

## **FILTER FLOW TECHNOLOGY, INC.** **(Colloid Polishing Filter Method®)**

### **TECHNOLOGY DESCRIPTION:**

The Colloid Polishing Filter Method® (CPFM®) uses inorganic, oxide-based sorption particles (FF-1000®) and optimized fluidics control to remove ionic, colloidal heavy metals and nontritium radionuclides from water. Beta- and alpha-emitting radionuclides can be treated selectively by modifying the bed formulation. The methodology efficiently removes inorganics from groundwater, pond water, or wastewater based on sorption, chemical and physical properties of the pollutant species, and filtration. The CPFM® is also an efficient heavy metals and radionuclide polishing filter for groundwater and wastewater. Excess solids and total dissolved solids must be removed first, since they overload the beds, resulting in frequent bed backwashing and regeneration cycles and shorter bed lifetimes.

Three different types of CPFM® equipment have been designed and successfully tested: (1) vertical plate design beds with FF-1000® sorption bed particles packaged in polymesh bags or filter packs for field applications; (2) small, filter-housing units for processing less than 1,000 gallons of contaminated

water; and (3) deep-bed, epoxy-coated, stainless steel and carbon steel tanks equipped with special fluidics controls and bed sluicing ports for continuous processing. The photograph below shows a mobile CPFM® unit.

### **WASTE APPLICABILITY:**

The CPFM® has proved to be effective in removing heavy metals and nontritium radionuclides from water to parts per million or parts per billion levels. The ion exchange/sorption method can be used separately to treat water with low total suspended solids; in a treatment train downstream from other technologies (such as soil washing, organics oxidation; or conventional wastewater treatment).

The CPFM®'s major advantages are its high performance; alpha and beta emitter efficiency; and its application to monovalent, divalent, multivalent, and high valence forms existing as colloids, and ionic, chelated, and complexed forms. The same equipment can treat water at different sites, but the preconditioning chemistry and pH must be optimized for each site through bench-scale and field testing.



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

## STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. EPA and the U.S. Department of Energy (DOE) cosponsored the technology evaluation. The SITE demonstration occurred in September 1993 at DOE's Rocky Flats Plant (RFP) in Denver, Colorado. The Demonstration Bulletin (EPA/540/MR-94/501), Technology Capsule (EPA/540/R-94/501a), and Innovative Technology Evaluation Report (EPA/540/R-94/501) are available from EPA.

The CPFM<sup>®</sup> has been demonstrated independent of the SITE Program at two locations at DOE's Hanford facility, where it removed Strontium-90, Cesium-137, Plutonium-239, and Americium-241 from water at K-Basin and Strontium-90 from groundwater at Site 100N Area (N-Spring). It also has proven to be effective at several other individual sites. A report detailing the results is available from DOE (DOE/RL-95-110).

## DEMONSTRATION RESULTS:

During the SITE demonstration, the CPFM<sup>®</sup> treated about 10,000 gallons of water that contained about 100 micrograms per liter of uranium and 100 picoCuries per liter of gross alpha contamination. The demonstration consisted of three tests. The first test consisted of three 4-hour runs, at a flow rate of about 5 gallons per minute (gpm). For the second test, also run for 4 hours at 5 gpm, the influent water was pretreated with sodium sulfide. The third test was a 15-hour run designed to determine the amount of contamination each filter pack could treat.

The CPFM<sup>®</sup> system removed up to 95 percent uranium and 94 percent gross alpha contamination. However, due to the significant variation in removal efficiencies between runs, average removal efficiencies were significantly less: 80 percent for uranium and 72 percent for gross alpha. Though removal is largely attributable to the colloid filter pack, uranium was significantly removed in runs one and four before colloid filter treatment. Significant gross alpha was also removed before colloid filter treatment in runs one and three. At less than the maximum removal efficiency, effluent from the CPFM<sup>®</sup> system did not meet the Colorado Water Quality Control Commission standards for discharge of waters from RFP.

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**GAS TECHNOLOGY INSTITUTE**  
**(formerly Institute of Gas Technology)**  
**(Cement-Lock™ Technology)**

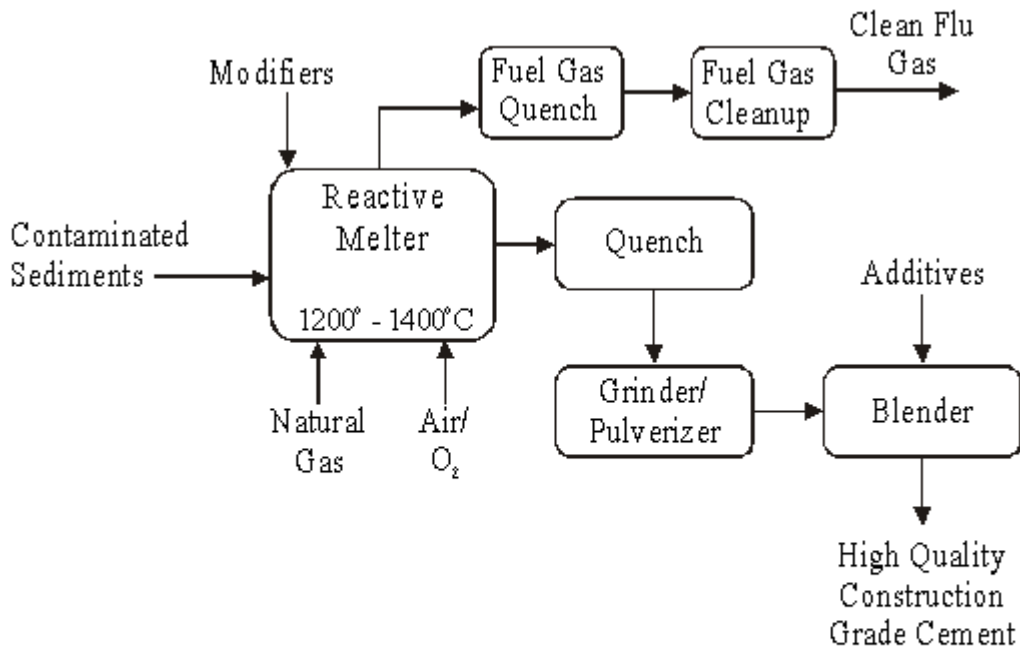
**TECHNOLOGY DESCRIPTION:**

The Gas Technology Institute (GTI) has developed the Cement-Lock™ Technology, which is a versatile, cost-effective, and environmentally friendly manufacturing technology. This method produces construction-grade cements from a variety of contaminated waste materials such as sediments, concrete and building debris, town gas site soils, Superfund site soils, sludges, chemical wastes, petroleum refinery wastes, and incinerator residues. Organic and inorganic contaminants are present in these wastes across a broad range of concentrations. In the Cement-Lock™ process, contaminated materials and proprietary modifiers are fed to a reactive melter operating under oxidizing conditions where all the organic compounds are completely destroyed and converted to innocuous carbon dioxide and water. Chlorine and sulfur compounds are sequestered and heavy metals are locked within the molten matrix to completely immobilize them.

During processing, the melt (Ecomelt™) is imparted with latent cementitious properties that allow it to be transformed into construction-grade cement. The Cement-Lock Technology is unique because it not only decontaminates the sediment but also converts it into a beneficial commercial commodity, namely, construction-grade cement. The effectiveness of the technology for remediating contaminated sediments has already been verified in bench- and pilot-scale test programs.

**WASTE APPLICABILITY:**

This technology is suitable for soils and sediments that are contaminated with petroleum hydrocarbons, PCBs, heavy metals and most other organic and inorganic contaminants.



Schematic Diagram of the Cement-Lock™ Process  
 For Treating Dredged Sediments

## **STATUS:**

This successful project has been transferred from Exploratory Research to the Industrial Program. GRI and Endesco Clean Harbors LLC have entered into a contract to further develop and commercialize this technology.

## **DEMONSTRATION RESULTS:**

Several bench-scale tests were conducted by IGT in which aged siliceous (silica-based aggregate) concrete was mixed with different amounts of inexpensive modifiers and melted at about 2,300°F. The melt was then rapidly quenched to retain the desired amorphous, glassy phase. In one test, the concrete was contaminated with 5,000 ppm of oil and 500 ppm of chromium. The amorphous, glassy material produced was then converted to blended cement per ASTM procedures. The results of the analyses and tests made on the product showed that organic destruction in excess of 99.9% was achieved in the ground melt. An analysis using the EPA TCLP (Toxicity Characteristic Leaching Procedure) procedure indicated the chromium leachability of the blended cement was only 0.097 mg/L in the leachate (the regulatory leachability limit is 5 mg/L). The 3, 7, and 28-day compressive strengths of the blended cement were 2530, 3370, and 5475 psi, respectively. These strengths significantly exceed ASTM C 595 and ASTM C 1157 requirements. Two bench-scale tests using a calcareous (limestone-based) concrete were also conducted. The melts produced were glassy in nature and suitable for producing blended cement.

A large-scale technology demonstration is on hold pending the decision of disposition of dredged sediments from the Detroit River.

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## **GENERAL ATOMICS (formerly Ogden Environmental) (Circulating Bed Combustor)**

### **TECHNOLOGY DESCRIPTION:**

General Atomics' circulating bed combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone that destroys toxic hydrocarbons. The commercial-scale, 3-foot combustion chamber can treat up to 150 tons of contaminated soil daily, depending on the heating value of the feed material.

The CBC operates at lower temperatures than conventional incinerators (1,450 to 1,600°F). The CBC's high turbulence produces a uniform temperature around the combustion chamber and hot cyclone. The CBC also completely mixes the waste material during combustion. Effective mixing and low combustion temperature reduce operating costs and potential emissions of such gases as nitrogen oxide (NO<sub>x</sub>) and carbon monoxide (CO). Natural gas, fuel oil, or diesel can be used as auxiliary fuel. No auxiliary fuel is needed for waste streams with a net heating value greater than 2,900 British thermal units per pound.

As shown in the figure below, waste material and limestone are fed into the combustion chamber along with the recirculating bed material. The limestone neutralizes acid gases. A conveyor transports the treated ash out of the system for proper disposal. Hot combustion gases pass through a convective gas cooler and baghouse before they are released to the atmosphere.

The CBC process can treat liquids, slurries, solids, and sludges contaminated with corrosives, cyanides, dioxins and furans, inorganics, metals, organics, oxidizers, pesticides, polychlorinated biphenyls (PCB), phenols, and volatile organic compounds. The CBC is permitted under the Toxic Substances Control Act to burn PCBs in all 10 EPA regions, having demonstrated a 99.99 percent destruction removal efficiency (DRE). Applications of the CBC include a variety of industrial wastes and contaminated site materials. Waste feed for the CBC must be sized to less than 1 inch. Metals in the waste do not inhibit performance and become less leachable after incineration. Treated residual ash can be replaced on site or stabilized for landfill disposal if metals exceed regulatory limits.

### **STATUS:**

The CBC (formerly owned by Ogden Environmental Services) was accepted into the SITE Demonstration Program in 1986. A treatability study on wastes from the McColl Superfund site in California was conducted under the guidance of the SITE Program, EPA Region 9, and the California Department of Health Services in March 1989. A pilot-scale demonstration was conducted at the General Atomics research facility in San Diego, California using a 16-inch-diameter CBC. The demonstration was conducted on soil from the McColl Superfund Site in Fullerton, California.

Several 3-foot-diameter CBCs have been built and successfully operated. At the Swanson River project in Alaska, over 100,000 tons of PCB-contaminated soil was successfully treated to limits of detection that were far below allowable limits. The process took just over 3 years, from mobilization of the transportable unit to demobilization. The unit operated at over 85 percent availability all year, including winter, when temperatures were below -50°F. The soil was delisted and returned to the original site. The unit has subsequently been moved to a Canadian site. Another unit of similar size treated soils contaminated with #6 fuel oil. Over 14,000 tons of soil was successfully treated and delisted.

Upon completion, the site was upgraded to permit operation as a merchant facility treating a wide range of materials from leaking underground fuel tanks at other sites. Two other units of the same size have been constructed in Germany for treatment of munitions wastes consisting of slurried explosives and propellant. These units have been operational since early 1995 and have been permitted under stringent German regulations.

## **DEMONSTRATION RESULTS:**

During the SITE demonstration, the CBC performed as follows:

- Achieved DRE values of 99.99 percent or greater for principal organic hazardous constituents
- Minimized formation of products of incomplete combustion
- Met research facility permit conditions and California South Coast Basin emission standards
- Controlled sulfur oxide emissions by adding limestone and residual materials (fly ash and bed ash); these emissions were nonhazardous. No significant levels of hazardous organic compounds were found in the system, the stack gas, or the bed and fly ash.
- Minimized emissions of sulfur oxide, NO<sub>x</sub>, and particulates. Other regulated pollutants were controlled to well below permit levels.

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**GENERAL ENVIRONMENTAL, INC.**  
**(formerly Hydrologies, Inc./Cure International, Inc.)**  
**(CURE®-Electrocoagulation Wastewater Treatment System)**

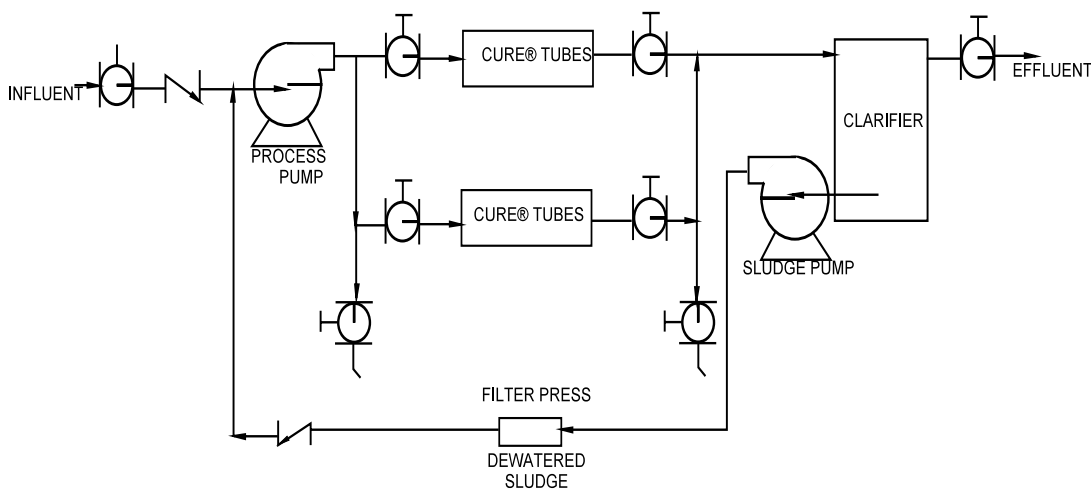
**TECHNOLOGY DESCRIPTION:**

The CURE® - Electrocoagulation (CURE®) system is designed to remove ionic metal species and other charged particles from water (see figure below). Because many toxic metal ions such as nickel, lead, and chromates are held in solution by electrical charges, they will precipitate out of solution if they are neutralized with oppositely charged ions. The CURE® system is effective at breaking oily emulsions and removing suspended solids. The system improves on previous electrocoagulation methods through a unique geometrical configuration.

The CURE® system's patented geometry maximizes liquid surface contact between the anode and concentric cathode electrocoagulation tubes, thus minimizing the power requirements for efficient operation. The CURE® system allows the contaminated water to flow continuously through the cathode tube, enabling a direct current to pass

uniformly through a water stream. The contaminated water then passes through the annular space between the cathode and anode tubes and is exposed to sequential positive and negative electrical fields. Typical retention time is less than 20 seconds. Water characteristics such as pH, oxidation-reduction potential, and conductivity can be adjusted to achieve maximum removal efficiencies for specific contaminants.

After the treated water exits the electrocoagulation tubes, the destabilized colloids are allowed to flocculate and are then separated with an integrated clarifier system. Polymers can be added to enhance flocculation, but in most cases they are not required. The sludge produced by this process is usually very stable and acid-resistant. Tests have shown that sludges produced by the CURE® system pass the toxicity characteristic leaching procedure (TCLP) and are often disposed of as nonhazardous waste.



CURE®-Electrocoagulation System

## **WASTE APPLICABILITY:**

The CURE® system can treat a broad range of dissolved metals, including aluminum, arsenic, barium, cadmium, chromium, cyanide, iron, lead, nickel, uranium, and zinc. The system can also treat contaminants such as emulsified oils, suspended solids, paints, and dyes. Radionuclides were removed by the system at the Rocky Flats Environmental Technology Site (RFETS).

Because this system treats a wide range of contaminants, it is suited for industries and utilities such as plating, mining, electronics, industrial wastewater, as well as remediation projects.

## **STATUS:**

This technology was accepted into the SITE Demonstration Program in 1993. A bench-scale test of the technology was conducted in April 1995 to determine the ability of the system to remove radionuclides from solar evaporation water at RFETS. The system removed over 90 percent of uranium and plutonium from the test water. The technology was demonstrated during August and September 1995 at RFETS under a joint agreement between the Department of Energy, the State of Colorado, and EPA.

The technology has proven to be very effective in a diverse number of industrial applications including metal refinishing, oil treatment plants, acid mine drainage and cooling towers in the U.S. and internationally. Full or pilot scale units are available from CURE® International, Inc.

## **DEMONSTRATION RESULTS:**

During the SITE demonstration, four 3-hour test runs were conducted at RFETS over a 2-week period. Prior to the demonstration, operating parameters were adjusted during several optimization runs.

The demonstration showed that the system removed 30 to 50 percent of uranium and 60 to 99 percent of plutonium from the solar pond water at RFETS. The radionuclide and metal content of the dewatered sludge indicated that these contaminants were highly concentrated in the sludge. Uranium and plutonium were only slightly leachable by TCLP and no metals were leachable by TCLP. These results suggest that the sludge is very stable and resistant to breakdown.

The Demonstration Bulletin (EPA/540/MR-96/502), Technology Capsule (EPA/540/R-92/502a), and Innovative Technology Evaluation Report (EPA/540/R-96/502) are available from EPA.

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## **GEOKINETICS INTERNATIONAL, INC.**

### **(Electroheat-Enhanced Nonaqueous-Phase Liquids Removal)**

#### **TECHNOLOGY DESCRIPTION:**

Geokinetics has developed and fully commercialized a novel in-situ process for the extraction and/or destruction of organic materials (nonaqueous phase liquids [NAPL]) from ground and groundwater. The process combines a novel direct electrical heating process with established soil vapor, dual phase and other extraction approaches. Heat is produced directly in the treatment zone by the passage of an AC current through the soil matrix. In effect, the ground and groundwater become the electrical resistor in a conventional resistive heating circuit.

Multi-phase electrical current is supplied to the soil matrix using proprietary high surface area electrodes inserted directly into the ground. Electrical current, heat-up rate, and other operating parameters are regulated by a proprietary computer-based (impedance matching) control system. This system incorporates automated data logging, fault tolerance, and remote operation to minimize field labor requirements.

The process works by gradually and uniformly heating the treatment zone to 60 to 80°C. This produces the following effects:

- NAPL viscosity is significantly reduced.
- A density inversion of many dense nonaqueous-phase liquid (DNAPL) components will occur causing it to float to the top of the saturated zone.
- The smear zone will greatly reduce or even collapse.

- Nascent biological activity will typically increase dramatically (provided the heat-up rate is managed carefully). This greatly increases natural biodegradation. When the treatment zone has reached its operating temperature, a combination of established extraction techniques are applied as appropriate to remove most or all of the NAPL.
- Treatment times typically include:
  - 1 month for heat-up
  - 4 to 8 months for primary extraction

#### **WASTE APPLICABILITY:**

The technology is broadly applicable for enhancing the removal of NAPLs and DNAPLs from a broad range of ground types. Recovered and destroyed contaminants include fuel oil, diesel, kerosene, PAHs, coal tar, hydraulic fluid, TCE, and other chlorinated solvents, ground types treated include clays, silty clays, shale beds, gravel deposits, etc. The technology has been deployed alongside, inside, and underneath existing buildings and structures.

#### **STATUS:**

Geokinetics first developed and commercialized the technology in Europe and had more than 40 projects completed or in progress. In the United States, Geokinetics' technology was accepted in the Superfund Innovative Technology Evaluation (SITE) program in 1997. The technology was demonstrated at the Pearl Harbor demonstration site in Oahu, Hawaii.

• **DEMONSTRATION RESULTS:**

The heating process was able to reach the required operating temperature. However, the test well was not installed in an aquifer that communicated with the contaminated zone, so no DNAPL was removed.

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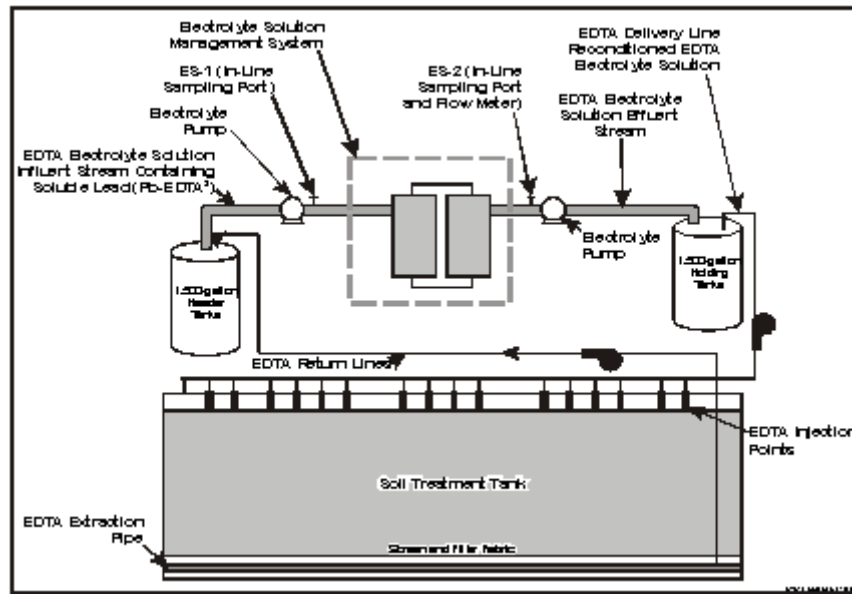
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## GEOKINETICS INTERNATIONAL INC. (Electrokinetics for Lead Recovery)

### TECHNOLOGY DESCRIPTION:

This technology mobilizes lead in soil by introducing a lead chelating agent, ethylene diamine tetra acetic acid (EDTA), into the soil mass. The chelating agent desorbs lead from the soil and forms an ionic complex with lead in solution. EDTA is a weak organic acid that is nonhazardous and environmentally safe which naturally biodegrades. EDTA was chosen after two treatability studies on site soil demonstrated that it was a successful chelating agent due to its ability to absorb lead from the highly buffered soil at the site.

A 4-cubic-yard batch ex situ treatment process is used to mobilize and remove lead from the site soil. Soil treatment involves flushing with an EDTA electrolyte solution. The electrolyte solution is introduced into the treatment tank containing the volume of soil to be treated through a manifold of microjets distributed across the top of the tank. The solution migrates through the soil column while the EDTA desorbs the lead from the soil, thus forming the Pb-EDTA<sup>2-</sup> complex. The electrolyte solution (containing the Pb-EDTA<sup>2-</sup> complex) is then allowed to drain through a port at the bottom of the tank. Once the electrolyte solution has been removed from the tank, it is then delivered to a holding tank prior to being cycled through a proprietary electrochemical processing unit. Here the lead is electroplated out of solution and recovered as metallic lead. Afterward, the electrolyte solution is delivered to a holding tank where it will be regenerated (pH adjusted) before being reintroduced to the soil undergoing treatment. Lead removed from the electrolyte solution is accumulated and delivered off-site for disposal or recycling. The entire system is a batch, closed-loop process. During operation, sensors monitor the concentration of lead in the electrolyte solution extracted from the soil.



**FOR FURTHER INFORMATION:**

**WASTE APPLICABILITY:**

This technology is suitable for any soils or sediments containing lead. EDTA has a strong affinity for lead and can effectively sequester lead in solution. However, the electrolyte solution containing the EDTA must be at a pH of 5 to 6 to be effective.

**STATUS:**

The Electrokinetics for Lead Recovery technology is due to undergo demonstration during the summer of 2002.

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## GEOTECH DEVELOPMENT CORPORATION (Cold Top Ex-Situ Vitrification of Chromium-Contaminated Soils)

### TECHNOLOGY DESCRIPTION:

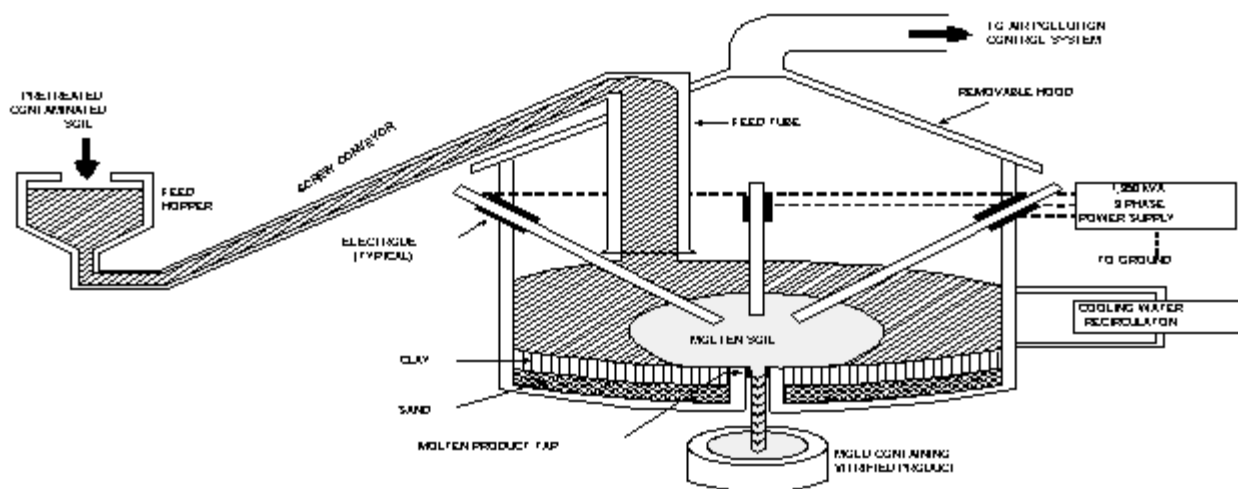
The Geotech Cold Top technology is an ex-situ vitrification process designed to transform metal-contaminated soils into a nonleachable product. The primary component of the technology is a water-cooled, double-walled, steel vessel or furnace with submerged-electrode resistance heating. The furnace and associated equipment are capable of attaining a melting temperature of up to 5,200°F.

The furnace is initially charged with a mixture of sand and alumina/silica clay. Through electrical resistance heating, a molten pool forms; the voltage to the furnace is properly adjusted; and, finally, contaminated soil is fed into the furnace by a screw conveyor. When the desired soil melt temperature is achieved, the furnace plug from below the molten product tap is removed. As the soil melts, the outflow is poured into refractory-lined and insulated molds for slow cooling, and additional soil is added to the furnace to maintain a “cold top.” Excess material can be discharged to a water sluice for immediate cooling and collection before off-site disposal. Geotech Development Corporation (Geotech) claims that the Cold Top Vitrification process converts quantities of contaminated soil from a large number of particles into an essentially monolithic, vitrified mass. According to Geotech,

vitrification transforms the physical state of contaminated soil from assorted crystalline matrices to a glassy, amorphous solid state comprised of interlaced polymeric chains. These chains typically consist of alternating oxygen and silicon atoms. It is expected that chromium can readily substitute for silicon in the chains. According to Geotech, such chromium should be immobile to leaching by aqueous solvents and, therefore, biologically unavailable and nontoxic.

### WASTE APPLICABILITY:

According to Geotech, the Cold Top Vitrification process has been used to treat soils contaminated with hazardous heavy metals such as lead, cadmium, and chromium; asbestos and asbestos-containing materials; and municipal solid waste combustor ash residue. Geotech claims that radioactive wastes can also be treated by this technology. All waste material must be reduced in size to less than 0.25 inches in diameter. The Cold Top Vitrification process is most efficient when feed materials have been dewatered to less than 5 percent water and organic chemical concentrations have been minimized. Some wastes may require the addition of carbon and sand to ensure that the vitrification process produces a glass-like product. Geotech claims that the vitrified product can have



Cold Top Ex-Situ Vitrification Technology

many uses, including shore erosion blocks, decorative tiles, road-bed fill, and cement or blacktop aggregate.

## **STATUS:**

This technology was accepted into the SITE Demonstration Program in December 1994. In February and March, 1997, this process was demonstrated at Geotech's pilot plant in Niagara Falls, New York. Approximately 10,000 pounds of chromium-contaminated soil from two New Jersey-Superfund sites in the Jersey City area were collected crushed, sieved, dried, mixed with carbon and sand, and shipped to the Geotech plant. The SITE demonstration consisted of one vitrification test run on soil from each site.

## **DEMONSTRATION RESULTS:**

The demonstration results indicate that the Cold Top Vitrification process reduced the concentration of leachable chromium to meet the Resource Conservation and Recovery Act (RCRA) toxicity characteristic leaching procedure (TCLP) total chromium standard. For example, concentrations of 29 and 58 mg/L of TCLP chromium in feed soils were reduced to 1.0 and 0.31 mg/L, respectively, in vitrified products. Field observations and measurements made during the demonstration indicate that several operational issues must be addressed during technology scale-up. First, a consistent and controlled feed system needs to be developed that spreads the waste uniformly over the surface of the molten soil. This feed system must also minimize dust generation. Second, an emission control system needs to be configured to control particulate and gaseous emissions from the furnace and feed system.

The SITE Demonstration Bulletin (EPA/540/HR-97/506) and Technology Capsule (EPA/540/R-97/506a) are available from EPA. Geotech owns a 50-ton-per-day Cold Top Vitrification pilot plant in Niagara Falls, New York. This facility has been

used for over 38 research and customer demonstrations, including the SITE demonstration. Geotech has built or assisted with the construction or upgrading of more than five operating vitrification plants. Geotech has tentative plans to build a commercial Cold Top Vitrification facility within 50 miles of the New Jersey sites. The planned capacity of this facility is 300 tons per day. The facility will be designed to receive, dry, vitrify, and dispose of vitrified product from the chromium sites and municipal solid waste incinerators, as well as other producers of hazardous and nonhazardous waste.

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## GIS\SOLUTIONS, INC. (GIS\Key™ Environmental Data Management System)

### TECHNOLOGY DESCRIPTION:

GIS\Key™ v.3.0 is a comprehensive environmental database management system that integrates site data and graphics, enabling the user to create geologic cross-sections, boring logs, potentiometric maps, isopleth maps, structure maps, summary tables, hydrographs, chemical time series graphs, and numerous other maps and line graphs (see table below). The software is networkable, multi-user, 32 bit and year 2000 compliant. It is menu-driven, making it relatively simple to use. All system outputs meet Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting requirements and are consistent with current industry practices.

In addition to complete integration between data and graphics, GIS\Key™ v.3.0 integrates different data types, allowing swift production of complex graphics such as geo-chemical cross sections and flux graphics.

GIS\Key™ v.3.0 stores and independently manages metadata (such as maps, graphs, reports, boring logs and sections) from multiple sites. Metadata is geocoded, stored separately from a facility's source data and retrieved by performance of a spatial query. Metadata from a facility may be retrieved, viewed and studied independently or combined with metadata from other facilities for multi-site management.

The GIS\Key™ software can directly export data into the leading three-dimensional visualization systems. These systems produce three-dimensional contaminant plume models and groundwater flow models as well as fence diagrams. GIS\Key™ includes audit or transaction logging capabilities for source data as well as metadata.

The GIS\Key™ v3.0 also employs two new project management and data navigation tools called Scout™ and Smart Query™. Scout™ helps users find and access existing projects, start new projects, browse data and initiate queries that result in reports, maps, and other graphics.

Scout™ also manages data security and multi-user network installations of GIS\Key™ v.3.0. Smart Query™ is a data “drill down” tool which helps users set conditions on project data, displays data meeting those conditions, then creates desired output. GIS\Key™ v3.0 also has new modules for radiological chemistry and RCRA Statistics. Site data related to ecological assessment and air emissions are not managed by this system.

The GIS\Key™ software can be used at any Superfund site to facilitate the collection, reporting, and analysis of site data. The software is designed with numerous checks to assure the quality of the data, including comprehensive quality assurance/quality control protocols. System outputs, listed in the table below, are presentation-

CHEMISTRY	GEOLOGY	HYDROLOGY
<ul style="list-style-type: none"> <li>• Isopleth maps of soil or water quality (plan or section view)</li> <li>• Graphs                             <ul style="list-style-type: none"> <li>- Time series graphs</li> <li>- Chemical versus chemical and inter-well and intra-well</li> <li>- Concentration versus position</li> <li>- Summary of statistics</li> </ul> </li> <li>• Trilinear Piper &amp; Stiff diagrams</li> <li>• User alerts                             <ul style="list-style-type: none"> <li>- When QA/QC results fall outside data quality objectives</li> <li>- When sample results fall outside historical ranges</li> <li>- When sample results exceed applicable regulatory standards</li> </ul> </li> <li>• Sample Tracking; Electronic Lab Interface</li> <li>• Presentation-quality data tables</li> </ul>	<ul style="list-style-type: none"> <li>• Completely customizable boring logs</li> <li>• Geologic cross-section maps</li> <li>• Isopach maps</li> <li>• Structure maps</li> <li>• Presentation-quality data tables</li> </ul> <p style="text-align: center;"><b>ALL MODULES:</b></p> <ul style="list-style-type: none"> <li>• GIS\Key Scout™ Interface</li> <li>• Independent management of metadata</li> <li>• Multi-site management capability</li> <li>• Integration between data types</li> <li>• Smart Query™ Data Retrieval</li> <li>• 3D Modeling, Statistics, GIS Integration</li> </ul>	<ul style="list-style-type: none"> <li>• Density-corrected water level, floating product, hydraulic conductivity, and contour maps</li> <li>• Water elevation and floating product thickness versus time graphs</li> <li>• Flow versus time and chemical flux graphs</li> <li>• Presentation-quality data tables</li> </ul> <p style="text-align: center;"><b>SYSTEM REQUIREMENTS:</b></p> <ul style="list-style-type: none"> <li>• Hardware: Pentium Class PC 32 MB RAM</li> <li>• Operating System: Windows 95/98 or Windows NT</li> </ul>

### GIS\Key™ Environmental Data Management System Outputs

quality and meet RCRA and CERCLA reporting requirements. GIS\Key™ software provides a three level data validation system which includes 1) sample tracking by custody, sample ID and/or date and time, 2) an electronic laboratory import program that immediately finds, and helps the user fix, quality control (QC) problems with the laboratory data delivery and 3) a series of “User Alert” reports which find data that falls outside of project QC objectives, historical data ranges, or above federal, state, and local or project specific action levels.

### **STATUS:**

This technology was accepted into the SITE Demonstration Program in summer 1992. The demonstration was held in August 1993 in San Francisco, California, and December 1993 in Washington, DC. The Demonstration Bulletin (EPA/540/MR-94/505), Technology Capsule (EPA/540/SR-94/505), Innovative Technology Evaluation Report (EPA/540/R-94/505), and project videotape are available from EPA.

### **DEMONSTRATION RESULTS:**

The GIS\Key™ software is in use at several Superfund sites including the Crazyhorse site near Salinas, California, and the Moffett Field site near San Jose, California. The U.S. Air Force’s Environmental Data Management and Decision Support working group has successfully tested the effectiveness of the GIS\Key™ technology at Norton Air Force Base in California. The technology is also being used by consultants at over 30 other U.S. Air Force and Department of Energy facilities.

Results from the SITE demonstration indicated that the GIS\Key™ software generated the four types of contour maps necessary to assist in groundwater mapping: hydrogeologic maps, chemical concentration isopleths, geologic structure maps, and geologic structure thickness isopach maps.

Several advanced chemistry reports and construction and borehole summary tables were also automatically prepared using customized GIS\Key™ menu commands. The system automated well and borehole logs based on the information contained in the database. GIS\Key™ provided several editable reference lists, including a list of regulatory thresholds, test methods, and a list of chemical names, aliases, and registry numbers. The GIS\Key™ database menu provided commands for electronic database import and export. Any of the database files used by GIS\Key™ can be used with the general import and export commands available in the database menu.

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## GRACE BIOREMEDIATION TECHNOLOGIES (DARAMEND™ Bioremediation Technology)

### TECHNOLOGY DESCRIPTION:

The GRACE Bioremediation Technologies organic amendment-enhanced bioremediation technology (DARAMEND™) is designed to degrade many organic contaminants in industrial soils and sediments, including pentachlorophenol (PCP), polynuclear aromatic hydrocarbons (PAHs), and petroleum hydrocarbons. The technology has been applied both in situ and ex situ. In either case, soil may be treated in lifts up to 2 feet deep using available mixing equipment. The technology may also be applied ex situ, as a biopile.

The technology treats batches of soil using DARAMEND™ soil amendments. These amendments are introduced using conventional agricultural equipment (see photograph below), followed by regular tilling and irrigation. DARAMEND™ soil amendments are solid-phase products prepared from natural organic materials to have soil-specific particle size distribution, nutrient content, and nutrient releases kinetics. Soil amendments sharply increase the ability of the soil

matrix to supply water and nutrients to the microorganisms that degrade the hazardous compounds. The amendments can also transiently bind contaminants, reducing the acute toxicity of the soil aqueous phase. This reduction allows microorganisms to survive in soils containing very high concentrations of toxic compounds.

DARAMEND™ treatment involves three fundamental steps. First, the treatment area is prepared. For the ex situ application, a lined treatment cell is constructed. In situ application requires the treatment area to be cleared and ripped to reduce soil compaction. Second, the soil is pretreated; this includes removing debris larger than 4 inches, such as metal or rocks, that may damage the tilling equipment. Sediments under-going treatment must be dewatered. And third, the DARAMEND™ soil amendment is incorporated, usually at 1 percent to 5 percent by weight, followed by regular tilling and irrigating.

Soil is tilled with a rotary tiller to reduce variation in soil properties and contaminant concentrations. Tilling also incorporates the required soil



DARAMEND™ Bioremediation Technology

amendments and helps deliver oxygen to contaminant-degrading microorganisms.

An irrigation system is used to maintain soil moisture in the desired range. If the treatment area is not covered, leachate or surface runoff caused by heavy precipitation is collected and reapplied to the soil as needed.

Equipment needed to implement this technology includes a rotary tiller, irrigation equipment, and excavation and screening equipment. Depending on site-specific factors such as contaminant type and initial concentration, and project schedule and climate, a waterproof cover may be constructed over the treatment area.

### **WASTE APPLICABILITY:**

The DARAMEND™ technology can treat soil, sediment, and other solid wastes such as lagoon sludge. These matrices may be contaminated by a wide range of organic compounds including, but not limited to, PAHs, PCP, petroleum hydrocarbons, and phthalates. Matrices of lead, manganese, and zinc have been effectively treated with the DARAMEND™ technology.

### **STATUS:**

This technology was accepted into the SITE Demonstration Program in spring 1993. The ex situ application of the technology was demonstrated from fall 1993 to summer 1994 at the Domtar Wood Preserving facility in Trenton, Ontario, Canada. The demonstration was one component of a 5,000-ton remediation project underway at the site.

Currently, the DARAMEND™ technology has received regulatory approval, and has been applied at field-scale at five sites in the United States. These sites include the full-scale treatment of PCP impacted soil in Montana, Washington, and Wisconsin, the full-scale treatment of phthalate impacted soil in New Jersey and a pilot-scale demonstration of toxaphene impacted soil in South

Carolina. In addition, the technology has been applied at a number of Canadian sites including a 2,500 tonne biopile in New Brunswick, and two pilot-scale projects targeting pesticides and herbicides in Ontario. The first full-scale application to soil containing organic explosives was scheduled for late 1998.

### **DEMONSTRATION RESULTS:**

In the ex situ demonstration area, the DARAMEND™ technology achieved the following overall reductions: PAHs, 94 percent (1,710 milligram/kilogram [mg/kg] to 98 mg/kg); chlorophenols, 96 percent (352 mg/kg to 13.6 mg/kg); and total petroleum hydrocarbons (TPH), 87 percent. These reductions were achieved in 254 days of treatment, including winter days when no activity occurred because of low soil temperatures. The control area showed a reduction of 41 percent in PAH concentrations; no reduction was seen in the concentration of either chlorinated phenols or TPH during the treatment time. Results from the toxicity analysis (earthworm mortality and seed germination) showed that the toxicity was eliminated or greatly reduced in the treated soil.

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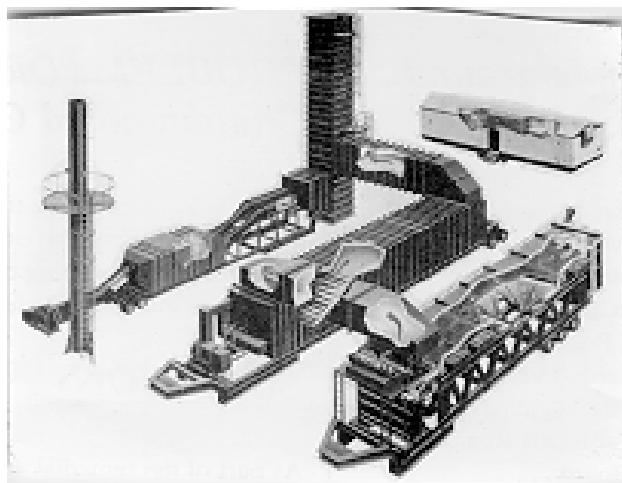
**GRUPPO ITALIMPRESSE**  
**(Developed by Shirco Infrared Systems, Inc.)**  
**(formerly Ecova Europa)**  
**(Infrared Thermal Destruction)**

**TECHNOLOGY DESCRIPTION:**

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

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

The ash material in the primary chamber is quenched with scrubber water effluent. The ash is then conveyed to an ash hopper, where it is removed to a holding area and analyzed for organic contaminants such as polychlorinated biphenyls (PCBs).



Mobile Thermal Processing System

Volatile gases from the primary chamber flow into the secondary chamber, which uses higher temperatures, greater residence time, turbulence, and supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system. In the emissions control system, the particulates are removed in a venturi scrubber. Acid vapor is neutralized in a packed tower scrubber. An induced draft blower draws the cleaned gases from the scrubber into the free-standing exhaust stack. The scrubber liquid effluent flows into a clarifier, where scrubber sludge settles and is removed for disposal. The liquid then flows through an activated carbon filter for reuse or to a publicly owned treatment works for disposal.

This technology is suitable for soils or sediments with organic contaminants. Liquid organic wastes can be treated after mixing with sand or soil. Optimal waste characteristics are as follows:

- Particle size, 5 microns to 2 inches
- Moisture content, up to 50 percent by weight
- Density, 30 to 130 pounds per cubic foot
- Heating value, up to 10,000 British thermal units per pound
- Chlorine content, up to 5 percent by weight
- Sulfur content, up to 5 percent by weight
- Phosphorus, 0 to 300 parts per million (ppm)
- pH, 5 to 9
- Alkali metals, up to 1 percent by weight

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## STATUS:

EPA conducted two evaluations of the infrared thermal destruction technology. A full-scale unit was evaluated during August 1987 at the Peak Oil Superfund site in Brandon, Florida. The system treated nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. A pilot-scale demonstration took place at the Rose Township-Demodé Road Superfund site in Michigan during November 1987. Organics, PCBs, and metals in soil were the target waste compounds. Two Applications Analysis Reports (EPA/540/A5-89/010 and EPA/540/ A5-89/007) and two Technology Evaluation Reports (EPA/540/5-88/002a and EPA/540/ 5-89/007a) are available from EPA. In addition, the technology has been used to remediate PCB contamination at the Florida Steel Corporation and the LaSalle Electric Superfund sites.

This technology is no longer available through vendors in the United States. For further information about the technology, contact the EPA Project Manager.

## DEMONSTRATION RESULTS:

The results from the two SITE demonstrations are summarized below.

- PCBs were reduced to less than 1 ppm in the ash, with a destruction removal efficiency (DRE) for air emissions greater than 99.99 percent (based on detection limits).
- In the pilot-scale demonstration, the Resource Conservation and Recovery Act standard for particulate emissions (0.08 gram per dry standard cubic foot) was achieved. In the full-scale demonstration, however, this standard was not met in all runs because of scrubber inefficiencies.

- Lead was not immobilized; however, it remained in the ash. Significant amounts were not transferred to the scrubber water or emitted to the atmosphere.
- The pilot-scale unit demonstrated satisfactory performance with high feed rate and reduced power consumption when fuel oil was added to the waste feed and the primary chamber temperature was reduced.
- Economic analysis suggests an overall waste remediation cost of less than \$800 per ton.

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**HIGH VOLTAGE ENVIRONMENTAL  
APPLICATIONS, INC.**  
**(formerly Electron Beam Research Facility, Florida  
International University, and University of Miami)**  
**(High-Energy Electron Irradiation)**

High-voltage electron irradiation of water produces a large number of reactive chemical species, including the aqueous electron ( $e_{aq}^-$ ), the hydrogen radical (H $\cdot$ ), and the hydroxyl radical (OH $\cdot$ ). These short-lived intermediates break down organic contaminants in aqueous wastes.

In the principal reaction, the aqueous electron transfers to halogen-containing compounds, breaking the halogen-carbon bond and liberating halogen anions such as chloride (Cl $^-$ ) or bromide (Br $^-$ ). The hydroxyl radical can undergo addition or hydrogen abstraction reactions, producing organic free radicals that decompose in the presence of other hydroxyl radicals and water. In most cases, organics are converted to carbon dioxide, water, and salts. Lower molecular weight aldehydes, haloacetic acids, and carboxylic acids form at low concentrations in some cases.

During the high-voltage electron irradiation process, electricity generates high energy electrons. The electrons are accelerated by the voltage to approximately 95 percent of the speed of light. They are then directed into a thin stream of water or sludge. All reactions are complete in less than 0.1 second. The electron beam and waste flow are adjusted to deliver the necessary dose of electrons. Although this is a form of ionizing radiation, there is no residual radioactivity.

High Voltage Environmental Applications, Inc. (High Voltage), has developed a mobile facility to demonstrate the treatment process (see photograph below).



The Mobile Electron Beam Hazardous Waste Treatment System

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## WASTE APPLICABILITY:

This treatment process can effectively treat more than 100 common organic compounds. These compounds include the following:

- Trihalomethanes (such as chloroform), which are found in chlorinated drinking water
- Chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromo-chloropropane, hexachlorobutadiene, and hexachloroethane
- Aromatics found in gasoline, including benzene, toluene, ethylbenzene, and xylene (BTEX)
- Chlorobenzene and dichlorobenzenes
- Phenol
- Dieldrin, a persistent pesticide
- Polychlorinated biphenyls
- A variety of other organic compounds

The treatment process is appropriate for removing various hazardous organic compounds from aqueous waste streams and sludges. The high-energy electron irradiation process was accepted into the SITE Emerging Technology Program (ETP) in June 1990. For further information on the pilot-scale facility evaluated under the ETP, refer to the Emerging Technology Bulletins (EPA/540/F-93/502, EPA/540/F-92/009, and EPA/540/F-93/509), which are available from EPA. Based on results from ETP, the process was invited to participate in the Demonstration Program.

The ability of the technology to treat contaminated soils, sediments, or sludges is also being evaluated under the ETP. For further information on this evaluation, refer to the the High Voltage profile in the ETP section (ongoing projects).

The treatment process was demonstrated at the U.S. Department of Energy's Savannah River site in Aiken, South Carolina during two different periods totaling 3 weeks in September and November 1994. A trailer-mounted treatment system was demonstrated on a portion of the Savannah River site known as M-Area.

## DEMONSTRATION RESULTS:

During the demonstration, the system treated about 70,000 gallons of M-Area groundwater contaminated with volatile organic compounds (VOC). The principal groundwater contaminants were TCE and PCE, which were present at concentrations of about 27,000 and 11,000 micrograms per liter ( $\mu\text{g/L}$ ), respectively. The groundwater also contained low levels of cis-1,2-dichloroethene ( $40 \mu\text{g/L}$ ). The following compounds were also spiked into the influent stream at approximately  $500 \mu\text{g/L}$ : 1,2-dichloroethane, carbon tetrachloride, 1,1,1-trichloroethane, chloroform, and BTEX.

The highest VOC removal efficiencies were observed for TCE (99.5 percent), PCE (99.0 percent), and dichloroethene (greater than 99 percent). Removal efficiencies for chlorinated spiking compounds ranged from 68 to 98 percent, and removal efficiencies for BTEX ranged from 88 to 99.5 percent.

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

### TECHNOLOGY DESCRIPTION:

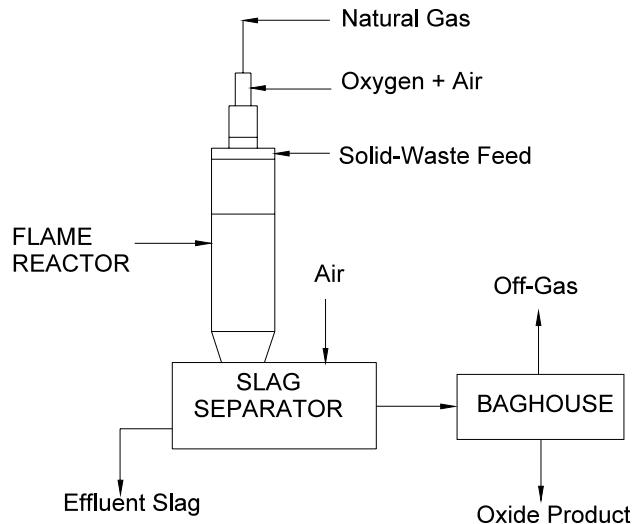
The Horsehead Resource Development Co., Inc. (HRD), flame reactor system is a patented, hydrocarbon-fueled, flash-smelting system that treats residues and wastes contaminated with metals (see figure below). The reactor processes wastes with hot (greater than 2,000°C) reducing gases produced by combusting solid or gaseous hydrocarbon fuels in oxygen-enriched air.

In a compact, low-capital cost, water-cooled reactor, the feed materials react rapidly, allowing a high waste throughput. The end products are glass-like slag; a potentially recyclable, heavy metal-enriched oxide; and in some cases, a metal alloy. The glass-like slag is not toxicity characteristic leaching procedure (TCLP) leachable. The volatile metals are fumed and captured in a baghouse; nonvolatile metals partition to the slag or may be separated as a molten alloy. Organic compounds should be destroyed at the elevated temperature of the flame reactor technology. Volume reduction (of waste to slag plus oxide) depends on the chemical and physical properties of the waste.

In general, the system requires that wastes be dry enough (less than 5 percent total moisture) to be pneumatically fed and fine enough (less than 200 mesh) to react rapidly. HRD claims larger particles (up to 20 mesh) can be processed; however, the efficiency of metals recovery is decreased. The prototype system has a capacity of 1 to 3 tons per hour. According to HRD, individual units can be scaled to a capacity of 7 tons per hour.

### WASTE APPLICABILITY:

The flame reactor system can be applied to granular solids, soil, flue dusts, slags, and sludges that contain heavy metals. HRD claims that the flame reactor technology has successfully treated the following wastes: (1) electric arc furnace dust, (2) lead blast furnace slag, (3) soil, (4) iron residues, (5) primary copper flue dust, (6) lead smelter nickel matte, (7) zinc plant leach residues and purification residues, (8) brass mill dusts and fumes, and (9) electroplating sludges.



HRD Flame Reactor Process Flow

The system has treated wastes with the following metal species and concentrations: zinc (up to 40 percent); lead (up to 10 percent); chromium (up to 4 percent); cadmium (up to 3 percent); arsenic (up to 1 percent); copper (up to 8 percent); cobalt; and nickel. According to HRD, the system can also treat soils that are contaminated with a variety of toxic organics.

## STATUS:

This technology was accepted into the SITE Demonstration Program in 1990. Currently, the prototype flame reactor system operates as a stationary unit at HRD's facility in Monaca, Pennsylvania. EPA and HRD believe that a mobile system could be designed and constructed for on-site treatment of hazardous waste.

The SITE demonstration was conducted in March 1991 using secondary lead smelter soda slag from the National Smelting and Refining Company (NSR) Superfund site in Atlanta, Georgia. The demonstration was conducted at the Monaca, Pennsylvania facility under a Resource Conservation and Recovery Act research, development, and demonstration permit. This permit allows treatment of wastes containing high concentrations of metals, but only negligible concentrations of organics.

The major objectives of the SITE technology demonstration were to investigate the reuse potential of the recovered metal oxides, evaluate the levels of contaminants in the residual slag and their leaching potential, and determine the efficiency and economics of processing.

A 30,000-standard-tons-per-year commercial flame reactor system processes steel mill baghouse dust (K061) at the North Star Steel Mini Mill near Beaumont, Texas. The plant was activated June 1, 1993, and is reported to be performing as designed.

## DEMONSTRATION RESULTS:

Approximately 72 tons of NSR waste material were processed during the demonstration. Partial test results are shown in the table below.

Metal Concentration Ranges in Influent and Effluent			
	Waste Feed (mg/kg)*	Effluent Slag (mg/kg)	Oxide Product (mg/kg)
Arsenic	428-1,040	92.1-1,340	1,010-1,170
Cadmium	356-512	<2.3-13.5	1,080-1,380
Copper	1,460-2,590	2,730-3,890	1,380-1,780
Iron	95,600-130,000	167,000-228,000	29,100-35,600
Lead	48,200-61,700	1,560-11,400	159,000-184,000
Zinc	3,210-6,810	709-1,680	10,000-16,200

\* milligrams per kilogram

All effluent slag passed toxicity characteristic leaching procedure criteria. The oxide was recycled to recover lead. The Technology Evaluation Report (EPA/540/5-91/005) and the Applications Analysis Report (EPA/540/A5-91/005) are available from EPA.

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**HRUBETZ ENVIRONMENTAL SERVICES, INC.**  
**(HRUBOUT® Hot Air Injection Process)**

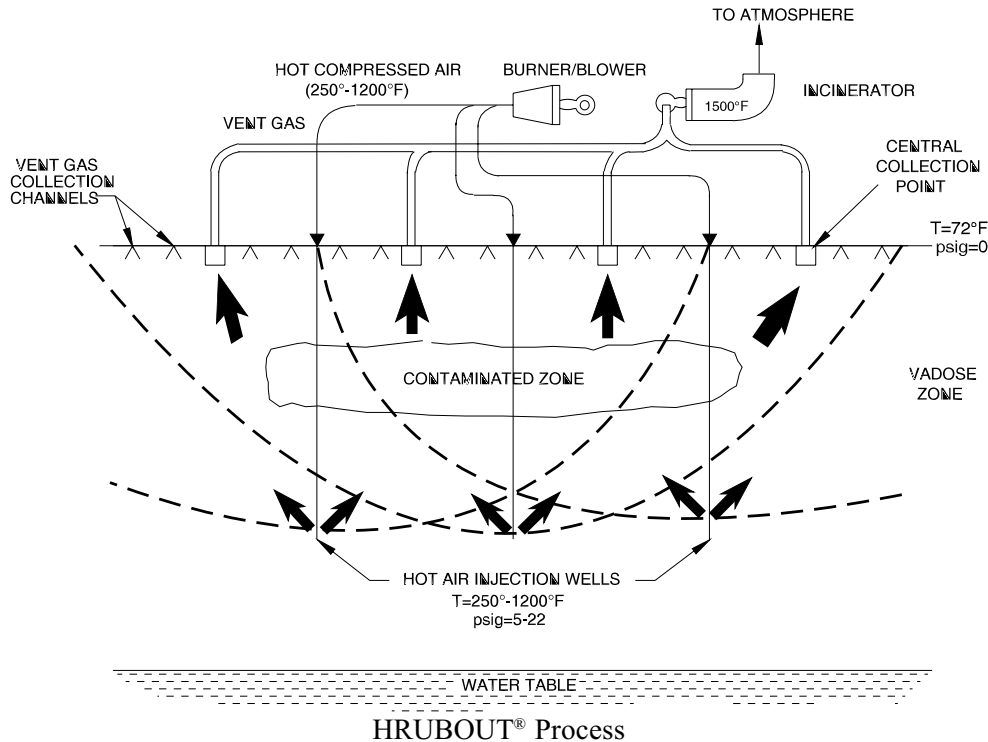
**TECHNOLOGY DESCRIPTION:**

The HRUBOUT® process is a thermal, in situ and ex situ treatment process designed to remove volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils. The in situ process is shown in the figure below. Heated air is injected into the soil below the contamination zone, evaporating soil moisture and removing volatile and semivolatile hydrocarbons. As the water evaporates, soil porosity and permeability increase, further facilitating the air flow at higher temperatures. As the soil temperature increases, the less volatile constituents volatilize or are thermally oxidized.

Injection wells are drilled in a predetermined distribution pattern to depths below the contamination zone. The wells are equipped with steel casings, perforated at the bottom, and cemented into the hole above the perforations.

Heated, compressed air is introduced at temperatures of up to 1,200 °F, and the pressure is slowly increased. As the air progresses upward through the soil, the moisture is evaporated, removing the VOCs and SVOCs. A surface collection system captures the exhaust gases under negative pressure. These gases are transferred to a thermal oxidizer, where the hydrocarbons are thermally destroyed in an incinerator at a temperature of 1,500°F.

The air is heated in an adiabatic burner at 2.9 million British thermal units per hour (MMBtu/hr). The incinerator has a rating of 3.1 MMBtu/hr. The air blower can deliver up to 8,500 pounds per hour. The units employ a fully modulating fuel train that is fueled by natural gas or propane. All equipment is mounted on custom-designed mobile units and can operate 24 hours per day.



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## WASTE APPLICABILITY:

The HRUBOUT® process can remediate soils contaminated with halogenated or nonhalogenated organic volatiles and semivolatiles, such as gasoline, diesel oil, jet fuel, heating oil, chemical solvents, or other hydrocarbon compounds.

## STATUS:

The HRUBOUT® process was accepted into the SITE Demonstration Program in July 1992. The technology was demonstrated at Kelly Air Force Base in San Antonio, Texas from January through February 1993. A 30-foot by 40-foot area of an 80,000-gallon JP-4 jet fuel spill site was chosen as the treatment area. Six heated air injection wells, spaced on a 3-by-2 grid 10 feet apart, were drilled to a depth of approximately 20 feet. The Demonstration Bulletin (EPA/540/MR- 93/524) is available from EPA.

In September 1993, an in situ project was completed at the Canadian Forces military base in Ottawa, Ontario, Canada. Levels up to 1,900 parts per million (ppm) of total petroleum hydrocarbons (TPH) were encountered over a 17-foot by 17-foot area on the base. Five injection wells were drilled to a depth of 30 feet. After 12 days of treatment, borehole samples ranged from nondetect to 215 ppm TPH, meeting closure requirements of 450 ppm TPH.

The containerized version of the HRUBOUT® process was tested in July 1993 at a west Texas site contaminated with Varsol, or naphtha. The soil was excavated for treatment in Hrubetz's insulated container. Analysis of untreated soil revealed TPH at 1,550 ppm. Three loads were treated for about 60 to 65 hours each. Post-treatment samples ranged from nondetect to 7 ppm TPH, meeting the Texas Natural Resource Conservation Commission's background target level of 37 ppm. Large-scale mobile container units, holding up to 40 cubic yards and capable of ex situ treatment of a load in 8 hours, are under development.

The ex situ version of the technology was selected to remediate a site in Toronto, Ontario, Canada, which consisted of about 1,500 cubic yards (yd<sup>3</sup>) of soil contaminated with gasoline and diesel. Soil contamination was measured at 200 ppm TPH. Following treatment, seven soil samples were collected. Two samples had detectable concentrations of TPH (25 and 37 ppm) and the remaining five samples had nondetectable levels of TPH, achieving the 100 ppm TPH cleanup goal.

About 100 yd<sup>3</sup> of toluene-contaminated soil was remediated in Orlando, Florida using the soil pile process with a smaller 5-ton unit. A composite analysis of the excavated soil found toluene at concentrations of up to 1,470 parts per billion; nondetect levels were required for closure. A composite soil sample collected after 96 hours of operation met the closure criteria.

Four patents have been granted, and additional patents are pending. The process was approved by the Texas Natural Resources Conservation Commission in 1991.

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

### TECHNOLOGY DESCRIPTION:

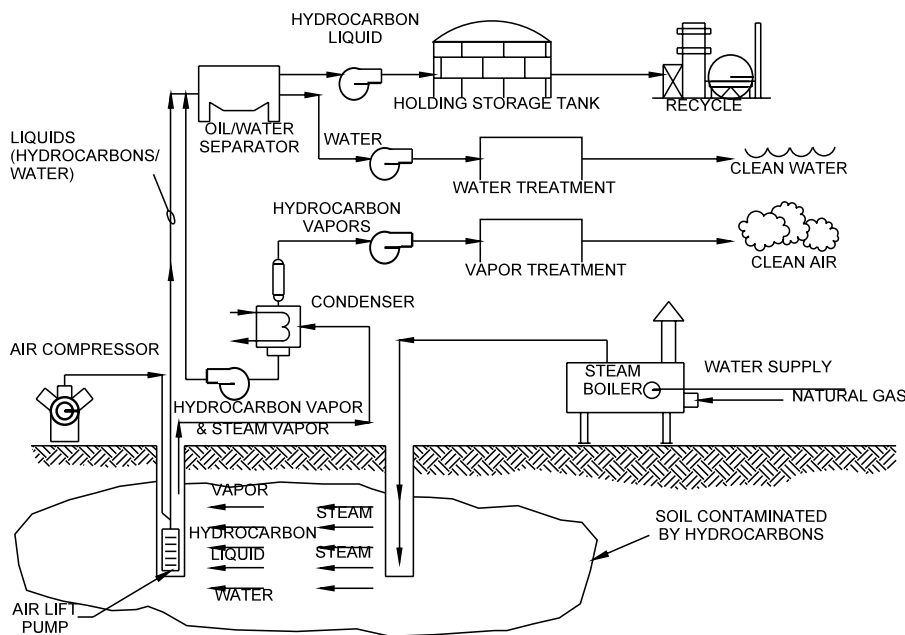
The Steam Enhanced Recovery Process (SERP) removes most volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from perched groundwater and contaminated soils both above and below the water table (see figure below). The technology is applicable to the in situ remediation of contaminated soils below ground surface and below or around permanent structures. The process accelerates contaminant removal rates and can be effective in all soil types.

Steam is forced through the soil by injection wells to thermally enhance the recovery of VOCs and SVOCs. Extraction wells are used for two purposes: to pump and treat groundwater, and to transport steam and vaporized contaminants to the surface. Recovered nonaqueous liquids are separated by gravity separation. Hydrocarbons are collected for recycling, and water is treated before being discharged to a storm drain or sewer. Vapors can be

condensed and treated by any of several vapor treatment techniques (for example, thermal oxidation and catalytic oxidation). The technology uses readily available components such as extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

### WASTE APPLICABILITY:

The SERP can extract VOCs and SVOCs from contaminated soils and perched groundwater. Compounds suitable for treatment are petroleum hydrocarbons such as gasoline and diesel and jet fuel; solvents such as trichloroethene, trichloroethane, and dichlorobenzene; or a mixture of these compounds. After application of the process, subsurface conditions are excellent for biodegradation of residual contaminants. The process cannot be applied to contaminated soil very near the ground surface unless a cap exists.



Steam Enhanced Recovery Process

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## STATUS:

This technology was accepted into the SITE Demonstration Program in 1991. The demonstration of the technology began in August 1991 and was completed in September 1993. The demonstration took place in Huntington Beach, California, at a site contaminated by a large diesel fuel spill. The Demonstration Bulletin (EPA/540/MR -94/510), Technology Capsule (EPA/540/R- 94/510a), and Innovative Technology Evaluation Report (EPA/540/R-94/510) are available from EPA.

For more information regarding this technology, see the profiles for Berkeley Environmental Restoration Center (completed projects) or Praxis Environmental Technologies, Inc., in the Demonstration Program section (ongoing profiles).

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

## DEMONSTRATION RESULTS:

Evaluation of the posttreatment data suggests the following conclusions:

- The geostatistical weighted average for total petroleum hydrocarbon (TPH) concentrations in the treated soils was 2,290 milligrams per kilogram (mg/kg). The 90 percent confidence interval for this average concentration is 996 mg/kg to 3,570 mg/kg, indicating a high probability that the technology did not meet the cleanup criterion. Seven percent of soil samples had TPH concentrations in excess of 10,000 mg/kg.

- The geostatistical weighted average for total recoverable petroleum hydrocarbon (TRPH) concentrations was 1,680 mg/kg, with a 90 percent confidence interval of 676 mg/kg to 2,680 mg/kg. Levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) were below the detection limit (6 micrograms per kilogram) in treated soil samples; BTEX was detected at low mg/kg levels in a few pretreatment soil samples.
- Analysis of triplicate treated soil samples showed marked variability in soil contaminant concentrations over short distances. Analogous results for TPH and TRPH triplicate samples suggest that the contaminant concentration variability exists within the site soil matrix and is not the result of analytical techniques. This variability is the reason that confidence intervals for the average concentrations are so large.
- The data suggest that lateral or downward migration of contaminants did not occur during treatment.

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**IIT RESEARCH INSTITUTE  
(Radio Frequency Heating)**

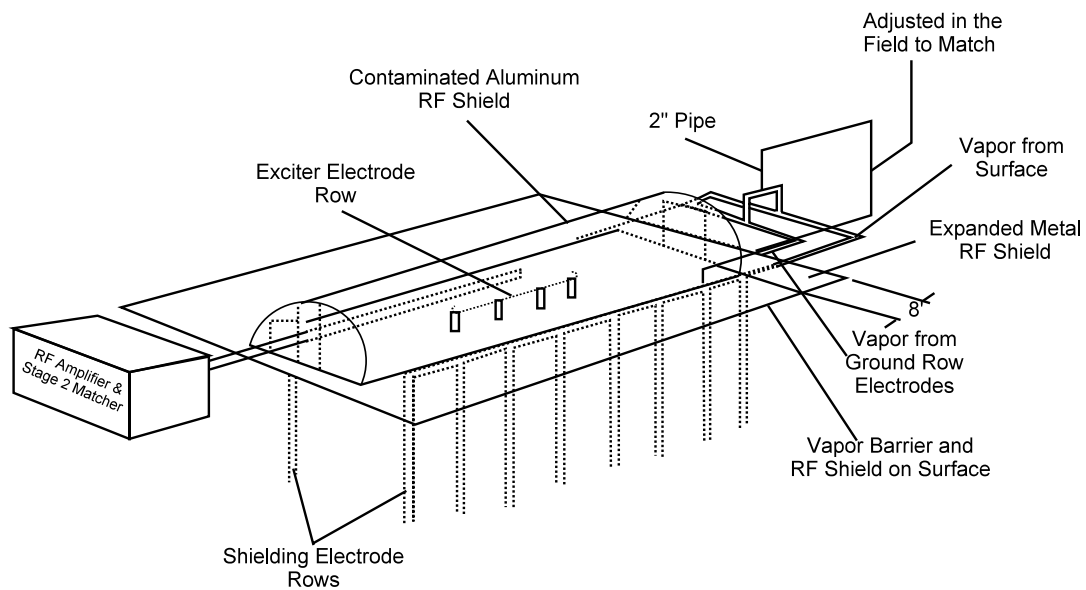
**TECHNOLOGY DESCRIPTION:**

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE). Developed by IIT Research Institute, the patented RFH technique heats a discrete volume of soil using rows of vertical electrodes embedded in soil (or other media). Heated soil volumes are bounded by two rows of ground electrodes with energy applied to a third row midway between the ground electrodes. The three rows act as a buried triplate capacitor. When energy is applied to the electrode array, heating begins at the top center and proceeds vertically downward and laterally outward through the soil volume. The technique can heat soils to over 300°C.

RFH enhances SVE in two ways: (1) contaminant vapor pressures are increased by heating, and (2) the soil permeability is increased by drying. Extracted vapor can then be treated by a variety of existing technologies, such as granular activated carbon or incineration.

**WASTE APPLICABILITY:**

RFH can treat petroleum hydrocarbons, volatile organic compounds, semivolatile organic compounds, and pesticides in 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 media.



In Situ Radio Frequency Heating System

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**STATUS:**

The RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated in August 1993 at Kelly Air Force Base (AFB), Texas, as part of a joint project with the U.S. Air Force. Brown and Root Environmental was the prime contractor evaluating and implementing RFH for the U.S. Air Force. A field demonstration of the KAI Technologies, Inc. (KAI), RFH technology was completed in June 1994 at the same site for comparison. The Demonstration Bulletin (EPA/540/MR-94/527), Technology Capsule (EPA/540/R-94/527a), and the Innovative Technology Evaluation Report (EPA/540/R-94-527) are available from EPA. For further information on the KAI technology, see the profile in the Demonstration Program section (completed projects).

In 1995, the RFH technique was tested at the former chemical waste landfill at Sandia National Laboratories in Albuquerque, New Mexico. Approximately 800 cubic yards of silty soil was heated. Preliminary results indicate that the contaminant concentration in the extracted vapors increased by a factor of 10 compared to in situ venting.

Two previous field tests were completed using in situ RFH. The first test was completed at a fire training pit, located at the Volk Air National Guard Base in Camp Douglas, Wisconsin. The sandy soil in the pit was contaminated with jet fuel. The second test was completed at Rocky Mountain Arsenal in Colorado, where clayey soil was contaminated by organochlorine pesticides.

**DEMONSTRATION RESULTS:**

Under the SITE demonstration, statistical analyses for the design treatment zone indicate that total recoverable petroleum hydrocarbons, pyrene, and bis(2-ethylhexyl)phthalate exhibited statistically significant decreases (at the 95 and 97.5 percent confidence levels). Chlorobenzene concentrations appeared to increase during treatment, possibly due to volatilization of chlorobenzene present in the groundwater.

Significant concentrations of 2-hexanone, 4-methyl-2-pentanone, acetone, and methyl ethyl ketone were found in the treated soils, although virtually no ketones were found before treatment. Soil temperatures as high as 1,000°C during the demonstration may have caused partial oxidation of petroleum hydrocarbons. Alternatively, the ketones may have been volatilized from groundwater. At this time, insufficient data are available to determine the source of ketones found in treated soils.

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## INTERNATIONAL WASTE TECHNOLOGIES AND GEO-CON, INC.

### (In Situ Solidification and Stabilization Process)

#### TECHNOLOGY DESCRIPTION:

The in situ solidification and stabilization process immobilizes organic and inorganic compounds in wet or dry soils, using reagents (additives) to produce a cement-like mass. The basic components of this technology are (1) Geo-Con, Inc.'s (Geo-Con), deep soil mixing (DSM) system, to deliver and mix the chemicals with the soil in situ; and (2) a batch mixing plant to supply proprietary additives (see figure below).

The proprietary additives generate a complex, crystalline, connective network of inorganic polymers in a two-phase reaction. In the first phase, contaminants are complexed in a fast-acting reaction. In the second phase, macromolecules build over a long period of time in a slow-acting reaction.

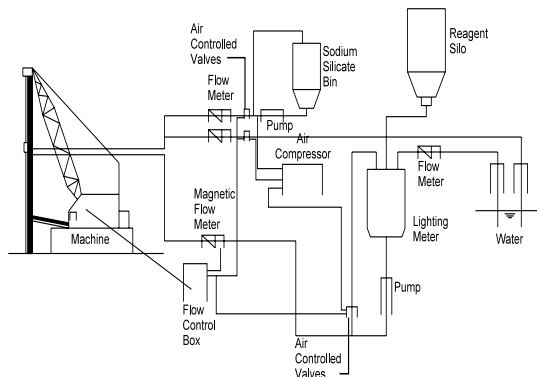
The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 revolutions per minute. Two conduits in the auger inject the additive slurry and supplemental water. Additives are injected on the downstroke; the slurry is further mixed upon auger withdrawal. The treated soil columns are 36 inches in diameter and are positioned in an overlapping pattern of alternating primary and secondary soil columns.

#### WASTE APPLICABILITY:

The process treats soils, sediments, and sludge-pond bottoms contaminated with organic compounds and metals. The process has been laboratory-tested on soils containing polychlorinated biphenyls (PCBs), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons.

#### STATUS:

A SITE demonstration was conducted as a joint effort between International Waste Technologies (IWT) and Geo-Con. The demonstration was conducted at the General Electric Service Shop site in Hialeah, Florida in April 1988. IWT provided the treatment reagent, specifically the proprietary additive (HWT-20), and Geo-Con provided both engineering and hardware for the in situ soil treatment. Two 10-by-20-foot areas were treated — one to a depth of 18 feet, and the other to a depth of 14 feet. Ten months after the demonstration, long-term monitoring tests were performed on the treated sectors. A four-auger process was later used to remediate the PCB-contaminated Hialeah site during the winter and spring of 1990. Cooperative efforts between Geo-Con and IWT ended with the remediation of the Hialeah site.



In Situ Solidification and Stabilization Process Flow Diagram

Presently, Geo-Con offers the entire in situ stabilization package, including the treatment chemicals. Geo-Con has used the process to complete over 40 in situ stabilization projects throughout the United States. Significant projects completed to date include the following:

- Construction of a 110,000-square-foot, 60-foot-deep, soil-bentonite DSM wall to contain contaminated groundwater from a former waste pond. All DSM permeabilities were less than  $10^{-7}$  centimeters per second (cm/s).
- Shallow soil mixing and stabilization of 82,000 cubic yards of contaminated soils at a former manufactured gas plant site. The site was declared clean and ultimately converted to a city park.

The DSM system augers have been scaled up to diameters as large as 12 feet. To date, Geo-Con has used this process to treat over 1 million cubic yards of contaminated soils and sludges.

## DEMONSTRATION RESULTS:

The SITE demonstration yielded the following results:

- PCB immobilization appeared likely, but could not be confirmed because of low PCB concentrations in the untreated soil. Leachate tests on treated and untreated soil samples showed mostly undetectable PCB levels. Leachate tests performed 1 year later on treated soil samples showed no increase in PCB concentrations, indicating immobilization.
- Data were insufficient to evaluate the system's performance on other organic compounds and metals.
- Each test sample showed high unconfined compressive strength (UCS), low permeability, and low porosity. These physical properties improved in samples retested 1 year later, indicating the potential for long-term durability.

- Bulk density of the soil increased 21 percent after treatment. This treatment increased the treated soil volume by 8.5 percent and caused a small ground rise of 1 inch per foot of treated soil.
- The UCS of treated soil was satisfactory, with values up to 1,500 pounds per square inch.
- The permeability of the treated soil was satisfactory, decreasing to  $10^{-6}$  and  $10^{-7}$  cm/s compared to  $10^{-2}$  cm/s for untreated soil.
- Data were insufficient to confirm immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the reagent.
- Process costs were \$194 per ton for the 1-auger machine used in the demonstration, and \$111 per ton for a commercial four-auger operation. More recent experience with larger scale equipment reduced process costs to about \$15 per ton plus the cost of reagents. The Technology Evaluation Report (EPA/540/5-89/004a) and the Applications Analysis Report (EPA/540/A5-89/004) are available from EPA.

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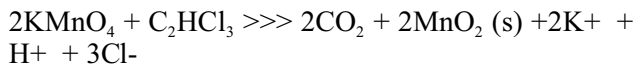


## IT CORPORATION

### KMnO<sub>4</sub> (Potassium Permanganate) Oxidation of TCE

#### TECHNOLOGY DESCRIPTION:

In situ chemical oxidation using potassium permanganate is a potentially fast and low cost solution for the destruction of a broad range of organic compounds, including chlorinated ethylenes and polycyclic aromatic hydrocarbons. This oxidation technology involves injecting a potassium permanganate solution that reacts with volatile organic compounds (VOCs) to form nontoxic by-products such as carbon dioxide, manganese dioxide, and chloride ions. The chemical reaction is as follows:

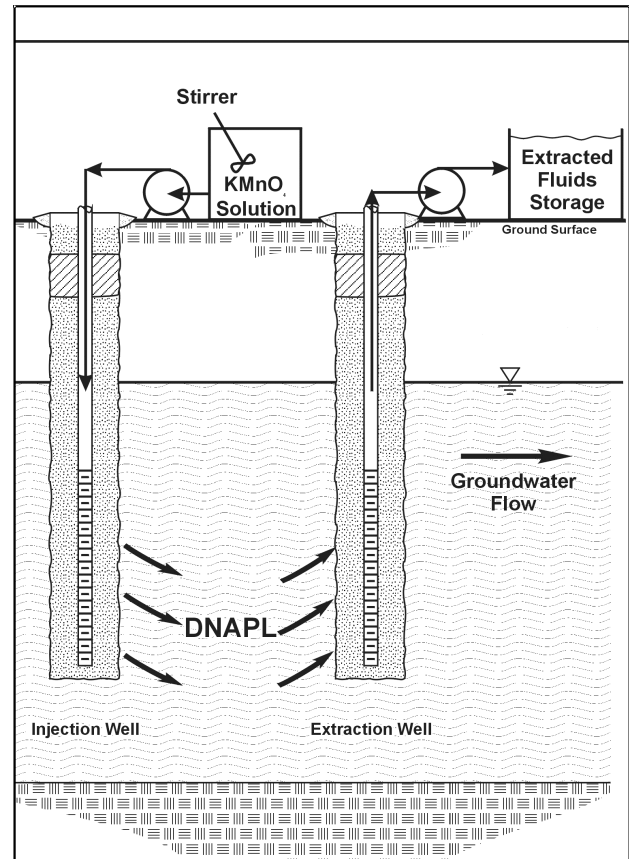


Oxidation using potassium permanganate involves cleavage of carbon-carbon bonds often facilitated by free-radical oxidation mechanisms. The impact of organic matter that will consume the oxidant can be significant and must be considered during the technology selection process at each specific site. In the absence of organic matter, the reaction is second ordered and the rate is governed by the concentration of both TCE and MnO<sub>4</sub><sup>-</sup> ions.

Several injection points spread throughout the plot will be used to deliver the KMnO<sub>4</sub> to the subsurface. A few centrally located groundwater recovery wells, each screened in different lithologic units, will facilitate flow and extract the injected fluids and groundwater.

#### WASTE APPLICABILITY:

Potassium permanganate reacts effectively with the double bonds in chlorinated ethylenes such as trichloroethylene, perchloroethylene, dichloroethylene isomers, and vinyl chloride. It is effective for remediation of DNAPL, adsorbed phase and dissolved phase contaminants, and produces innocuous breakdown products, such as carbon dioxide, chloride ions and manganese dioxide.



**Conceptual Illustration of In Situ Oxidation Technology**

#### STATUS:

IT Corporation injected potassium permanganate from 20 points across 15 two-foot intervals to a depth of 45 feet in a 50- × 75-foot test cell. These injection intervals encompass three lithologic zones, consisting of a layered mix of sand, shell hash, silts, sandy clays and clay lenses. Permanganate solution, at concentrations of one to three percent, was prepared in an automated feed system and pumped under pressure to each point. This solution is easily handled, mixed and injected, and is nonhazardous.

## DEMONSTRATION RESULTS:

The demonstration treatment effectiveness was evaluated by EPA as part of the Superfund Innovative Technology Evaluation (SITE) Program. The total reduction in TCE mass within the oxidation cell was calculated through collection and analysis of soil cores from 12 soil borings with over 192 discrete sample intervals analyzed for TCE. Sampling was performed before treatment and one month after treatment. The results show that the mass of TCE in the oxidation cell was reduced by 82%. DNAPL concentrations (defined as any TCE soil concentration greater than 300 mg/kg) were reduced by as much as 84%. The TCE concentrations were reduced to nondetectable levels at 85 of the 192 sample intervals from initial soil concentrations as high as 10,500 mg/kg. As permanganate was still present throughout the cell during the posttreatment sampling effort, additional TCE reductions may occur. The test results clearly show that the technology was effective in the reduction of TCE (dissolved, absorbed phase and DNAPL).

The posttreatment soil data could be used to target an additional application of permanganate to the remaining TCE areas for full cell reductions to nondetectable levels. A cost model for prediction of the project costs for application of permanganate at other facilities has been prepared and is available for use at other sites.

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**IT CORPORATION**  
**(formerly OHM Remediation Services Corp.,**  
**formerly Chemical Waste Management, Inc.)**  
**(X\*TRAX™ Thermal Desorption)**

**TECHNOLOGY DESCRIPTION:**

The X\*TRAX™ technology is a patented thermal desorption process that removes organic contaminants from soils, sludges, and other solid media (see photograph below). X\*TRAX™ is not, however, an incinerator or a pyrolysis system. Chemical oxidation and reactions are discouraged by maintaining an inert environment and low treatment temperatures. Combustion by-products are not formed in X\*TRAX™, as neither a flame nor combustion gases are present in the desorption chamber.

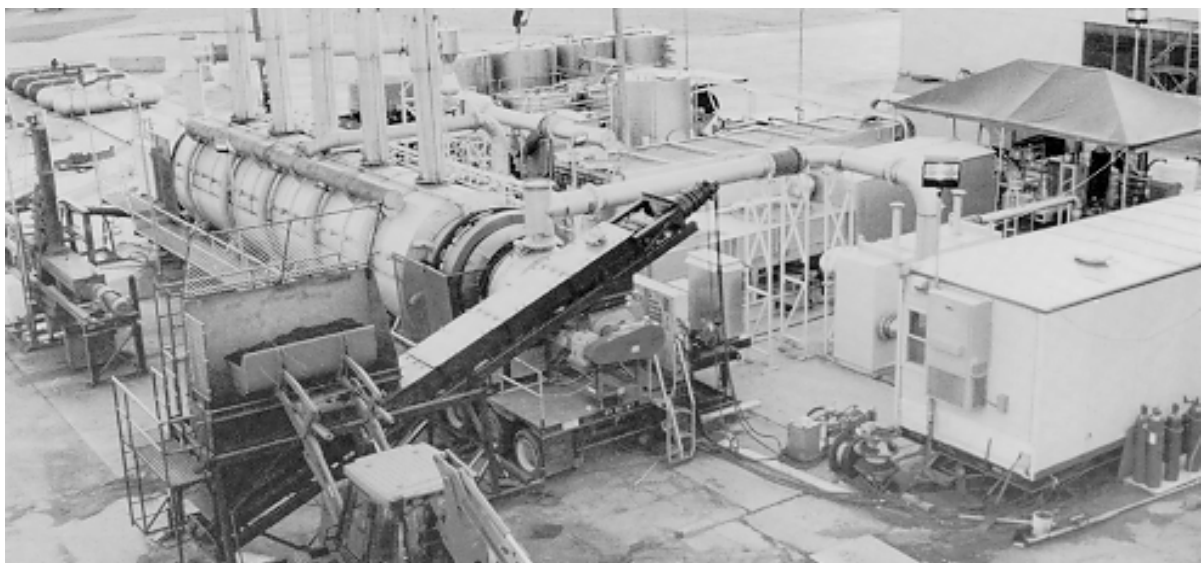
The organic contaminants are removed as a condensed liquid, which is characterized by a high heat rating. This liquid may then be destroyed in a permitted incinerator or used as a supplemental fuel. Low operating temperatures of 400 to 1,200°F and low gas flow rates optimize treatment of contaminated media.

An externally fired rotary dryer volatilizes the water and organic contaminants from the contaminated media into an inert carrier gas stream. The inert nitrogen carrier gas transports the organic

contaminants and water vapor out of the dryer. The carrier gas flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed and recovered. The gas first passes through a high-energy scrubber, which removes dust particles and 10 to 30 percent of the organic contaminants. The gas then passes through two condensers in series, where it is cooled to less than 40°F.

Most of the carrier gas is reheated and recycled to the dryer. About 5 to 10 percent of the gas is separated from the main stream, passed through a particulate filter and a carbon adsorption system, and then discharged to the atmosphere. This discharge allows addition of make-up nitrogen to the system to keep oxygen concentrations below 4 percent (typically below 1 percent). The discharge

also helps maintain a small negative pressure within the system and prevents potentially contaminated gases from leaking. The volume of gas released from this process vent is approximately 700 times less than from an equivalent capacity incinerator.



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## WASTE APPLICABILITY:

The X\*TRAX™ process has been used to treat solids contaminated with the following wastes: polychlorinated biphenyls (PCB); halogenated and nonhalogenated solvents; semivolatile organic compounds, including polynuclear aromatic hydrocarbons, pesticides, and herbicides; fuel oils; benzene, toluene, ethylbenzene, and xylene; and mercury.

## STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. The demonstration was conducted in May 1992 at the Re-Solve, Inc., Superfund site in Massachusetts. After the demonstration, the full-scale X\*TRAX™ system, Model 200, remediated 50,000 tons of PCB-contaminated soil at the site. The Demonstration Bulletin (EPA/540/MR-93/502), which details results from the demonstration, is available from EPA.

The full-scale system, Model 200, is presently operating at the Sangamo-Weston Superfund site in South Carolina. More than 45,000 tons of PCB-contaminated soil, clay, and sludge have been thermally treated at this site. Feed material with PCB concentrations of more than 8,800 milligrams per kilogram (mg/kg) has been successfully treated to produce (discharge) PCB levels of less than 2 mg/kg. PCB removal efficiency was demonstrated to be greater than 99.97 percent.

Laboratory-, pilot-, and full-scale X\*TRAX™ systems are available. Two laboratory-scale, continuous pilot systems are available for treatability studies. More than 108 tests have been completed since January 1988.

## DEMONSTRATION RESULTS:

During the SITE demonstration, X\*TRAX™ removed PCBs from feed soil and met the site-specific treatment standard of 25 mg/kg for treated soils. PCB concentrations in all treated soil samples were less than 1.0 mg/kg and were reduced from an average of 247 mg/kg in feed soil to an average of 0.13 mg/kg in treated soil. The average PCB removal efficiency was 99.95 percent.

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans were not formed within the X\*TRAX™ system. Organic air emissions from the X\*TRAX™ process vent were negligible (less than 1 gram per day). PCBs were not detected in vent gases.

X\*TRAX™ removed other organic contaminants from feed soil. Concentrations of tetrachloroethene, total recoverable petroleum hydrocarbons, and oil and grease were reduced to below detectable levels in treated soil. Metals concentrations and soil physical properties were not altered by the X\*TRAX™ system.

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