

KAI TECHNOLOGIES, LLC. (Radio Frequency Heating)

TECHNOLOGY DESCRIPTION:

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance bioventing and soil vapor extraction (SVE). The patented RFH technique, developed by KAI Technologies, Inc. (KAI), uses an antenna-like applicator inserted in a single borehole to heat a volume of soil. Large volumes of soil can be treated by RFH employing a control system and an array of applicators. When energy is applied by the applicator to the soil, heating begins near the borehole and proceeds radially outward. This technique can achieve soil temperatures from just above ambient to over 250°C.

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

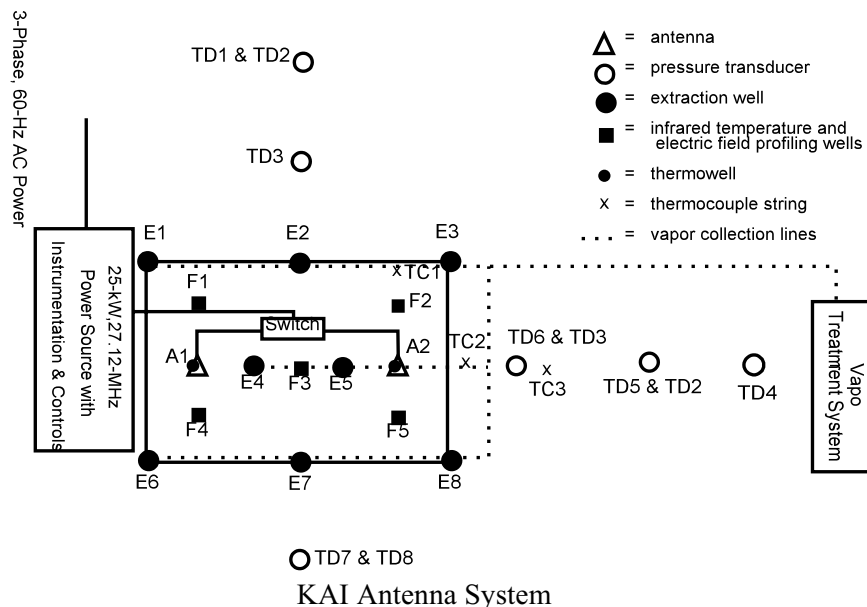
WASTE APPLICABILITY:

The RFH technique has been tested using pilot-scale vertical and horizontal antenna orientations to remove petroleum hydrocarbons and volatile and

semivolatile organics from soils. The technology is most efficient in subsurface areas with low groundwater recharge. In theory, the technology should be applicable to any polar compound in any nonmetallic medium. The flexible design permits easy access for in situ treatment of organics and pesticides under buildings or fuel storage tanks.

STATUS:

The KAI RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated between January and July 1994 at Kelly Air Force Base, Texas as part of a joint project with the U.S. Air Force Armstrong Laboratory. Brown and Root Environmental was the prime contractor evaluating and implementing RFH for the U.S. Air Force. A field demonstration of the IIT Research Institute RFH technology was completed in summer 1993 at the same site for comparison. The Demonstration Bulletin (EPA/540/MR- 94/528), Technology Capsule (EPA/540/R- 94/528a), and Innovative Technology Evaluation Report (EPA/540/R-94/528) are available from EPA. For further information on the IIT Research Institute technology, see the profile in



the Demonstration Program section (completed projects). KAI is now leasing commercial units to engineering companies around the U.S.

DEMONSTRATION RESULTS:

For this demonstration, the original treatment zone was 10 feet wide, 15 feet long, and 20 feet deep. This treatment zone was based on RFH operation at 13.56 megahertz (MHz); however, RFH was applied at 27.12 MHz to the top 10 feet of the original treatment zone to reduce the time on site by half. Demonstration results were as follows:

- Uniform heating within the revised heating zone: significant regions had soil temperatures in excess of 100 °C with soil temperatures within a 3-foot radius of the antenna exceeding 120 °C.
- Significant amounts of liquid were heated to around 240 °C as strongly suggested by a measurement of 233.9 °C on the outside wall of the heating well liner.
- Soil permeability increased by a factor of 20 within the revised treatment zone.
- In the original treatment zone, the mean removal for total recoverable petroleum hydrocarbons (TRPH) was 30 percent at the 90 percent confidence level. Concentrations in the pretreatment samples varied from less than 169 to 105,000 parts per million (ppm); posttreatment concentrations varied from less than 33 to 69,200 ppm.
- In the revised treatment zone, the mean removal for TRPH was 49 percent at the 95 percent confidence level. Concentrations in the pretreatment samples varied from less than 169 ppm to 6,910 ppm; posttreatment concentrations varied from less than 33 ppm to 4,510 ppm.

- Benzo(o)fluoranthene, benzo(a)pyrene, and bis(2-ethylhexyl)phthalate exhibited statistically significant removals within the original treatment zone. Benzo(o)-fluoranthene, benzo(a)pyrene, chrysene, pyrene, and fluoranthene exhibited statistically significant removals within the revised treatment zone.
- Contaminants may have migrated into and out of the revised treatment zone due to the design and operation of the SVE system. The design of the heated vapor recovery system is an essential component of the efficiency of the overall system.
- Cleanup costs are estimated to range from less than \$80 per ton for large scale to between \$100 to \$250 per ton for small-scale (hot spot) treatments.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Laurel Staley
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7863
Fax: 513-569-7105
e-mail: staley.laurel@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

Raymond Kasevich or Michael Marley
KAI Technologies, LLC.
94 West Avenue
Great Barrington, MS
413-528-4651
Fax: 413-528-6634
e-mail: raykase@taconic.net

KSE, INC.
(Adsorption-Integrated-Reaction Process)

TECHNOLOGY DESCRIPTION:

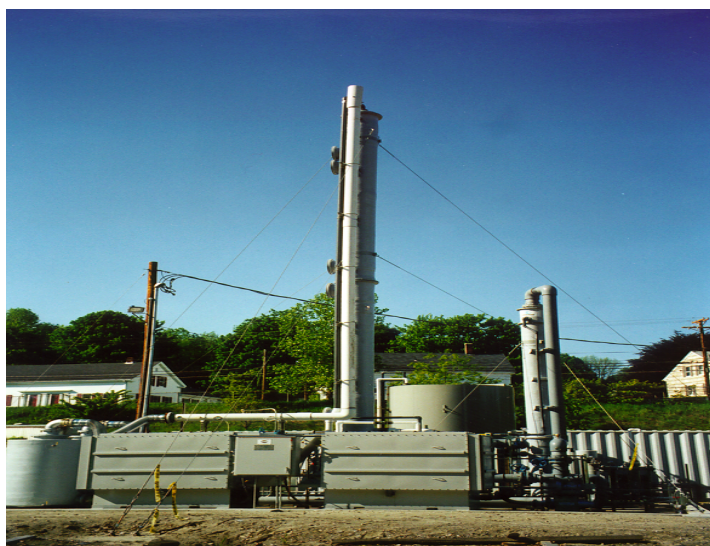
The Adsorption-Integrated-Reaction (AIR 2000) process combines two unit operations, adsorption and chemical reaction, to treat air streams containing dilute concentrations of volatile organic compounds (VOCs) (see photograph below).

The contaminated air stream containing dilute concentrations of VOCs flows into a photocatalytic reactor, where chlorinated and nonchlorinated VOCs are destroyed. The VOCs are trapped on the surface of a proprietary catalytic adsorbent. This catalytic adsorbent is continuously illuminated with ultraviolet light, destroying the trapped, concentrated VOCs through enhanced photocatalytic oxidation. This system design simultaneously destroys VOCs and continuously regenerates the catalytic adsorbent. Only oxygen in the air is needed as a reactant.

The treated effluent air contains carbon dioxide and water, which are carried out in the air stream exiting the reactor. For chlorinated VOCs, the chlorine atoms are converted to hydrogen chloride with some chlorine gas. If needed, these gases can be removed from the air stream with conventional scrubbers and adsorbents. The AIR 2000 process offers

advantages over other photocatalytic technologies because of the high activity, stability, and selectivity of the photocatalyst. The photocatalyst, which is not primarily titanium dioxide, contains a number of different semiconductors, which allows for rapid and economical treatment of VOCs in air. Previous results indicate that the photocatalyst is highly resistant to deactivation, even after thousands of hours of operation in the field.

The particulate-based photocatalyst allows for more freedom in reactor design and more economical scale-up than reactors with a catalyst film coated on a support medium. Packed beds, radial flow reactors, and monolithic reactors are all feasible reactor designs. Because the catalytic adsorbent is continuously regenerated, it does not require disposal or removal for regeneration, as traditional carbon adsorption typically does. The AIR 2000 process produces no residual wastes or by-products needing further treatment or disposal as hazardous waste. The treatment system is self-contained and mobile, requires a small amount of space, and requires less energy than thermal incineration or catalytic oxidation. In addition, it has lower total system costs than these traditional technologies, and can be constructed of fiberglass reinforced plastic (FRP) due to the low operating temperatures.



AIR2000

WASTE APPLICABILITY:

The AIR 2000 process is designed to treat a wide range of VOCs in air, ranging in concentration from less than 1 to as many as thousands of parts per million. The process can destroy the following VOCs: chlorinated hydrocarbons, aromatic and aliphatic hydrocarbons, alcohols, ethers, ketones, and aldehydes.

The AIR 2000 process can be integrated with existing technologies, such as thermal desorption, air stripping, or soil vapor extraction, to treat additional media, including soils, sludges, and groundwater.

STATUS:

The AIR 2000 process was accepted into the SITE Emerging Technology Program in 1995. Studies under the Emerging Technology Program are focusing on (1) developing photocatalysts for a broad range of chlorinated and nonchlorinated VOCs, and (2) designing advanced and cost-effective photocatalytic reactors for remediation and industrial service.

The AIR 2000 Process was initially evaluated at full-scale operation for treatment of soil vapor extraction off-gas at Loring Air Force Base (AFB). Destruction efficiency of tetrachloroethene exceeded 99.8 percent. The performance results were presented at the 1996 World Environmental Congress.

The AIR-I process, an earlier version of the technology, was demonstrated as part of a groundwater remediation demonstration project at Dover AFB in Dover, Delaware, treating effluent air from a groundwater stripper. Test results showed more than 99 percent removal of dichloroethane (DCA) from air initially containing about 1 ppm DCA and saturated with water vapor.

The AIR 2000 Process was accepted into the SITE Demonstration program in 1998. A demonstration was completed at a Superfund site in Rhode Island. A project bulletin was to be completed in 2001 and other project reports are still in preparation.

DEMONSTRATION RESULTS:

A 700 SCFM commercial unit is now operating at a Superfund Site in Rhode Island, destroying TCE, DCE and vinyl chloride in the combined off-gas from a SVE system and a groundwater stripper. Results collected during August to October 1999 show that the system is operating at 99.6% destruction efficiency. The AIR 2000 unit is operating unattended, with the number of UV lamps being illuminated changing automatically in response to changing flow conditions for maximum performance at minimum cost.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Vince Gallardo
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7176
Fax: 513-569-7620
e-mail: gallardo.vincente@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

J.R. Kittrell
KSE, Inc.
P.O. Box 368
Amherst, MA 01004
413-549-5506
Fax: 413-549-5788
e-mail: kseinc@aol.com

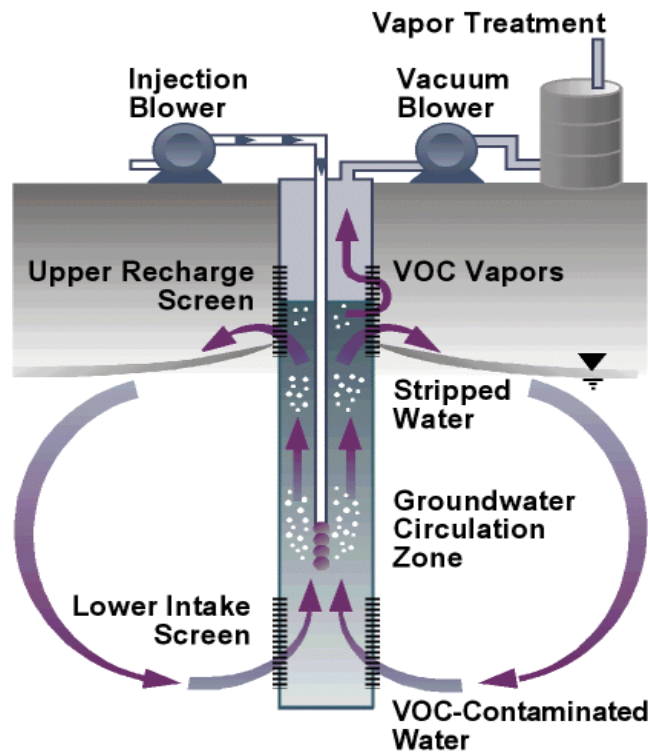
MACTEC-SBP TECHNOLOGIES COMPANY, L.L.C.
 (formerly EG&G Environmental, Inc.)
 (NoVOCs™ In-Well Stripping Technology)

TECHNOLOGY DESCRIPTION:

MACTEC-SBP provides the patented NoVOCs™ in-well stripping technology for the in situ removal of volatile organic compounds (VOC) from groundwater (see figure below). NoVOCs™ combines air-lift pumping with in-well vapor stripping to remove VOCs from groundwater without the need to remove, treat, and discharge a wastewater stream. The process also can be adapted to remove both VOCs and soluble metals from groundwater. NoVOCs™ consists of a well screened both beneath the water table and in the vadose zone. An air line within the well runs from an aboveground blower and extends below the water table. Pressurized air injected below the water table aerates the water within the well, creating a density gradient between the aerated water and the more

dense water in the surrounding aquifer. As a result, groundwater flows through the lower well screen and forces the aerated water upward within the well, and is in turn accelerated. The result is arising column of aerated water within the well, essentially acting as an air-lift pump.

As the aerated groundwater column rises within the well, VOC mass transfer occurs from the dissolved phase to the vapor phase. Above the water table, a packer is installed at the upper screen to prevent the passage of rising water or bubbles. The rising water column hits the packer, the bubbles burst, and the entrained VOC vapor is stripped off laterally through the screen by an upper vacuum casing. The VOC-rich vapor is brought to the surface for treatment while the laterally deflected water circulates back into the aquifer. Reinfiltrating water



Schematic Diagram of the NoVOCs™ Technology

creates a toroidal circulation pattern around the well, enabling the groundwater to undergo multiple treatment cycles before flowing downgradient. The VOC-rich vapor is treated using commercially available techniques chosen according to the vapor stream characteristics.

NoVOCs™ also can be used to remove readily reduced metals from groundwater and stabilize them in the vadose zone. Solubilized metals in their oxidized states enter the lower screen by the same route as dissolved VOCs in the groundwater. The nonvolatile metals remain in solution as the VOCs are stripped at the upper screen and the water circulates out of the well. The groundwater and soluble metals then pass through an infiltration and treatment gallery surrounding the upper well screen. This treatment gallery is impregnated with a reducing agent that reduces the soluble metals to an insoluble valence state. The insoluble metals accumulate in the infiltration gallery high above the water table and can be either capped or excavated at the conclusion of remedial action.

WASTE APPLICABILITY:

The process treats groundwater contaminated with volatile petroleum hydrocarbons including benzene, ethylbenzene, and toluene, as well as chlorinated solvents such as tetrachloroethene and trichloroethene. Highly soluble organics like alcohols and ketones are not easily air-stripped from water but are readily biodegraded in the oxygen-rich environment produced by NoVOCs™.

STATUS:

The NoVOCs™ technology was accepted into the SITE Demonstration Program in 1995. The demonstration at Installation Restoration Program Site 9 of Naval Air Station North Island in San Diego, California, was completed in June 1998.

DEMONSTRATION RESULTS:

VOC results for groundwater samples collected from the influent and effluent of the NoVOCs™ system indicated that 1,1-dichloroethene (1,1-DCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and trichloroethene (TCE) concentrations were reduced by greater than 98, 95, and 93% respectively. The mean concentrations of 1,1-DCE, *cis*-1,2-DCE, and TCE in the untreated water were approximately 3,530, 45,000 and 1,650 micrograms per liter (µg/L), respectively, and the mean concentrations of 1,1-DCE, *cis*-1,2-DCE, and TCE in the treated water discharged from the NoVOCs™ system were 27, 1,400, and 32 µg/L, respectively. The average total VOC mass removed by the NoVOCs™ system ranged from 0.01 to 0.14 pound per hour and averaged 0.10 pound per hour. Accounting for the intermittent operation of the NoVOCs™ system, the mass of total VOCs removed during the entire operation period from 4/20-6/19/98 was estimated to be approximately 92.5 pounds.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Michelle Simon
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7469
Fax: 513-569-7676
e-mail: simon.michelle@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

Mark McGlathery
MACTEC-SBP Technologies Company,
L.L.C.
1819 Denver West Drive, Suite 400
Golden, CO 80401
303-278-3100
Fax: 303-273-5000

MAGNUM WATER TECHNOLOGY (CAV-OX® Process)

TECHNOLOGY DESCRIPTION:

The CAV-OX® process uses a combination of hydrodynamic cavitation and ultraviolet (UV) radiation to oxidize contaminants in water. The process (see figure below) is designed to remove organic contaminants from wastewater and groundwater without releasing volatile organic compounds into the atmosphere.

The process generates free radicals to degrade organic contaminants. The cavitation process alone has been demonstrated to achieve trichloroethene (TCE) reductions of up to 65 percent. UV excitation and, where necessary, addition of hydrogen peroxide and metal catalysts, provide synergism to achieve overall reductions of over 99 percent. Neither the cavitation chamber nor the UV lamp or hydrogen peroxide reaction generates toxic by-products or air emissions.

Magnum Water Technology (Magnum) estimates the cost of using the CAV-OX® process to be about half the cost of other advanced UV oxidation systems and substantially less than carbon adsorption. Because the process equipment has one moving part, maintenance costs are minimal. According to Magnum, the CAV-OX® process does not exhibit the quartz tube scaling common with other UV equipment.

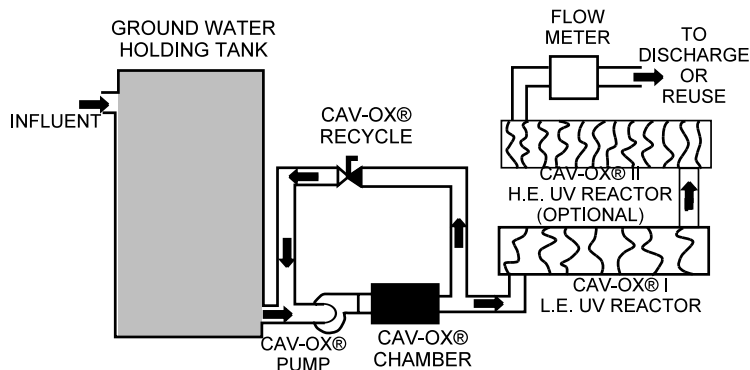
WASTE APPLICABILITY:

The process is designed to treat groundwater or wastewater contaminated with organic compounds. Contaminants such as halogenated solvents; phenol; pentachlorophenol (PCP); pesticides; polychlorinated biphenyls; explosives; benzene, toluene, ethylbenzene, and xylenes; methyl tertiary butyl ether; other organic compounds; and cyanide are suitable for this treatment process. Bacteria and virus strains are also eliminated.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992 and was demonstrated for 4 weeks in March 1993 at Edwards Air Force Base (AFB) Site 16 in California. The Applications Analysis Report (EPA/540/AR-93/520), Technology Evaluation Report (EPA/540/R-93/520), and a videotape are available from EPA.

Magnum reports that improvements in UV lamp and reactor technologies have improved the efficiency of the CAV-OX® process three- to five-fold, compared with the pilot-scale unit tested at Edwards AFB under the SITE Program. CAV-OX® recently (1996) has proven very effective in potentiating ozone concentrations in water reclamation applications.



The CAV-OX® Process

Ozone gas (O₃) is relatively insoluble in water. However, hydrodynamic cavitation used in the CAV-OX[®] process continuously develops micro bubbles which enhances the dispersion of ozone in water. Three O₃ techniques are available to Magnum: corona discharge with air feed, electrochemical 'water splitting' method, and electrochemical anodic oxidation.

The CAV-OX[®] process has been tested at several public and private sites, including the San Bernadino and Orange County Water Department in California. At a Superfund site, the process treated leachate containing 15 different contaminants. PCP, one of the major contaminants, was reduced by 96 percent in one test series. The process has also been used to remediate former gasoline station sites and successfully reduced contaminants in process streams at chemical and pharmaceutical plants.

The CAV-OX[®] unit was part of an ongoing evaluation at the U.S. Army Aberdeen Proving Ground (Aberdeen). Special features of the unit tested include remote monitoring and control systems for pH, flow rates, H₂O₂ flow rate, storage level and pump rate, UV lamp, main power, pump function, and remote system shutdown control. The 15-gallon-per-minute CAV-OX[®] I Low Energy unit was operated by Army contractors for 9 months. Upon completion of testing at Aberdeen, further CAV-OX[®] II High Energy Tests were conducted at El Segundo. The CAV-OX[®] process achieved contaminant concentrations of greater than 95

percent. During 1997 tests of CAV-OX[®] equipment and/or Pilot Tests were made in Taiwan, Thailand, and Australia. Also, a continuing series of tests for major U.S. corporations are on-going. The CAV-OX[®] process achieved removal efficiencies of greater than 99.9 percent for TCE, benzene, toluene, ethylbenzene, and xylenes. SITE demonstration results for the CAV-OX[®] process are shown in the table below. Results are presented for both the CAV-OX[®] I (cavitation chamber by itself) and CAV-OX[®] II (cavitation chamber combined with UV) demonstrations.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Richard Eilers
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7809
Fax: 513-569-7111
eilers.richard@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:
Dale Cox or Jack Simser
Magnum Water Technology
600 Lairport Street
El Segundo, CA 90245
310-322-4143 or 310-640-7000
Fax: 310-640-7005

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

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

CAV-OX[®] Process Demonstration Results

MATRIX PHOTOCATALYTIC INC. (Photocatalytic Aqueous Phase Organic Destruction)

TECHNOLOGY DESCRIPTION:

The Matrix Photocatalytic Inc. (Matrix) photocatalytic oxidation system, shown in the photograph below, removes dissolved organic contaminants from water and destroys them in a continuous flow process at ambient temperatures. When excited by light, the titanium dioxide (TiO₂) semiconductor catalyst generates hydroxyl radicals that oxidatively break the carbon bonds of hazardous organic compounds.

The Matrix system converts organics such as polychlorinated biphenyls (PCB); phenols; benzene, toluene, ethylbenzene, and xylene (BTEX); and others to carbon dioxide, halides, and water. Efficient destruction typically occurs between 30 seconds and 2 minutes actual exposure time. Total organic carbon removal takes longer, depending on the other organic molecules and their molecular weights. The Matrix system was initially designed to destroy organic pollutants or to remove total organic carbon from drinking water, groundwater, and plant process water. The Matrix system also destroys organic pollutants such as PCBs, polychlorinated dibenzodioxins, polychlorinated

dibenzofurans, chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones, aldehydes, and amines. Inorganic pollutants such as cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion, sulphate ion, and nitrate ion, respectively.

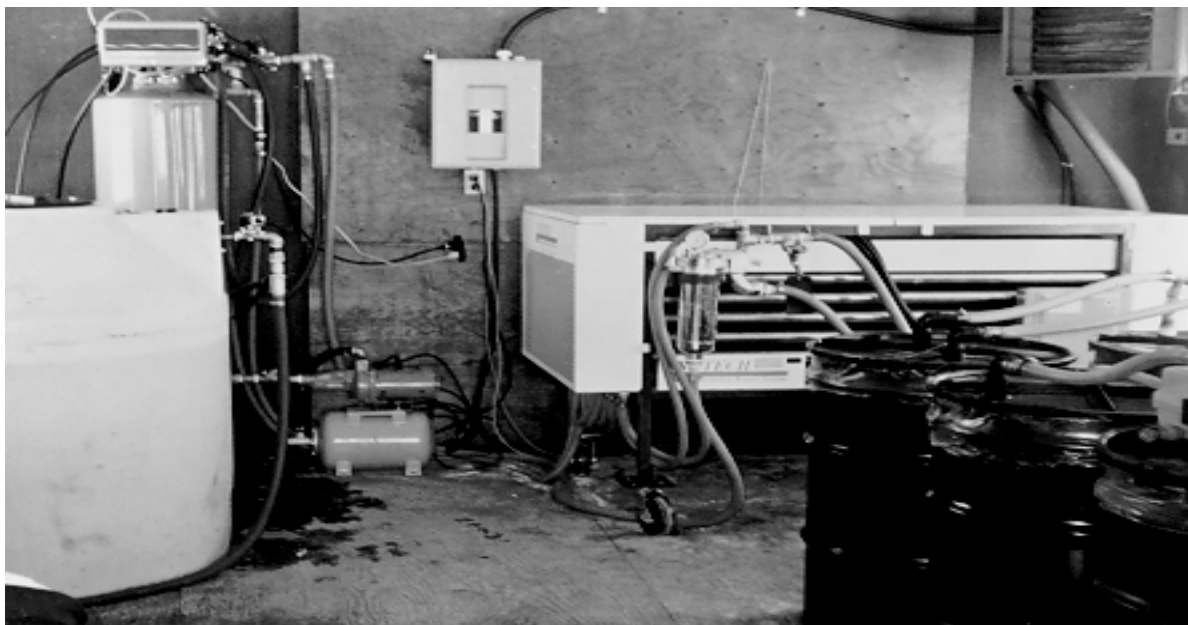
WASTE APPLICABILITY:

The Matrix system can treat a wide range of concentrations of organic pollutants in industrial wastewater and can be applied to the ultrapure water industry and the drinking water industry. The Matrix system can also remediate groundwater.

STATUS:

The system was accepted into the SITE Emerging Technology Program (ETP) in May 1991. Results from the ETP evaluation were published in a journal article (EPA/540/F-94/503) available from EPA. Based on results from the ETP, Matrix was invited to participate in the Demonstration Program.

During August and September 1995, the Matrix system was demonstrated at the K-25 site at the



10-Gallon-Per-Minute TiO₂ Photocatalytic System Treating BTEX in Water

Department of Energy's Oak Ridge Reservation in Oak Ridge, Tennessee. Reports detailing the results from the demonstration are available from EPA.

DEMONSTRATION RESULTS:

Results from the demonstration are detailed below:

- In general, high percent removals (up to 99.9 percent) were observed for both aromatic volatile organic compounds (VOCs) and unsaturated VOCs. However, the percent removals for saturated VOCs were low (between 21 and 40 percent).
- The percent removals for all VOCs increased with increasing number of path lengths and oxidant doses. At equivalent contact times, changing the flow rate did not appear to impact the treatment system performance for all aromatic VOCs and most unsaturated VOCs (except 1,1-dichloroethene [DCE]). Changing the flow rate appeared to impact the system performance for saturated VOCs.
- The effluent met the Safe Drinking Water Act maximum contaminant levels (MCL) for benzene; cis-1,2-DCE; and 1,1-DCE at a significant level of 0.05. However, the effluent did not meet the MCLs for tetrachloroethene (PCE); trichloroethene (TCE); 1,1-dichloroethane (DCA); and 1,1,1-trichloroethane (TCA) at a significant level of 0.05. The influent concentrations for toluene and total xylenes were below the MCLs.
- In tests performed to evaluate the effluent's acute toxicity to water fleas and fathead minnows, more than 50 percent of the organisms died. Treatment by the Matrix system did not reduce the groundwater toxicity for the test organisms at a significant level of 0.05.

- In general, the percent removals were reproducible for aromatic and unsaturated VOCs when the Matrix system was operated under identical conditions. However, the percent removals were not reproducible for saturated VOCs. The Matrix system's performance was generally reproducible in (1) meeting the target effluent levels for benzene; cis-1,2-DCE; and 1,1-DCE; and (2) not meeting the target effluent levels for PCE; TCE; 1,1-DCA; and 1,1,1-TCA.
- Purgable organic compounds and total organic halides results indicated that some VOCs were mineralized in the Matrix system. However, formulation of aldehydes, haloacetic acids, and several tentatively identified compounds indicated that not all VOCs were completely mineralized.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Richard Eilers
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7809 Fax: 513-569-7111
e-mail: eilers.richard@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

Bob Henderson
Matrix Photocatalytic Inc.
22 Pegler Street
London, Ontario, Canada
N5Z 2B5
519-660-8669 Fax: 519-660-8525

MAXYMILLIAN TECHNOLOGIES, INC.
(formerly Clean Berkshires, Inc.)
(Thermal Desorption System)

TECHNOLOGY DESCRIPTION:

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

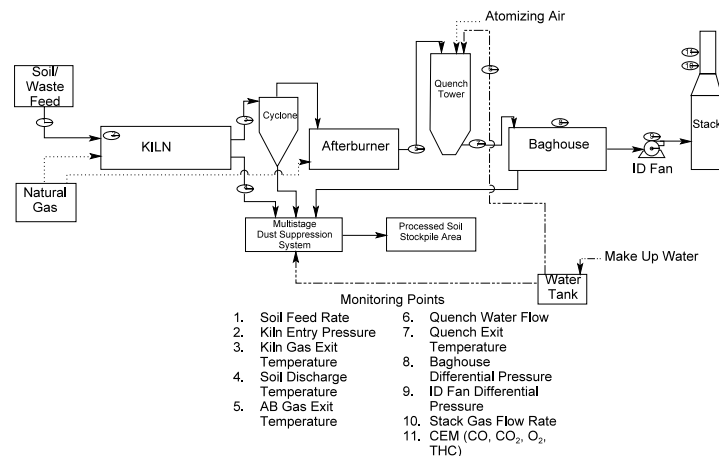
The TDS consists of the following components (see figure below):

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

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

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

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



Mobile Thermal Desorption System

WASTE APPLICABILITY:

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

STATUS:

The TDS was accepted into the SITE Demonstration Program in 1993. The demonstration was conducted in November and December 1993 at the Niagara Mohawk Power Corporation Harbor Point site, a former gas plant in Utica, New York. During the demonstration, the TDS processed three replicate runs of four separate waste streams. Stack emissions and processed soil were measured to determine achievement of cleanup levels. The Demonstration Bulletin (EPA/540/MR-94/507) and Technology Capsule (EPA/540/R-94/507a) are available from EPA.

Following the SITE demonstration, the TDS was chosen to remediate approximately 17,000 tons of VOC-contaminated soil at the Fulton Terminals Superfund site in Fulton, New York. This project was completed in 1995. The system has since been moved to a location in North Adams, Massachusetts.

DEMONSTRATION RESULTS:

Results from the SITE Demonstration are summarized below:

- The TDS achieved destruction removal efficiencies (DRE) of 99.99 percent or better in all 12 runs using total xylenes as a volatile principal organic hazardous constituent (POHC).

- DREs of 99.99 percent or better were achieved in 11 of 12 runs using naphthalene as a semivolatile POHC.
- Average concentrations for critical pollutants in treated soils were 0.066 milligram per kilogram (mg/kg) benzene, toluene, ethylbenzene, and xylene (BTEX); 12.4 mg/kg PAHs; and 5.4 mg/kg total cyanide.
- Comparison of the dry weight basis concentration of pollutants in the feed and treated soil showed the following average removal efficiencies: 99.9 percent for BTEX; 98.6 percent for PAHs; and 97.4 percent for total cyanide.
- The TDS showed good operating stability during the demonstration with only a minor amount of downtime.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Annette Gatchett
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7697
Fax: 513-569-7105
e-mail: gatchett.annette@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

Neal Maxymillian
Maxymillian Technologies, Inc.
84 State Street
Boston, MA 02109
617-557-6077
Fax: 617-557-6088

MICRO-BAC® INTERNATIONAL, INC. (Bioaugmentation Process)

TECHNOLOGY DESCRIPTION:

The M-1000PCB™ is a biological product specifically designed and formulated for the degradation of chlorinated compounds and complex aromatic compounds found in contaminated and/or hazardous wastes. The M-1000PCB™ product consists of live, specially selected, naturally occurring microorganisms, along with a supply of balanced nutrients in a ready-to-use liquid medium. The microorganisms work either anaerobically or aerobically and the system requires no expensive machinery.

The product is nonpathogenic and free of slime-forming and sulfate-reducing bacteria. The live cultures contained in the product do not need to be activated or require an acclimation period prior to use. In a proprietary selection process, MBI isolates and sustains specific strains of bacteria that work together to degrade specific organic compounds. Reportedly, these microorganisms have the ability to thrive in a variety of site conditions characterized by diverse soils and water chemistries, and are capable of using hazardous waste substances as a carbon source.

For soil applications, the product is typically applied

via a spray, as shown in the photograph below. M-1000™ product and nutrient application rates for soil are based on specific site characteristics. Information such as soil type, nutrient availability, soil moisture content, and contaminant type and concentration are considered before applying the technology at a site. The general application rate for the M-1000™ products in soil is one quart of bacteria per one cubic yard of soil. This treatment provides a bacterial concentration of approximately 1,250 ppm. The bacteria is typically applied first, followed by the nutrient formulation.

At a number of sites, the addition of nutrients is used to augment the activity of the product in conditions where macronutrients such as carbon, nitrogen, or phosphate are limited. MBI produces its own nutrient mixtures that are specifically formulated for use with MBI bacteria. The nutrient mixtures are shipped as a dry powder and packaged in single packets or in four packet containers. A single packet of nutrients is typically mixed on-site with 55 gallons of water. This mixture is used to amend approximately 10,000 gallons or 50 cubic yards of the bacteria mix.

Depending upon the duration of treatment, it is often necessary for multiple applications of microbe and



nutrient mixtures. The treated soil is then routinely mixed with a roto-tiller. The frequency of this mixing may vary over the duration of a project, but will generally not be more frequent than once a week.

WASTE APPLICABILITY:

The MBI bioremediation products are specifically targeted for the contaminant groups most frequently encountered; including products for total petroleum hydrocarbons (TPH), polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), other aromatic and chlorinated hydrocarbons, gasolines, crude oils, and jet fuels. The M-1000™ products have been applied in a number of different ways. The product has been used successfully in a variety of in situ and ex situ applications, but has also been applied as part of a bioreactor process, in land farms, in biopiles, and in pump-and-treat scenarios. According to the MBI, it apparently works well as an augmentation to other methods or as a stand-alone solution.

STATUS:

The MBI bioaugmentation technology was accepted into the SITE Demonstration Program in 1999. A demonstration is currently in progress at the Lower Colorado River Authority (LCRA) Goldthwaite, Texas, substation. At this site PCB-contaminated soil is being treated with M-1000PCB™ product in an approximate 16- × 8- × 2-ft treatment cell. The overall goal of the project is to reduce PCB concentrations in the soil to a levels of 50 mg/kg or less, on a dry weight basis of the original soil, thus enabling the LCRA to dispose of their soils in a less costly in-state landfill (as opposed to a TSCA landfill).

The SITE Program is conducting soil sampling to evaluate the effectiveness of the MBI technology for treating the PCBs in the soil. The LCRA is performing periodic rototilling of the soil within the treatment cell (see photograph below). As of August 2001, a total of four sampling events have been completed. These included a baseline sampling event conducted in August 2000 to establish pretreatment PCB levels, and three Intermediate sampling events for tracking treatment progress. These intermediate events were conducted in October and December of 2000, and in June of 2001. A final sampling event is scheduled for October 2001.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Ronald Herrmann
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7741
Fax: 513-569-7105
e-mail: herrmann.ronald@epa.gov

TECHNOLOGY DEVELOPER

CONTACT:

Todd Kenney
Micro-Bac® International, Inc.
3200 N. IH-35
Round Rock, Texas 78681
(512) 310-9000
FAX: (512) 310-8800

MINERGY CORP.
(Glass Furnace Technology for Dredged Sediments)

TECHNOLOGY DESCRIPTION:

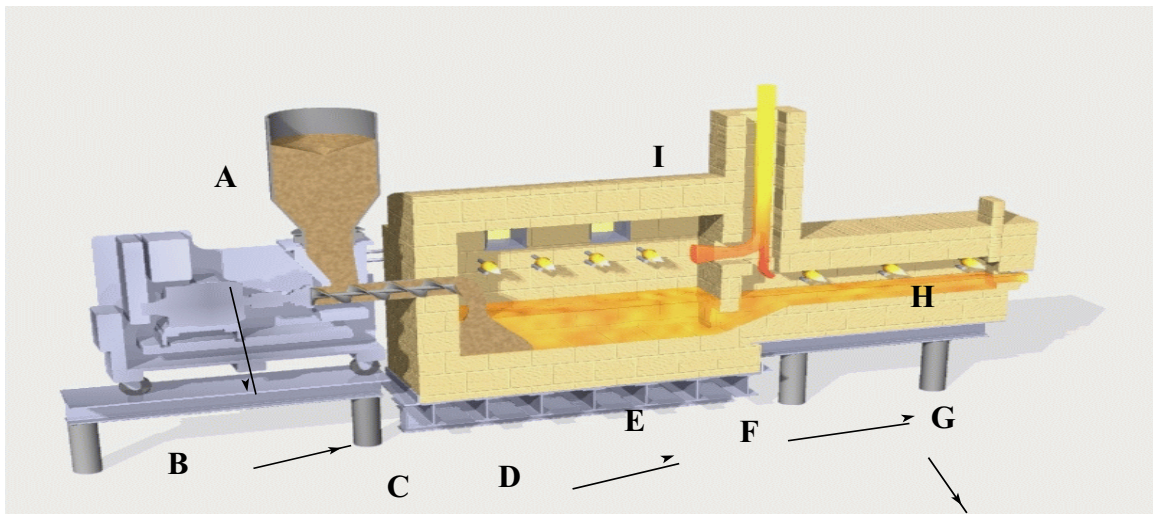
The Glass Furnace Technology is an adaptation of systems that have been used for decades in glass manufacturing. Because a glass furnace has temperatures high enough to melt minerals into glass, there is a corollary benefit of destruction of organic contaminants such as PCBs, and permanent stabilization of trace metals in the resultant glass product matrix.

A glass furnace is a refractory-lined, rectangular melter. Refractory is brick or concrete, which has been specially treated to resist chemical and physical abrasion, has a high melting point, and provides a high degree of insulating value to the process. Current glass furnaces use oxy-fuel burners, combining natural gas and oxygen for a bright flame above the glass. These burners raise the internal temperature of the melter to 2,900 degrees Fahrenheit. At these high

temperatures, PCB contaminants are destroyed, and the sediment melts and flows out of the processing system as molten glass. The molten glass is water quenched to produce an inert aggregate that is marketed to construction companies.

Process Description

Sediment (A) is fed to the hopper above the screw feeder (B). The feeder conveys the sediment continuously into the main section of the melter (C). The extremely high temperatures in the melter cause the sediment to become molten, liquid glass (D). The molten glass flows under a skimmer block (E), into the forehearth (F), where the material continues to form a stable glass. At the end of the melter, the glass flows out (G) into a water quenching tank. A removable block is included at the end of the forehearth (H) to stop the flow of glass if desired. Exhaust gases (I) flow out from the furnace up the square flue, to the air sampling equipment.



Internal View of Melter (Sediment Feeding and Melting)

WASTE APPLICABILITY:

The target applicable waste for the technology is sediments or soils that have PCB and metals contamination. The process design of a glass

furnace is focused on melting low energy feedstock materials (that is, those with low Btu values). Silica is one of the primary constituents of sediments, making it a perfectly suited material for processing. Because a glass furnace has temperatures high

enough to melt minerals into glass, it has a high destruction efficiency of organic contaminants such as PCBs, and permanent stabilization of trace metals in the resultant glass product matrix. Exhaust gas volumes from a glass furnace are very low, thus enabling downstream carbon filtering to capture contamination by mercury or other light metals.

STATUS:

In August 2001, the Glass Furnace Technology (GFT) was demonstrated in Minergy's pilot glass furnace, located in Winneconne, Wisconsin. The pilot demonstration was performed using 60 tons of sediment dredged from the Lower Fox River, Wisconsin, from which 30 tons of glass were made. EPA SITE was on-site for the two-week demonstration. The SITE report was not yet complete at the time of this writing. The objectives of the SITE analysis are:

- To determine the treatment efficiency (TE) of PCBs in dredged-and-dewatered river sediment when processed in the Minergy GFT.
- To determine whether the GFT glass aggregate product meets the criteria for beneficial reuse under relevant federal and state regulations.
- Determine the unit cost of operating the GFT on dewatered dredged river sediment.
- Quantify the organic and inorganic contaminant losses resulting from the existing or alternative drying process used for the dredged-and-dewatered river sediment.
- Characterize organic and inorganic constituents in all GFT process input and output streams. Of principal concern is the formation of dioxin and furan during the vitrification step.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:
Marta K. Richards
U.S. EPA/NRMRL
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7271
Fax: 513-569-7676
e-mail: richards.marta@epa.gov

TECHNOLOGY DEVELOPER
CONTACTS:
Terrence W. Carroll, P.E.
Regional Manager
Minergy Corporation
1512 S. Commercial Street
Neenah, WI 54956
920-727-1411
e-mail: rcarroll@minergy.com

**MORRISON KNUDSEN CORPORATION/
SPETSTAMPONAZHGEOLGIA ENTERPRISES
(Clay-Based Grouting Technology)**

TECHNOLOGY DESCRIPTION:

Morrison Knudsen Corporation (MK) is working under a joint venture agreement with Spetstamponazhgeologia Enterprises (STG) of Ukraine to demonstrate the effectiveness of a clay-based grouting technology. This technology uses clay slurries as a base for grout solutions, which are injected into bedrock fracture systems to inhibit or eliminate groundwater flow in these pathways. The clay slurries may also be used as a base for slurry wall construction.

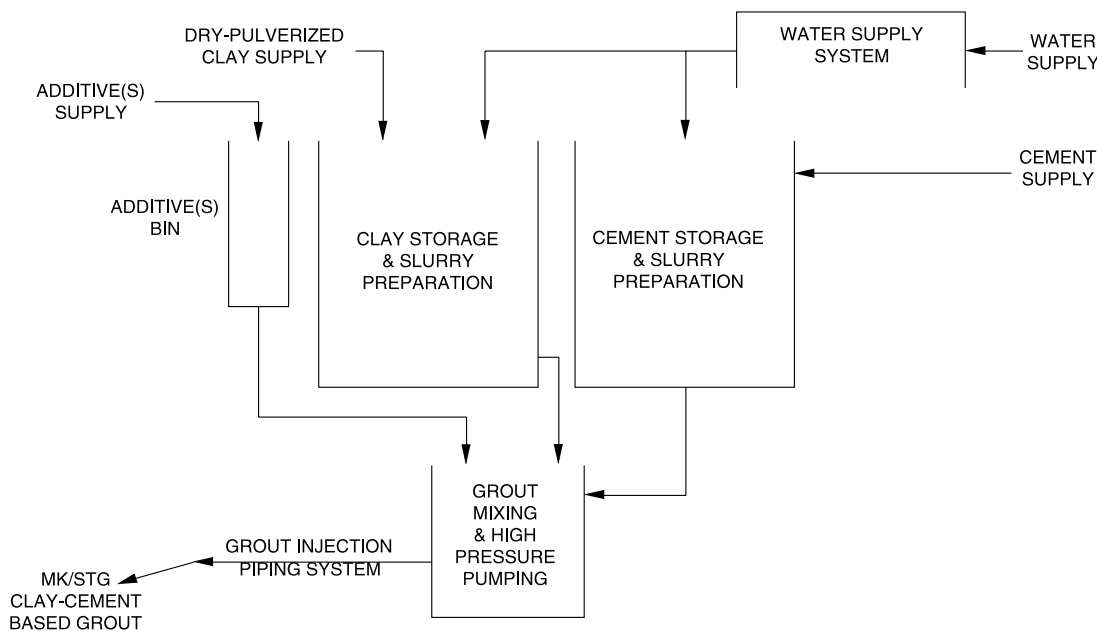
The MK/STG clay-based grouting technology is an integrated method involving three primary phases: obtaining detailed site characteristics; developing a site-specific grout formulation; and grout mixing and injection. The first phase, site characterization, includes obtaining geophysical, geochemical, mineralogical, and hydrogeological information about the target area.

The second phase, a site-specific grout formulation,

is developed in the laboratory. The overall properties of clay-based grout depend on the physical and mechanical properties of the clay, cement, and other additives. Formulated clay-based grouts are viscoplastic systems composed primarily of clay mineral mortar and structure-forming cement. The clay is normally a kaolin/illite obtained from a local source; other additives may be required. The formulation is laboratory-tested to determine suitability for the desired application.

The third phase is grout mixing and placement. The process for preparing and injecting the clay-based grout is shown in the diagram below. Boreholes drilled during the site characterization phase may be used for grout placement. Additional boreholes may be drilled to complete the injection program. A quality assurance program ensures that placement and project objectives are met. After injection, the clay-based grout retains its plasticity and does not crystallize, providing permanent underground protection.

WASTE APPLICABILITY:



Process Flow Diagram of the Clay-Based Grouting Technology

This technology is suitable for providing a flow barrier to groundwater contaminated with both heavy metals and organics. The clay-based grout can be formulated to withstand detrimental conditions such as low pH. The technology can be used at inactive mine sites that produce acid mine drainage. Other potential applications include liquid effluent control from landfills, containment of groundwater contaminated with chemicals or radionuclides, and reduction of brine inflows.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1993. It was partially installed in fall 1994 at the abandoned Mike Horse Mine site in Montana; operations were suspended due to winter weather conditions. The third phase, to complete installation of the grout, was canceled due to EPA budget constraints. The demonstration was completed in 1996, but the technology was not fully evaluated due to loss of accessibility to the site.

Over 200 projects using this technology have been completed during the last 20 years in the former Soviet Union and Eastern block countries, as well as in China and Australia. The technology has not been applied in the United States or western hemisphere other than at the Mike Horse Mine site.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Annette Gatchett
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7697
Fax: 513-569-7620
e-mail: gatchett.annette@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

Rick Raymondi
Morrison Knudsen Corporation/STG
P.O. Box 73
Boise, ID 83729
208-386-5000
Fax: 208-386-6669

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

TECHNOLOGY DESCRIPTION:

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

The figure below illustrates the process; the separator, filter, and coalescer unit is shown on the next page. The pressure-sensitive filtering bed is regenerated by automatic backflushing. This automatic regeneration eliminates the expense associated with regeneration of carbon and similar filtration media. Recovered hydrocarbons coalesce and can thus be removed by simple gravity separation.

This technology provides cost-effective oil and water separation, removes free and emulsified hydrocarbon contaminants, and significantly reduces hydrocarbon loading to air strippers and

carbon systems. The technology can achieve a concentration of less than 7 parts per million oil and grease in the treated effluent.

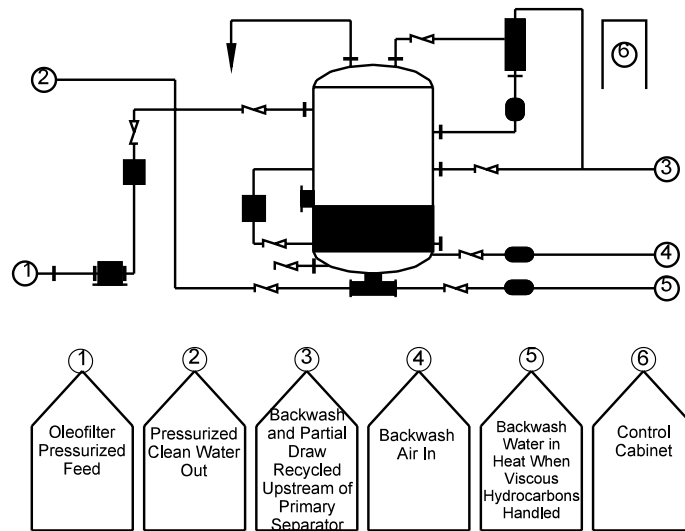
WASTE APPLICABILITY:

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

Treatment systems incorporating this technology have been designed for various applications, including (1) contaminated groundwater pump-and-treat systems; (2) in-process oil and water separation; (3) filtration systems; (4) combined oil and water separator-filter-coalescer systems for on-site waste reduction and material recovery; and (5) treatment of marine wastes (bilge and ballast waters).

STATUS:

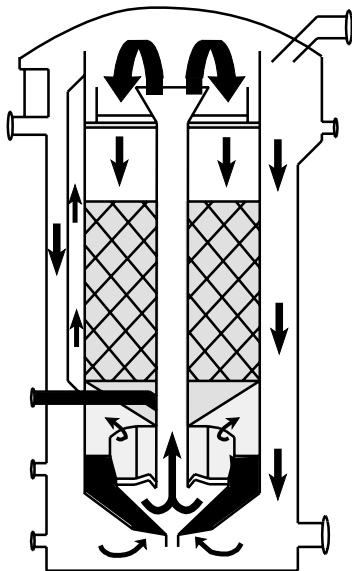
This technology was accepted into the SITE



Schematic Diagram of the Oleofilter Technology

Demonstration Program in December 1992. The SITE demonstration was completed in June 1994 at the Petroleum Products Corporation site in Fort Lauderdale, Florida. The site is a former oil recycling facility where groundwater has been contaminated with a variety of organic and inorganic constituents. The Demonstration Bulletin (EPA/540/MR-94/525) and Innovative Technology Evaluation Report (EPA/540/ R-94/525) are available from EPA.

The technology has been used for several full-scale projects. Several separator-filter-coalescers (see figure below) are in use treating industrial process waters and oily wash waters.



Separator, Filter, and Coalescer

DEMONSTRATION RESULTS:

For the demonstration, five separate evaluation periods (runs) were initiated. Each run used the same feed oil, except run four. The oil for run four was a 3:1 mixture of oil to kerosene. The average total recoverable petroleum hydrocarbon (TRPH) concentrations for the feed streams ranged from 422 to 2,267 milligrams per liter (mg/L). Preliminary data indicate that the system removed at least 90 percent of the TRPH from the emulsified oil and water feed stream.

For the runs where the system operated within normal design parameters, TRPH concentrations in the treated water effluent were reduced to 15 mg/L or less. The oleophilic granules achieved a 95 percent reduction of TRPH concentration for the runs with similar feed oil.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Laurel Staley

U.S. EPA

National Risk Management Research
Laboratory

26 West Martin Luther King Drive

Cincinnati, OH 45268

513-569-7863

Fax: 513-569-7620

e-mail: staley.laurel@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

Tim Torrillion

North American Technologies Group, Inc.

4710 Bellaire Boulevard, Suite 301

Bellaire, TX 77401

713-662-2699

Fax: 713-662-3728

**NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL
CONSERVATION/ENSR CONSULTING AND ENGINEERING and
LARSEN ENGINEERS
(Ex Situ Biovault)**

TECHNOLOGY DESCRIPTION:

The Ex Situ Biovault, developed by ENSR Consulting and Engineering (ENSR) and Larsen Engineers (Larsen), is a specially designed, aboveground soil pile designed to treat soils contaminated with volatile organic compounds (VOC) and semivolatle organic compounds (SVOC). The biovault is enclosed by a double liner system; the bottom half of the liner contains a leak detection system. The bottom half of the liner is supported by soil berms that serve as side walls.

To construct a biopile, a layer of gravel containing an air distribution system is placed on the bottom liner. The soil to be treated is then placed over the gravel. After placing the soil, a layer of sand containing a second air distribution system is placed on top of the soil. Soaker hoses are also placed on top of the pile. Finally, the top liner is placed on the pile and sealed at all seams. The air distribution systems are designed to control gas flows throughout the pile while the soaker hoses add water and nutrients. A sump is located in the lowest corner of the biovault with a pump that removes the liquids that drain through the soil pile. This liquid is amended with nutrients as needed and recirculated through the soaker hoses. Together, the sump and

soaker hoses form the liquid management system (LMS).

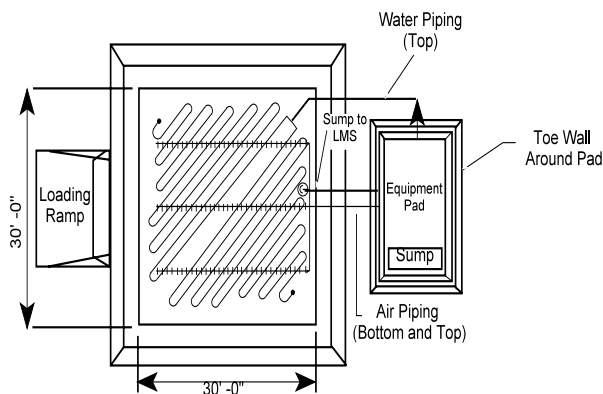
One of the control parameters for biovault operation is the rate of air supply. For the SITE demonstration, two identical vaults were constructed. One vault was operated with a continuous supply of air throughout the course of treatment. In the other biovault, air was supplied intermittently in an effort to cycle the biovault between aerobic and anaerobic conditions.

WASTE APPLICABILITY:

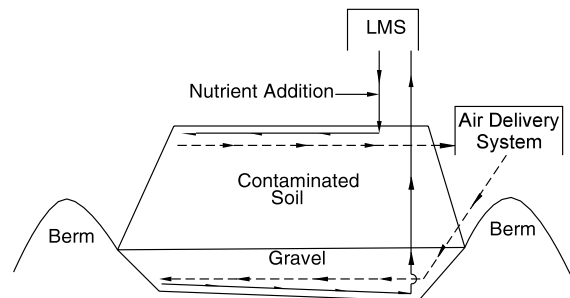
The ex situ biovault is intended to treat soil contaminated with chlorinated and nonchlorinated VOCs, as well as SVOCs. Soil contaminated with VOCs was treated during the demonstration.

STATUS:

ENSR's and Larsen's ex situ biovault was accepted into the SITE Demonstration Program in June 1994. The pilot-scale, multivendor treatability demonstration (MVTD) was jointly sponsored by the New York State Department of Environmental Conservation (NYSDEC), the New York State Center for Hazardous Waste Management, and the



Schematic of the Ex Situ Biovault System



Cross Section of the Ex Situ Biovault System

SITE Program. The objectives of the MVTD were to (1) generate field data for biological processes, and (2) evaluate the performance of each biological process in meeting NYSDEC clean-up goals.

The demonstration was conducted from July to December 1994 at the Sweden 3-Chapman site in Sweden, New York. The soil at the site was contaminated with elevated levels of acetone, trichloroethene, tetrachloroethene, cis-1,2-dichloroethene, 2-butanone, 4-methyl-2-pentanone, and toluene. The final report is available from the vendor.

In addition to the ENSR and Larsen process, the following systems also were demonstrated:

- SBP Technologies, Inc., Vacuum-Vaporized Well System
- R.E. Wright Environmental, Inc., In Situ Bioventing Treatment System

For information on these technologies, refer to the NYSDEC profiles in the Demonstration Program section (completed projects).

The Demonstration Bulletin (EPA/540/MR-95/524) is available from EPA. The Innovative Technology Evaluation Report, which provides more detailed demonstration results, is being prepared.

DEMONSTRATION RESULTS:

The primary objective of the SITE demonstration was to determine the effectiveness of the biovaults in reducing the concentrations of six target VOCs. The results of the ex situ biovault technology demonstration were as follows:

- Soil concentrations of six target VOCs were significantly reduced over the 5-month demonstration period, but the treatment did not meet NYSDEC criteria.
- Analytical results and field measurements indicated that both biovaults supported biological processes.

- The aerobic and aerobic/anaerobic biovaults performed similarly.

The biovault process is sensitive to ambient temperatures, and cool temperatures during the operating period may have negatively impacted microbial activity. The developers suggest initiating biovault operation in the spring and discontinuing operation when weather conditions become too cold to sustain microbial activity.

FOR FURTHER INFORMATION:

EPA CONTACT:

Annette Gatchett
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7697 Fax: 513-569-7105
e-mail: gatchett.annette@epa.gov

NEW YORK STATE CONTACTS:

Jim Harrington
New York State Department of
Environmental Conservation
50 Wolf Road, Room 268
Albany, NY 12233-7010
518-457-0337 Fax: 518-457-9639
e-mail: harrington.jim@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

David Ramsden, Ph.D.
ENSR Consulting and Engineering
3000 Richmond Avenue
Houston, TX 77098
713-520-9900 Fax: 713-520-6802

N. Sathiyakumar, Ph.D., P.E.
Larsen Engineers
700 West Metro Park
Rochester, NY 14623-2678
716-272-7310 Fax: 716-272-0159

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION/SCIENCE APPLICATIONS INTERNATIONAL CORP.

(In Situ Bioventing Treatment System)

TECHNOLOGY DESCRIPTION:

The In Situ Bioventing Treatment System, process uses bioventing technology to induce aerobic biological degradation of chlorinated compounds. A series of extraction and injection wells is used to amend the soil environment, creating optimum growth conditions for the indigenous bacteria. Anhydrous ammonia and methane are injected into the subsurface to stimulate the growth of methanotrophic microorganisms. Methanotrophs have the enzymatic capabilities to degrade chlorinated solvents through a cometabolic process.

The treatment system consists of an injection and extraction well field and a soil gas extraction-amendment injection blower unit (see photograph below). The blower unit is operated in the vacuum mode long enough to adequately aerate the subsoil and provide oxygen for the aerobic

bacteria. Injection wells are located between the extraction wells and are manifolded to the pressure port of the blower unit. Anhydrous ammonia is periodically injected into the subsoil to provide a source of nitrogen for the aerobic bacteria. In addition, methane gas is periodically injected to stimulate the growth of methanotrophs. The positive displacement blower unit is equipped with a moisture knockout tank, an automatic water discharge pump, and a control panel that allows remote operation of the system. Air and water discharges are typically treated with granular activated carbon prior to final discharge.

Normal system monitoring consists of periodic soil sampling and analysis and soil gas monitoring. Soil samples are collected and analyzed for volatile organic compounds (VOC), soil fertility parameters, and microbiological parameters such as trichloroethene (TCE) degraders and



In Situ Bioventing Treatment System

methanotrophs. In situ respiration tests are conducted to determine the relative activity of the bacteria in the soil.

WASTE APPLICABILITY:

The technology can treat both chlorinated and nonchlorinated VOCs and semivolatile organic compounds that are biodegradable. The in situ bioventing system process was developed to treat volatile chlorinated aliphatic and aromatic hydrocarbons in the unsaturated soil zone.

STATUS:

The in situ bioventing system process was accepted into the SITE Demonstration Program in June 1994. The in situ bioventing system process was part of a pilot-scale, multivendor treatability demonstration (MVTD) that was jointly sponsored by the New York State Department of Environmental Conservation (NYSDEC), the New York State Center for Hazardous Waste Management, and the SITE Program. The objectives of the MVTD were to (1) generate field data for three biological processes, and (2) evaluate the performance of each biological process in meeting NYSDEC cleanup goals.

The demonstration took place from July to December 1994 at the Sweden 3-Chapman site in Sweden, New York and coincided with the ongoing remediation of the site. Soil at the site contained elevated levels of TCE, acetone, tetrachloroethene, dichloroethene, and toluene. The Demonstration Bulletin (EPA/540/MR-95/525) is available from EPA. The Innovative Technology Evaluation Report, which provides more detailed demonstration results, is being prepared.

In addition to the in situ bioventing process, the following technologies were also demonstrated:

- SBP Technologies, Inc., Vacuum-Vaporized Well system
- ENSR Consulting and Engineering and Larsen Engineers Ex Situ Biovault

For information on these technologies, refer to the NYSDEC profiles in the Demonstration Program section (completed projects).

DEMONSTRATION RESULTS:

The SITE demonstration results indicated that the REWEI process reduced contaminants in the soil. The initial mass of TCE in the soil was reduced by 92 percent with 80 percent removal attributed to biodegradation and 12 percent removed by vapor extraction. Results of the microbiological analyses indicate that the number of total heterotrophic, TCE-degrading, and methane-degrading microorganisms increased during treatment. The inorganic soil nitrogen content increased due to the subsurface injection of anhydrous ammonia.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Annette Gatchett
National Risk Management Research
Laboratory
U.S. EPA
26 West Martin Luther Drive
Cincinnati, OH 45268
513-569-7697
Fax: 513-569-7105
e-mail: gatchett.annette@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

Jim Harrington
New York State Department of
Environmental Conservation
50 Wolf Road, Room 268
Albany, NY 12233-7010
518-457-3337
Fax: 518-457-9639
e-mail: harrington.jim@epa.gov

Richard Cronce
Science Applications International Corp.
6310 Allentown Blvd.
Harrisburg, PA 17112
717-901-8100
Fax: 717-901-8105

**NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL
CONSERVATION/SBP TECHNOLOGIES, INC.
(Groundwater Circulation Biological Treatment Process)**

TECHNOLOGY DESCRIPTION:

The SBP Technologies, Inc. (SBP), remediation program uses an in situ Unterdruck-Verdampfer-Brunnen (UVB) vertical groundwater circulation well technology, which has been enhanced with an in situ bioreactor to treat soil and groundwater contaminated with chlorinated and non-chlorinated volatile organic compounds (VOC). This process consists of a specially adapted groundwater circulation well, reduced-pressure stripping reactor, an in situ bioreactor, and an aboveground vapor-phase bioreactor.

The UVB technology was developed by IEG mbH in Germany and is distributed in the U.S. by IEG Technologies Corporation. SBP obtained the rights to implement this technology and enhanced it to create a more effective in situ bioremediation technology.

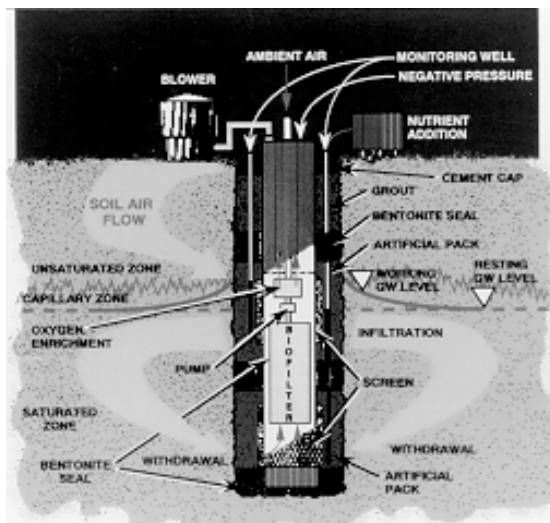
The microbiologically enhanced vertical circulation well technology simultaneously treats the vadose zone, capillary fringe, and saturated zones. During the demonstration, a groundwater convection

(circulation) cell was created radially within the aquifer around the 16-inch UVB well. The UVB well consisted of upper and lower screens separated by a solid riser casing (see the figure below). The lower screen was isolated from the upper screen by a packer, creating two separate screened zones. Contaminated groundwater flowed into the lower screen of the UVB well and was pumped to the upper section. The water rose through the in situ fixed film bioreactor, initially reducing the contaminant load. Groundwater then flowed to the in situ aerator/stripping reactor, where fresh ambient air was mixed with the contaminated groundwater.

The convection cell was developed by allowing the treated groundwater to exit into the upper aquifer. The untreated VOCs exiting the in situ bioreactor system were stripped before the groundwater flowed out of the upper screen into the aquifer as clean water. Oxygenated groundwater from the shallow aquifer circulated to the deep aquifer zone and through the fixed film bioreactor to provide for aerobic degradation. This circulation created a remediation circulation cell in a glacial till geologic formation.

In conjunction with the groundwater remediation, the upper double-cased screen in the well allowed for a one-way soil air flow from the vadose zone to the UVB. This one-way soil venting, created by the reduced-pressure developed in the well by the blower, simultaneously remediated the contaminated unsaturated and capillary fringe zones.

The off-gases from the in situ aerator/stripping reactor passed through an ex situ gas-phase bioreactor for further biotreatment followed by granular activated carbon treatment before they were vented. This bioreactor consisted of spirally wound, microporous, polyvinyl chloride-silica sheets that served as a biosupport for *Pseudomonas cepacia* (strain 17616), a known trichloroethene (TCE) degrader. VOCs in the off-gases, such as toluene, benzene, xylene, TCE, and others, were



Vacuum-Vaporized Well (UVB)
System Standard Circulation

also biologically treated rough a cometabolic process in the gas-phase bioreactor.

WASTE APPLICABILITY:

This technology treats soil and groundwater contaminated with chlorinated and nonchlorinated VOCs.

STATUS:

The UVB system was accepted into the SITE Demonstration Program in June 1994. The pilot-scale, multivendor treatability demonstration (MVTD) was jointly sponsored by the New York State Department of Environmental Conservation (NYSDEC), the New York State Center for Hazardous Waste Management, and the SITE Program. The objectives of the MVTD were to (1) generate field data for three biological processes, and (2) evaluate the performance of each biological process in meeting NYSDEC cleanup goals.

The demonstration took place at the Sweden 3-Chapman site in Sweden, New York. Field work began in July 1994 and was completed in fall 1995. Final reports from the demonstration are available from EPA.

The UVB demonstration coincided with the remediation of the site. Soil at the site contained elevated levels of TCE, acetone, tetrachloroethene, dichloroethene, and toluene. The contaminants of concern (COC) were monitored at 15 groundwater monitoring wells, across the in situ bioreactor, the vadose zone soils, and the ex situ bioreactor, to evaluate the system's performance. A dye tracer test was conducted to determine the extent of the groundwater circulation cell.

In addition to the SBP process, the following technologies were also demonstrated:

- R.E. Wright Environmental, Inc., In Situ Bioventing Treatment System
- ENSR Consulting and Engineering and Larsen Engineers Ex Situ Biovault

For information on these technologies, refer to the NYSDEC profiles in the Demonstration Program section (completed projects).

DEMONSTRATION RESULTS:

During the demonstration, an in situ vertical groundwater circulation cell was established with an effective radius of 40 feet. The UVB system reduced the concentration of COCs in groundwater. The in situ bioreactor provided biotreatment of the COCs in the dissolved phase; removal of COCs from soils was also demonstrated. An ex situ bioreactor was effective in treating off-gas vapors from the UVB system prior to final polishing. Mass balance calculations determined that at least 75 percent of the target COCs in soil and groundwater, within the UVB's radius of influence, were removed during the demonstration.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Michelle Simon
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7469 Fax: 513-569-7676
e-mail: simon.michelle@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

Jim Harrington
New York State Department of
Environmental Conservation
50 Wolf Road, Room 268
Albany, NY 12233-7010
518-457-0337 Fax: 518-457-9639
e-mail: harrington.jim@epa.gov

Richard Desrosiers
SBP Technologies, Inc.
106 Corporate Park Drive
White Plains, NY 10604
914-694-2280 Fax: 914-694-2286

NOVATERRA ASSOCIATES
(formerly Toxic Treatment, Inc.)
(In Situ Soil Treatment [Steam and Air Stripping])

TECHNOLOGY DESCRIPTION:

This technology treats contaminated soils and contained groundwater by the simultaneous in situ injection of treatment agents below ground during active mixing by augers or drilling blades (see figure below). The in situ injection of steam and air during mixing strips the volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) from the soil and contained groundwater. The removed organics are captured at the surface and disposed of in an environmentally safe manner.

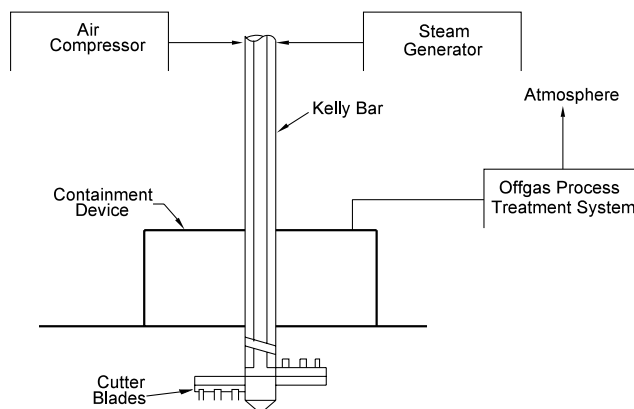
The technology is implemented by a drill unit that can consist of a single or double blade or auger mounted on a large crane or backhoe. The diameter of the drill or auger can vary from 5 to 8 feet, and it is mounted on a kelly that reaches depths of 60 feet.

The steam and air are carried down the center of the kelly(s) and injected into the ground through jets located on the blade or auger arms. The steam is supplied by an oil- or natural gas-fired boiler at 450°F and 500 pounds per square inch gauge (psig). The air heated by the compressor is injected at 250 °F and 200 psig. The steam heats the contaminants in the soil and contained water, increasing the vapor pressure of the VOCs and SVOCs and increasing their removal rates. The direct application of the steam on the soil thermally desorbs the VOCs and SVOCs, increasing their removal percentage. Almost all the VOCs and SVOCs of interest form

azeotropes with steam that boil below 212 °F and contain low concentrations (such as a few percent) of contaminants. These azeotropes significantly increase contaminant removal rates, especially for the higher-boiling-point SVOCs.

The VOC- and SVOC-laden air and steam vapor stream removes the contamination to the surface where it can be captured, if necessary, in a metal container. The container, which makes a tight seal to the ground surface, is connected to a process stream by piping. A suction blower draws the waste stream to the process stream where it is collected or destroyed. The blower creates a slight vacuum in the container and piping as well as a positive displacement inward to the collection or destruction system, thus protecting the outside environment from contamination.

The simplest form of the process system uses a catalytic oxidizer or thermal oxidizer to destroy the contamination before exhausting to the atmosphere. When treating chlorinated VOCs and SVOCs, an acid scrubber can be added if required by the amount of material being processed. Another simple process uses activated carbon to recover the contamination. For the carbon to work efficiently, a cooling system must precede the carbon bed, so the process must also treat contaminated water. If recovery and reuse of the contamination is important or economically desirable, a process system that condenses the gas stream can be used.



In Situ Soil Treatment Process Schematic

The in situ soil treatment technology has also treated contaminated soil by injecting and mixing other agents. Chemical injection processes include the stabilization and solidification of heavy metals, neutralization of acids and bases, and oxidation. The technology has been successfully used to perform bioremediation. The equipment is capable of injecting cement into the soil and making slurry walls. The technology has the unique feature of being able to inject two materials simultaneously or sequentially.

WASTE APPLICABILITY:

This technology can treat solid materials which do not contain obstructions, including soils, sludges, lagoons, and the liquids contained within, such as water and dense and light nonaqueous-phase liquids. The technology is applicable to most VOCs and SVOCs, including pesticides. It is particularly applicable to free product and removal of highly concentrated contamination. It is most effective for removals of 95 to 99 percent of the contamination as a result of the low temperature thermal desorption. After treatment is completed, the soil can meet construction engineering requirements by compacting or injecting small amounts of cement.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. A SITE demonstration was performed in September 1989 at the Annex Terminal, San Pedro, California. Twelve soil blocks were treated for VOCs and SVOCs. Liquid samples were collected during the demonstration, and the operating procedures were closely monitored and recorded. In January 1990, six blocks that had been previously treated in the saturated zone were analyzed by EPA methods 8240 and 8270.

The Applications Analysis Report (EPA/540/A5-90/008) was published in June 1991. The technology remediated 30,000 cubic yards at the Annex Terminal after completion of the SITE demonstration and has been used at five other contaminated sites.

DEMONSTRATION RESULTS:

The SITE technology demonstration yielded the following results:

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

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Paul dePercin
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7797
Fax: 513-569-7105
E-Mail: deperc.paul@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

Phil La Mori
NOVATERRA Associates
2419 Outpost Drive
Los Angeles, CA 90068-2644
310-328-9433
E-mail: NOVATERRA@aol.com

U.S. EPA NRMRL (Alternative Cover Assessment Program)

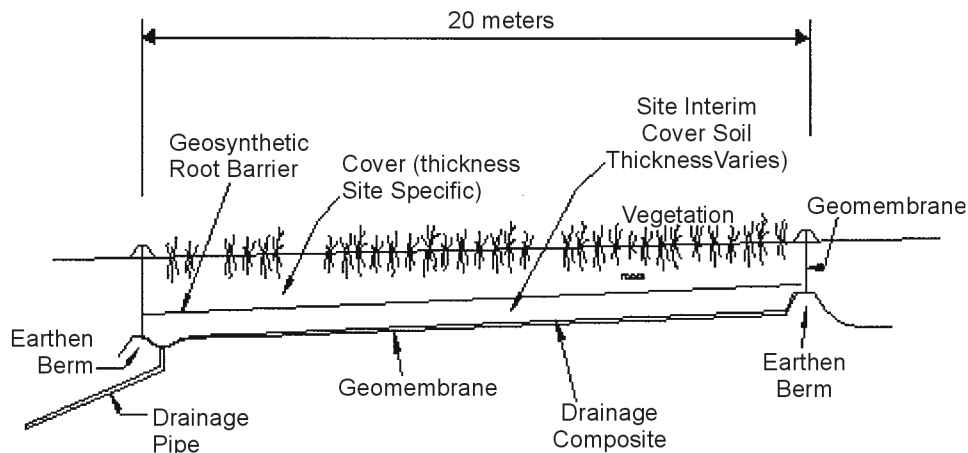
TECHNOLOGY DESCRIPTION:

The goal of the Alternative Cover Assessment Program (ACAP) is the development of field-scale performance data for landfill final cover systems. Both prescriptive (RCRA) and innovative alternative cover designs are currently being tested in the project. The ACAP demonstration has four phases:

- Phase 1 – Initial review of current data collection efforts and numerical modeling capabilities relative to landfill cover design
- Phase 2 – Design, construction, and operation (for 5 years) of a network of alternative cover testing facilities
- Phase 3 – Analysis of field results with improved numerical models to predict long-term performance of alternative cover systems at the selected testing sites
- Phase 4 – Development of a comprehensive guidance document on alternative cover systems

A primary function of a landfill final cover system is to minimize deep percolation to prevent surface and groundwater contamination. Landfill and waste site covers are constructed to meet the requirements of current regulatory guidance, and typically rely on a combination of layers of specified thickness to limit percolation through the cover.

The large costs associated with the construction of the landfill and waste site covers and the desire for constant innovation and performance improvement have resulted in a growing interest for alternative designs. It is ACAP's goal to evaluate the various proposed alternative cover systems. ACAP is currently focusing on evapotranspiration (ET) type covers. ET covers utilize plants to cycle water from the soil profile to the atmosphere during the growing season thus minimizing year-round drainage from the cover system.



WASTE APPLICABILITY:

ACAPs are generally constructed for landfills and waste sites of all scales. In theory, ACAPs can be installed at any location where environmental contaminants must be contained.

STATUS:

Test sections have been installed at landfills in Sacramento County, California; Lake County, Montana; Lewis & Clark County, Montana; Monticello, Utah; Cedar Rapids, Iowa; Omaha, Nebraska; Boardman, Oregon; Altamont, California; Monterey, California; and the Marine Corps Logistics Base in Albany, Georgia. In addition, retrofit monitoring (to study existing alternative covers constructed prior to ACAP) has been established in Cincinnati and Logan, Ohio.

The basic components of the alternative covers for these sites are vegetation and soil. Different communities of trees, shrubs, and grasses are incorporated depending on local soil and climatological conditions. The cover soil is generally local soil, with depth differing in accordance with soil water holding capacity, precipitation patterns, and vegetation selected. Several of the sites include a prescriptive RCRA cover test section. Such side-by-side comparisons will allow direct evaluation of the performance of an alternative to meet or exceed that of the conventional, prescriptive cover.

Each site will contain at least one test section (10 meters x 20 meters) that consists of a large-scale, pan-type *lysimeter* to monitor percolation through tested covers over a period of five years.

During the five years, EPA will monitor and record the climatological conditions (rainfall, snowfall, air temperature, solar radiation, and humidity), and soil parameters (moisture content, moisture potential, and temperature) of each test section. Data will be recorded on a data logger connected to a telemetry unit. The telemetry unit allows remote communication with the data logger and enables data to be downloaded, stored, and analyzed for performance and system status.

Annually during the five years of this project, EPA will release performance reports for each site. EPA predicts that the data collected through ACAP will lead to the development of new computer models for designing and evaluating future landfill covers, new designs, and new methods to regulate such systems.

FOR FURTHER INFORMATION:

EPA Project Manager
Steve Rock
U.S. EPA
National Risk Management Research
Laboratory (NRMRL)
26 W. Martin Luther King Dr.
Cincinnati, OH 45268
513-569-7149
Fax: 513-569-7105
e-mail: rock.steven@epa.gov

**U.S. EPA NATIONAL RISK MANAGEMENT
RESEARCH LABORATORY
(Base-Catalyzed Decomposition Process)**

TECHNOLOGY DESCRIPTION:

The base-catalyzed decomposition (BCD) process is a chemical dehalogenation technology developed by the National Risk Management Research Laboratory in Cincinnati, Ohio. The process is initiated in a medium-temperature thermal desorber (MTTD) at temperatures ranging from 600 to 950°F. Sodium bicarbonate is added to contaminated soils, sediments, or sludge matrices containing hazardous chlorinated organics including polychlorinated biphenyls (PCB) and polychlorinated dioxins and furans. Chlorinated contaminants that are thermally desorbed from the matrix are condensed and treated by the BCD process. The BCD process chemically detoxifies the condensed chlorinated organic contaminants by removing chlorine from the contaminants and replacing it with hydrogen.

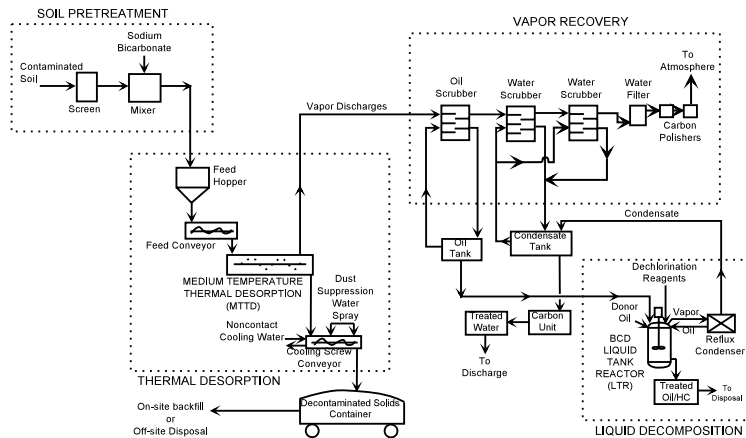
ETG Environmental, Inc. (ETG), and Separation and Recovery Systems, Inc. (SRS), developed the THERM-O-DETOX® and SAREX® systems and combined them with the BCD process chemistry. The combined process begins by initiating solid-phase dechlorination in the MTTD step (see figure below). In addition to the dechlorination that occurs in the MTTD, organics are thermally desorbed from the matrix, and are condensed and sent to the BCD liquid tank reactor (LTR).

Reagents are then added and heated to 600 to 650°F for 3 to 6 hours to dechlorinate the remaining organics. The treated residuals are recycled or disposed of using standard, commercially available methods. Treated, clean soil can be recycled as on-site backfill.

ETG has continued to develop the THERM-O-DETOX® system and now offers continuous systems and batch vacuum systems. The batch vacuum system offers greater operational flexibility for removal and destruction of high hazard, high boiling point contaminants to ensure that treatment standards are met. The vapor recovery system can be set up to use noncontact condensers or chillers and additional final polishing steps to meet the most stringent air emission standards.

WASTE APPLICABILITY:

The BCD process can treat soils, sediments, and sludges contaminated with the following chlorinated compounds: halogenated semivolatile organic compounds (SVOC), including herbicides and pesticides; PCBs; pentachlorophenol (PCP) and other chlorinated phenols; and polychlorinated dioxins and furans.



Base-Catalyzed Decomposition (BCD) Process

STATUS:

The combined BCD process was demonstrated under the SITE Program at the Koppers Company Superfund site in Morrisville, North Carolina, from August through September 1993. The process removed PCP from clay soils to levels below those specified in the Record of Decision. The process also removed dioxins and furans from contaminated soil to 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalent concentrations less than the concentration specified in the Record of Decision.

ETG is also currently operating the batch vacuum system at a New York State Department of Environmental Conservation cleanup site in Binghamton, New York. Approximately 1,500 cubic yards of soil contaminated with herbicides pesticides, dioxins, and furans (F027 waste) are being treated. The Michigan Department of Natural Resources has also approved BCD for a project involving treatment of about 200 cubic yards of F027 soils. At another site, multiple systems will treat soils contaminated with chlorinated volatile organic compounds and high boiling point (800-1150 °F) organic lubricants. The batch vacuum system has also been used to treat sludges at an operating refinery in Puerto Rico and a chemical company in Texas.

For information on the SAREX[®] system, see the profile for SRS in the Demonstration Program section (ongoing projects).

DEMONSTRATION RESULTS:

The SITE demonstration consisted of four test runs in the MTTD and two test runs in the LTR. Feed soil consisted of a dry, clayey silt and had a residence time of 1 to 2 hours in the MTTD, which was heated to 790 °F to 850 °F. The MTTD off-gases were treated by passing through an oil scrubber, water scrubbers, and carbon filters. The oil from the oil scrubber was transferred to the LTR for BCD treatment. The oil in each LTR test run was batch-processed for 3 to 4 hours at 600 to 630 of.

Key findings from the SITE demonstration are summarized as follows:

- The MTTD achieved removal efficiencies of 99.97 percent or better for PCP and 99.56 percent or better for total dioxins and total furans.
- The treated soils were well below toxicity characteristic leaching procedure limits for SVOCs.
- Treated soil met the cleanup goal of 95 parts per million PCP in all test runs. Treated soil also met a cleanup goal of 7 micrograms per kilogram 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents in all test runs.
- The LTR batch tests reduced PCP concentrations by 96.89 percent or better, and total dioxin and total furan concentrations by 99.97 percent or better.

FOR FURTHER INFORMATION:**EPA PROJECT MANAGER:**

Terrence Lyons
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7589
Fax: 513-569-7676
e-mail: lyons.terrence@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

George Huffman
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive, MS-445
Cincinnati, OH 45268
513-569-7431
Fax: 513-569-7549

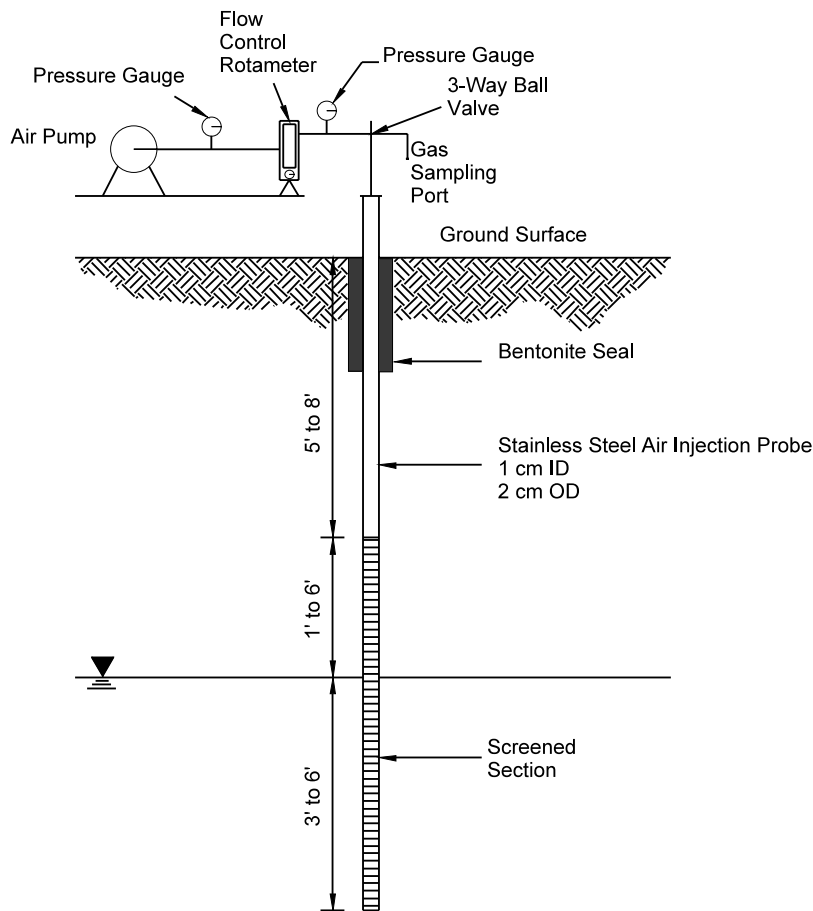
Yei-Shong Shieh
Environmental, Inc.
Blue Bell, PA
213-832-0700

**U.S. EPA NATIONAL RISK MANAGEMENT
RESEARCH LABORATORY
(Bioventing)**

TECHNOLOGY DESCRIPTION:

Lack of oxygen in contaminated soil often limits aerobic microbial growth. The bioventing biological system treats contaminated soil in situ by injecting atmospheric air. This air provides a continuous oxygen source, which enhances the growth of microorganisms naturally present in the soil. Additives such as ozone or nutrients may be introduced to stimulate microbial growth.

Bioventing technology uses an air pump attached to one of a series of air injection probes (see figure below). The air pump operates at extremely low pressures, providing inflow of oxygen without significantly volatilizing soil contaminants. The treatment capacity depends on the number of injection probes, the size of the air pump, and site characteristics such as soil porosity.



Bioventing System

WASTE APPLICABILITY:

Bioventing is typically used to treat soil contaminated by industrial processes and can treat any contamination subject to aerobic microbial degradation. Bioventing treats contaminants and combinations of contaminants with varying degrees of success.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration began in November 1992 at the Reilly Tar site in St. Louis Park, Minnesota. Soil at this site is contaminated with polynuclear aromatic hydrocarbons.

DEMONSTRATION RESULTS:

Between 1917 and 1972, the 80-acre Reilly Tar site was used for coal tar distillation and wood preserving operations. Wood preserving solutions were estimated to consist of 60-70 percent creosote oil and petroleum oils. Soils at this site consist of approximately 0.6 meters of a topsoil cover underlain by an asphaltic layer, below which coarse sand extends to the water table at approximately 3 meters below ground surface. Sandy soils within the demonstration area were contaminated with PAHs in concentrations as high as 873 mg/Kg.

Respiration tests conducted after two years of system operation suggested that initial oxygen utilization correlated to concentration reductions in the more readily degradable carrier oils (23 percent for naphthalene). Concentrations of the three- and higher-ring PAHs, however, remained unchanged. Final soil data collected in 1997 after five years of treatment showed that bioventing significantly treated the higher-ring PAHs as well. Data analysis indicated concentration reductions of 62 percent, 50 percent, 31 percent, 20 percent, and 24 percent for the 2, 3,4, 4, 5, and 6-ring PAHs, respectively.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER AND TECHNOLOGY DEVELOPER CONTACT:

Paul McCauley
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7444
Fax: 513-569-7105
e-mail: mccauley.paul@epa.gov

U.S. EPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY and IT CORPORATION (Debris Washing System)

TECHNOLOGY DESCRIPTION:

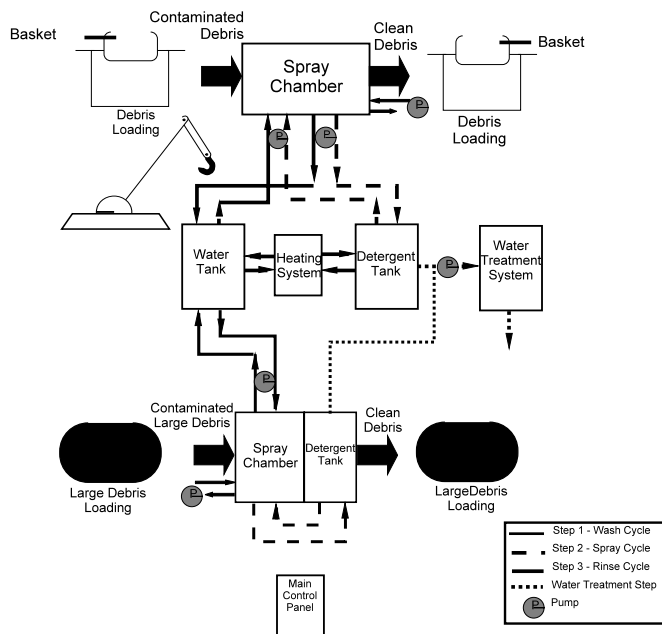
This technology was developed by EPA's National Risk Management Research Laboratory and IT Corporation (IT) for on-site decontamination of metallic and masonry debris at Comprehensive Environmental Response, Compensation, and Liability Act sites. The entire system is mounted on three 48-foot flatbed semi-trailers and can be readily transported from site to site.

The full-scale debris washing system (DWS) is shown in the figure below. The DWS consists of dual 4,000-gallon spray-wash chambers that are connected to a detergent solution holding tank and rinse water holding tank. Debris is placed into one of two 1,200-pound baskets, which in turn is placed into one of the spray-wash chambers using a 5-ton crane integral to the DWS. If debris is large

enough, the crane places it directly into one of the two chambers. Process water is heated to 160°F using a diesel-fired, 2,000,000-British-thermal-unit-per-hour (Btu/hr) water heater. The water is continuously reconditioned using particulate filters, an oil-water separator, and other devices such as charcoal columns or ion-exchange columns. About 8,000 to 10,000 gallons of water is required for the decontamination process. The system is controlled by an operator stationed in a trailer-mounted control room.

WASTE APPLICABILITY:

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



Pilot-Scale Debris Washing System

metals.

STATUS:

The first pilot-scale tests were performed in September 1988 at the Carter Industrial Superfund site in Detroit, Michigan. An upgraded pilot-scale DWS was tested at a PCB-contaminated Superfund site in Hopkinsville, Kentucky in December 1989. The DWS was also field tested in August 1990 at the Shaver's Farm Superfund site in Walker County, Georgia. The contaminants of concern were benzonitrile and Dicamba. After being cut into sections, 55-gallon drums were decontaminated in the DWS.

Results from the SITE demonstration have been published in a Technology Evaluation Report (EPA/540/5-91/006a), entitled "Design and Development of a Pilot-Scale Debris Decontamination System" and in a Technology Demonstration Summary (EPA/540/S5-91/006).

In 1993, a manual version of the full-scale DWS was used to treat PCB-contaminated scrap metal at the Summit Scrap Yard in Akron, Ohio. During the 4-month site remediation, 3,000 tons of PCB-contaminated scrap metal (motors, cast iron blocks) was cleaned on site. The target level of 7.7 $\mu\text{g}/100\text{ cm}^2$ was met, in most cases, after a single treatment with the DWS. The cleaned scrap was purchased by a scrap smelter for \$52 per ton. The net costs for the on-site debris decontamination ranged from \$50 to \$75 per ton. The National Risk Management Research Laboratory and IT estimate that the system can decontaminate 50 to 120 tons of typical debris per day.

DEMONSTRATION RESULTS:

At the Carter Industrial Superfund site, PCB reductions averaged 58 percent in batch 1 and 81 percent in batch 2. Design changes based on these tests were made to the DWS before additional field testing.

At the Hopkinsville, Kentucky site, PCB levels on the surfaces of metallic transformer casings were reduced to less than or equal to 10 micrograms PCB per 100 square centimeters ($\mu\text{g}/\text{cm}^2$). All 75 contaminated transformer casings on site were decontaminated to EPA cleanup criteria and sold to a scrap metal dealer.

At the Shaver's Farm Superfund site, benzonitrile and Dicamba levels on the drum surfaces were reduced from the average pretreatment concentrations of 4,556 and 23 $\mu\text{g}/100\text{ cm}^2$ to average concentrations of 10 and 1 $\mu\text{g}/100\text{ cm}^2$, respectively.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

John Martin
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7758
Fax: 513-569-7620
e-mail: martin.john@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

Majid Dosani
IT Corporation
11499 Chester Road
Cincinnati, OH 45246-4012
513-782-4700
Fax: 513-782-4807

**U.S. EPA NATIONAL RISK MANAGEMENT
RESEARCH LABORATORY
and INTECH 180 CORPORATION
(Fungal Treatment Technology)**

TECHNOLOGY DESCRIPTION:

This biological treatment system uses lignin-degrading fungi to treat excavated soils. These fungi have been shown to biodegrade a wide catalogue of organic contaminants.

The contaminated soil is inoculated with an organic carrier infested with the selected fungal strain. The fungi break down soil contaminants, using enzymes normally produced for wood degradation as well as other enzyme systems.

This technology has the greatest degree of success when optimal growing conditions for the fungi are used. These conditions include moisture control (at 90 percent of field capacity), and temperature and aeration control. Organic nutrients such as peat may be added to soils deficient in organic carbon.

WASTE APPLICABILITY:

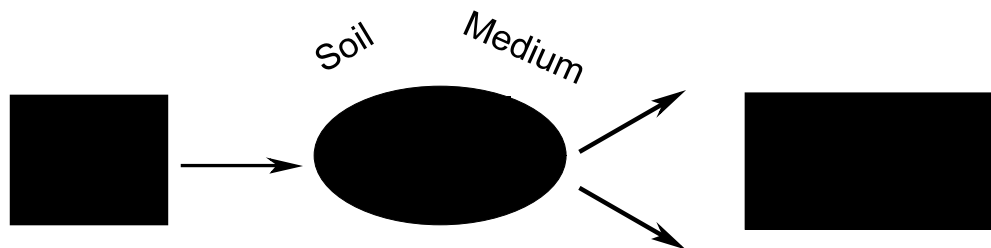
This biological treatment system was initially applied to soil contaminated with organic chemicals found in the wood-preserving industry. These contaminants are composed of chlorinated organics and polynuclear aromatic hydrocarbons (PAH). The treatment system may remediate different contaminants and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

STATUS:

This biological treatment system was accepted into the SITE Demonstration Program in April 1991. In September 1991, a treatability study was conducted at the Brookhaven Wood Preserving site in Brookhaven, Mississippi. Site soils were contaminated with 200 to 5,200 milligrams per kilogram (mg/kg) PCP and up to 4,000 mg/kg PAHs.

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

The extent of treatment in the full-scale demonstration was disappointing for the time of treatment. The full-scale demonstration was hampered by excessive rainfall which did not permit the treatment beds to be sufficiently tilled. Without this processing, oxygen-depleted conditions developed, leading to loss of fungal biomass and activity. Soil bed applications of this technology may not be suitable in climates of high rainfall. Current costs of fungal treatment operation are estimated at \$150 to \$200 per ton. Lower costs may be achieved with new inoculum formulations which permit reduction in the amount of inoculum mass required for treatment.



In Situ White Rot Fungal Treatment of Contaminated Soil

DEMONSTRATION RESULTS:

The full-scale project involved a 0.25-acre plot of contaminated soil and two smaller control plots. The soil was inoculated with *Phanaerochaete sordida*, a species of lignin-degrading fungus. No other amendments were added to the prepared soil. Field activities included tilling and watering all plots. No nutrients were added. The study was conducted for 20 weeks.

Some key findings from the demonstration were:

- Levels of PCP and the target PAHs found in the underlying sand layer and the leachate from each of the plots were insignificant, indicating low leachability and loss of these contaminants due to periodic irrigation of the soil and heavy rainfall.
- Levels of PCP, the target PAHs, and dioxins in the active air samples collected during the soil tilling events were insignificant, indicating a very low potential for airborne contaminant transport.
- Air emissions data showed that soil tilling activities did not pose significant hazards to field technicians. Contaminated soil, underlying sand, and leachate had no significant contamination.

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Teri Richardson
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7949
Fax: 513-569-7105
e-mail: richardson.teri@epa.gov

TECHNOLOGY DEVELOPER CONTACTS:

John Glaser
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7568
Fax: 513-569-7105
e-mail: glaser.john@epa.gov

Richard Lamar
INTECH 180 Corporation
1770 N. Research Parkway, Suite 100
North Logan, UT 84341
801-753-2111
Fax: 801-753-8321

**U.S. EPA NATIONAL RISK MANAGEMENT
RESEARCH LABORATORY,
UNIVERSITY OF CINCINNATI, and FRX, INC.
(Hydraulic Fracturing)**

TECHNOLOGY DESCRIPTION:

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

The fracturing process begins by injecting water into a sealed borehole until the water pressure exceeds a critical value and a fracture is nucleated (see photograph below). A slurry composed of a coarse-grained sand, or other granular material, and guar gum gel is then injected as the fracture grows away from the well. After pumping, the grains hold the fracture open while an enzyme additive breaks down the viscous fluid. The thinned fluid is pumped from the fracture, forming a permeable

subsurface channel suitable for delivering or recovering a vapor or liquid. These fractures function as pathways for fluid movement, potentially increasing the effective area available for remediation.

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

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



Hydraulic Fracturing Process (Well is at center of photograph)

WASTE APPLICABILITY:

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

STATUS:

The hydraulic fracturing technology was accepted into the SITE Demonstration Program in July 1991. Demonstrations have been conducted in Oak Brook, Illinois and Dayton, Ohio. The hydraulic fracturing process was integrated with soil vapor extraction at the Illinois site and with in situ bioremediation at the Ohio site. The project was completed in September 1992. The Technology Evaluation and Applications Analysis Reports, which were published under one cover (EPA/540/R-93/505), and the Technology Demonstration Summary (EPA/540/SR-93/505) are available from EPA.

DEMONSTRATION RESULTS:

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

- Over a 1-year period, the vapor yield from hydraulically fractured wells was one order of magnitude greater than from unfractured wells.
- The hydraulically fractured wells enhanced remediation over an area 30 times greater than the unfractured wells.

- The presence of pore water decreased the vapor yield from wells; therefore, water must be prevented from infiltrating areas where vapor extraction is underway.

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

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

FOR FURTHER INFORMATION:

EPA PROJECT MANAGER:

Michael Roulier
U.S. EPA
National Risk Management Research
Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7796
Fax: 513-569-7620
e-mail: roulier.michael@epa.gov

TECHNOLOGY DEVELOPER CONTACT:

William Slack
FRX Inc.
P.O. Box 498292
Cincinnati, OH 45249
513-469-6040
Fax: 513-469-6041

U.S. EPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY (Mobile Volume Reduction Unit)

TECHNOLOGY DESCRIPTION:

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

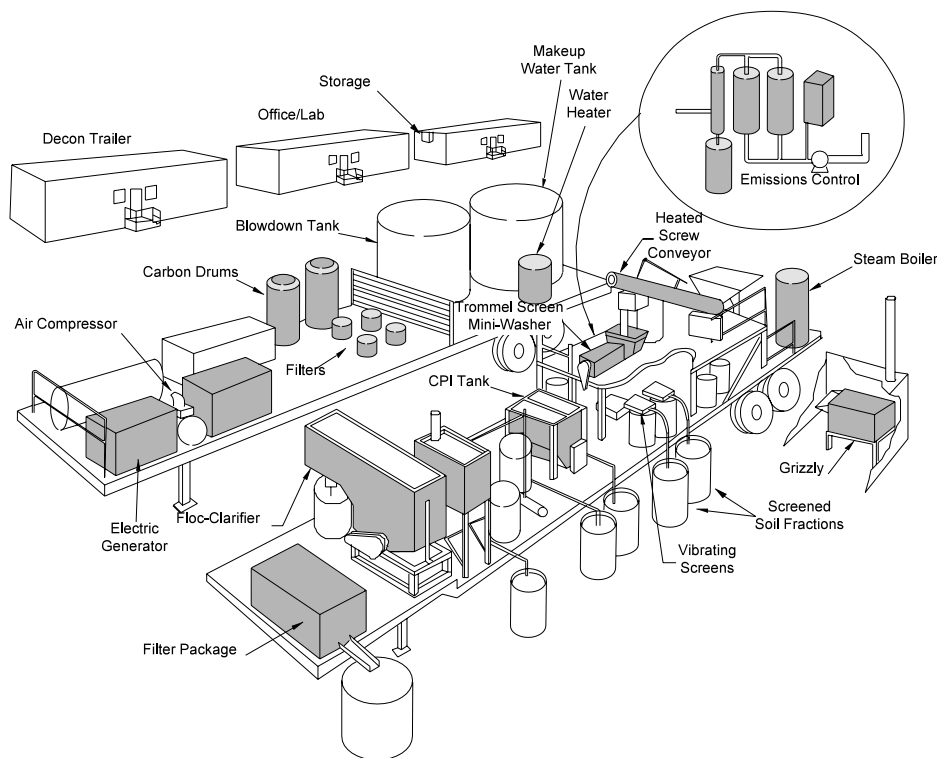
The process subsystems consist of soil handling and conveying, soil washing and coarse screening, fine particle separation, flocculation-clarification, water treatment, and utilities. The VRU is controlled and monitored with conventional industrial process instrumentation and hardware.

WASTE APPLICABILITY:

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

STATUS:

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



Typical VRU Operational Setup