soil. Average TPH concentrations in the treated soil were less than 6 mg/kg.

The total capital cost for this application was $335,000 and the total annual operating costs were $132,000. In monitoring biodegradation rates, oxygen depletion was found to be a more accurate estimator of biodegradation rate than carbon dioxide formation. Carbon dioxide sinks, such as biomass, solubility in water, and reaction with the soil, limited the usefulness of carbon dioxide formation as a process control parameter.

Soil Vapor Extraction at North Fire Training Area (NFTA) Luke AFB, Arizona

Site Name:
Luke Air Force Base, North Fire Training Area

Contaminants:
Total Petroleum Hydrocarbons (TPH)
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX), and Methyl ethyl ketone (MEK)
- **Initial soil contamination in two fire training pits - Benzene - 0.2 to 16 mg/kg; Toluene - 10 to 183 mg/kg; Ethylbenzene - 21 to 84 mg/kg; Xylenes - 69 to 336 mg/kg; and Total Recoverable Petroleum Hydrocarbons (TRPH) - 151 to 1,380 mg/kg**

Period of Operation:
October 1991 to December 1992

Location:
Arizona

Cleanup Type:
Full-scale cleanup

Vendor:
Dan McCaffery
Envirocon, Inc.
James Ramm
Rust Environment

Technology:
Soil Vapor Extraction
- **1 extraction well for each of 2 fire pits**
- **Wells constructed with 35-foot screens to depths up to 57 feet**
- **Thermal oxidizer used for destruction of organics in extracted vapors**

Cleanup Authority:
State: Arizona

SIC Code:
9711 (National Security)

Point of Contact:
Jerome Stolinksi
CERMO
U.S. Army Corps of Engineers, Omaha District

Waste Source:
Fire Training Area

Type/Quantity of Media Treated:
Soil
- **Permeable silty sands, very permeable, clean well graded to poorly graded sands, and permeable to low permeability inorganic silts**
- **Moisture content 10%**
- **Permeability of top soils ranged from 1×10^{-4} to 3×10^{-3} cm/sec**
- **Porosity ranged from 36 to 46%**

Purpose/Significance of Application:
Full-scale cleanup of two fire training pits using soil vapor extraction.

Regulatory Requirements/Cleanup Goals:
- **Arizona Action Levels for soil - TPH - 100 mg/kg; and BTEX - 412 mg/kg**
- **Applicable state air emissions standards**

Results:
- **Treated soil concentrations indicated TPH and BTEX were below the Arizona Action Levels**
- **12,000 lbs of contaminants were removed during 30 weeks of operation**
- **Removal rate remained at 40 lbs/day after 30 weeks of operation**
- **Soil gas concentration reductions achieved in 6 months for 8 constituents ranged from 72 to 96% (benzene)**

Soil Vapor Extraction at North Fire Training Area (NFTA) Luke AFB, Arizona (Continued)

Cost Factors:
Total cost - $507,185
- **Capital costs - $297,017 (including site preparation, site work, startup, engineering, pipes, buildings, permitting, and regulatory)**
- **Annual operating costs - $210,168 (including labor, laboratory charges, monitoring, fuel, electricity, maintenance, and disposal of residuals)**

Description:
Routine fire training exercises were conducted at Luke Air Force Base in Arizona between 1963 and 1990, using petroleum, oil, and lubricant wastes, and JP-4 fuel. Fire training pits number 3 and 4 were used since 1973. During site investigations conducted between 1981 and 1989, soil at these two pits were determined to be contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). Cleanup goals were established for TPH and BTEX in soil based on Arizona Action Levels (AALs) - TPH at 100 mg/kg, and BTEX at 412 mg/kg.

A full-scale cleanup using Soil Vapor Extraction (SVE) of the soil in the two pits was conducted from October 1991 until December 1992. A thermal oxidizer was used for destruction of organic vapors extracted from the soil. The full-scale system, which used the thermal oxidizer, removed 12,000 pounds of contaminants in 30 weeks of operation. TPH and BTEX levels were below the AALs after five months of operation, with TPH and benzene reported as not detected in March 1992. Results of sampling in November 1992 showed ethylbenzene, toluene, and xylenes as not detected. System downtime was about 1% during this period. After a temporary shutdown period, an attempt to restart the system caused a malfunction in the thermal oxidizer and the destruction of the burner. As of December 1992, future activities at the site were pending.

The total cost of this treatment application was $507,185. It was noted that the site investigation underestimated the amount of contamination at the site. A pilot-scale study was conducted at Luke prior to implementing the full-scale system. The pilot-scale system used vapor-phase granular activated carbon to treat extracted soil gas. Due to unexpectedly high concentrations of volatile organic constituents, the carbon supply was exhausted after two days of operation and the study was aborted. In discussing remediation of sites contaminated with JP-4 jet fuel, the report includes a discussion of the relative benefits of using SVE and bioventing techniques.

In Situ Soil Vapor Extraction at McClellan Air Force Base California

<table>
<tr><td>Site Name:
McClellan Air Force Base Superfund Site, Operable Unit D, Site S</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
Tetrachloroethene (PCE), Trichloroethene (TCE), 1,1-Dichloroethene (1,1-DCE), Vinyl Chloride, 1,1,1-Trichloroethane (TCA), 1,2-Dichloroethene (1,2-DCA), Freon 113
- PCE, TCE, 1,1-DCE, TCA, and Freon 113 account for over 99% of the speciated VOC mass in the vadose zone
- Maximum borehole concentration of VOCs in vadose zone reported up to 2,975,000 μg/kg</td><td>Period of Operation:
Status - Ongoing
Report covers - 1993 to 5/94</td></tr>
<tr><td>Location:
Sacramento, California</td><td>Cleanup Type:
Field Demonstration</td></tr>
<tr><td>Vendor:
CH2M Hill</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 17 vapor extraction wells in three contamination zones
- 5 vacuum blowers, 2 vapor/liquid separators
- Catalytic oxidizer and scrubber used to control air emissions
- Total system average air flow rate was 2,500 scfm</td><td>Cleanup Authority:
CERCLA and State: California
- ROD Date: pending (scheduled for issuance mid-1995)</td></tr>
<tr><td>SIC Code:
9711 (National Security)</td><td>Point of Contact:
Kendall Tanner
Remedial Project Manager
McClellan, AFB</td></tr>
<tr><td>Waste Source:
Disposal Pit (for fuel and solvents)</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Three zones of contamination - waste pit (landfilled silty sands and sandy silt with oily material, wire wood, debris, etc.); intermediate alluvium; and deep alluvium
- Permeability ranged from 0.001 (for silty clay) to 1.7 (for sand) darcies</td></tr>
<tr><td>Purpose/Significance of Application:
A demonstration of soil vapor extraction to remediate VOCs in waste pit materials and vadose zone soils, and to assess performance of catalytic oxidation and scrubbing.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Cleanup criteria not yet established for this site at McClellan
- Air Emissions - 95% destruction of total VOCs, required by the Sacramento Air Quality Management District</td></tr>
</table>

In Situ Soil Vapor Extraction at McClellan Air Force Base California (Continued)

Results:
- **Demonstration not complete at time of report; no soil samples to characterize post-treatment vadose zone were collected at time of report**
- **Approximately 46,000 lbs of speciated VOCs were extracted and treated during initial 6 weeks of operation; 113,000 lbs during initial 15 weeks of operation**
- **TCE, 1,1-DCE, and TCA accounted for more than 90% of the mass of contaminants removed**
- **Up to 150,000 lbs of contaminants (hexane-equivalents) believed to have been biodegraded in situ during initial 6 weeks of operation**
- **Overall DRE averaged 99% for total VOCs during second and third months of demonstration; lower DRE in first month attributed to operational concerns**

Cost Factors:
- **Field demonstration budget - $1.8 million for 1993 and $2.0 million for 1994 (including site characterization; air permeability testing; installation and operation of SVE wells; vapor probes and manifold; air/water separators; blowers; scrubber; catalytic oxidizer (rented); resin adsorption (rented); electronic beam technology testing; laboratory analysis; and engineering support)**

Description:

The McClellan Air Force Base in Sacramento, California is an Air Force Command Logistics Center that has been in operation since 1943. The base was placed on the National Priorities List in 1987 and Site S within Operable Unit D is one of the areas of confirmed contamination at the base. Site S is the location of a former fuel and solvent disposal pit, used from the early 1940s to mid-1970s. Soil at Site S has been contaminated with chlorinated and petroleum-based volatile organic constituents (VOCs). No cleanup goals had been established for Site S at the time of this report. The report indicates that a Record of Decision for Operable Unit D (which includes the disposal pit site) is scheduled to be issued in mid-1995. A 95% destruction and removal efficiency (DRE) for total VOCs in the extracted vapors was required by the Sacramento Air Quality Management District.

A field demonstration of soil vapor extraction (SVE) at Site S began in mid-1993. This demonstration is being conducted as part of a series of field programs designed to optimize remedial technologies to be used in a full-scale cleanup at McClellan. This SVE system includes 17 vapor extraction wells, vapor/liquid separators, a catalytic oxidizer, and a scrubber. Results from the field demonstration of SVE to date showed that approximately 113,000 pounds of VOCs were extracted in 15 weeks of operation; mostly consisting of TCE, 1,1-DCE, and TCA. In addition, up to 150,000 pounds of contaminants (hexane-equivalents) were believed to have been biodegraded in situ during the initial 6 weeks of the SVE demonstration. The average DRE for total VOCs during the second and third months of the demonstration was 99 percent.

It was noted during this application that the heterogeneity of the soils at this site caused the radius of influence for the extraction wells to vary from 15 to 60 feet for a single well. The calculated mass of contaminants was almost two orders of magnitude less than the mass extracted in the first six weeks of system operation. It was also noted that SVE air pollution control systems should be designed with sufficient capacity to provide for operational flexibility.

Soil Vapor Extraction at the Rocky Mountain Arsenal Superfund Site Motor Pool Area (OU-18) Commerce City, Colorado

<table>
<tr><td>Site Name:
Rocky Mountain Arsenal Superfund Site (Motor Pool Area - Operable Unit 18)</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
- Trichloroethylene (TCE)
- Levels of TCE in soil vapor of up to 65 ppm</td><td>Period of Operation:
July 1991 to December 1991</td></tr>
<tr><td>Location:
Commerce City, Colorado</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Rick Beyak
Woodward-Clyde Federal Services
4582 S. Ulster St., Suite 1200
Denver, CO 80237
(303) 740-2600</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 1 shallow vapor extraction well and 1 deep vapor extraction well
- Shallow well screened between 13 and 28 feet below ground surface (bgs); deep well screened between 43 and 58 feet bgs
- Liquid/vapor separator tank, sediment filter, and regenerative blower
- Exhaust air from blower treated using two granular activated carbon systems in series</td><td>Cleanup Authority:
CERCLA
- Federal Facilities Agreement
- ROD Date: 2/26/90</td></tr>
<tr><td>SIC Code:
7699 (Repair Shops and Related Services, Not Elsewhere Classified)</td><td>Point of Contact:
James D. Smith
Program Manager
Rocky Mountain Arsenal
Attn: AMCPM-RME
Commerce City, CO 80022-1749
(303) 289-0249</td></tr>
<tr><td>Waste Source:
Other: Motor Vehicle, Railcar, and Heavy Equipment Maintenance, Repair, and Cleaning Activities</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 34,000 yd^3 (70 ft radius by 60 ft deep)
- Unconsolidated deposits beneath Motor Pool Area consist of discontinuous sand and gravel lenses
- 1-3 foot low-permeability clayey sand to clay layer 32 to 38 feet bgs
- Moisture content - 4.7 to 30.9%; permeability - 167 darcys at 38 ft bgs and 2,860 darcys at 55 ft bgs</td></tr>
<tr><td>Purpose/Significance of Application:
This application demonstrated that a pilot-scale SVE system removed sufficient vapor contaminants from the vadose zone, and expansion of the system beyond a pilot-scale was not necessary.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- No specific cleanup goals were specified for Motor Pool Area OU-18</td></tr>
<tr><td colspan="3">Results:
- TCE concentrations decreased to less than 1 ppm after 5 months of operation of the SVE system
- Rate of TCE extraction decreased from 35 pounds per month to less than 10 pounds per month
- Approximately 70 pounds of TCE removed during operation of the system</td></tr>
</table>

Soil Vapor Extraction at the Rocky Mountain Arsenal Superfund Site Motor Pool Area (OU-18) Commerce City, Colorado (Continued)

Cost Factors:

- **Costs attributed to treatment activities: $75,600 (installation and operation)**
- **Costs attributed to before-treatment activities: $88,490 (including mobilization and preparatory work, monitoring, and laboratory analytical)**
- **Costs attributed to after-treatment activities: $19,650 (including pilot study)**

Description:

Soil vapor extraction (SVE) was performed at the Rocky Mountain Arsenal (RMA) Superfund site, Motor Pool Area, in Commerce City, Colorado to remove halogenated volatile organic compounds (VOCs), primarily trichloroethylene, from the vadose zone. The Motor Pool Area at RMA, referred to as Operable Unit 18, had been used for cleaning and servicing equipment, vehicles, and railroad cars, and for storing diesel, gasoline, and oil products in aboveground and underground storage tanks. VOCs, detected in the Motor Pool Area's soil and groundwater have been attributed to releases of chlorinated solvents used during cleaning operations; these solvents were discharged through floor drains and pipes into unlined ditches at the site.

This system was initially considered to be a pilot study because it was expected to provide performance data on SVE at this site that could be used to expand the system to a full-scale operation. This application, operated from July to December 1991, demonstrated that a pilot-scale SVE system removed sufficient vapor contaminants from the vadose zone, and expansion of the system beyond pilot-scale was not necessary. The SVE system used within the Motor Pool Area consisted of one shallow vapor extraction well and one deep vapor extraction well. Four clusters of vapor monitoring wells were installed to aid in the assessment of the performance of the SVE system. TCE levels in soil vapors collected from the vapor monitoring wells were reduced to non-detect or to levels of less than 1 ppm from initial vapor monitoring well samples as high as 65 ppm. Approximately 70 pounds of TCE were recovered during this cleanup action.

The operating parameters collected during the system's 1991 operation indicated that a clay lense located beneath the site affected the SVE system's performance by limiting both the shallow and deep vapor extraction wells' vertical zones of influence. The contract award cost for procuring, installing, and operating the SVE pilot system, as well as preparing a pilot study report was $182,800. This cost was approximately 15% less than the preliminary cost estimate provided by the remediation contractor for the project. Factors contributing to the lower cost included lower construction and system operating costs.

Soil Vapor Extraction at the Sacramento Army Depot Superfund Site, Tank 2 Operable Unit Sacramento, California

<table>
<tr><td>Site Name:
Sacramento Army Depot Superfund Site, Tank 2 (Operable Unit #3)</td><td rowspan="2">Contaminants:
Chlorinated and Non-Chlorinated Aliphatics
- 2-Butanone (0.011 to 150 mg/kg); Ethylbenzene (0.006 to 2,100 mg/kg), Tetrachloroethene (0.006 to 390 mg/kg), and Xylenes (0.005 to 11,000 mg/kg)</td><td>Period of Operation:
August 1992 to January 1993</td></tr>
<tr><td>Location:
Sacramento, California</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
James Perkins
Terra Vac, Inc.
14798 Wicks Boulevard
San Leandro, CA 94577
(510) 351-8900</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 8 vacuum extraction wells, positive displacement blower, vapor-liquid separator, and primary and secondary carbon filters
- Wells installed to depths of 15 to 28 feet below ground surface</td><td>Cleanup Authority:
CERCLA and Other: Federal Facilities Agreement
- ROD Date: 12/9/91</td></tr>
<tr><td>SIC Code:
3471 (Electroplating, Plating, Polishing, Anodizing, and Coloring)
3479 (Coating, Engraving, and Allied Services, Not Elsewhere Classified)</td><td>Point of Contact:
Dan Obern
Sacramento Army Depot
8350 Fruitridge Road
Sacramento, CA 95813-5052
(916) 388-2489</td></tr>
<tr><td>Waste Source:
Underground Storage Tank</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 650 yd^3 (25 ft by 35 ft by 20 ft deep)
- Silt with clay content of <30%; moisture content - 25.6 to 26.5%; air permeability 1.7 x 10^{-7} to 6.2 x 10^{-5} cm/sec; porosity - 44.3 to 45.8%; TOC 0.011 to 0.44%</td></tr>
<tr><td>Purpose/Significance of Application:
This application of SVE was in a relatively small volume of low permeability, heterogenous, contaminated soil.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- 1991 ROD specified soil cleanup levels for the Tank 2 Operable Unit of 2-Butanone (1.2 ppm); ethylbenzene (6 ppm); tetrachloroethene (0.2 ppm); and total xylenes (23 ppm)
- Cleanup levels were to be achieved within 6 months of system operation</td></tr>
<tr><td colspan="3">Results:
- The specified cleanup levels were achieved within six months of system operation
- Levels of 2-butanone, ethylbenzene, tetrachloroethene, and total xylenes were reduced to below detection limits</td></tr>
<tr><td colspan="3">Cost Factors:
Total cost of $556,000 - costs directly associated with treatment (including mobilization/setup, startup, operation, sampling and analysis, demobilization)
- $290,000 of total cost attributed to treatment of non-Freon contaminants (adjusted assuming operation costs equivalent for Freon and non-Freon contaminants)</td></tr>
</table>

Soil Vapor Extraction at the Sacramento Army Depot Superfund Site, Tank 2 Operable Unit Sacramento, California (Continued)

Description:

The Sacramento Army Depot (SAAD) located in Sacramento, California is an Army support facility. Past and present operations conducted at the site include equipment maintenance and repair, metal plating, parts manufacturing, and painting. During investigations of the facility in 1981, soil contamination was identified in the area of an underground storage tank and designated as Tank 2 Operable Unit. Tank 2 had been used to store solvents and the primary contaminants of concern included ethylbenzene, 2-butanone, tetrachloroethene, and xylenes. These constituents were detected in the soil at levels up to 11,000 mg/kg. A Record of Decision (ROD), signed in December 1991, specified soil cleanup levels for the four primary constituents of concern and specified a six month timeframe for achieving these levels. SVE was selected for remediating the contaminated soil because it was determined to be the most cost effective alternative.

The SVE system consisted of 8 vacuum extraction wells, a vapor-liquid separator, and primary and secondary carbon adsorption units, and was operated from August 6, 1992 to January 25, 1993. The system achieved the specified soil cleanup levels a month ahead of the specified timeframe. In addition, the SVE system removed approximately 2,300 pounds of VOCs. During system operation, Freon 113 was unexpectedly encountered. Extraction of Freon 113 significantly increased the quantity of carbon required to treat the extracted vapors.

The total treatment cost for this application was $556,000. This cost was greater than originally estimated primarily as a result of the additional carbon required as a result of the presence of Freon 113. A computer model treatability study was used for this application. The study predicted SVE using 4 extraction wells could reduce concentrations of volatile organics to non-detectable levels within 6 months.

Soil Vapor Extraction at the SMS Instruments Superfund Site Deer Park, New York

Site Name:
SMS Instruments Superfund Site

Location:
Deer Park, New York

Contaminants:
Chlorinated and Non-Chlorinated Aliphatics and Semivolatile Organic Compounds
- **Concentration of specific volatiles ranged as high as 1,200 mg/kg in source area soils**
- **Concentration of specific semivolatiles ranged as high as 1,800 mg/kg in source area soils**

Period of Operation:
May 1992 to October 1993

Cleanup Type:
Full-scale cleanup

Vendor:
Bill Ballance
Four Seasons Environmental, Inc.
3107 South Elm - Eugene Street
P.O. Box 16590
Greensboro, NC 27416-0590
(919) 273-2718

Technology:
Soil Vapor Extraction
- **Two horizontal vapor extraction wells**
- **Installed in trenches 15-feet deep, 2-feet wide, and 75-feet long**
- **Extracted vapors treated using catalytic incineration and scrubbing**
- **Remote monitoring used for process control**

Cleanup Authority:
CERCLA and State: New York
- ROD Date: 9/29/89
- Fund Lead

SIC Code:
3728 (Aircraft parts and auxiliary equipment, not elsewhere classified)

Point of Contact:
Abram Miko Fayon
Remedial Project Manager
U.S. EPA Region 2
Jacob K. Javits Federal Building
New York, NY 10278-0012
(212) 264-4706

Waste Source:
Underground Storage Tank; Other: Leaching Pool

Type/Quantity of Media Treated:
Soil
- **1,250 cubic yards of soil treated in this application**
- **Well-sorted sands to silty sands with fine gravel**
- **Permeability 0.00227 to 0.00333 cm/sec**

Purpose/Significance of Application:
Full-scale SVE system that used horizontal vapor extraction wells and a process control system which allowed for remote system monitoring and oversight.

Regulatory Requirements/Cleanup Goals:
- **Soil cleanup levels established for 9 volatiles and 9 semivolatiles; levels ranged from 0.5 to 5.5 mg/kg**
- **Additional criteria specified for soil cleanup effort based on percent reductions**
- **Air emissions required to meet New York State ambient air guidelines for toxic air contaminants**

Results:
- **Soil cleanup levels and criteria were achieved within approximately 400 days after system operation began**

Soil Vapor Extraction at the SMS Instruments Superfund Site Deer Park, New York (Continued)

Cost Factors:

- **Total treatment system cost was $450,520 (including $182,700 for one year of monthly operation and maintenance, mobilization, system design and construction, demobilization, drum relocation)**

Description:

The SMS Instruments site in Deer Park, NY was used for overhauling military aircraft components. Past waste disposal practices at the site included discharging untreated wastewater from degreasing and other refurbishing operations to an underground leaching pool. In addition, jet fuel was stored at the site in an underground storage tank. The results of a Remedial Investigation at the site indicated soil contamination in the areas of the leaching pool and the underground storage tank. Contaminant concentrations in soil ranged as high as 1,200 mg/kg for volatiles and 1,800 mg/kg for semivolatiles. The New York Department of Environmental Conservation developed soil cleanup levels for 9 volatile and 9 semivolatile constituents.

Soil vapor extraction (SVE) was used at SMS to treat the contaminated soil. The SVE system, operated from May 1992 to October 1993, included two horizontal vapor extraction wells installed in trenches adjacent to the contaminated areas, a catalytic oxidizer, and acid gas scrubber. Based on the results of soil boring data, collected in June 1993, SVE achieved the cleanup levels and standards for 17 of the 18 specified organic constituents. For one constituent, BEHP, concentrations were above the specified cleanup level. However, according to the EPA RPM, this result may be an anomaly since the concentration of BEHP in the treated soil was greater than concentrations of BEHP identified during the remedial investigation at the site. In addition, the state ambient air guidelines were met during the operation of this system.

The total treatment cost for this application was $450,420. The treatment vendor indicated that the costs associated with instrumentation were greater than anticipated and that there was a problem with corrosion of ductwork. The vendor suggested several ideas for reducing costs of future similar applications including ways to reduce air monitoring costs.

Soil Vapor Extraction at the Verona Well Field Superfund Site, Thomas Solvent Raymond Road (OU-1) Battle Creek, Michigan

<table>
<tr><td>Site Name:
Verona Well Field Superfund Site, Thomas Solvent Raymond Road (OU-1)</td><td rowspan="2">Contaminants:
Chlorinated and Non-Chlorinated Aliphatics
- Tetrachloroethene (PCE), 1,1,1-trichloroethane, acetone, and toluene
- Light nonaqueous phase liquids (LNAPL) in groundwater
- Volume of organic compounds estimated to be 3,900 lbs in groundwater and 1,700 lbs in soil</td><td>Period of Operation:
March 1988 to May 1992</td></tr>
<tr><td>Location:
Battle Creek, Michigan</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Robert Pinewski
Terra-Vac, Inc.
9030 Secor Road
Temperance, MI 48182
(313) 847-4444</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 23 extraction wells with 14 of 23 wells in operation at a given time
- Catalytic oxidation and activated carbon adsorption of offgases</td><td>Cleanup Authority:
CERCLA
- ROD Date: 8/12/85
- Fund Lead</td></tr>
<tr><td>SIC Code:
7389 (Business Services, Not Elsewhere Classified)</td><td>Point of Contact:
Margaret Guerriero (RPM)
U.S. EPA Region 5
77 W. Jackson Boulevard
Chicago, IL 60604
(312) 886-0399</td></tr>
<tr><td>Waste Source:
Other: Solvent Storage, Blending, Repackaging, Distribution, and Disposal</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 26,700 yd^3 of soil (based on capture zone of 36,000 ft^2 and depth of 20 ft)
- Clay content < 5%
- Moisture content 5%
- Permeability 10^{-3} cm/sec</td></tr>
<tr><td>Purpose/Significance of Application:
EPA's first application of SVE at a Superfund site.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- 1991 ROD specified soil and groundwater cleanup standards for 19 constituents
- Standards in soil ranged from 0.014 mg/kg for carbon tetrachloride, 1,1-dichloroethane, 1,1-dichloroethene, and tetrachloroethene to 16 mg/kg for toluene
- Standards in groundwater ranged from 0.001 mg/L for vinyl chloride, 1,1,2-trichloroethane, tetrachloroethene, and benzene to 0.8 mg/kg for toluene</td></tr>
<tr><td colspan="3">Results:
- SVE achieved the cleanup standards for all VOCs
- A total of 45,000 lbs of VOCs were removed</td></tr>
</table>

Soil Vapor Extraction at the Verona Well Field Superfund Site, Thomas Solvent Raymond Road (OU-1) Battle Creek, Michigan (Continued)

Cost Factors:

- **Cost attributed to treatment activities - approximately $1,600,000 (including solids preparation and handling, mobilization/setup, startup/testing/permits, operation, cost of ownership, and demobilization)**
- **Cost attributed to before-treatment activities - approximately $480,000 (including monitoring, sampling, testing and analysis, and drums/tanks/structures/miscellaneous demolition and removal)**
- **Cost attributed to after-treatment activities - approximately $5,000 (including well abandonment and disposal of drums)**

Description:

The Verona Well Field Superfund site is the location of the former primary well field that supplied potable water for the city of Battle Creek, Michigan. In early 1984, 27 of the 30 wells were determined to be contaminated. The Thomas Solvent Raymond Road area was determined to be a source of contamination. Soil in this area was determined to be contaminated with chlorinated solvents, primarily tetrachloroethene and 1,1,1-trichloroethane. The amount of volatile organic compounds in the soil at this site was estimated to be 1,700 pounds.

Full-scale operation of an SVE system to treat the soil began in March 1988 and ran intermittently until May 1992. Over the course of the SVE operation, both carbon adsorption and catalytic oxidation were utilized to treat the extracted vapors prior to atmospheric discharge. Dual vacuum extraction and nitrogen sparging were implemented to enhance recovery rates during the latter stages of the groundwater remediation effort. A total of 45,000 pounds of VOCs were removed from the subsurface soil, and 10,000 pounds from the groundwater, during the remediation. Cleanup verification sampling of the soil occurred in June 1992 and the analytical results indicated that SVE reduced the constituent concentrations in the soil at this operable unit. The constituent-specific soil cleanup standards established in a 1991 ROD were met.

The cost attributed to treatment activities for this SVE application was approximately $1,600,000. The SVE system used at Verona accommodated both carbon adsorption and catalytic oxidation for the treatment of extracted vapors. Catalytic oxidation was identified as preferable for treatment of extracted vapors instead of carbon adsorption for the period of the application where the contaminant mass removed by SVE was much greater than 10 to 20 lb/day.

This page intentionally left blank.

5.0 REMEDIATION CASE STUDIES: THERMAL DESORPTION, SOIL WASHING, AND IN SITU VITRIFICATION

Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification

Thermal Desorption at the Anderson Development Company Superfund Site Adrian, Michigan

<table>
<tr><td>Site Name:
Anderson Development Company Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics, PAHs, Other Organics, and Metals
- MBOCA (4,4-methylene bis(2-chloroaniline) primary contaminant concentration in untreated soil
- Manganese at levels up to 10%</td><td>Period of Operation:
January 1992 to June 1993</td></tr>
<tr><td>Location:
Adrian, Michigan</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Michael G. Cosmos
Weston Services
1 Weston Way
West Chester, PA 19380
(610) 701-7423</td><td rowspan="2">Technology:
Thermal Desorption
- Solids pretreated by shredding, screening, and dewatering
- Thermal processor consisting of 2 jacketed troughs
- Hollow screw conveyors in the troughs mix, transport, and heat the contaminated soil
- Soil residence time 90 minutes, temperature of soil/sludge 500-530°F
- Treated soil was discharged into a conditioner, where it was sprayed with water</td><td>Cleanup Authority:
CERCLA and State: Michigan
- ROD Date: 9/30/91
- PRP Lead</td></tr>
<tr><td>SIC Code:
2869 (Industrial Organic Chemicals, Not Elsewhere Classified)</td><td>Point of Contact:
Jim Hahnenburg (HSRW-6J)
Remedial Project Manager
U.S. EPA Region 5
77 West Jackson Boulevard
Chicago, IL 60604
(312) 353-4213</td></tr>
<tr><td>Waste Source:
Surface Impoundment/Lagoon</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil and Sludge
- 5,100 tons treated
- Moisture content: soil - not available, sludge - 65-70% (before dewatering), 41-44% (after dewatering)
- pH: <7 (before dewatering), 10.9-11.2 (after dewatering)</td></tr>
<tr><td>Purpose/Significance of Application:
Treatment using a thermal auger system; main contaminant is a hardener for plastics.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Soil - MBOCA: 1.684 mg/kg
- Soils/sludges - VOCs and SVOCs: Michigan Environmental Response Act (MERA) Number 307, Regulation 299.5711, compliance with Type B criteria for soil standards; off-site disposal required for treated soil due to elevated manganese levels</td></tr>
<tr><td colspan="3">Results:
- Analytical data for 6 piles of treated soil indicated that the cleanup goals for MBOCA and VOCs were met
- Seven of eight SVOCs met cleanup goals; analytical problems were identified for bis(2-ethylhexyl)phthalate
- Treated soil disposed off site due to elevated manganese levels</td></tr>
<tr><td colspan="3">Cost Factors:
Information not available</td></tr>
</table>

Thermal Desorption at the Anderson Development Company Superfund Site Adrian, Michigan (Continued)

Description:
Between 1970 and 1979, the Anderson Development Company (ADC) site located in Adrian, Lewanee County, Michigan, was used for the manufacture of 4,4-methylene bis(2-chloroaniline) or MBOCA, a hardening agent used in plastics manufacturing. Process wastewaters were discharged to an unlined lagoon. A remedial investigation determined that soil and sludges in and around the lagoon were contaminated. Contaminated soils and sludges were excavated, dewatered, and stockpiled. A Record of Decision (ROD), signed in September 1991, specified thermal desorption as the remediation technology for the excavated soil. Soil cleanup goals were established for MBOCA and specific volatile and semivolatile organic constituents.

Thermal desorption using the Roy F. Weston LT^3 system was performed from January 1992 to June 1993. The LT^3 thermal processor consists of two jacketed troughs. Hollow-screw conveyors move soil across the troughs, and act to mix and heat the contaminated soil. The thermal processor discharges treated soil to a conditioner where it is sprayed with water. Thermal desorption achieved the soil cleanup goals specified for MBOCA and all volatile organic constituents. Seven of eight semivolatile organic constituents met cleanup goals; analytical problems were identified for bis(2-ethylhexyl)phthalate.

Information on costs for this application were not available at the time of this report. Originally, the treated soils were to be used as backfill for the lagoon. However, the state required off-site disposal of treated soils due to the presence of elevated levels of manganese.

Soil Washing at the King of Prussia Technical Corporation Superfund Site Winslow Township, New Jersey

<table>
<tr><td>Site Name:
King of Prussia Technical Corporation Superfund Site</td><td rowspan="2">Contaminants:
Metals
- Beryllium, chromium, copper, nickel, zinc, lead, mercury
- Highest metals concentrations in sediments - chromium (8,010 mg/kg), copper (9,070 mg/kg), mercury (100 mg/kg)
- Highest metals concentration in sludge - chromium (11,300 mg/kg), copper (16,300 mg/kg), lead (389 mg/kg), nickel (11,100 mg/kg)</td><td>Period of Operation:
June 1993 to October 1993</td></tr>
<tr><td>Location:
Winslow Township, New Jersey</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Mike Mann
Alternative Remediation Technologies, Inc.
14497 Dale Mabry Highway
Tampa, FL 33618
(813) 264-3506</td><td rowspan="2">Technology:
Soil Washing
Materials Handling
- Selective excavation of metals-contaminated soil using visual inspection, confirmed using on-site X-ray fluorescence
Soil Washing System
- Four components - screening, separation, froth flotation, sludge management; rated feed capacity of 25 tons/hour
- Screening - multiple screens; coarse screen (>8 inches) and process oversize (>2 inches); wet screening of <2 inch materials
- Separation - hydroclones separate coarse and fine-grained materials
- Froth flotation - air flotation treatment units
- Sludge management - overflow from hydroclones sent through clarifier, sludge thickener, filter press; filter cake disposed off site; water reused for wet screening</td><td>Cleanup Authority:
CERCLA
- ROD Date: 9/28/90
- PRP Lead</td></tr>
<tr><td>SIC Code:
4953 (Sanitary Services-Refuse Systems)</td><td>Point of Contact:
John Gorin
Remedial Project Manager
U.S. EPA Region 2
26 Federal Plaza
New York, NY
(202) 264-7592</td></tr>
<tr><td>Waste Source:
Surface Impoundments/Lagoons</td><td colspan="2">Type/Quantity of Media Treated:
Soil and Sludge
- 19,200 tons of soil and sludge
- Moisture content of approximately 15%
- pH of approximately 6.5</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
EPA's first full-scale application of soil washing to remediate a Superfund site. Innovative on-site monitoring technique; selective excavation techniques, including use of X-ray fluorescence, to screen soil for cleanup.</td></tr>
</table>

Soil Washing at the King of Prussia Technical Corporation Superfund Site Winslow Township, New Jersey (Continued)

Regulatory Requirements/Cleanup Goals:
1990 ROD identified soil cleanup levels for 11 metals
- **Arsenic (190 mg/kg), beryllium (485 mg/kg), cadmium (107 mg/kg), chromium (483 mg/kg), copper (3,571 mg/kg), lead (500 mg/kg), mercury (1 mg/kg), nickel (1,935 mg/kg), selenium (4 mg/kg), silver (5 mg/kg), zinc (3,800 mg/kg)**

Results:
- **Cleanup goals were met for all 11 metals**
- **Cleanup goals were achieved in less than 4 months**

Cost Factors:
- **Total cost of $7,700,000 (including off-site disposal cost)**

Description:
The King of Prussia (KOP) Technical Corporation Superfund site had been used as a waste recycling facility from 1971 to 1974. An estimated 15 million gallons of liquid industrial waste were processed in six lagoons. These activities resulted in soil and sludge contamination at the site. The primary constituents of concern were chromium (at levels up to 11,300 mg/kg), copper (at levels up to 16,300 mg/kg), and nickel (at levels up to 11,100 mg/kg). The ROD, signed in September 1990, specified complete excavation of soils, sediments, and sludges from these lagoons and use of contaminant extraction (soil washing) to achieve the specified soil cleanup levels for 11 metals.

The soil washing system at KOP was selected based on the results of a treatability study and data from a demonstration run using KOP soil at a full-scale unit in the Netherlands. The soil washing system was operated at KOP from June 1993 to October 1993. The system consisted of a series of hydroclones, conditioners, and froth flotation cells. Approximately 19,200 tons of contaminated soil and sludge were treated during this application. The soil washing system achieved the specified soil cleanup levels for all 11 metals, and the treated soil was used as backfill at the site. Of note for this full-scale cleanup was the use of selective excavation techniques to screen contaminated soil and sludge for treatment. Selective excavation was performed through visual examination confirmed using on-site X-ray fluorescence, and resulted in fewer tons of soil requiring treatment.

The total cost for this application was $7,700,000, including off-site disposal costs for the sludge cake. Selective excavation reduced the overall costs for the application by reducing the amount of soil requiring treatment by a factor of two. Further, the data from the demonstration run expedited the design schedule of the full-scale unit by more than a year.

Thermal Desorption at the McKin Company Superfund Site Gray, Maine

<table>
<tr><td>Site Name:
McKin Company Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics; Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX); Polynuclear Aromatic Hydrocarbons (PAHs)
- Excavated soil contained up to 3,310 mg/kg TCE, 130 mg/kg Ethylbenzene, and 35 mg/kg Toluene</td><td>Period of Operation:
July 1986 to April 1987</td></tr>
<tr><td>Location:
Gray, Maine</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Canonie Environmental
800 Canonie Drive
Porter, IN 46304
(219) 926-8651</td><td rowspan="2">Technology:
Thermal Desorption
- Rotary kiln desorber 7 feet in diameter and 28 feet long
- Soil heated to 250-400°F and a residence time of 6 minutes
- Offgases treated using HEPA filter, baghouse, scrubber, and carbon adsorption</td><td>Cleanup Authority:
CERCLA
- ROD Date: 7/22/85
- PRP Lead</td></tr>
<tr><td>SIC Code:
4953E (Refuse Systems - Sand and Gravel Pit Disposal)</td><td>Point of Contact:
Sheila Eckman
Remedial Project Manager
U.S. EPA Region I
John F. Kennedy Federal Bldg., Room 2203
Boston, MA 02203
(617) 573-5784</td></tr>
<tr><td>Waste Source:
Disposal Pit</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 11,500 cubic yards
- No information available on matrix characteristics</td></tr>
<tr><td>Purpose/Significance of Application:
This treatment application is notable for being one of the earliest full-scale applications of thermal desorption to remediate halogenated volatile organic compounds at a Superfund site.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Soil performance standard of 0.1 mg/kg for TCE, with retreatment as necessary
- Performance standards of 1 mg/kg for individual aromatic organic compounds, 1 mg/kg for individual PAHs, and 10 mg/kg for total PAHs</td></tr>
<tr><td colspan="3">Results:
- All cleanup goals achieved
- 11,500 tons of soil treated within 10-month period
- Ambient air concentrations for VOCs were less than 2 ppm above background</td></tr>
</table>

Thermal Desorption at the McKin Company Superfund Site Gray, Maine (Continued)

Cost Factors:
- Total Cost - $2,900,000 (including salaries and wages, rental, supplies, subcontracts, fuel, and other professional services)

Description:
The McKin Company (McKin), in Gray, Maine, was a former waste collection, transfer, storage, and disposal facility. Soil at McKin was contaminated with halogenated VOCs and petroleum products, including polynuclear aromatic hydrocarbons (PAHs) and aromatic compounds. During the remedial investigation at McKin, soil contamination levels were measured as high as 1,500 mg/kg for trichloroethylene (TCE), 49 mg/kg for methylene chloride, and 21 mg/kg for xylenes. The ROD identified several areas at McKin that required on-site thermal desorption treatment for contaminated soil. These areas were grouped into a "VOC-Contaminated Area" and a "Petroleum-Contaminated Area." The treatment performance standard, stipulated in the ROD, required treatment of TCE in the soil to a concentration of 0.1 mg/kg. In addition to the TCE requirement, treatment performance standards for PAHs and aromatic organics were specified for the petroleum-contaminated area. Ambient air monitoring was required during the application.

The thermal desorption system included a rotary kiln desorber with offgases treated using a filter, baghouse, scrubber, and carbon adsorption. Thermal desorption of approximately 11,000 cubic yards of soil was completed at McKin between July 1986 and April 1987. This treatment application is notable for being one of the earliest full-scale applications of thermal desorption to remediate halogenated volatile organic compounds at a Superfund site. Treatment performance and air monitoring data collected during this application indicated that all performance standards and monitoring requirements were achieved through use of the thermal desorption technology.

The total cost for this application was $2,900,000. According to the vendor, this cost included rental supplies, labor, subcontracts, fuel and other professional services, and estimated that over 80% of the cost was associated with the treatment of the contaminated soil. A pilot-scale treatability study indicated that thermal desorption would be effective in treating soils at the McKin site.

Thermal Desorption at the Outboard Marine Corporation Superfund Site Waukegan, Illinois

<table>
<tr><td>Site Name:
Outboard Marine Corporation Superfund Site</td><td rowspan="2">Contaminants:
Polychlorinated Biphenyls (PCBs)
- PCB concentrations in material feed to thermal desorber ranged from 2,400 to 23,000 mg/kg PCBs</td><td>Period of Operation:
January 1992 to June 1992</td></tr>
<tr><td>Location:
Waukegan, Illinois</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Joseph Hutton
SoilTech ATP System, Inc.
800 Canonie Drive
Porter, IN 46304
(219) 926-8651</td><td rowspan="2">Technology:
Thermal Desorption
- Rotary kiln desorber with proprietary sand seals
- Retort zone temperature 1,207°F
- Preheat and retort zone residence time 30-40 minutes
- Air emissions controlled using cyclones, baghouse, scrubbers, fractionator, condenser, gas-oil-water separator, and carbon adsorption
- Water treated on site using sand filtration, Klensorb® filtration, ultraviolet oxidation, cartridge filtration, and carbon adsorption</td><td>Cleanup Authority:
CERCLA
- ROD Date: 3/31/89
- PRP Lead</td></tr>
<tr><td>SIC Code:
3363 (Aluminum Die-Casting)</td><td>Point of Contact:
Bill Bolen - RPM
(Cindy Nolan - former RPM)
U.S. EPA, Region 5
77 West Jackson
Chicago, IL 60604
(312) 353-6316</td></tr>
<tr><td>Waste Source:
Other: Discharge to Sewer/Surface Water; Surface Disposal Area</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil and Sediment
- 12,755 tons treated
- 12.9% moisture; pH of 8.59</td></tr>
<tr><td>Purpose/Significance of Application:
This application was an early application of SoilTech's ATP system for treating soil and sediment at a Superfund Site contaminated with PCBs.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Soil and Sediment - PCBs: 97% removal by mass
- Air - PCBs: Destruction and Removal Efficiency (DRE) of 99.9999%, Dioxins/Furans: 30 ng/dscm</td></tr>
<tr><td colspan="3">Results:
Soil and Sediment - Achieved PCB cleanup goal for soil and sediment; average PCB removal efficiency of 99.98%; PCB concentrations in treated soil ranged from 0.4 mg/kg to 8.9 mg/kg; most samples less than 2 mg/kg
Air - Stack gas requirements met for PCBs; stack gas requirements met for dioxins/furans after system modifications</td></tr>
</table>

Thermal Desorption at the Outboard Marine Corporation Superfund Site Waukegan, Illinois (Continued)

Cost Factors:

- **$2,474,000 - Actual total costs for cost elements directly associated with treatment (including solids preparation and handling, startup/testing/permits, operation, capital equipment, and demobilization)**
- **$900,000 for before-treatment costs (including mobilization and preparatory work, and monitoring, sampling, testing, and analysis)**

Description:

Outboard Marine Corporation (OMC), located on Lake Michigan, performed marine product manufacturing operations at the site. Contamination of the soil and sediments at the site resulted from the discharge of hydraulic fluid containing PCBs through floor drains which discharged to several areas at the site and into Waukegan Harbor. An estimated 700,000 pounds of PCBs were discharged to the OMC site and 300,000 pounds of PCBs were discharged to Waukegan Harbor. Based on a 1989 Consent Decree and Record of Decision, remedial activities selected for the site included excavation, stockpiling, and treatment of soil and sediment contaminated with PCBs. A cleanup goal for PCBs in soil and sediment of 97% removal was specified in the 1989 ROD.

SoilTech's mobile Anaerobic Thermal Processor (ATP) system was selected for treating the PCB-contaminated soil and sediment at OMC. The ATP system was operated at the site from January 23, 1992 until June 23, 1992. During this time, 12,755 tons of PCB-contaminated soils and sediments were treated. The ATP system met the cleanup goal for PCBs in soil and sediment by achieving an average removal efficiency of 99.98% for total PCB concentrations. PCBs in treated soil ranged from 0.4 to 8.9 mg/kg. The PCB DRE of 99.9999% and total dioxin and furan stack emission requirements of 30 ng/dscm were met during the cleanup.

During the proof-of-process period (January 23 until March 5), the DRE for PCBs was not met, and EPA shut the system down. From March 5 until May 30, SoilTech made modifications to the system, and the stack gas emissions requirements were met during the remainder of the soil cleanup. An EPA SITE Demonstration was conducted at the OMC site in June 1992. During this demonstration, 255 tons of soil and sediment were treated. The total cost for the full-scale application of thermal desorption at the OMC site was $2,474,000.

In Situ Vitrification at the Parsons Chemical/ETM Enterprises Superfund Site Grand Ledge, Michigan

<table>
<tr><td>Site Name:
Parsons Chemical/ETM Enterprises Superfund Site</td><td rowspan="2">Contaminants:
Pesticides, Heavy Metals, Phthalates, Polynuclear Aromatic Hydrocarbons (PAHs), and Dioxins
- Pesticides - up to 340 mg/kg for DDT
- Heavy metals - up to 34 mg/kg for mercury
- Dioxin - up to 1.13 μg/kg</td><td>Period of Operation:
May 1993 to May 1994</td></tr>
<tr><td>Location:
Grand Ledge, Michigan</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
James E. Hanson
Geosafe Corporation
2950 George Washington Way
Richland, WA 99352
(509) 375-0710</td><td rowspan="2">Technology:
In Situ Vitrification
- 9 melt cells; each cell 26 feet by 26 feet with cells installed in a 16-foot deep treatment trench
- Air emissions control system - offgas collection, hood, water scrubber, and thermal oxidizer</td><td>Cleanup Authority:
CERCLA (Removal Action) and State: Michigan
- Action Memo Date: 9/21/90
- Fund Lead</td></tr>
<tr><td>SIC Code:
2879 (Agricultural Chemicals, Not Elsewhere Classified)</td><td>Point of Contact:
Len Zintak, OSC
U.S. EPA Region 5
77 West Jackson Boulevard
Chicago, IL 60604
(312) 886-4246</td></tr>
<tr><td>Waste Source:
Other: Discharge to sewer/surface water (floor drains, septic tank, leach field)</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 3,000 cubic yards
- Silty clay with high moisture content
- Soil reported to be difficult to work with under very wet and very dry conditions</td></tr>
<tr><td>Purpose/Significance of Application:
First application of full-scale in situ vitrification at a Superfund site to treat soils and sediments contaminated with pesticides, heavy metals, and dioxins.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Soil cleanup standards and standards for offgases established for four constituents. Soil cleanup/offgas standards were - chlordane (1 mg/kg / 25 lbs/hr); DDT (4 mg/kg / 0.01 lbs/hr); dieldrin (0.08 mg/kg / 0.00028 lbs/hr); mercury (12 mg/kg / 0.00059 lbs/hr)
- Offgas standards based on State ARARs</td></tr>
</table>

In Situ Vitrification at the Parsons Chemical/ETM Enterprises Superfund Site Grand Ledge, Michigan (Continued)

Results:
- **Specific performance data for soils were not available at the time of this report**
- **According to the vendor, near-surface vitrified materials had "acceptable" levels of pesticides and mercury**
- **Additional samples will not be taken until after the melt has cooled (estimated May 1995)**
- **Data on air emissions indicates offgases met the state air emissions standards**

Cost Factors:
- **Cost objectives were $800,000 for vitrification activities; approximately $800,000 for before-treatment activities (mobilization, site administration and preparation, sampling and analysis, and site configuration); and $90,000 for after-treatment activities (backfill and restoration, drainage structures, and demobilization)**

Description:

A full-scale soil remediation system using in situ vitrification (ISV) was conducted at the Parsons Chemical/ETM Enterprises Superfund site (Parsons). Soils and sediments at the site were contaminated with pesticides, heavy metals, phthalates, PAHs, and dioxins as a result of former agricultural chemical manufacturing processes. Dioxin levels in soil at the site were reported as high as 1.13 μg/kg. Maximum levels of other contaminants in the soil range from 0.99 mg/kg for phenanthrene to 340 mg/kg for DDT. Soil cleanup requirements were established for four constituents (chlordane, DDT, dieldrin, and mercury). In addition, the offgases from the ISV unit were required to meet state air requirements for these constituents during operation.

The ISV system used at Parsons included 9 melt cells and an air emissions control system. Contaminated soil was excavated and staged at the site due to the shallow nature of the contamination. The melt cells were installed in a treatment trench. Eight melts were completed from June 1993 to May 1994. The melts ranged in duration from 10 to 19.5 days and consumed between 559,000 and 1,100,000 kilowatt-hours of electricity per melt. Several operational problems were encountered during this period including fires and equipment problems. These problems were addressed through modifications to equipment and operating practices.

Because the melt requires approximately one year to cool before samples of the subsurface can be collected, data on the performance of the ISV will not be available until after May 1995. According to the vendor, initial results of samples taken from the surface indicate that near-surface vitrified materials contained acceptable levels of pesticides and mercury. Data on typical air emissions indicates that stack gas emissions were in compliance with state standards during operation. The cost ceiling identified in the action memorandum for this application was $1,763,000.

Thermal Desorption at the Pristine, Inc. Superfund Site Reading, Ohio

<table>
<tr><td>Site Name:
Pristine, Inc. Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics, Pesticides, Polynuclear Aromatic Hydrocarbons (PAHs), and Metals
- VOCs up to 0.14 ppm
- SVOCs up to 130 ppm
- 4,4'-DDT ranging from 0.11 ppm to 8.2 ppm
- Lead ranging from 26 ppm to 1,100 ppm</td><td>Period of Operation:
November 1993 to March 1994</td></tr>
<tr><td>Location:
Reading, Ohio</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Joseph Hutton
SoilTech ATP System, Inc.
800 Canonie Drive
Porter, IN 46304
(219) 926-8651</td><td rowspan="2">Technology:
Thermal Desorption
- Rotary kiln desorber with proprietary sand seals
- Retort zone temperature 1,009.9-1,034.1°F
- Air emissions controlled using cyclones, baghouse, scrubbers, fractionator, condenser, and gas-oil-water separator
- Water treated on site using oil/water separation, hydrogen peroxide oxidation, sand filtration, and carbon adsorption</td><td>Cleanup Authority:
CERCLA
- ROD Date: 3/30/90
- PRP Lead</td></tr>
<tr><td>SIC Code:
4953W - Waste Management; Refuse Systems (Waste Processing Facility, Miscellaneous)</td><td>Point of Contact:
Tom Alcamo
Remedial Project Manager
U.S. EPA - Region 5
230 South Dearborn Street
Chicago, IL 60604
(312) 886-7278</td></tr>
<tr><td>Waste Source:
Storage-Drums/Containers; Waste Treatment Plant</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Approximately 12,800 tons treated
- 12-25% moisture; pH of 1-2 for some feed soils</td></tr>
<tr><td>Purpose/Significance of Application:
This application is notable for treating soils with a wide range of pH and moisture conditions.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Soil - Numeric cleanup goals identified for 11 constituents, including PAHs, pesticides, dioxin, benzene, and chlorinated aliphatics; cleanup goals ranged from 0.99 to 3,244 μg/kg
- Air - Total Dioxins/Furans: <30 mg/dscm, particulates: 0.015 gr/dscf, and four other stack gas emission parameters</td></tr>
<tr><td colspan="3">Results:
Soil - Cleanup goals for all constituents were met in all soil piles tested; 6 of 11 constituents removed to levels at or below detection limit
Air - Stack gas requirements met for dioxin/furan emissions and particulates</td></tr>
</table>

Thermal Desorption at the Pristine, Inc. Superfund Site Reading, Ohio (Continued)

Cost Factors:
No data available

Description:
Pristine, Inc. performed liquid waste disposal operations at the site from 1974 to 1981. Spills and on-site disposal of treated wastes led to soil contamination. Soils at the Pristine site were contaminated with volatile and semivolatile organics, polynuclear aromatic hydrocarbons (PAHs), pesticides, and metals. The soils also contained greater than 2% of elemental sulfur. This application was notable for treating soil with a wide range of pH and moisture conditions.

SoilTech's 10 ton/hr mobile Anaerobic Thermal Processor (ATP) system was used for treating the contaminated soil at the Pristine site. The SoilTech ATP system included a feed system, the ATP unit (rotary kiln thermal desorber), a vapor recovery system, a flue gas treatment system, and a tailings handling system. Wastewater from the vapor recovery system was treated in an on-site wastewater treatment system. The ATP system was operated at the Pristine site from November 1, 1993 until March 4, 1994 and was used to treat approximately 12,800 tons of contaminated soil.

The ATP System treated contaminants in soil to levels below the cleanup goals. Levels of 6 of the 11 target constituents were reduced to concentrations at or below the reported detection limits. All stack gas air emission performance standards were met in this application, with occasional spikes of THC over the 20 ppm performance standard. Average throughput was approximately 6.5 tons/hr, and average on-line availability was approximately 62 percent.

Thermal Desorption at the T H Agriculture & Nutrition Company Superfund Site Albany, Georgia

<table>
<tr><td>Site Name:
T H Agriculture & Nutrition Company Superfund Site</td><td rowspan="2">Contaminants:
Halogenated Organic Pesticides
- Dieldrin, toxaphene, DDT, lindane</td><td>Period of Operation:
July 1993 to October 1993</td></tr>
<tr><td>Location:
Albany, Georgia</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Mark Fleri
Williams Environmental Services, Inc.
2076 West Park Place
Stone Mountain, GA 30087
(404) 498-2020</td><td rowspan="2">Technology:
Thermal Desorption
- Rotary dryer desorber
- Temperature of soil exiting heating chamber ranged from 833 to 1,080°F
- Soil residence time 15 minutes
- Offgases - routed through a baghouse, a water quenching unit, a reheater, and a vapor phase carbon adsorption bed</td><td>Cleanup Authority:
CERCLA (Removal Action) and State: Georgia
- Unilateral Administrative Order - 3/92
- PRP Lead</td></tr>
<tr><td>SIC Code:
2879 (Pesticides and Agricultural Chemicals, Not Elsewhere Classified)</td><td>Point of Contact:
R. Donald Rigger
On-Scene Coordinator
U.S. EPA Region IV
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-3931</td></tr>
<tr><td>Waste Source:
Manufacturing Process</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 4,300 tons
- Bulk density - 125.8 to 129.7 lbs/ft^3; moisture content - 13 to 19%; pH - 5.7 to 6.2; particle size distribution - up to 2.38 mm; TOC - 0.2 to 0.23 mg/kg</td></tr>
<tr><td>Purpose/Significance of Application:
First full-scale application of thermal desorption under the Superfund program to remediate soil contaminated with a mixture of organochlorine pesticides.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
Cleanup goals identified in March 1992 Unilateral Administrative Order and October 1992 Treatability Variance for proof-of-process performance test and full-scale treatment
- Total OCL pesticides < 100 mg/kg and 4 constituents (DDT, toxaphene, BHC-alpha, BHC-beta) > 90% measured reduction in concentration; air emissions - stack gas total hydrocarbons < 100 ppmv
- Additional air emissions limits during proof-of-process test - Georgia Guideline for Ambient Impact Assessment of Toxic Air Pollutant Emissions</td></tr>
</table>

Thermal Desorption at the T H Agriculture & Nutrition Company Superfund Site Albany, Georgia (Continued)

Results:
- **The cleanup goals for soil were met for both total OCL pesticides and individual constituents**
- **Air emission standards were achieved during both the proof-of-process test and during the full-scale remediation**
- **Average OCL pesticides concentration in treated soil was 0.51 mg/kg**
- **Average removal efficiencies for individual constituents were greater than 98%**

Cost Factors:
- **Estimated Total Treatment Cost - $849,996 (including solids preparation and handling, mobilization, startup, system operation, and demobilization)**
- **Estimated Before-Treatment Costs - $252,582 (including mobilization and preparatory work, monitoring, sampling, testing, and analysis, including the treatability study)**

Description:

The T H Agriculture & Nutrition (THAN) Company Superfund site in Albany, Georgia was used from the 1950s to 1982 for pesticide formulation and storage. As a result of these operations, soils at the site were contaminated with pesticides, primarily organochlorine (OCL) pesticides and the site was placed on the National Priorities List (NPL) in 1989. In March 1992, EPA issued a Unilateral Administrative Order to THAN for removal of contaminated soil and debris. Contaminated soil with concentrations of OCL pesticides greater than 1,000 mg/kg was excavated and stockpiled.

Thermal desorption was used at THAN to treat approximately 4,300 tons of stockpiled soil contaminated with OCL pesticides. The thermal desorption unit consisted of a rotary kiln thermal desorber operated at 833 to 1,080°F (soil exit temperature) and a 15-minute residence time. An interlock (waste feed cutoff) process control system was used in this application to maintain operation of the unit within allowable limits. The system was operated from July to October 1993. Thermal desorption achieved the specified cleanup levels for OCL pesticides and air emission rates. Total OCL pesticide concentrations in the treated soil ranged from 0.009 to 4.2 mg/kg with an average concentration of 0.5 mg/kg. Average removal efficiencies for the four target OCL pesticides were greater than 98%.

The total estimated treatment cost for this application was approximately $850,000. The proof-of-process performance test results provided information on operating conditions and air emissions that were used for the full-scale treatment application. In addition, the bench-scale treatability study provided data to support a treatability variance request by THAN, approved by EPA in October 1992, to place treated soils on site.

Thermal Desorption/Dehalogenation at the Wide Beach Development Superfund Site Brant, New York

<table>
<tr><td>Site Name:
Wide Beach Development Superfund Site</td><td rowspan="2">Contaminants:
Polychlorinated Biphenyls (PCBs)
- Stockpiled soil contained 10 to 5,000 mg/kg PCBs
- Material feed to thermal desorber contained 11 to 68 mg/kg PCBs</td><td>Period of Operation:
October 1990 to September 1991</td></tr>
<tr><td>Location:
Brant, New York</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Joseph Hutton
SoilTech ATP System, Inc.
800 Canonie Drive
Porter, IN 46304
(219) 926-8651</td><td rowspan="2">Technology:
Thermal Desorption/Dehalogenation
- Rotary kiln desorber with proprietary sand seals
- Retort zone temperature 1,160°F
- Preheat and retort zone residence time 30-40 minutes
- Alkaline polyethylene glycol (APEG) sprayed onto contaminated soil to dechlorinate PCBs
- Air emissions controlled using cyclones, baghouse, scrubbers, fractionator, condenser, gas-oil-water separator, and carbon adsorption
- Water treated on site using filtration, oxidation, settling, air stripping, and carbon adsorption</td><td>Cleanup Authority:
CERCLA and State: New York (per interagency agreement between EPA and USACE)
- ROD Date: 9/30/85
- Fund Lead</td></tr>
<tr><td>SIC Code:
Not applicable</td><td>Point of Contact:
Herb King (RPM)
U.S. EPA Region 2
26 Federal Plaza
New York, NY 10278
(212) 264-1129
Joe Salvatore
USACE c/o 914 TAG, Bldg. 322
Niagara Falls Int'l. Airport
Niagara Falls, NY 14304
(716) 297-8531</td></tr>
<tr><td>Waste Source:
Road Oiling - Application of PCB-containing waste oils to the roadways for dust control</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- 42,000 tons treated
- 18.3% moisture; 12.8% clay; 30.3% silt; pH of 7.7</td></tr>
<tr><td>Purpose/Significance of Application:
The Wide Beach project is notable for being the first full-scale treatment application using SoilTech's ATP system in conjunction with APEG dechlorination to treat soil at a Superfund Site contaminated with PCBs.</td></tr>
</table>

Thermal Desorption/Dehalogenation at the Wide Beach Development Superfund Site Brant, New York (Continued)

Regulatory Requirements/Cleanup Goals:
- **Soil - PCBs: 2 mg/kg**
- **Air - PCBs: 3.33×10^{-5} lbs/hr, PEG: 4.16×10^{-5} lbs/hr, particulates: 0.05 gr/dscf**

Results:
- **Soil - PCB concentrations reduced from up to 68 to less than 2 mg/kg**
- **Air - Stack gas requirements met for PCBs, PEG, and particulates; dioxin/furan emissions equivalent to a 2,3,7,8-TCDD concentration of 0.707 ng/dscm**

Cost Factors:
- **Actual total costs for cost elements directly associated with treatment - $11,600,000 (including solids preparation and handling, startup, equipment, and operation)**
- **Before-treatment costs - $908,000 (including mobilization/preparatory work, monitoring)**
- **After-treatment costs - $3,400,000 (disposal)**

Description:

Contamination of soil at the Wide Beach Development Superfund site (Wide Beach) resulted from the spraying of waste oil containing polychlorinated biphenyls (PCBs) over the roadways in the community to control dust. In response to a 1985 Record of Decision and a 1988 interagency agreement between EPA and the U.S. Army Corps of Engineers (USACE), SoilTech's mobile anaerobic thermal processor (ATP) system was used in conjunction with alkaline polyethylene glycol (APEG) dechlorination from October 1990 to September 1991 to treat contaminated soil at Wide Beach. Approximately 42,000 tons of stockpiled soil contaminated with PCBs, mainly Arochlor 1254, at concentrations ranging from 10 to 5,000 mg/kg, were treated at Wide Beach. The USACE specified that the concentration of PCBs in soil treated at Wide Beach should not exceed 2 mg/kg. The Wide Beach project is notable for using full-scale treatment application using SoilTech's ATP system in conjunction with APEG dechlorination to treat soil at a Superfund Site contaminated with PCBs.

During the full-scale treatment of soils at Wide Beach, samples of untreated soil were occasionally collected from the feed conveyor of the ATP system. The concentrations of PCBs measured in these samples ranged from 11 to 68 mg/kg, with an average PCB concentration of 24 mg/kg. Samples of the treated soil were collected either from the treated solids staging area or the tailings conveyor of the ATP system. The concentrations of PCBs measured in these samples were generally less than or near the detection limit (approximately 0.5 mg/kg) and all samples were below the 2 mg/kg cleanup level during the treatment application. A lack of structural integrity in the treated soils led to a need for off-site disposal.

The cost for this full-scale application was $11,600,000, for costs directly associated with treatment. The level of dechlorination achieved by the ATP/APEG process was measured during a demonstration test conducted prior to full-scale operation of the system. The demonstration test results indicated that the ATP/APEG process dechlorinated 76 percent of the PCBs that entered the ATP system during the test. However, this figure does not account for dechlorination from recycling residual oil through the system. In addition, an EPA SITE Demonstration was conducted during the full-scale operation in May of 1991. The SITE Demonstration results indicated that 98 percent of the PCBs that entered the ATP system were dechlorinated.