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

TECHNOLOGY DESCRIPTION:

Terra-Kleen Response Group, Inc. (Terra-Kleen), developed the solvent extraction treatment system to remove semivolatile and nonvolatile organic contaminants from soil. This batch process system uses a proprietary solvent blend to separate hazardous constituents from soils, sediments, sludge, and debris.

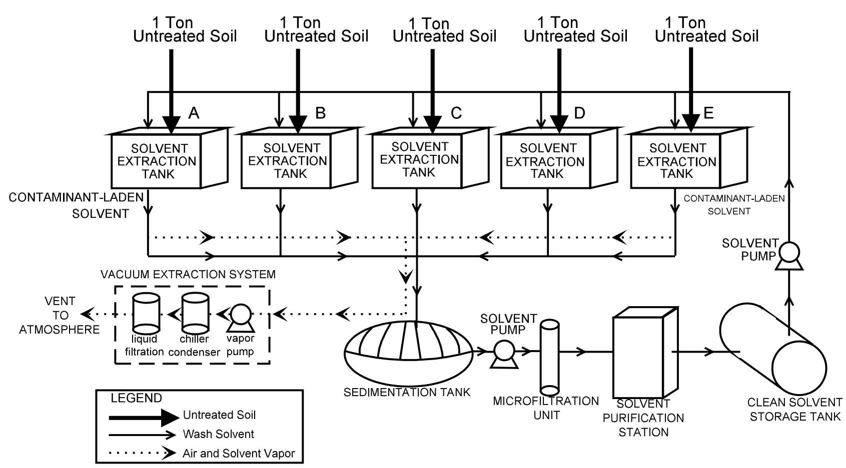
A flow diagram of the Terra-Kleen treatment system is shown below. Treatment begins after excavated soil is loaded into the solvent extraction tanks. Clean solvent from the solvent storage tank is pumped into the extraction tanks. The soil and solvent mixture is held in the extraction tanks long enough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

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

Contaminant-laden solvents are cleaned for reuse by Terra-Kleen's solvent regeneration process. The solvent regeneration process begins by pumping contaminant-laden solvent from the sedimentation tank through a microfiltration unit and a proprietary solvent purification station. The microfiltration unit first removes any fines remaining in the solvent. The solvent purification station separates organic contaminants from the solvent and concentrates them, reducing the amount of hazardous waste for off-site disposal. The solvent is pumped into the solvent storage tank for use in treating additional soil.

WASTE APPLICABILITY:

The Terra-Kleen solvent extraction treatment system is a waste minimization process designed to remove the following organic contaminants from soils: polychlorinated biphenyls (PCB), chlorinated pesticides, polynuclear aromatic hydrocarbons (PAH), pentachlorophenol, creosote, polychlorinated dibenzo-p-dioxins (PCDD), chlorinated pesticides, and polychlorinated dibenzofurans (PCDF). The system is transportable and can be configured to treat small quantities of soil (1 to 1,000 cubic yards) as well as large volumes generated at remedial sites.



Solvent Extraction Treatment System

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

STATUS:

The solvent extraction treatment system was demonstrated during May and June 1994 at Naval Air Station North Island (NASNI) Site 4 in San Diego, California. Soils at Site 4 are contaminated with heavy metals, volatile organic compounds (VOC), PCBs (Aroclor 1260), and furans. The Technology Capsule (EPA/540/R-94/521a) and Demonstration Bulletin (EPA/540/MR-94/521) are available from EPA. The Innovative Technology Evaluation Report is available from EPA.

Several full-scale solvent extraction units are in operation at this time. Terra-Kleen has removed PCBs from 10,000 tons of soil at three sites within NASNI, and completed cleanup of a remote Air Force Base PCB site in Alaska. A full-scale system has also removed DDT, DDD, and DDE from clay soil at the Naval Communication Station in Stockton, California.

Terra-Kleen has been selected to participate in the Rapid Commercialization Initiative (RCI). RCI was created by the Department of Commerce, Department of Defense, Department of Energy (DOE), and EPA to assist in the integration of innovative technologies into the marketplace. Under RCI, Terra-Kleen is expanding its capabilities to process PCBs and VOCs in low-level radioactive wastes. The pilot project for this effort was completed in 1997 at DOE's Fernald Plant near Cincinnati, Ohio.

DEMONSTRATION RESULTS:

Findings from the SITE demonstration are summarized as follows:

- PCB Aroclor 1260 concentrations were reduced from an average of 144 milligrams per kilogram (mg/kg) to less than 1.71 mg/kg, an overall removal efficiency of 98.8 percent.
- NASNI untreated soil contained a moisture content of 0.83 percent; a particle size distribution of 80 percent sand, 15 percent gravel, and 5 percent clay; and an overall oil and grease concentration of 780 mg/kg.
- Hexachlorodibenzofuran and pentachlorodibenzofuran concentrations were reduced by 92.7 percent and 84.0 percent, respectively. Oil and grease concentrations were reduced by 65.9 percent.

Additional data were collected at the Naval Communication Station in Stockton, California. The system treated soil contaminated with chlorinated pesticides at concentrations up to 600 mg/kg. Samples taken during system operation indicated that soil contaminated with DDD, DDE, and DDT was reduced below 1 mg/kg, an overall removal efficiency of 98.8 to 99.8 percent.

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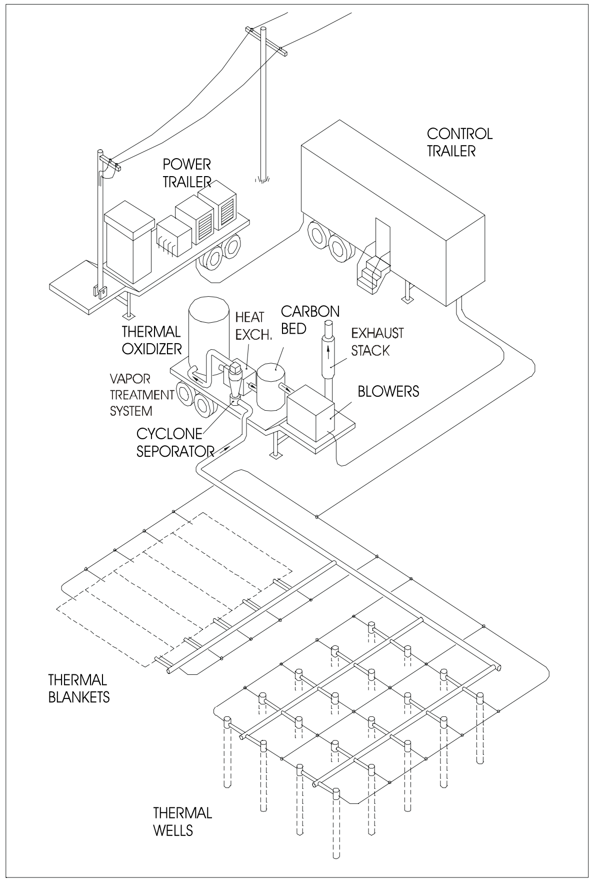
The SITE Program assesses but does not approve or endorse technologies.

TERRATHERM, INC.
(In Situ Thermal Destruction)

TECHNOLOGY DESCRIPTION:

TerraTherm, Inc.'s patented In Situ Thermal Destruction (ISTD) process utilizes conductive heating and vacuum to remediate soil contaminated with a wide range of organic compounds. Heat and vacuum are applied simultaneously to subsurface soil, either with an array of vertically or horizontally positioned heaters under imposed vacuum. The electrically powered heating elements are operated at temperatures of up to 800°C. In a typical installation for soils contaminated with organochlorine pesticides, polychlorinated biphenyls (PCBs), or polynuclear aromatic hydrocarbons (PAHs), the heater wells are installed at 6 ft to 7.5 ft spacing, with an impermeable liner installed at the soil surface. More volatile compounds can be treated with more widely spaced wells. Heat flows through the soil from the heating elements primarily by thermal conduction, which results in uniform heat distribution because unlike other soil physical properties such as permeability that tend to vary over orders of magnitude, thermal conductivity is nearly invariant over a wide range of soil types (e.g., clay to sand).

As the soil is heated, volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) are vaporized and/or destroyed by a number of mechanisms, including evaporation, boiling of water/steam distillation, boiling of the contaminants, oxidation and pyrolysis. The vaporized water and contaminants are drawn counter-current to the heat flow into the heater-vacuum wells. In practice, most (e.g., 95-99 percent) of the contaminants are destroyed within the soil as they arrive in the superheated soil in proximity of the heated extraction wells. The small fraction of the contaminant mass that has not been destroyed in situ is removed from the vapor stream at the surface with an air pollution control system.



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The vapor treatment train usually consists of a thermal oxidizer, heat exchanger, dry scrubber, carbon adsorbers, and vacuum blowers. Destruction and removal efficiencies of 99.9 percent have been achieved in the stack effluent with this system for PCBs.

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

WASTE APPLICABILITY:

Based on the results of completed ISTD remediation projects conducted at seven contaminated sites and numerous treatability studies, the ISTD technology has been proven to be highly effective in removing a wide variety of organic contaminants from soil and buried waste, including pesticides, PCBs, dioxins, chlorinated solvents, PAHs, coal tar, wood-treatment wastes, explosives residues, and heavy and light petroleum hydrocarbons. Achievement of non detect levels throughout the treatment zone is a typical result of approximately two to three months of heating. Soil, waste and sediment can be treated both above and below the water table, although in the case of treatment of SVOCs below the water table, recharge of groundwater into the heated zone must be controlled.

STATUS:

Since 1995, ISTD has been applied at seven field sites, including three demonstrations and four full-scale projects. Of these, four were at CERCLA and/or Department of Defense sites. Currently, TerraTherm, Inc. is engaged in design and implementation of ISTD at four additional project sites. In particular, remediation of the Hex Pit at the Rocky Mountain Arsenal, Commerce City, Colorado, by ISTD is a U.S. EPA Superfund Innovative Technology Evaluation (SITE) demonstration project.

A total of 266 thermal wells, including 210 heater-only and 56 heater-vacuum wells, will be installed during the fall of 2001 in a hexagonal pattern at 6.0-ft spacing and to a depth of 12 feet to treat 2,500 cubic yards of soil. Heating of the Hex Pit is scheduled to begin in January 2002. The treatment zone will be heated over an approximately 75-day period to interwell temperatures of >325°C. Subsurface monitoring will track the progress of heating. SITE will carry out isokinetic stack testing as well as pre- and posttreatment soil sampling both within and just outside the boundaries of the thermal treatment zone to evaluate the degradation efficiency, degree of in-situ destruction, effects on fringe areas, and discharge concentrations.

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

TERRA VAC
(In Situ and Ex Situ Vacuum Extraction)

TECHNOLOGY DESCRIPTION:

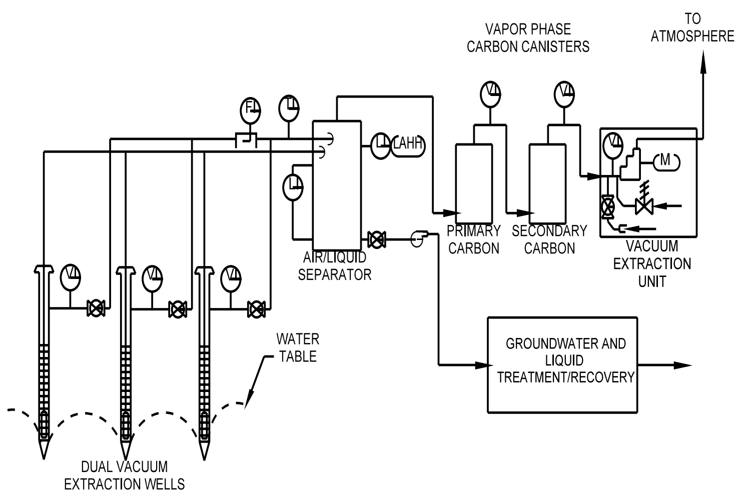
In situ or ex situ vacuum extraction is a process that removes volatile organic compounds (VOC) and many semivolatile organic compounds (SVOC) from the vadose, or unsaturated, soil zone. These compounds can often be removed from the vadose zone before they contaminate groundwater. Soil piles also may be cleaned by ex situ vacuum extraction. The in situ vacuum extraction process has been patented by others and licensed to Terra Vac and others in the United States.

The extraction process uses readily available equipment, including extraction and monitoring wells, manifold piping, air-liquid separators, and vacuum pumps. Vacuum extraction systems may vent directly to the atmosphere or through an emission control device. After the contaminated area is generally characterized, extraction wells are installed and connected by piping to the vacuum extraction and vapor treatment systems.

First, a vacuum pump creates a vacuum in the soil causing in situ volatilization and draws air through the subsurface. Contaminants are removed from the extraction wells and pass to the air-liquid separator. The vapor-phase contaminants may be treated with an activated carbon adsorption filter, a catalytic oxidizer, or another emission control system before the gases are discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations are monitored with vadose zone monitoring wells.

The technology can be used in most hydrogeological settings and may reduce soil contaminant levels from saturated conditions to nondetectable. The process also works in fractured bedrock and less permeable soils (clays) with sufficient permeability. The process may be used to enhance bioremediation (bioventing). It also may be used in conjunction with dual vacuum extraction, soil heating, pneumatic fracturing, and chemical oxidation to recover a wide range of contaminants. The figure below illustrates one possible configuration of the process.

Typical contaminant recovery rates range from 20 to 2,500 pounds (10 to 1,000 kilograms) per day, depending on the degree of site contamination and the design of the vacuum extraction system.



In Situ Dual Vacuum Extraction Process

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

WASTE APPLICABILITY:

The vacuum extraction technology may treat soils containing virtually any VOC. It has removed over 40 types of chemicals from soils and groundwater, including solvents and gasoline- and diesel-range hydrocarbons.

STATUS:

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

The vacuum extraction process was first demonstrated at a Superfund site in Puerto Rico in 1984. Terra Vac has since applied the technology at more than 20 additional Superfund sites and at more than 700 other waste sites throughout the United States, Europe, and Japan.

DEMONSTRATION RESULTS:

During the Groveland Wells SITE demonstration, four extraction wells pumped contaminants to the process system. During a 56-day period, 1,300 pounds of VOCs, mainly TCE, were extracted from both highly permeable strata and less permeable (10^{-7} centimeters per second) clays. The vacuum extraction process achieved nondetectable VOC levels at some locations and reduced the VOC concentration in soil gas by 95 percent. Average reductions of soil concentrations during the demonstration program were 92 percent for sandy soils and 90 percent for clays. Field evaluations yielded the following conclusions:

- Permeability of soils is an important consideration when applying this technology.
- Pilot demonstrations are necessary at sites with complex geology or contaminant distributions.
- Treatment costs are typically $40 per ton of soil but can range from less than $10 to $80 per ton of soil, depending on the size of the site and the requirements for gas effluent or wastewater treatment.
- Contaminants should have a Henry's constant of 0.001 or higher.

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

TEXACO INC.
(Texaco Gasification Process)

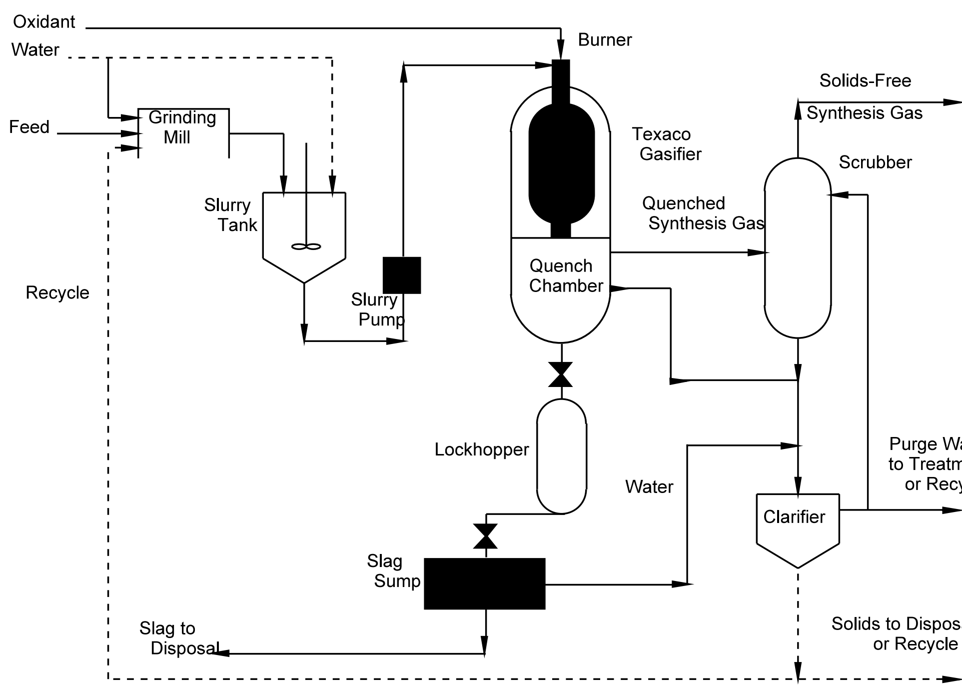
TECHNOLOGY DESCRIPTION:

The Texaco Gasification Process (TGP) is an entrained-bed, noncatalytic, partial oxidation process in which carbonaceous substances react at elevated temperatures and pressures, producing a gas containing mainly carbon monoxide and hydrogen (see figure below). This product, called synthesis gas, can be used to produce other chemicals or can be burned as fuel. Inorganic materials in the feed melt are removed as a glass-like slag.

This technology has operated commercially for over 40 years with feedstocks such as natural gas, heavy oil, coal, and petroleum coke. The TGP processes waste feedstocks at pressures above 20 atmospheres and temperatures between 2,200 and 2,800°F.

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

After the TGP converts organic materials into synthesis gas, the cooled, water-scrubbed product gas, consisting mainly of hydrogen and carbon monoxide, essentially contains no hydrocarbons heavier than methane. Metals and other ash constituents become part of the glassy slag.The TGP can be configured as a transportable system capable



Texaco Gasification Process

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

of processing about 100 tons of hazardous waste per day. This system would produce about 6 million standard cubic feet of usable synthesis gas per day with a heating value of approximately 250 British thermal units per standard cubic foot.

WASTE APPLICABILITY:

The TGP can treat the following wastes:

- Contaminated soils, sludges, and sediments that contain both organic and inorganic constituents
- Chemical wastes
- Petroleum residues

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

Texaco has demonstrated gasification of coal liquefaction residues, petroleum production tank bottoms, municipal sewage sludge, and surrogate contaminated soil. Texaco is operating a gasification facility at its El Dorado, Kansas refinery that will convert up to 170 tons per day of petroleum coke and Resource Conservation and Recovery Act-listed refinery wastes into usable synthesis gas.

STATUS:

The TGP was accepted into the SITE Demonstration Program in July 1991. A demonstration was conducted in January 1994 at Texaco's Montebello Research Laboratory in California using a mixture of clean soil, coal, and contaminated soil from the Purity Oil Sales Superfund site, located in Fresno, California. The mixture was slurried and spiked with lead, barium, and chlorobenzene. Forty tons of slurry was gasified during three demonstration runs. The Demonstration Bulletin (EPA/540/MR-95/514), Technology Capsule (EPA/540/R-94/514a), and Innovative Technology Evaluation Report (EPA/540/R-94/514) are available from EPA.

DEMONSTRATION RESULTS:

Findings from the SITE demonstration are summarized below:

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

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

TORONTO HARBOR COMMISSION
(Soil Recycling)

TECHNOLOGY DESCRIPTION:

The Toronto Harbor Commission's (THC) soil recycling process removes inorganic and organic contaminants from soil to produce a reusable fill material (see photograph below). The process consists of three technologies operating in series: a soil washing technology; a technology that removes inorganic contamination by chelation; and a technology that uses chemical and biological treatment to reduce organic contaminants.

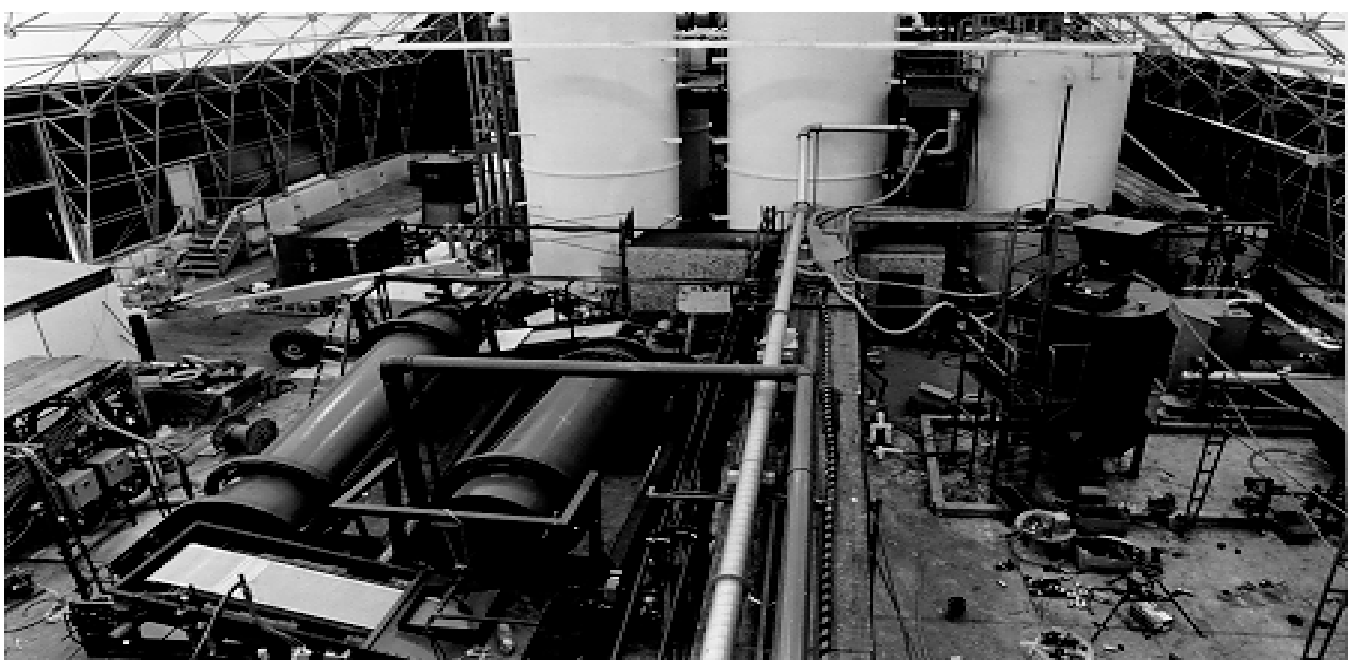
The process uses an attrition soil wash plant to remove relatively uncontaminated coarse soil fractions using mineral processing equipment while concentrating the contaminants in a fine slurry which is routed to the appropriate process for further treatment. The wash process includes a trommel washer to remove clean gravel, hydrocyclones to separate the contaminated fines, an attrition scrubber to free fines from sand particles, and a density separator to remove coal and peat from the sand fraction.

If only inorganic contaminants are present, the slurry can be treated in the inorganic chelator unit. This process uses an acid leach to free the inorganic contaminant from the fine slurry and then removes the metal using solid chelating agent pellets in a patented countercurrent contactor. The metals are recovered by electrowinning from the chelation agent regenerating liquid.

Organic removal is accomplished by first chemically pretreating the slurry from the wash plant or the metal removal process. Next, biological treatment is applied in upflow slurry reactors using the bacteria which have developed naturally in the soils. The treated soil is dewatered using hydrocyclones and returned to the site from which it was excavated.

WASTE APPLICABILITY:

The technology is designed to reduce organic and inorganic contaminants in soils. The process train approach is most useful when sites have been contaminated as a result of multiple uses over a



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

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

period of time. Typical sites where the process train might be used include refinery and petroleum storage facilities, sites with metal processing and metal recycling histories, and manufactured gas and coal or coke processing and storage sites. The process is less suited to soils with undesirable high inorganic constituents which result from the inherent mineralogy of the soils.

STATUS:

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

Results have been published in the Demonstration Bulletin (EPA/520-MR -92/015), the Applications Analysis Report (EPA/540-AR-93/517), the Technology Evaluation Report (EPA/540/R-93/517), and the Technology Demonstration Summary (EPA/540/SR-93/517). These reports are available from EPA.

This technology is no longer available through a vendor. For further information on the technology, contact the EPA Project Manager.

DEMONSTRATION RESULTS:

The demonstration results showed that soil washing produced clean coarse soil fractions and concentrated the contaminants in the fine slurry.

The chemical treatment process and biological slurry reactors, when operated on a batch basis with a nominal 35-day retention time, achieved at least a 90 percent reduction in simple polyaromatic hydrocarbon compounds such as naphthalene, but did not meet the approximately 75 percent reduction in benzo(a)pyrene required to achieve the cleanup criteria.

The biological process discharge did not meet the cleanup criteria for oil and grease, and the process exhibited virtually no removal of this parameter. THC believes that the high outlet oil and grease values are the result of the analytical extraction of the biomass developed during the process.

The hydrocyclone dewatering device did not achieve significant dewatering. Final process slurries were returned to the excavation site in liquid form.

The metals removal process achieved a removal efficiency for toxic heavy metals such as copper, lead, mercury, and nickel of approximately 70 percent.

The metals removal process equipment and chelating agent were fouled by free oil and grease contamination, forcing sampling to end prematurely. Biological treatment or physical separation of oil and grease will be required to avoid such fouling.

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

UNIVERSITY OF IDAHO RESEARCH FOUNDATION
(formerly licensed to J.R. SIMPLOT COMPANY)
(The SABRE™ Process)

TECHNOLOGY DESCRIPTION:

The patented Simplot Anaerobic Biological Remediation (SABRE™) process reduces contamination through on-site bioremediation of soils contaminated with the herbicide dinoseb (2-*sec*-butyl-4,6-dinitrophenol) or nitroaromatic explosives. The biodegradation process begins when contaminated soil is placed in a bioreactor and flooded with buffered water. A source of carbon and a nitroaromatic-degrading consortium of anaerobic bacteria are then added to the bioreactor. Anaerobic conditions are quickly established, allowing the bacteria to degrade the target compounds while preventing polymerization of intermediate breakdown products. A photograph of the technology in operation is shown below.

WASTE APPLICABILITY:

Soil can be treated in above- or in-ground containment ponds. Temperature, pH, and redox potential in the bioreactor are monitored during treatment. A hydromixing system has been engineered to efficiently solubilize the target compound from the soil while maint-aining anaerobic conditions. Frequency of mixing depends upon the contaminants present, concentration, soil heterogeneity, and soil type.

This technology is designed to treat soils contaminated with nitroaromatic pesticides and explosives. This contamination most often occurs at rural crop dusting aircraft sites and at ordnance handling and manufacturing facilities.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Based on bench- and pilot-scale results from the Emerging Technology Program, this technology was accepted in the SITE Demonstration Program in winter 1992. Demonstrations for dinoseb and the explosive TNT (2,4,6-trinitrotoluene) were performed at Bowers Field in Ellensberg, Washington and at Weldon Spring Ordnance Works in Weldon Spring, Missouri, respectively. A Technology Capsule describing the dinoseb project (EPA/540/R-94/508a) and an Innovative Technology Evaluation Report describing the TNT project (EPA/540/R-95/529) are available from EPA.

Bioreactors and Soil Mixing System at a TNT-Contaminated Site in Washington

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

Since then, the process has been evaluated at several other sites. During the winters of 1994 and 1995, two 10-cubic-yard (yd^3) batches of soils from Bangor Naval Submarine Base, Washington were treated using the SABRE™ Process. One batch contained TNT, while the other was contaminated with TNT and RDX. Cost savings were realized by using in-ground ponds for bioreactors and efficient mixing. Heaters were also installed to maintain optimum biological activity during the sub-freezing temperatures. Treatment goals were met or surpassed in the 90 days allowed for the project.

A full-scale remediation of 321 yd^3 of dinoseb-contaminated soils was completed in October 1995. The site was a former herb-icide distributor located near Reedley, CA. The treatment was performed in an above-ground containment already existing on site. Concentrations ranging from 40 to 100 milligrams per kilogram were reduced to nondetect after 28 days of treatment. The soil was mixed three times during treatment using a full-scale, expandable hydromixing system.

A larger evaluation was conducted in fall 1996 at Naval Weapons Station - Yorktown. About 500 yd^3 of soil were contained in an in-ground pond measuring 86 ft by 150 ft deep. A full-scale hydromixing system was used to periodically slurry the soil and water mixture.

Process optimization work is ongoing. Collaborative projects with the U.S. Army Corps of Engineers Waterways Experiment Station and the U.S. Army Environmental Center are underway.

DEMONSTRATION RESULTS:

During the Weldon Spring demonstration, TNT was reduced from average concentrations of 1,500 parts per million (ppm) to an average of 8.7 ppm, for an average removal rate of 99.4%. Toxicity testing, which included early seedling growth, root elongation, and earthworm reproduction tests, showed that soil toxicity was signifi-cantly reduced. The Weldon Spring demon-stration showed the effectiveness of this process even in unfavorable conditions. The treatment time was lengthened by unsea-sonably cool ambient temperatures. Temperatures in the bioreactor were as low as 4°C; ideal temperatures for the SABRE™ process are 35 to 37 °C.

During the Ellensburg demonstration, dinoseb was reduced from 27.3 ppm to below the detection limit, a greater than 99.8% removal. Other pesticides were also degraded in this process, highlighting the effectiveness of the process even in the presence of co-contaminants. The process was completed in just 23 days, despite 18°C temperatures.

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

UNIVERSITY OF NEBRASKA - LINCOLN
(Center Pivot Spray Irrigation System)

TECHNOLOGY DESCRIPTION:

Spray irrigation technology with "center pivots" and "linear" systems can be used to remediate groundwater contaminated with volatile organic compounds (VOC). The technology is commonly used to apply irrigation water to vegetable and row crops. While the systems were introduced to irrigate hilly terrain and excessively well-drained soils, the technology has been adapted in both groundwater quality and quantity management areas as a best management practice. This technology severely reduces water application rates and leaching relative to flood irrigation techniques.

The systems consist of an elevated pipeline with nozzles placed at close intervals. Groundwater is pumped through the pipeline and sprayed uniformly over a field as the pipeline pivots or linearly passes over the cropped area. The typical pump rate is between 800 and 2,000 gallons per minute (gpm). These self-propelled systems are highly mechanized and have low labor and operating requirements. The systems do not require level ground, and start-up costs are low.

The sprinkler method applies water over the irrigated area with a fine spray (see the photograph below). Water coverage over the irrigated area is controlled by the speed with which the "pivot" or "linear" system travels across the field. The heart of the sprinkler irrigation system is the nozzle, which has a small opening through which a high-velocity stream of water is emitted. As the high-velocity water stream leaves the nozzle, it strikes an impact pad and forms a thin film of water. The thin film of water produced by these pads breaks up into small droplets as it leaves the impact pad. Droplet size depends on the stream pressure and design of the impact pad.

The system used in the SITE demonstration program was a center pivot and was located on a seed-corn field in Hastings, Nebraska. The system was equipped with off-the-shelf, fog-producing impact pads for improved volatilization efficiency.

A stratified water droplet collector (SWDC) simultaneously collected spray at four fall heights above ground level, and was specifically contracted for this project by the Dutton-Lainson Company in Hastings, Nebraska. With this device, droplets were collected at heights of 1.5, 4.5, 7.5, and 10.5 feet above the ground surface. Twelve SWDCs were installed parallel to the pivot arm to determine average volatilization efficiencies from the 340 nozzles on the pivot arm.

Center Pivot spray Irrigation System

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

WASTE APPLICABILITY:

The sprinkler irrigation system is capable of remediating VOC-contaminated groundwater. Removal rates in excess of 95 percent have been demonstrated for groundwater containing ethylene dibromide (EDB), trichloroethene (TCE), 1,1,1-trichloroethane (TCA), and carbon tetrachloride (CT). The method will efficiently volatilize all common volatiles in groundwater that may originate from landfills, degreasers, dry cleaners, electrical industries, gas stations, or refineries. The residuals are transferred to the atmosphere where they are dispersed and most are rapidly degraded in ultraviolet light.

The technique may be limited to individual groundwater VOC concentrations that are less than 1 part per million if residual concentrations of VOCs are mandated to be near or below the maximum contaminant level prior to reaching the ground surface. Otherwise, the technique can be used in any agricultural setting where sufficient groundwater and irrigatable land are available.

The Center Pivot Spray Irrigation system was accepted into the SITE Demonstration Program in late 1995. Under a University of Nebraska project funded by the Cooperative State Research Service of the Department of Agriculture, field tests were completed in the summers of 1994 and 1995 in a seed-corn field in Hastings, Nebraska. The technology was demonstrated under the SITE Program in July 1996 at the North Landfill/FAR-MAR-CO Subsite in Hastings, Nebraska. The 50-acre site is a furrow-irrigated corn field underlain by commingled plumes of groundwater containing EDB, TCE, TCA, CT, 1,1-dichloroethene, and chloroform. The primary goal of the demonstration was to determine the efficiency of the system to remediate VOCs in groundwater to concentrations below the maximum contaminant levels. The results of this demonstration are available in an Innovative Technology Evaluation Report (EPA/540/R-98/502).

Clients involved in large pump-and-treat projects at several military bases are investigating the suitability of the system to their specific site situations. Potential clients include the U.S. Navy, the Army Corps of Engineers, and several state agencies. The technology is currently being used at the Lindsey Manufacturing site in Nebraska and near some grain elevators being remediated by Argonne Laboratory.

DEMONSTRATION RESULTS:

The results of this demonstration, combined with previous results obtained by UNL, provide significant performance data and serves as the foundation for conclusions about the system's effectiveness and applicability to similar remediation projects.

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

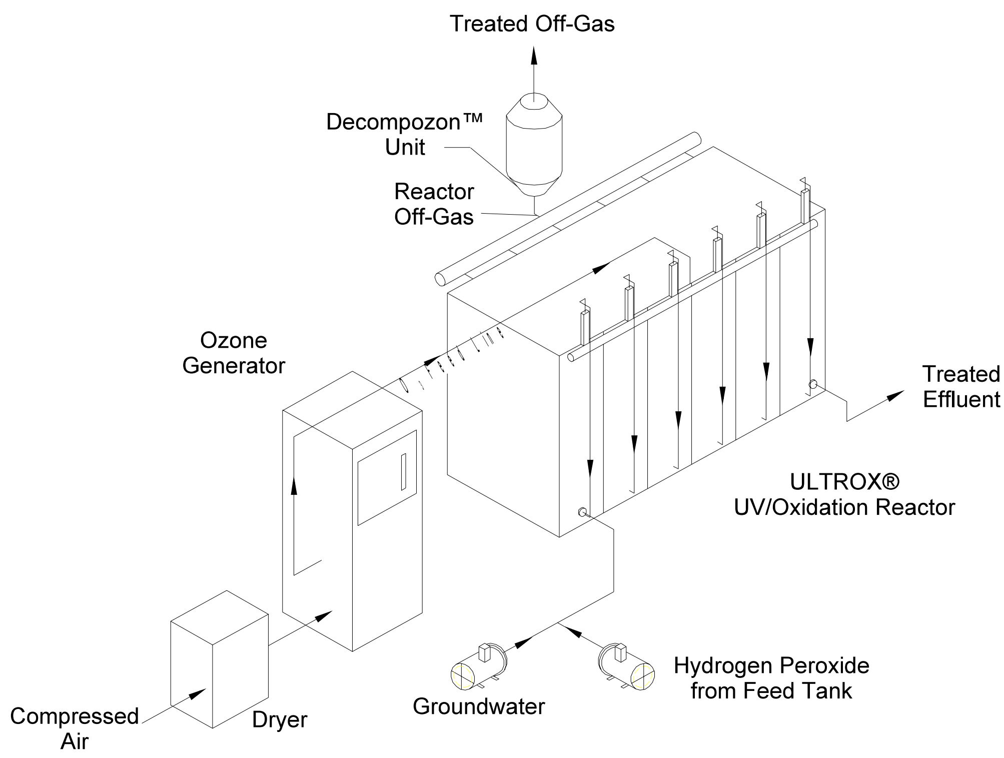
U.S. FILTER
(formerly Ultrox International, Inc.)
(Ultraviolet Radiation and Oxidation)

TECHNOLOGY DESCRIPTION:

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

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

Reactor influent is simultaneously exposed to UV radiation, ozone, and hydrogen peroxide to oxidize the organic compounds. Off-gas from the reactor passes through a catalytic ozone destruction Decompozon™ unit, which reduces ozone levels before air venting. The Decompozon™ unit also destroys volatile organic compounds (VOC) stripped off in the reactor.



UV Radiation and Oxidation System (Isometric View)

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

Effluent from the reactor is tested and analyzed before disposal.

WASTE APPLICABILITY:

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

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. A field-scale demonstration of the system was completed in March 1989 at the Lorentz Barrel and Drum Company site in San Jose, California. The testing program was designed to evaluate system performance while varying five operating parameters: (1) influent pH, (2) retention time, (3) ozone dose, (4) hydrogen peroxide dose, and (5) UV radiation intensity. The Demonstration Bulletin (EPA/540/M5-89/012), Technology Demonstration Summary (EPA/540/S5-89/ 012), Applications Analysis Report (EPA/540/A5-89/012), and Technology Evaluation Report (EPA/540/5-89/012) are available from EPA.

The technology is fully commercial, with over 30 systems installed. Units with flow rates ranging from 5 gallons per minute (gpm) to 1,050 gpm are in use at various industries and site remediations, including aerospace, U.S. Department of Energy, U.S. Department of Defense, petroleum, pharmaceutical, automotive, woodtreating, and municipal facilities. UV radiation and oxidation technology has been included in records of decision for several Superfund sites where groundwater pump-and-treat remediation methods will be used.

DEMONSTRATION RESULTS:

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

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

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

US EPA REGION 9
(Excavation Techniques and Foam Suppression Methods)

TECHNOLOGY DESCRIPTION:

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

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

WASTE APPLICABILITY:

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

STATUS:

This technology was demonstrated at the McColl Superfund site in Fullerton, California, in June and July 1990. An enclosure 60 feet wide, 160 feet long, and 26 feet high was erected over an area contaminated with VOCs and sulfur dioxide. A backhoe removed the overburden and excavated underlying waste. Three distinct types of waste were encountered during excavation: oily mud, tar, and hard coal-like char.

Excavation Area Enclosure

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

The following documents, which contain results from the demonstration, are available from EPA:

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

DEMONSTRATION RESULTS:

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

The concentrations of air contaminants inside the enclosure were higher than expected. These high concentrations were due in part to the inability of the vapor suppressant foams to form an impermeable membrane over the exposed wastes. The foam reacted with the highly acidic waste, causing the foam to degrade. Furthermore, purge water from foaming activities made surfaces slippery for workers and equipment. A total of 101 cubic yards of overburden and 137 cubic yards of contaminated waste was excavated. The tar waste was solidified and stabilized by mixing with fly ash, cement, and water in a pug mill. The char wastes did not require further processing.

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WASTECH, INC.
(Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

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

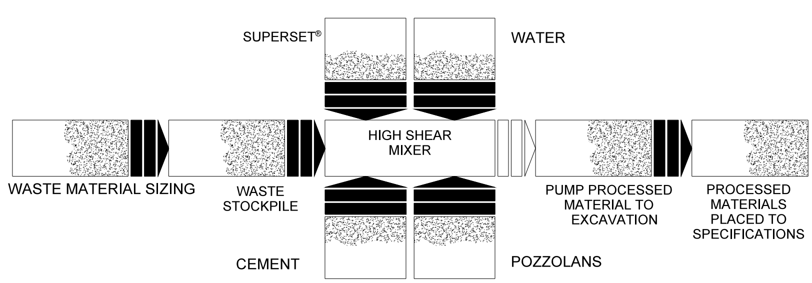
The WASTECH, Inc. (WASTECH), technology uses standard engineering and construction equipment. Because the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula.

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

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

WASTE APPLICABILITY:

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



WASTECH Solidification and Stabilization Process

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

STATUS:

The technology was accepted into the SITE Demonstration Program in spring 1989. A field demonstration at Robins Air Force Base in Warner Robins, Georgia was completed in August 1991. WASTECH subsequently conducted a bench-scale study in 1992 under glovebox conditions to develop a detailed mass balance of volatile organic compounds.

This technology is no longer available from the vendor. For further information about the process, contact the EPA Project Manager.

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

WEISS ASSOCIATES
(ElectroChemical Remediation Technologies [ECRTs])

TECHNOLOGY DESRIPTION:

ElectroChemical Remediation Technologies (ECRTs) utilize an AC/DC current passed between an electrode pair (one anode and one cathode) in soil, sediment, or groundwater to either mineralize organic contaminants through the ElectroChemicalGeoOxidation (ECGO) process, or complex, mobilize, and remove metal contaminants through the Induced Complexation (IC) process, either in situ or ex situ. Field remediation data suggest that ECRTs-IC cause electrochemical reactions in soil, sediment, and groundwater to generate metallic ion complexes from the target contaminant metals. Electric power is passed through a proprietary direct current (DC)/alternating current (AC) converter that produces a low-voltage and low-amperage DC/AC current. When this modified electrical current is passed through the sediment via the electrodes, the sediment particles become polarized and are purported to develop electrical properties similar to a capacitor. These complexes subsequently migrate to the electrodes down the electrokinetic gradient and are deposited onto the electrodes, which can be removed and recycled. ECRTs-IC operates at electrical power levels below those of conventional electrokinetic methods. A unique feature of ECRTs-IC, in marked contrast to electrokinetics, is that metals migrate to both the anode and cathode. According to the technology developer, when the polarized particles discharge electricity in the ECGO, the energy given off induces chemical reactions (redox reactions), which decompose organic contaminants.

Typically, ECRTs are preferred to be implemented in situ. As such, site activities are only minimally disturbed in contrast to excavation and off-site disposal. ECRTs are powered by the existing site electrical grid or through a power generator.

WASTE APPLICABILITY:

ECRT is capable of remediating mercury, phenolic compounds, metal, and organic contaminants in sediments, soil, and groundwater.

STATUS:

The Washington Department of Ecology (Ecology) is proposing to amend an existing legal agreement (Agreed Order for Interim Action) with Georgia-Pacific (G-P) to provide Ecology access to the Georgia-Pacific Log Pond (Log Pond) to conduct a sediment treatment pilot study. The Log Pond is located in Bellingham Bay adjacent to the G-P facility at 300 W. Laurel Street, Bellingham. Under the amendment, Ecology and other partners will conduct a sediment treatment pilot study on a small area of the Log Pond.

The Log Pond is a subunit of the Whatcom Waterway Site and consists of intertidal and subtidal aquatic lands adjacent to the Whatcom Waterway Federal Navigation Channel in Bellingham.

The Log Pond is part of the Whatcom Waterway contaminated sediment site and was capped with clean sediments from other Puget Sound Corps of Engineers maintenance dredging projects in February 2001. This capping was conducted under an Agreed Order for Interim Action with Ecology. The ECRT apparatus will be installed in 2002.

Installation of the pilot study infrastructure will generally involve placing two pairs of sheet pile electrodes into the sediment (four sheet piles: two positive and two negative electrodes). The sheet piles will be placed in parallel at a distance of 30 to 50 feet. The sheet piles will be placed into the sediment by vibratory hammer equipment in such a manner as to minimize any disturbance of contaminated sediments and the sediment cap.

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

Operation of the ECRT apparatus, along with monitoring activities outlined above, will continue until the objectives of the pilot study have been met, whichever is earlier.

An in-progress U.S. bench-scale test strongly suggests migration of total mercury to the anode. These results show that ECRTs-IC are rapid and effective.

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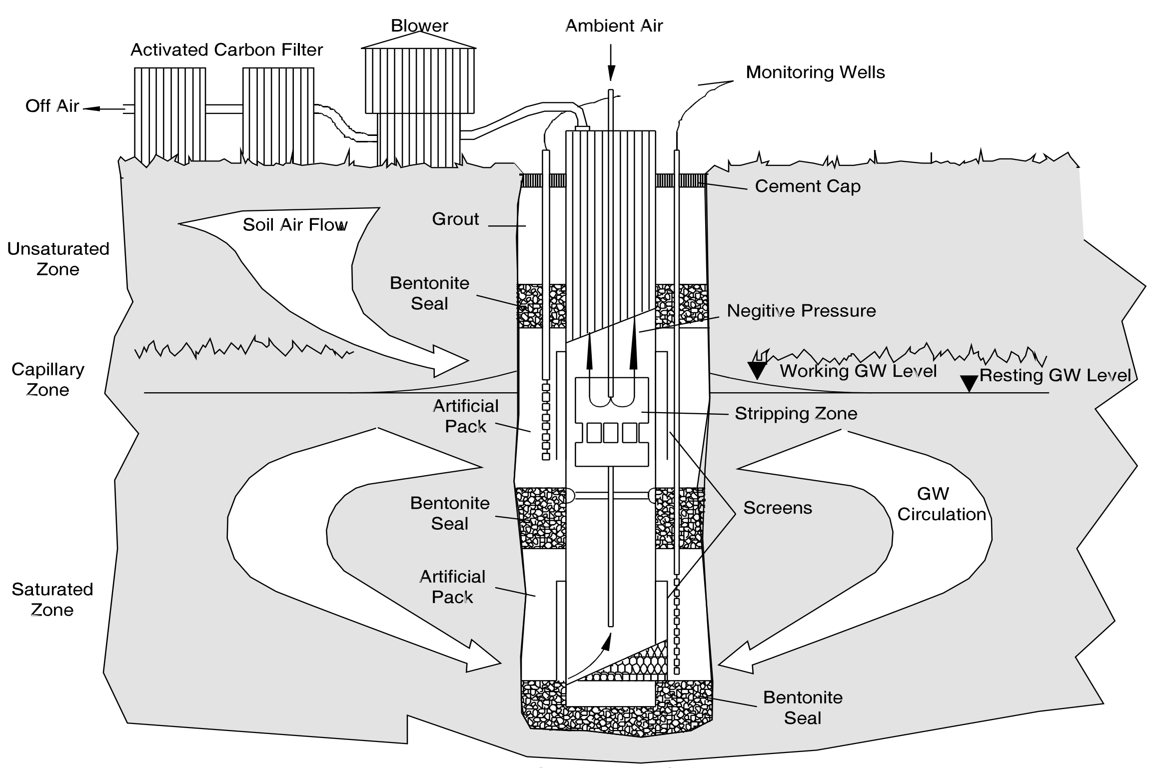
The SITE Program assesses but does not approve or endorse technologies.

ROY F. WESTON, INC./IEG TECHNOLOGIES
(UVB - Vacuum Vaporizing Well)

TECHNOLOGY DESCRIPTION:

The Unterdruck-Verdampfer-Brunnen (UVB) system is an in situ system for remediating contaminated aquifers. The basic system is simple in design and operation, consisting of a well, a groundwater extraction pump, a negative pressure stripping reactor, and an electric blower. While in operation, the water level rises inside the UVB well casing due to reduced atmospheric pressure generated by the blower, increasing the total hydraulic head in the well. Atmospheric air enters the well through a fresh air pipe connected to the stripping reactor. The incoming fresh air forms bubbles as it jets through the pinhole plate of the stripping reactor and mixes with the influent groundwater in the well casing, creating an "air lift" effect as the bubbles rise and expand to the stripping reactor. After treatment, the movement of water out of the well develops a groundwater circulation cell around a remediation well. The circulating groundwater transports contaminants from the adjacent soils and groundwater to the well, where these contaminants are removed using a combination of physical, chemical and biological treatment processes. The technology is capable of mobilizing and treating contaminants that are water soluble (dissolved phase) or are present as dense non aqueous phase liquids (DNAPL) or light non aqueous phase liquids (LNAPL). The technology also can extract and treat soil gas from the unsaturated zone.

Due to the presence of a natural groundwater flow, the total amount of water circulating around the UVB well at any given time consists of (1) a portion of up gradient groundwater captured by the influent screen section, and (2) recirculated groundwater. This ratio is typically 15 to 85 percent respectively. Groundwater leaving the circulation cell exits



UVB Standard Circulation

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

through the downstream release zone in a rate equal to the up gradient groundwater being captured. These flow dynamics and the dimensions of the capture zone, circulation cell, and release zone can be calculated using design aids based on numerical simulations of the groundwater hydraulics and can be validated by monitoring the actual performance results of the system.

The advantage of the UVB technology over external pump-and-treat technologies is its ability to treat contaminants while maintaining a net equilibrium flow in the aquifer, eliminating adverse effects associated with excessive mounding or draw-down of groundwater due to continuous extraction and replacement of equal volumes of water. Additionally, the circulation well serves as a mechanism for flushing contaminants from the soils and aquifer to the well casing for treatment on a continuous basis. As a secondary benefit, because the primary treatment process is physical removal through air stripping, the dissolved oxygen levels in the groundwater passing through the well can theoretically increase up to 10 milligrams per liter within the aquifer, enhancing bioremediation by indigenous micro-organisms.

WASTE APPLICABILITY:

This technology can be used to assist in treating a variety of soil and groundwater pollutants ranging from chlorinated solvents to gasoline constituents, polycyclic aromatic hydrocarbons, heavy metals, and nitrates.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993, and a demonstration was completed at March Air Force Base, California, in May 1994. The Demonstration Bulletin (EPA/540/MR- 95/500), Technology Capsule (EPA/540/R- 95/500a), and Innovative Technology Evaluation Report (EPA/540/R-95/500) are available from EPA.

DEMONSTRATION RESULTS:

Demonstration results indicate that the UVB system reduced trichloroethene (TCE) in groundwater by an average of 94 percent. The average TCE concentration from the outlet of the UVB system in the treated groundwater was approximately 3 micrograms per liter (µg/L), with only one event above 5 µg/L. The inlet TCE concentration averaged 40 µg/L. Results of a dye tracer study indicated that the radius of the circulation cell was at least 40 feet. Modeling of the study indicated a circulation cell radius of 60 feet. In general, TCE in the shallow and intermediate screened wells showed a concentration reduction both vertically and horizontally during the demonstration. TCE concentrations in these wells appeared to homogenize as indicated by their convergence and stabilization. Variations in TCE concentrations were noted in the deep screened wells.

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

ROY F. WESTON, INC.
(Low Temperature Thermal Treatment System)

TECHNOLOGY DESCRIPTION:

The Roy F. Weston, Inc. (Weston), low temperature thermal treatment (LT$^{3®}$) system thermally desorbs organic compounds from contaminated soil without heating the soil to combustion temperatures. The transportable system (see photograph below) is assembled on three flat-bed trailers and requires an area of about 5,000 square feet, including ancillary and support equipment. The LT$^{3®}$ system consists of three segments: soil treatment, emissions control, and water treatment.

The LT$^{3®}$ thermal processor consists of two jacketed troughs, one above the other. Each trough houses four intermeshed, hollow screw conveyors. A front-end loader feeds soil or sludge onto a conveyor that discharges into a surge hopper above the thermal processor. Hot oil circulating through the troughs and screws heats the soil to 400 to 500°F, removing contaminants. A second stage indirect heater is available to achieve 1,000°F discharge temperatures. Soil is discharged from the thermal processor into a conditioner, where a water spray cools the soil and minimizes dust emissions.

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

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

Low Temperature Thermal Treatment (LT$^{3®}$) System

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

WASTE APPLICABILITY:

This system treats soils and sludges contaminated with volatile and semivolatile organic compounds (VOC and SVOC). Bench-, pilot-, and full-scale LT$^{3®}$ systems have treated soil contaminated with the following wastes: coal tar, drill cuttings (oil-based mud), No. 2 diesel fuel, JP-4 jet fuel, leaded and unleaded gasoline, petroleum hydrocarbons, halogenated and nonhalogenated solvents, VOCs, SVOCs, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, pesticides, herbicides, dioxins, and furans.

STATUS:

The LT$^{3®}$ system was accepted into the SITE Demonstration Program in September 1991. In November and December 1991, the LT$^{3®}$ system was demonstrated under the SITE Program as part of a proof-of-process test for full-scale remediation of the Anderson Development Company (ADC) Superfund site in Adrian, Michigan. The system was tested on lagoon sludge from the ADC site. This sludge was contaminated with VOCs and SVOCs, including 4,4-methylene bis(2-chloroaniline) (MBOCA).

The Demonstration Bulletin (EPA/540/ MR-92/019) and Applications Analysis Report (EPA/540/AR-92/019) are available from EPA.

DEMONSTRATION RESULTS:

During the demonstration, the system throughput was approximately 2.1 tons per hour. Six replicate tests were conducted, each lasting approximately 6 hours. The SITE demonstration yielded the following results:

- The LT$^{3®}$ system removed VOCs to below method detection limits (less than 0.060 milligram per kilogram [mg/kg] for most compounds).
- The LT$^{3®}$ system achieved MBOCA removal efficiencies greater than 88 percent; MBOCA concentrations in the treated sludge ranged from 3.0 to 9.6 mg/kg.
- The LT$^{3®}$ system decreased the concentrations of all SVOCs in the sludge, with the exception of phenol, which increased possibly due to chlorobenzene .
- Dioxins and furans were formed in the system, but the 2,3,7,8-tetra-chlorodibenzo-p-dioxin isomer was not detected in treated sludges.
- Stack emissions of nonmethane total hydrocarbons increased from 6.7 to 11 parts per million by volume during the demonstration; the maximum emission rate was 0.2 pound per day (ppd). The maximum particulates emission rate was 0.02 ppd, and no chlorides were measured in stack gases.

The economic analysis of the LT$^{3®}$ system's performance compared the costs associated with treating soils containing 20, 45, and 75 percent moisture. The treatment costs per ton of material were estimated to be \$37, \$537, and \$725, respectively.

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

WHEELABRATOR CLEAN AIR SYSTEMS, INC.
(formerly Chemical Waste Management, Inc.)
(PO*WW*ER™ Technology)

TECHNOLOGY DESCRIPTION:

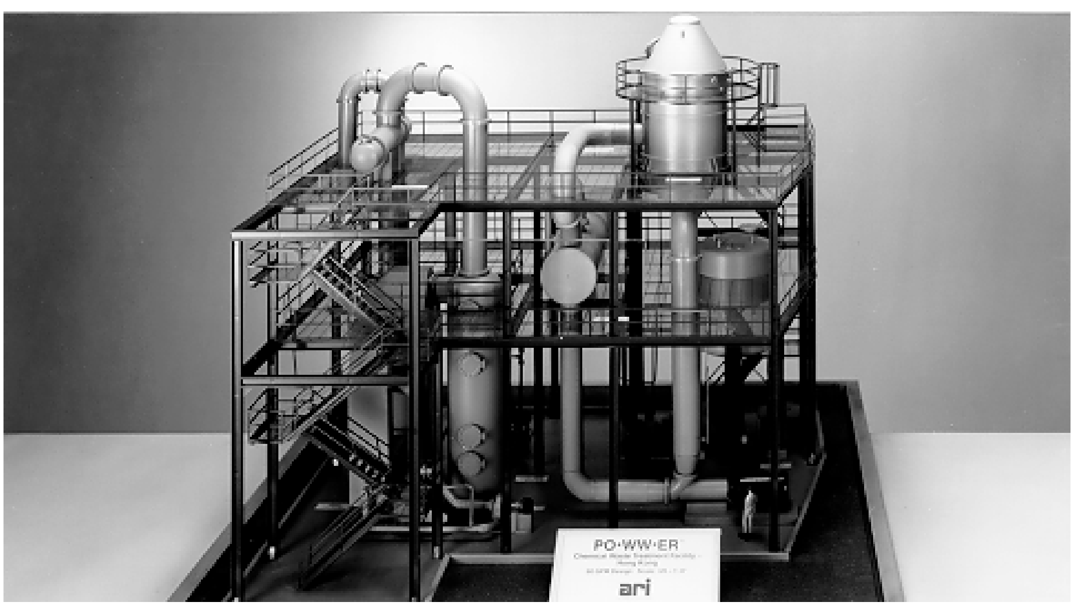
The PO*WW*ER™ technology is used to treat and reduce complex industrial and hazardous wastewaters containing mixtures of inorganic salts, metals, volatile and nonvolatile organics, volatile inorganics, and radionuclides. The proprietary technology combines evaporation with catalytic oxidation to concentrate and destroy contaminants, producing a high-quality product condensate.

Wastewater is first pumped into an evaporator, where most of the water and contaminants are vaporized and removed, concentrating the contaminants into a small volume for further treatment or disposal. The contaminant vapors then pass over a bed of proprietary robust catalyst, where the pollutants are oxidized and destroyed. Depending on the contaminant vapor composition, effluent vapors from the oxidizer may be treated in a scrubber. The vapors are then condensed to produce water (condensate) that can be used as either boiler or cooling tower makeup water, if appropriate. Hazardous wastewater can thus be separated into a small contaminant stream (brine) and a large clean water stream without using expensive reagents or increasing the volume of the total stream. The photograph below illustrates a PO*WW*ER™ - based wastewater treatment plant.

WASTE APPLICABILITY:

The PO*WW*ER™ technology can treat wastewaters containing a mixture of the following contaminants:

Organic	Inorganic	Radioactive
• Halogenated volatiles • Halogenated semivolatiles • Nonhalogenated volatiles • Nonhalogenated semivolatiles • Organic pesticides/herbicides • Solvents • Benzene, toluene, ethyl- benzene, and xylene • Organic cyanides • Nonvolatile organics	• Heavy metals • Nonmetallic toxic elements • Cyanides • Ammonia • Nitrates • Salts	• Plutonium • Americium • Uranium • Technetium • Thorium • Radium • Barium



PO*WW*ER™-Based Wastewater Treatment Plant

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

Suitable wastewaters for treatment by the PO*WW*ER™ technology include landfill leachates, contaminated groundwaters, process wastewaters, and low-level radioactive mixed wastes.

STATUS:

The technology was accepted into the SITE Demonstration Program in 1991. The demonstration took place in September 1992 at the Chemical Waste Management, Inc., Lake Charles, Louisiana, facility. Landfill leachate, an F039 hazardous waste, was treated in a pilot-scale unit. The Applications Analysis Report (EPA/540/AR-93/506) and Technology Evaluation Report (EPA/540/R-93/506) are available from EPA.

A commercial system with a capacity of 50 gallons per minute is in operation at Ysing Yi Island, Hong Kong. A pilot-scale unit, with a capacity of 1 to 1.5 gallons per minute, is available and can treat radioactive, hazardous, and mixed waste streams.

DEMONSTRATION RESULTS:

The ability of the PO*WW*ER™ system to concentrate aqueous wastes was evaluated by measuring the volume reduction and concentration ratio achieved. The volume of brine produced during each 9-hour test period was about 5 percent of the feed waste volume processed in the same period. The concentration ratio, defined as the ratio of total solids (TS) concentration in the brine to the TS concentration in the feed waste, was about 32 to 1.

The feed waste contained concentrations of volatile organic compounds (VOC) ranging from 320 to 110,000 micrograms per liter (µg/L); semivolatile organic compounds (SVOC) ranging from 5,300 to 24,000 µg/L; ammonia ranging from 140 to 160 milligrams per liter (mg/L); and cyanide ranging from 24 to 36 mg/L. No VOCs, SVOCs, ammonia, or cyanide were detected in the product condensate.

The PO*WW*ER™ system removed sources of feed waste toxicity. The feed waste was acutely toxic with median lethal concentrations (LC_{50}) consistently below 10 percent. The product condensate was nontoxic with LC_{50} values consistently greater than 100 percent, but only after the product condensate was cooled and its pH, dissolved oxygen level, and hardness or salinity were increased.

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

WILDER CONSTRUCTION COMPANY
(MatCon™ Modified Asphalt Cap)

TECHNOLOGY DESCRIPTION:

MatCon™ is an asphalt mixture produced by using a proprietary binder and a specified aggregate gradation in a conventional hot mix asphalt plant. A MatCon™ cover can be constructed within a few days using conventional asphalt paving equipment. Maintenance of the cover is relatively easy, using conventional asphalt paving repair equipment and materials. According to the manufacturer, MatCon™ asphalt is much less permeable and possesses superior flexural strength compared to conventional asphalt. MatCon™ asphalt has a permeability of 1.0×10^{-8} cm/sec or less, which far exceeds the requirement of less than 1.0×10^{-5} cm/sec established for landfill covers that do not have a geomembrane liner.

WASTE APPLICABILITY:

The MatCon™ technology is applicable as a final cover at many hazardous waste sites. The potential for hazardous waste site reuse is a major advantage of this technology. Uses being planned for the MatCon™ cover include the following: staging area for heavy equipment and vehicles; light industrial manufacturing; and sports facilities, such as tennis courts and tracks.

STATUS:

Wilder Construction Company installed a pilot-scale cover system at the Dover Air Force Base site in April 1999 for purposes of evaluating the MatCon™ technology. The evaluation cover measures approximately 126 by 220 feet and consists of three sections: (1) 12-inch-thick MatCon™ asphalt with a drainage layer (Section I), (2) 4-inch-thick MatCon™ asphalt (Section II), and (3) 4-inch-thick conventional asphalt (Section III). The drainage layer in Section I was constructed as a 4-inch-thick channel of open-graded asphalt between two 4-inch-thick MatCon™ layers. The purpose of this drainage layer was to collect and allow measurement of the water that infiltrated through the top 4 inches of the cover. The purpose of constructing both conventional asphalt and MatCon™ sections was to allow a direct comparison of the physical properties of each type of asphalt based on laboratory testing of cover samples. To monitor surface runoff, a lined ditch was constructed downgradient from the cover, and berms were constructed to direct the runoff from Section I of the cover into the drainage ditch. Surface runoff was measured continuously with a flowmeter, which recorded both instantaneous and cumulative flow.

The two primary objectives of the SITE Program evaluation of the MatCon™ technology were to: (1) compare the in-field permeability of the MatCon™ cover to the RCRA requirement of less than 1.0×10^{-5} cm/sec, and (2) compare the permeability and flexural properties of MatCon™ asphalt to those of conventional hot mix asphalt. Secondary objectives of the evaluation were to: (1) compare various laboratory-measured physical characteristics (including load apacity/deformation, shear strength, joint permeability, and aging and degradation characteristics) of MatCon™ asphalt with those of conventional asphalt covers; (2) assess the field performance of the MatCon™ cover under extreme weather conditions and vehicle loads; (3) estimate a cumulative hydrologic balance for the MatCon™ cover at the DAFB site; and (4) estimate the costs of MatCon™ cover installation.

DEMONSTRATION RESULTS:

Preliminary laboratory testing results indicate that the permeability of the MatCon™ cover at the DAFB site is less than 1.0×10^{-8} cm/sec, whereas the permeability of the adjacent conventional asphalt cover is between 2.70×10^{-4} cm/sec and 1.0×10^{-5} cm/sec. Flexural tests of samples of the MatCon™ and the conventional asphalt covers indicate that the MatCon™ cover tolerates three times more deflection without cracking compared to the conventional asphalt cover. Field hydrologic data obtained to date at the DAFB site indicates an average field permeability of about 2.3×10^{-8} cm/sec, respectively. Complete data from the field permeability testing are available in the EPA Technology Evaluation Report.

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

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

ASC/EMR WPAFB
(U.S. Air Force)
(Phytoremediation of TCE in Groundwater)

TECHNOLOGY DESCRIPTION:

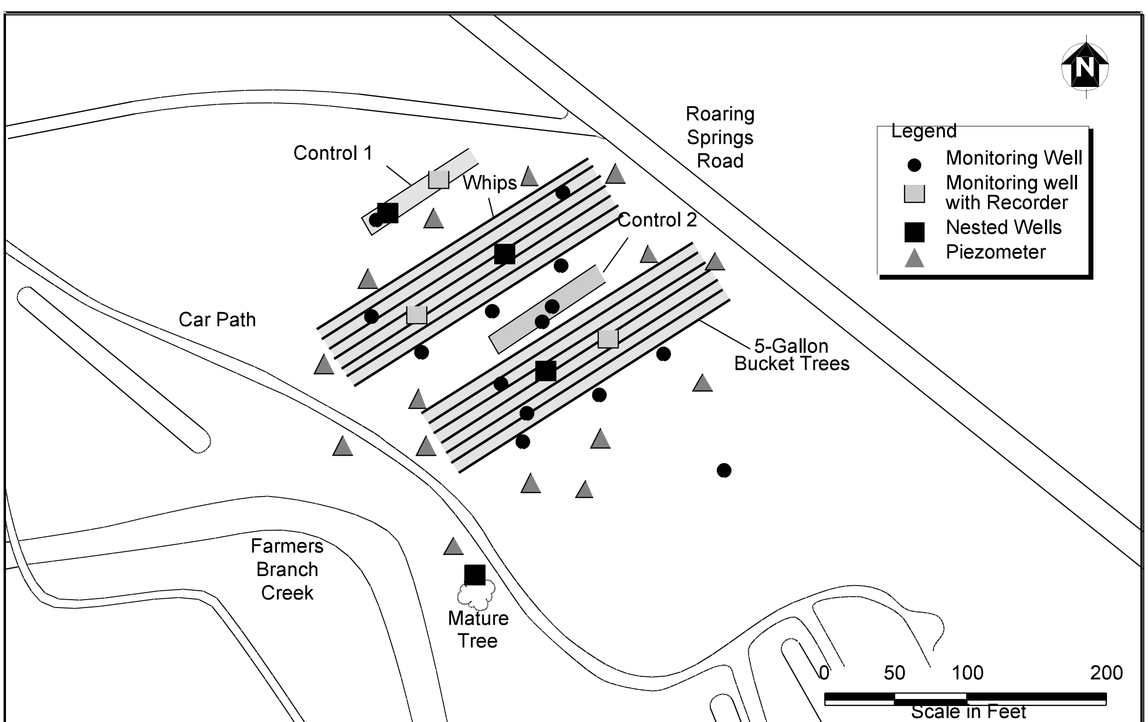
The phytoremediation system is a low-cost, low-maintenance system that is consistent with a long-term contaminant reduction strategy. Trees were planted in trenches as a short rotation woody crop employing standard techniques developed by the U.S. Department of Energy (DOE). The phytoremediation system was designed to intercept and remediate a chlorinated ethene contaminant plume. The system relies on two mechanisms to achieve this goal: (1) hydraulic removal of contaminated groundwater through tree transpiration and (2) biologically mediated in situ reductive dechlorination of the contaminant. The tree root systems introduce organic matter to the aquifer system, which drives the microbial communities in the aquifer from aerobic to anaerobic communities that support the reductive dechlorination.

WASTE APPLICABILITY:

This technology is suitable for any groundwater contaminated with dense non-aqueous phase liquid contaminants such as TCE.

STATUS:

The U.S. Air Force Plant 4 and adjacent Naval Air Station, Fort Worth, Texas, has sustained contamination in an alluvial aquifer through the use of chlorinated solvents in the manufacture and assembly of military aircraft. Dispersion and transport of TCE and its degradation products have occurred, creating a plume of contaminated groundwater. Planting and cultivating of Eastern Cottonwood (*Populus deltoids*) trees above the dissolved TCE plume in a shallow (under 12 feet) aerobic aquifer took place in spring 1996. The trees



Schematic Diagram of the Site Layout at Naval Air Station Ft. Worth

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

were planted as a short rotation woody crop employing standard techniques developed by the DOE to grow biomass for energy and fiber. Data are being collected to determine the ability of the trees to perform as a natural pump-and-treat system.

DEMONSTRATION RESULTS:

The first three growing seasons resulted in a remediation system that reduced the mass of contaminants moving through the site. The maximum observed reduction in the mass flux of TCE across the downgradient end of the site during the three-year demonstration period was 11 percent. Increases in the hydraulic influence and reductive dechlorination of the dissolved TCE plume are expected in the future, and may significantly reduce the mass of contaminants. Modeling results indicate that hydraulic influence alone may reduce the volume of contaminated groundwater that moves off-site by up to 30 percent. The decrease in mass flux that can be attributed to in situ reductive dechlorination has yet to be quantified.

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

X-19 BIOLOGICAL PRODUCTS
(Microbial Degradation of PCBs)

TECHNOLOGY DESCRIPTION:

X-19 Biological Products of Santa Clara, CA (X-19), has developed and marketed a microbiological polymer that was originally developed for use in the agricultural and horticultural industry as a soil conditioner. The product, which has the appearance and consistency of fine-grained organic humus, has been applied to soils to degrade pesticides and herbicides. Fresh X-19 product may contain upwards of a half billion colonies of bacteria per gram.

The X-19 product is applied in a semidry state. It is mixed with the contaminated soil at a 30% mix ratio. During this mixing ("the primary processing stage") a light application of moisture is added to activate the microflora.

The X-19 treatment can be accomplished both in situ and ex situ. Ex situ techniques using some type of aboveground enclosure are faster and easier to control. The product is also able to absorb moisture, preventing the leaching or transporting of contaminants to lower levels. The application of the product is simple, requires few personnel, and a single application is normally sufficient to meet any site-specific remedial goals.

Soil moisture is the primary monitoring requirement for the technology, and should be conducted on a biweekly schedule. Should soil moisture levels drop below 28%, more water should be added to the soil.

Depending upon a number of site-specific factors, soil being treated in an aboveground enclosure might have to be turned once near the middle of the treatment period, but generally there is no need for periodic tilling. The aboveground enclosures used for treating the soil are simply covered with plastic and are generally left undisturbed throughout the treatment period.

According to X-19, the product is nontoxic to plants and animals, and no permits are required to ship or apply the product.

WASTE APPLICABILITY:

The product is successful in bioremediating soils containing a large variety of chlorinated hydrocarbon insecticides including toxaphene, dieldrin, and others. X-19 has applied the product to soils contaminated with petroleum hydrocarbons (motor spirits, diesel fuels, oils) and has claimed that the product facilitated the complete degradation of semivolatile compounds such as polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), and polynuclear aromatic hydrocarbons (PAHs). The vendor has also claimed complete degradation of trichloroethene (TCE), trichloroethane (TCA), and other common volatile organic compounds (VOCs).

STATUS:

A demonstration of X-19's bioaugmentation process was conducted at a Lower Colorado River Authority (LCRA) electrical substation in Goldthwaite, Texas. At this site PCB-contaminated soil was treated with the X-19 product in an approximate 16 ft × 8 ft × 2 ft treatment cell. The overall goal of the study was to reduce PCB concentrations in the soil to a level of 50 mg/kg or less, on a dry weight basis of the original soil. The < 50 mg/kg threshold would enable the LCRA to dispose of the soils in a less costly in-state landfill.

DEMONSTRATION RESULTS:

The SITE Program conducted a multievent soil sampling to evaluate the effectiveness of the X-19 technology for treating the PCBs in the soil. The LCRA conducted periodic monitoring of the amended soil mixture within the treatment cell. A total of five sampling events were conducted. These events included a baseline sampling (August 2000) to establish pretreatment PCBs levels; three intermediate sampling events for tracking treatment progress (conducted in October and December of 2000, and in June of 2001); and a final posttreatment sampling event conducted in October 2001. Preliminary results for the demonstration are not yet available.

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

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

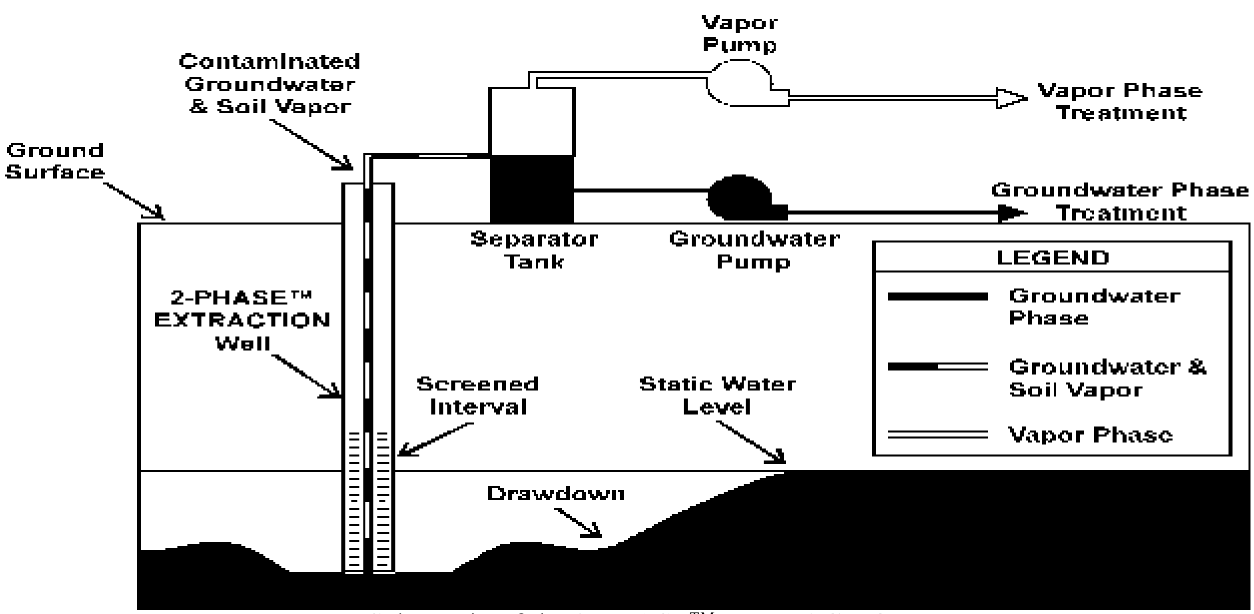
XEROX CORPORATION
(2-PHASE™ EXTRACTION Process)

TECHNOLOGY DESCRIPTION:

The 2-PHASE™ EXTRACTION Process was developed as an alternative to conventional pump-and-treat technology, particularly in low conductivity formations such as silts and clays that are impacted by volatile organic compounds (VOC). 2-PHASE™ EXTRACTION uses a high-vacuum source applied to an extraction tube within a water well to increase groundwater removal rates (consequently the dissolved phase of contamination) and to volatilize and extract that portion of contaminant from the sorbed or free product phases. Vacuum lift of water is not a limiting factor in the application of the technology. Since a mixed vapor-liquid column is extracted from the well, the 2-PHASE™ EXTRACTION technology allows a single piece of equipment (a high vacuum source) to remove contaminants in both the liquid and vapor phases.

To extract both groundwater and soil vapor from a single extraction well, the 2-PHASE™ EXTRACTION process uses a vacuum pump to apply a high vacuum (generally 18 to 29 inches of mercury) through a central extraction tube, which extends down the well. Soil vapor drawn into the well by the vacuum provides for a high velocity vapor stream at the bottom tip of the extraction tube, which entrains the contaminated groundwater and lifts it to ground surface. As groundwater moves through the extraction system, as much as 95 percent of the VOCs in the water phase are transferred to the vapor phase. The vapor and water phases are then separated at the surface in a separator tank. The water phase requires only carbon polishing prior to discharge, provided that the compounds are adsorbable. With some compounds the water carbon treatment can be eliminated. The vapor phase is subjected to carbon treatment, bioremediation, resin regeneration, catalytic oxidation, or other vapor phase treatment (based on contaminant characteristics, mass loadings, and economics) prior to release to atmosphere.

A kick-start system can induce flow and help dewater the well. The flow of atmospheric air can be regulated by adjustment of the gate valve to: (1) optimize the air-to-water flow ratio to minimize



Schematic of the 2-PHASE™ EXTRACTION Process

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

water "slug" production at startup (the term slug refers to an irregular pulsation of water through the extraction tube which indicates irregular water flow); (2) maximize tube penetration into the saturated zone; and (3) maximize the groundwater flow rate by optimizing the applied vacuum to the well's annular space.

Recent technology improvements include a well design that allows for contaminant removal from desired vertical zones within the subsurface. By providing a means to manipulate preferential flow, this innovative well design provides the ability to focus contaminant extraction at shallow zones and deep zones within the same well which results in a thorough removal of contaminants from the impacted area. Xerox and Licensee experience with 2-PHASE™ EXTRACTION typically has shown a reduction in remediation time by 1 to 2 orders of magnitude over conventional pump and treat/soil vapor extraction.

WASTE APPLICABILITY:

2-PHASE™ EXTRACTION has been successfully demonstrated for the removal of total petroleum hydrocarbons and chlorinated hydrocarbons from groundwater and soils.

The Xerox 2-PHASE™ EXTRACTION process was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in August 1994 at a contaminated groundwater site at McClellan Air Force Base in Sacramento, California, and was completed in February 1995. Reports of the demonstration are available from EPA.

The Xerox 2-PHASE™ EXTRACTION received eight patents from 1991-1998 and several patents are pending. The technology is available under license and is used extensively in the United States, Canada, South America, Great Britain, and Europe.

DEMONSTRATION RESULTS:

Results from the demonstration are detailed below:

- The total contaminant (trichloroethene, tetrachloroethene, Freon 133™) mass removal during the 6-month demonstration was estimated at 1,600 pounds, of which 99.7 percent was extracted from the vapor phase.
- The system extracted 1.4 million gallons of groundwater and 24.4 million cubic feet of soil vapor.
- The radius of capture in the groundwater extended from 100 to 300 feet from the extraction well. The radius of influence in the vadose zone extended 200 feet from the extraction well.
- The estimated cost of using the process was $28 per pound compared to an estimated $1370 per pound for a conventional pump and treat system.

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

ZENON ENVIRONMENTAL INC.
(Cross-Flow Pervaporation System)

TECHNOLOGY DESCRIPTION:

The ZENON Environmental Inc. (ZENON), cross-flow pervaporation technology is a membrane-based process that removes volatile organic compounds (VOC) from aqueous matrices. The technology uses an organophilic membrane made of nonporous silicone rubber, which is permeable to organic compounds, and highly resistant to degradation.

In a typical field application, contaminated water is pumped from an equalization tank through a prefilter to remove debris and silt particles, and then into a heat exchanger that raises the water temperature to about 165°F (75°C). The heated water then flows into a pervaporation module containing the organophilic membranes. The composition of the membranes causes organics in solution to adsorb to them. A vacuum applied to the system causes the organics to diffuse through the membranes and move out of the pervaporation module. This material is then passed through a condenser generating a highly concentrated liquid called permeate. Treated water exits the pervaporation module and is discharged from the system. The permeate separates into aqueous and organic phases. Aqueous phase permeate is sent back to the pervaporation module for further treatment, while the organic phase permeate is discharged to a receiving vessel.

Because emissions are vented from the system downstream of the condenser, organics are kept in solution, thus minimizing air releases. The condensed organic materials represent only a small fraction of the initial wastewater volume and may be subsequently disposed of at significant cost savings. This process may also treat industrial waste streams and recover organics for later use.

WASTE APPLICABILITY:

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

ZENON Cross-Flow Pervaporation System

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

STATUS:

This technology was accepted into the SITE Emerging Technology Program (ETP) in January 1989. The Emerging Technology Report (EPA/540/F-93/503), which details results from the ETP evaluation, is available from EPA. Based on results from the ETP, ZENON was invited to demonstrate the technology in the SITE Demonstration Program. A pilot-scale pervaporation system, built by ZENON for Environment Canada's Emergencies Engineering Division, was tested over a 2-year period (see photograph on previous page). During the second year, testing was carried out over several months at a petroleum hydrocarbon-contaminated site in Ontario, Canada.

A full-scale SITE demonstration took place in February 1995 at a former waste disposal area at Naval Air Station North Island in San Diego, California. The demonstration was conducted as a cooperative effort among EPA, ZENON, the Naval Environmental Leadership Program, Environment Canada, and the Ontario Ministry of Environment and Energy.

Organics were the primary groundwater contaminant at the site, and trichloroethene (TCE) was selected as the contaminant of concern for the demonstration. The Demonstration Bulletin (EPA/540/MR- 95/511) and Demonstration Capsule (EPA/540/R-95/511a) are available from EPA.

DEMONSTRATION RESULTS:

Analysis of demonstration samples indicate that the ZENON pervaporation system was about 98 percent effective in removing TCE from groundwater. The system achieved this removal efficiency with TCE influent concentrations of up to 250 parts per million at a flow rate of 10 gallons per minute (gpm) or less. Treatment efficiency remained fairly consistent throughout the demonstration; however, the treatment efficiency decreased at various times due to mineral scaling problems.

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

ZENON ENVIRONMENTAL INC.
(ZenoGem™ Process)

TECHNOLOGY DESCRIPTION:

ZENON Environmental Inc.'s, ZenoGem™ Process integrates biological treatment with membrane-based ultrafiltration (see figure below). This innovative system treats high strength wastes at long sludge retention time but short hydraulic residence time. As a result, the bioreactor's size is significantly reduced. Membrane filtration reduces the turbidity of the treated wastewater to less than 1 nephelometric turbidity unit.

In the ZenoGem™ Process, wastewater contaminated with organic compounds first enters the bioreactor, where contaminants are biologically degraded. Next, the process pump circulates the biomass through the ultrafiltration membrane system, or ultrafilter. The ultrafilter separates treated water from biological solids and soluble materials with higher molecular weights, including emulsified oil. The solids and soluble materials are then recycled to the bioreactor.

The ZenoGem™ Process captures higher molecular weight materials that would otherwise pass through conventional clarifiers and filters. The ZenoGem™ Process pilot-scale system is mounted on a 48-foot trailer and consists of the following six major components:

- Polyethylene equalization/holding tank: reduces the normal flow concentration fluctuations in the system
- Polyethylene bioreactor tank: contains the bacterial culture that degrades organic contaminants
- Process and feed pumps: ensures proper flow and pressure for optimum system performance
- Ultrafiltration module: contains rugged, clog-free, tubular membranes that remove solids from treated water.
- Clean-in-place tank: includes all the necessary valves, instrumentation, and controls to clean the membrane filters
- Control panel and computer: monitors system performance

ZenoGem™ Process

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

The treatment capacity of the pilot-scale, trailer-mounted system is about 500 to 1,000 gallons of wastewater per day; however, a full-scale system can treat much larger quantities of wastewater. The trailer is also equipped with a laboratory that enables field personnel to conduct tests to evaluate system performance. The system is computer-controlled and equipped with alarms to notify the operator of mechanical and operational problems.

WASTE APPLICABILITY:

The ZenoGem™ Process is designed to remove biodegradable materials, including most organic contaminants, from wastewater to produce a high quality effluent. The process consistently nitrifies organics and can denitrify organics with the addition of an anoxic bioreactor. The process is limited to aqueous media and may be used to treat high strength leachates, contaminated groundwater, and soil washing effluent.

STATUS:

The ZenoGem™ Process was accepted into the SITE Demonstration Program in summer 1992. The ZenoGem™ Process was demonstrated at the Nascolite Superfund site in Millville, New Jersey, from September through November 1994. Groundwater at this 17.5-acre site is contaminated with methyl methacrylate (MMA) and other volatile organic compounds from manufacturing polymethyl methacrylate plastic sheets, commonly known as Plexiglas. The Demonstration Bulletin (EPA/540/MR-95/503), and Technology Capsule (EPA/540/R-95/503a), and Innovative Technology Evaluation Report (EPA/540/R-95/503) are available from EPA.

Since the development of the ZenoGem™ technology in 1987, ZENON has performed pilot tests for government and private clients on several different types of wastewater, including oily wastewater, metal finishing wastes, cleaning solutions containing detergents, alcohol-based cleaning solutions, landfill leachate, aqueous paint-stripping wastes, and deicing fluids. Information about the two demonstrations conducted in Canada and the United States is available from ZENON.

DEMONSTRATION RESULTS:

During the 3-month demonstration, sampling results showed that the system achieved average removal efficiencies of greater than 99.9 percent for MMA and 97.9 percent for chemical oxygen demand. MMA concentrations measured in the off-gas emission stream indicated insignificant volatilization. The ultrafiltration system effectively dewatered the process sludge, which yielded a smaller waste volume for off-site disposal. Sludge dewatering resulted in an approximate volume reduction of 60 percent and a solids increase from 1.6 to 3.6 percent. The process effluent was clear and odorless, and accepted for discharge by the local publicly owned treatment works. During the demonstration, the system was left unattended at night and on weekends, demonstrating that computer control is practical for extended operating periods.

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