

**EARTH TECH, INC.**  
**(formerly ITT Night Vision)**  
**(In Situ Enhanced Bioremediation of Groundwater)**

**TECHNOLOGY DESCRIPTION:**

ITT Night Vision is conducting in situ enhanced aerobic bioremediation of contaminated groundwater in fractured bedrock utilizing technologies developed at the U.S. Department of Energy Savannah River Site. The site demonstration involved remediation of groundwater in the vicinity of one contaminant source area as a pilot-scale operation, with the possibility of applying the technology elsewhere on site. Contaminants of concern in on-site groundwater included chlorinated solvents and their products, plus acetone and isopropanol. To accelerate the intrinsic (natural) biodegradation observed at the site, the selected remedy involves the subsurface injection of air, gaseous-phase nutrients (triethyl phosphate and nitrous oxide), and methane. The amendments were added to stimulate existing microbial populations (particularly methanotrophs) so that they could more aggressively break down the contaminants of concern. Amendment delivery to the surface was accomplished through an injection well, and the injection zone of influence was confirmed using surrounding groundwater monitoring wells and soil vapor monitoring points.

The patented PHOSter™ process for injection of triethyl phosphate in a gaseous phase was licensed for use at this site as an integral element of the enhanced bioremediation operation. This technology maximizes the subsurface zone of influence of nutrient injection as compared to technologies injecting nutrients in liquid or slurry form. Monitoring of contaminant (and breakdown product) concentrations in groundwater and soil vapor, measurement of microbiological population density and diversity, and monitoring of nutrient concentrations and groundwater geochemical parameters provides feedback on system effectiveness. This in turn allows adjustments to be made in the sequencing and rate of delivery of air, nutrients, and methane in response to changing subsurface conditions.

**WASTE APPLICABILITY:**

The Enhanced In-Situ Bioremediation process is applicable for creating volatile organic compounds (VOCs) in groundwater that can be naturally biodegraded, including some hard to degrade chlorinated VOCs. The mixture of air and gaseous phase nutrients that is injected into the subsurface provides an aerobic environment for contaminant degradation. Toxic products resulting from anaerobic degradation of chlorinated solvents (e.g., vinyl chloride) may be broken down completely in this aerobic environment. The in-situ process is especially applicable for hydrogeologically complex sites where injected nutrient flow patterns are uncertain (i.e., in fractured bedrock gaseous phase nutrient injection is more likely to affect a larger area than liquid nutrient injection). The process is also applicable in situations where subsurface utilities limit or preclude the use of technologies requiring excavation.

The enhanced bioremediation system, currently being used in the ongoing RCRA corrective action interim measure at the ITT Night Vision facility, was accepted into the SITE program in 1997, (the demonstration was conducted March 1998 to August 1999) with system start up occurring in March of 1998. The technology had previously been approved by EPA Region 3 as an Interim Measure part of the facility's ongoing RCRA Corrective Action program.

Due to the positive performance of the technology during the SITE Demonstration project, the remediation system was expanded to address the entire contamination plume at the site. Demonstration results are shown in Table 1. Results were based on 28 baseline and 28 final samples for the four critical analytes are presented in Table 1. VOC concentrations were determined by EPA SW-846 Method 8260. The results indicate that the targeted 75 percent reduction was achieved or exceeded for two of the four critical compounds, from baseline to final events.

**FOR FURTHER INFORMATION:**

Target Compound	Contaminant Concentration ( $\mu\text{g/L}$ )		Average Percent Reduction	Statistically Significance Present Reduction
	Baseline	Final		
CA	256	210	36	4
1,1-DCA	960	190	80	71
<i>cis</i> -1,2-DCE	1,100	90	97	55
VC	1,100	45	96	52

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**ELECTRO-PETROLEUM, INC.**  
**(Electro-Kinetically Aided Remediation [EKAR])****TECHNOLOGY DESCRIPTION:**

Electrokinetics is a general term describing a variety of physical changes, electrochemical reactions and coupled flows, which can occur when electrical current flows through soils containing one or more phases of fluids. Electrokinetically-Aided Remediation (EKAR), which utilizes electric fields to drive fluids and charged particles through a porous medium, is being developed for in-situ soil remediation. In this process, an electrical current or potential difference is applied across electrodes placed into soil in the treatment area. The applied electrical current effectively enlarges the throat diameter of soil pores, compared to Darcy flow, and changes the capillary forces allowing NAPL to pass through. Dissolved organic and non-aqueous phase liquids (NAPLs) will also accompany the increased electroosmotic water flux toward the cathode. Hydrolyzed ionic species and charged colloidal particles will drift toward the electrode of opposite polarity.

A typical electrokinetic field deployment is set up as follows: A seven-spot pattern consisting of six anode wells surrounding a central cathode extraction well is used to remediate a volume of subsurface material. NAPL concentrations are extracted at the electrode wells for further treatment or disposal. The mobility of the ions and pore fluids decontaminates the soil mass. EKAR can supplement or replace conventional pump and treat technologies.

**WASTE APPLICABILITY:**

Electrokinetically aided remediation has particular applicability to both organic and inorganic contaminants in low permeability soils. Electrokinetic mechanisms increase fluid flow through fine grained porous media. This mechanism increases the removal of mobile non-aqueous phase liquid, its residual, and its aqueous phases. It is equally effective with both LNAPL and DNAPL. Because of the electrokinetically imposed electric field's ability to drive charged particles through a fluid, the technology can be used to increase particulate contaminant flux through soil and transport microbes to contaminated zones for bioremediation. Electrochemical treatment may be engineered to extract soluble species of cations and anions without the need for water flushing and secondary treatments.

**STATUS:**

Bench laboratory studies investigating the metals, organics, and radionuclides, have been completed. Organics investigated included acetone, BTEX, and PAHs. Metals removal investigations focused on arsenic, cadmium, chromium, lead, nickel and mercury.

Radionuclides investigated included cesium, cobalt, technetium, strontium, and uranium. Bench scale treatability tests have shown significant removal of TCE from core samples.

The technology is scheduled to be demonstrated at Offut Air Force Base, Nebraska in 2003, and evaluated for its ability to remediate TCE contaminated soils.

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**HARDING ESE, A MACTEC COMPANY**  
**(formerly ABB Environmental Services, Inc.)**  
**(Two-Zone, Plume Interception, In Situ Treatment Strategy)**

**TECHNOLOGY DESCRIPTION:**

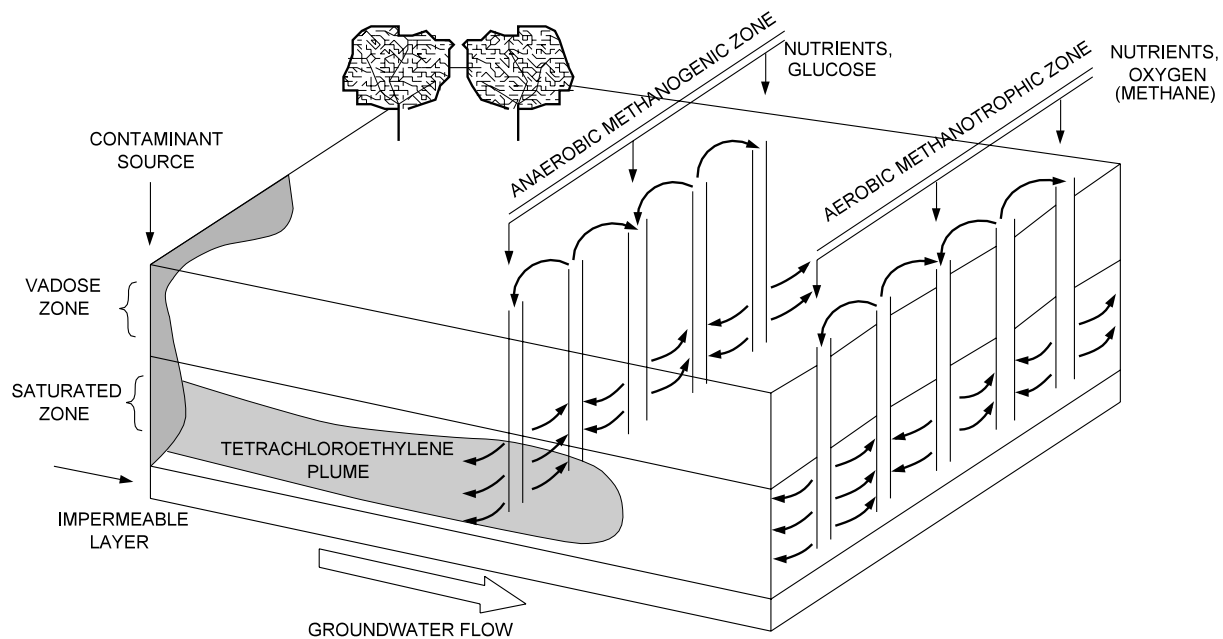
The two-zone, plume interception, in situ treatment strategy is designed to treat chlorinated and nonchlorinated organic compounds in saturated soils and groundwater using a sequence of anaerobic and aerobic conditions (see figure below). The in situ anaerobic and aerobic system constitutes a treatment train that biodegrades a wide assortment of chlorinated and nonchlorinated compounds.

When applying this technology, anaerobic and aerobic conditions are produced in two distinct, hydraulically controlled, saturated soil zones. Groundwater passes through each zone as it is recirculated through the treatment area. The first zone, the anaerobic zone, is designed to partially dechlorinate highly chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane with natural biological processes. The second zone, the

aerobic zone, is designed to biologically oxidize the partially dechlorinated products from the first zone, as well as other compounds that were not susceptible to the anaerobic treatment phase.

Anaerobic conditions are produced or enhanced in the first treatment zone by introducing a primary carbon source, such as lactic acid, and mineral nutrients, such as nitrogen and phosphorus. When proper anaerobic conditions are attained, the target contaminants are reduced. For example, PCE is dechlorinated to TCE, and TCE is dechlorinated to dichloroethene (DCE) and vinyl chloride. Under favorable conditions, this process can completely dechlorinate the organics to ethene and ethane.

Aerobic conditions are produced or enhanced in the second treatment zone by introducing oxygen, mineral nutrients such as nitrogen and phosphorus, and possibly an additional carbon source, such as methane



Two-Zone, Plume Interception, In Situ Treatment Strategy

(if an insufficient supply of methane results from the pstream, anaerobic zone). When proper aerobic conditions are attained in this zone, partially dechlorinated products and other target compounds from the first zone are oxidized. For example, less-chlorinated ethenes such as DCE and vinyl chloride are cometabolized during the aerobic microbiological degradation of methane.

The treatment strategy is designed to biologically remediate subsoils by enhancing indigenous microorganism activity. If indigenous bacterial populations do not provide the adequate anaerobic or aerobic results, specially adapted cultures can be introduced to the aquifer. These cultures are introduced using media-filled trenches that can support added microbial growth.

### **WASTE APPLICABILITY:**

The two-zone, plume interception, in situ treatment strategy is designed to treat groundwater and saturated soils containing chlorinated and nonchlorinated organic compounds.

### **STATUS:**

The two-zone, plume interception, in situ treatment strategy was accepted into the SITE Emerging Technology Program in July 1989. Optimal treatment parameters for field testing were investigated in bench-scale soil aquifer simulators. The objectives of bench-scale testing were to (1) determine factors affecting the development of each zone, (2) evaluate indigenous bacterial communities, (3) demonstrate treatment of chlorinated and nonchlorinated solvent mixtures, and (4) develop a model for the field remediation design. The Emerging Technology Bulletin (EPA/540/F-95/510), which details the bench-scale testing results, is available from EPA.

A pilot-scale field demonstration system was installed at an industrial facility in Massachusetts. Pilot-scale testing began in September 1996. Results from this testing indicate the following:

- The reductive dechlorination of PCE and TCE to DCE, VC, and ethene has been accomplished primarily by sulfate-reducing bacteria.
- A time lag of about 4 months was required before significant reductive dechlorination occurred. This corresponded to the time and lactic acid dosing required to reduce the redox to about -100 throughout the treatment cell.
- Sequential anaerobic-aerobic (Two-Zone) biodegradation of PCE and its degradation products appear to be a viable and cost-effective treatment technology for the enhancement of natural reductive dechlorination processes.

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**LEWIS ENVIRONMENTAL SERVICES, INC./  
HICKSON CORPORATION**  
**(Chromated Copper Arsenate Soil Leaching Process)**

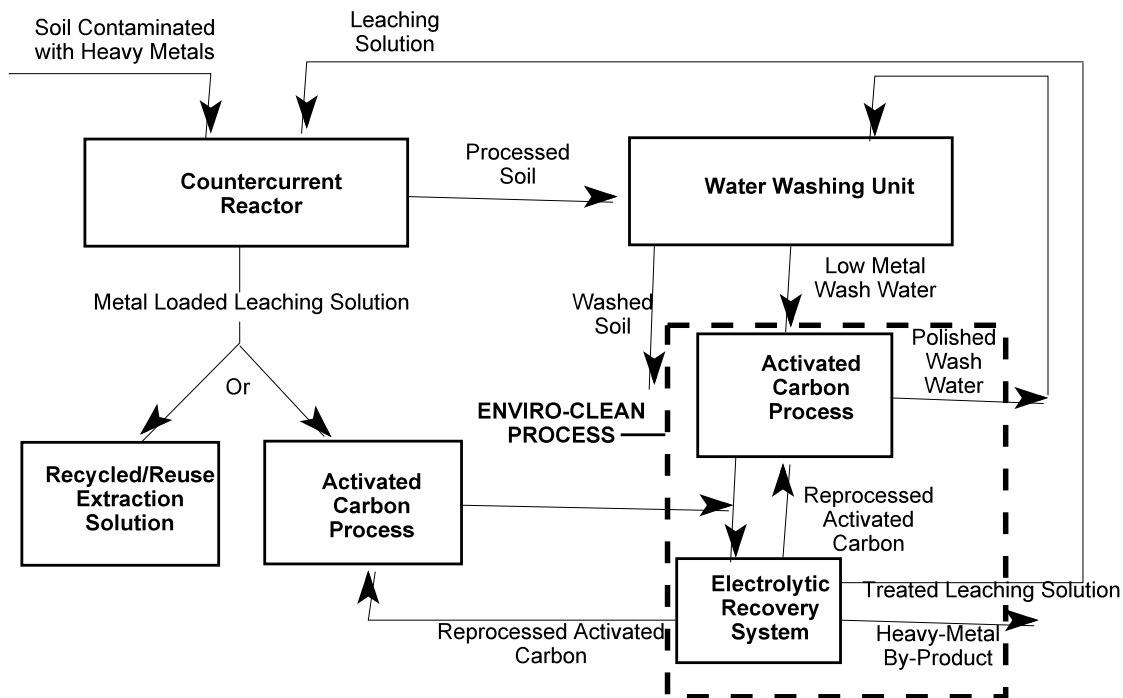
**TECHNOLOGY DESCRIPTION:**

Lewis Environmental Services, Inc. (Lewis), has developed a soil leaching process to remediate soils contaminated with inorganics and heavy metals including chromium, copper, cadmium, mercury, arsenic, and lead.

The soil leaching process consists of leaching contaminated soil in a countercurrent stirred reactor system (see figure below). A screw feeder delivers the soil into the reactor, where it is leached with sulfuric acid for 30 to 60 minutes. The sulfuric acid solubilizes the inorganics and heavy metals into the leaching solution. Any organic contaminants are separated and

decanted from the leaching solution, using strong acid leachate, space separation, and skimming. The processed soil is then washed with water and air-dried.

The wash water is then treated with Lewis' ENVIRO-CLEAN PROCESS, which consists of a granulated activated carbon system followed by an electrolytic recovery system. The ENVIRO-CLEAN PROCESS recovers the heavy metals from the leaching solution and wash water and produces an effluent that meets EPA discharge limits for heavy metals. The treated wash water can then be reused in the soil washing step. The leaching solution can be returned directly to the stirred reactor system, depending on its metals concentration.



Chromated Copper Arsenate Soil Leaching Process

Contaminated soil must be properly sized and screened to facilitate leaching in the stirred reactor system. Large pieces of debris such as rocks, wood, and bricks must be removed before treatment. Standard screening and classification equipment, such as that used in municipal waste treatment plants, is suitable for this purpose.

The soil leaching process does not generate appreciable quantities of treatment by-products or waste streams containing heavy metals. The treated soil meets toxicity characteristic leaching procedure (TCLP) criteria and can be either returned to the site or disposed of at a nonhazardous landfill. The granular activated carbon requires disposal after about 20 to 30 treatment cycles and should also meet TCLP criteria. Heavy metals recovered by the ENVIRO-CLEAN process can be reused by industry.

### **WASTE APPLICABILITY:**

The soil leaching process can treat wastes generated by the wood preserving and metal plating industries, battery waste sites, and urban lead sites.

### **STATUS:**

The soil leaching process was accepted into the Emerging Technology Program in 1993. Laboratory-scale tests have shown that the process successfully treats soil contaminated with chromated copper arsenate (CCA). The evaluation of the technology under the SITE Program was completed in September 1996. Results from the evaluation will be available in 1997.

In 1992, Lewis treated a 5-gallon sample of CCA-contaminated soil from Hickson Corporation (Hickson), a major CCA chemical manufacturer. The treated soil met TCLP criteria, with chromium and arsenic, the two main leaching solution constituents, averaging 0.8 milligram per kilogram (mg/kg) and 0.9 mg/kg, respectively.

Analysis also revealed 3,330 milligrams per liter (mg/L) of chromium, 13,300 mg/L of copper, and 22,990 mg/L of iron in the leaching solution. In addition, analysis indicated 41.4 mg/L of chromium, 94.8 mg/L of copper, and 3.0 mg/L of arsenic present in the wash water. After treatment, the wash water contained metals levels below 0.01 mg/L for copper and chromium and 0.3 mg/L for arsenic.

Lewis plans further laboratory-scale testing at its Pittsburgh, Pennsylvania facility, followed by bench- or pilot-scale testing at Hickson's facility in Conley, Georgia.

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## MATRIX PHOTOCATALYTIC INC. (Photocatalytic Air Treatment)

### TECHNOLOGY DESCRIPTION:

Matrix Photocatalytic Inc. is developing a titanium dioxide (TiO<sub>2</sub>) photocatalytic air treatment technology that destroys volatile organic compounds (VOC) and semivolatile organic compounds in air streams. During treatment, contaminated air at ambient temperatures flows through a fixed TiO<sub>2</sub> catalyst bed activated by ultraviolet (UV) light. Typically, organic contaminants are destroyed in fractions of a second.

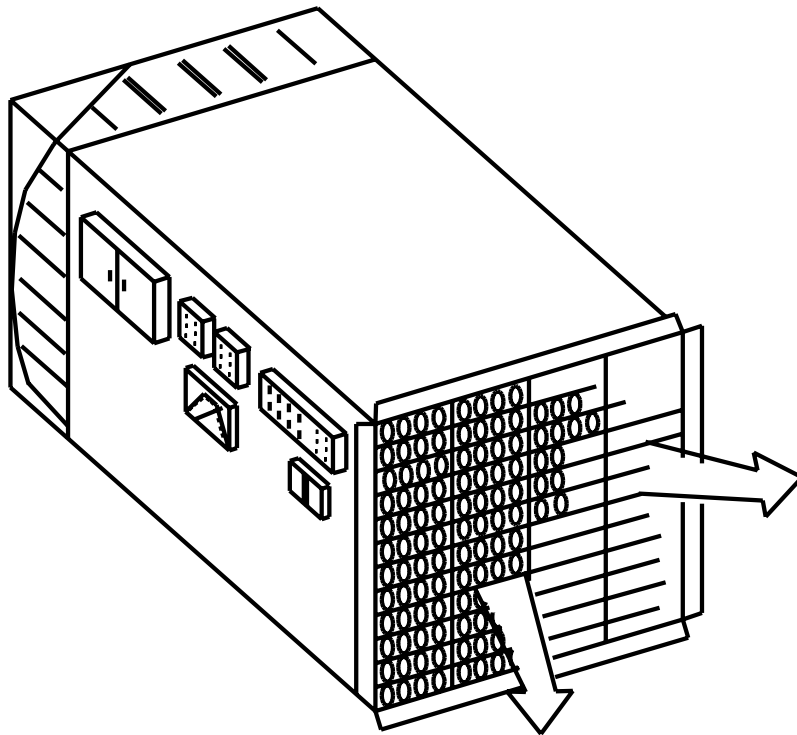
Technology advantages include the following:

- Robust equipment
- No residual toxins
- No ignition source
- Unattended operation
- Low direct treatment cost

The technology has been tested on benzene, toluene, ethylbenzene, and xylene; trichloroethene; tetrachloroethane; isopropyl alcohol; acetone; chloroform; methanol; and methyl ethyl ketone. A field-scale system is shown in the photograph on the next page.

### WASTE APPLICABILITY:

The TiO<sub>2</sub> photocatalytic air treatment technology can effectively treat dry or moist air. The technology has been demonstrated to purify contaminant steam directly, thus eliminating the need to condense. Systems of 100 cubic feet per minute have been successfully tested on vapor extraction operations, air stripper emissions, steam from desorption processes, and VOC emissions from manufacturing facilities. Other potential applications include odor removal,



Full-Scale Photocatalytic Air Treatment System

stack gas treatment, soil venting, and manufacturing ultra-pure air for residential, automotive, instrument, and medical needs. Systems of up to about 1,000 cubic feet per minute can be cost- competitive with thermal destruction systems.

**STATUS:**

The TiO<sub>2</sub> photocatalytic air treatment technology was accepted into SITE Emerging Technology Program (ETP) in October 1992; the evaluation was completed in 1993. Based on results from the ETP, this technology was invited to participate in the SITE Demonstration Program. For further information about the evaluation under the ETP, refer to the journal article (EPA/600/A-93/282), which is available from EPA. A suitable demonstration site is being sought.

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**PROCESS TECHNOLOGIES INCORPORATED**  
**(Photolytic Destruction of Vapor-Phase Halogens)**

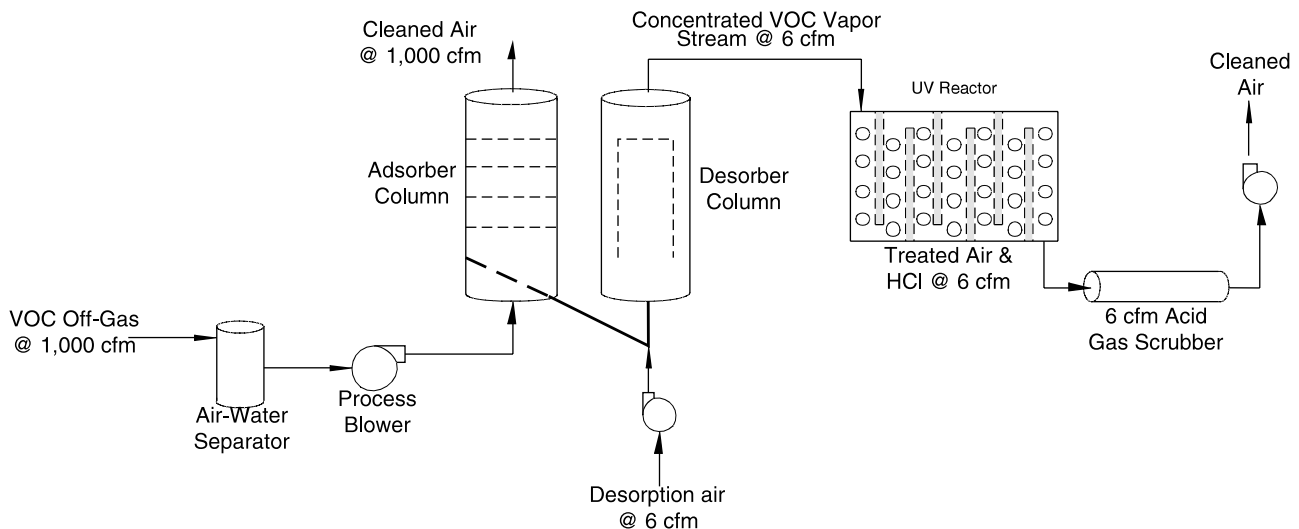
**TECHNOLOGY DESCRIPTION:**

The proprietary, nonthermal technology developed by Process Technologies Incorporated (PTI), is a method of photochemically oxidizing gaseous organic compounds within a reaction chamber. PTI's Photolytic Destruction Technology (PDT) uses low-pressure ultraviolet (UV) lamps, with UV emissions primarily at wavelengths in the 185 to 254 nanometer range, located within the reaction chamber. Photons emitted from these lamps break apart the chemical bonds making up the volatile organic compound (VOC) molecule. The process is capable of destroying mixtures of chlorinated and nonchlorinated VOCs.

The PDT system is designed and fabricated in 3- to 12-cubic-feet-per-minute (cfm) modules. The size of the module applied is dependent on the gas flow rate and VOC concentrations in the gas stream. PTI implements a fluid bed concentrator to allow for the treatment of high flow gas streams, or those with rates greater than 1,000 cfm. Significant cost savings can be realized if the gas flow can be reduced, and concentration increased prior to destruction.

PTI uses a proprietary reagent that forms a liner within the process chamber. The reagent reacts chemically with the gaseous degradation products formed during the photolytic destruction of halocarbon molecules to form solid, stable reaction products.

Reagent lifetime depends on flow rate, influent concentrations, and specific chemical composition of destruction targets. PTI has performed tests on spent reagent to determine whether the material would be classified as a hazardous waste under federal regulations. Those tests indicated that the spent reagent is likely nontoxic. The spent reagent is also not reactive, corrosive, or flammable, and thus PTI is confident that it is not a hazardous waste under federal law. PTI accordingly believes that the spent reagent material can be disposed of as ordinary solid waste or used as a feedstock for cement manufacturing. The PTI process is simple in design and easy to operate. The system is designed to run continuously, 24-hours per day.



Simplified Process Flow Diagram  
of Photolytic Destruction

## WASTE APPLICABILITY:

The technology was developed to destroy a number of groups of compounds, including chlorinated solvents, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons. Example sources of process off-gas that contains chlorinated and nonchlorinated VOCs, CFCs, and HCFCs include steam vapor extraction, tank vents, air strippers, steam strippers, and building vent systems.

The process is capable of destroying as high as 50,000 parts per million by volume VOC streams. The system is capable of achieving greater than 90 percent on-line availability, inclusive of scheduled maintenance activities.

## STATUS:

The PTI technology was accepted into the SITE Demonstration Program in summer 1994. The demonstration began in September 1994 at McClellan Air Force Base (AFB) in Sacramento, California. The SITE demonstration was postponed shortly thereafter. Activities under the SITE Program were rescheduled in 1997. Additional tests incorporating an improved design for treating soil vapor extraction off-gas were successfully completed at the AFB in January 1996.

PTI completed a four month demonstration of the combined fluid bed concentrator and PDT system at the U.S. Navy's North Island Site 9 in February, 1998. This demonstration was performed to evaluate the effectiveness and cost to remove and destroy VOC vapor from an existing SVE system. The results of the demonstration at the Navy's North Island Site 9 showed the PTI System was capable of achieving greater than 95 percent destruction and removal efficiency of VOCs in the soil vapor at a 250 standard cfm flow rate. Furthermore, the Navy determined that the PTI System provided a 45 percent cost savings over activated carbon or flameless thermal oxidation.

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**SELENTEC ENVIRONMENTAL TECHNOLOGIES, INC.**  
**(Selentec MAG\*SEP<sup>SM</sup> Technology)**

**TECHNOLOGY DESCRIPTION:**

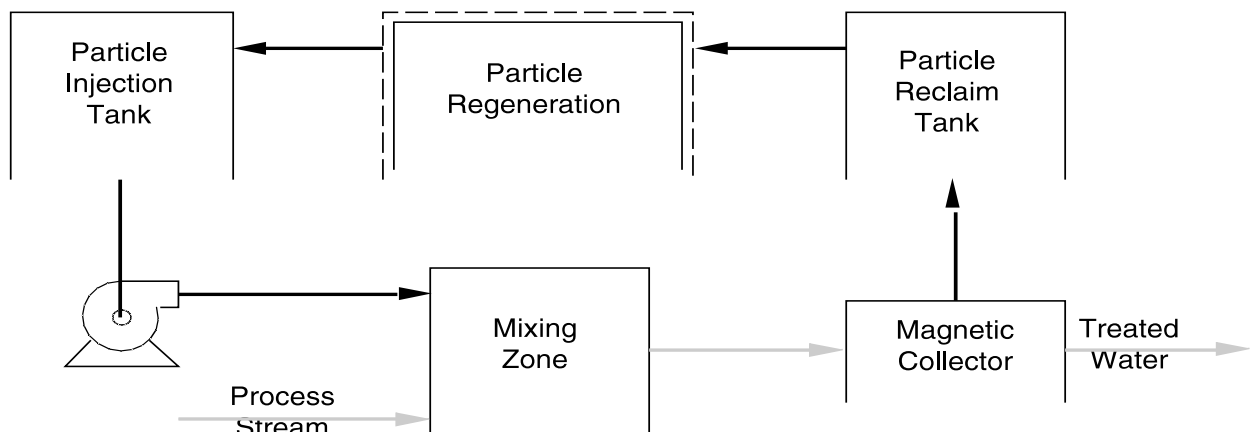
The MAG\*SEP<sup>SM</sup> process uses the principles of chemical adsorption and magnetism to selectively bind and remove heavy metals or radionuclides from aqueous solutions such as groundwater, wastewater, and drinking water. Contaminants are adsorbed on specially formulated particles which have a core made from magnetic material; these particles are then separated (along with the adsorbed contaminants) from the solution using a magnetic filter or magnetic collector. The magnetic core has no interaction with the contaminant.

The proprietary adsorbing particles are made of a composite of organic polymers and magnetite. The particles can be manufactured in two forms: one with an ion exchanger and/or chelating functional group attached to the particle surface (amidoxime functionalized resin), or one with inorganic adsorbers bound to the surface of the particles (clinoptilolite). These particles have high surface areas and rapid adsorption kinetics.

A typical MAG\*SEP<sup>SM</sup> treatment system consists of:

- a particle contact zone
- a particle handling system, including particle injection components, a magnetic separator, and particle reclaim components
- a particle regeneration system (where applicable)

The process stream enters a contact zone (usually a tank - other configurations are used for particular applications) where MAG\*SEP<sup>SM</sup> particles are injected and mixed. The contact zone provides the necessary solution flow characteristics and contact time with the particles to ensure that the contamination will be adsorbed onto the active surface sites of the particles. The mixture then flows through a magnetic collector, where the contaminated particles are retained while the treated process stream passes through (see figure below).



Schematic Diagram of the Mag\*SEP<sup>SM</sup> Treatment System

Depending on the application, type of particle, and contaminant concentration, the particles may be re-injected into the flow stream, collected and disposed of, or regenerated and reused. The regeneration solution is processed to recover (concentrate and remove) the contaminants and may be recycled.

The MAG\*SEP<sup>SM</sup> process is able to selectively remove (either ex situ or in situ) the following contaminants from aqueous solutions: titanium, copper, cadmium, arsenic, cobalt, molybdenum, platinum, selenium, chromium, zinc, gold, iodine, manganese, technetium, mercury, strontium, iron, ruthenium, thallium, cesium, cobalt, palladium, lead, radium, nickel, silver, bismuth, thallium, antimony, zirconium, radium, cerium, and all actinides. The process operates at flow rates up to 2,000 gallons per minute (gpm).

### **WASTE APPLICABILITY:**

The MAG\*SEP<sup>SM</sup> technology reduces heavy metal and radionuclide contamination in water and wastewater. The technology has specific applications in environmental remediation and restoration, treatment of acid mine drainage, resource recovery, and treatment of commercial industrial wastewater. MAG\*SEP<sup>SM</sup> particles can be produced to incorporate any known ion exchanger or sorbing material. Therefore, MAG\*SEP<sup>SM</sup> can be applied in any situation where conventional ion exchange is used.

### **STATUS:**

The MAG\*SEP<sup>SM</sup> technology was accepted into the SITE Program in 1996 and is also one of 10 technologies participating in the White House's Rapid Commercialization Initiative. In addition, in 1997 the MAG\*SEP<sup>SM</sup> technology received a Research and Development (R&D) 100 Award from the R&D trade publication as one of the 100 Most Technologically Significant New Products of 1997.

Selentec has completed a demonstration of the MAG\*SEP<sup>SM</sup> technology at the U.S. Department of Energy's Savannah River Site. Heavy metal concentrations in coal pile runoff water were significantly reduced to below drinking water standards. Another demonstration of the technology is planned for Savannah River whereby radioactive cesium will be removed streams. The technology is also being used to remove mercury from heavy water drums at Savannah River.

The first commercial unit of the MAG\*SEP<sup>SM</sup> technology was put into service on November 18, 1998, at a dairy in Ovruch, Ukraine. For this application, the unit is removing radioactive cesium from contaminated milk produced near the Chernobyl Nuclear Reactor Plant.

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