EBERLINE SERVICES, INC.

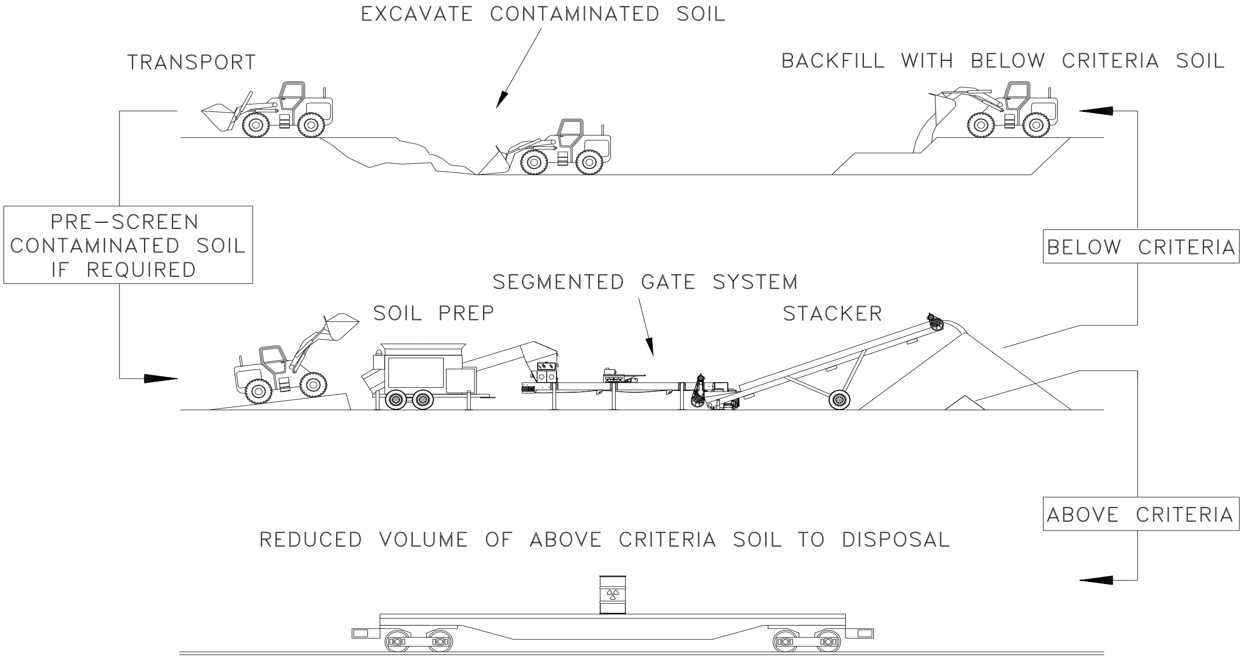
(formerly Thermo Nutech, Inc./TMA Thermo Analytical, Inc.)

(Segmented Gate System)

TECHNOLOGY DESCRIPTION:

Eberline Services, Inc. has conducted many radiological surveys of soil contaminated with low and intermediate levels of radioactivity. Cleanup of these sites is a highly labor-intensive process requiring numerous personnel to conduct radiological surveys with portable handheld instruments. When contamination is encountered, an attempt is made to manually excise it. When surveys disclose larger areas of contamination, heavy equipment is used to remove the contaminated material. Since pinpoint excision with earthmoving equipment is difficult, large amounts of uncontaminated soil are removed along with the contaminant. Few sites have been characterized as uniformly and/or homogeneously contaminated above release criteria over the entire site area.

As a result, Eberline Services developed the Segmented Gate System (SGS) to physically separate and segregate radioactive material from otherwise "clean" soil (see figure below). The SGS removes only a minimal amount of clean soil with the radioactive particles, significantly reducing the overall amount of material requiring disposal. The SGS works by conveying radiologically contaminated feed material on moving conveyor belts under an array of sensitive, rapidly reacting radiation detectors. The moving material is assayed, and the radioactivity content is logged. Copyrighted computer software tracks the radioactive material as it is transported by the conveyor and triggers a diversion by one or more of the SGS chutes when the material reaches the end of the conveyor. Clean soil goes in one direction, and the contaminated material in another.



The key advantage to this system is automation, which affords a much higher degree of accuracy compared to manual methods. Contaminants can be isolated and removed by locating small particles of radioactive material dispersed throughout the soil. All of the soil is analyzed continuously during processing to document the level of radioactivity in the waste and to demonstrate that cleaned soil meets release criteria. This automation and analysis results in a significant cost reduction for special handling, packaging, and disposal of the site's radioactive waste.

The SGS locates, analyzes, and removes gamma-ray-emitting radionuclides from soil, sand, dry sludge, or any host matrix that can be transported by conveyor belts. The SGS can identify hot particles, which are assayed in units of picoCuries (pCi), and can quantify distributed radioactivity, which is assayed in units of pCi per gram (pCi/g) of host material. The lower limit of detection (LLD) for the system depends on the ambient radiation background, conveyor belt speed, thickness of host material on conveyor, and contaminant gamma ray energy and abundance. However, LLDs of 2 pCi/g for americium-241 and 4 pCi/g for radium-226 have been successfully demonstrated.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. Pilot- and field-scale tests using Eberline Services' mobile equipment were initiated at a U.S. Department of Energy facility in March 1995.

A field test at the DOE site in Ashtabula, Ohio was conducted in October 1998. Soil containing thotium-232, radium-226, and uranium-238 was processed.

A similar system was operated by Eberline Services on Johnston Atoll in the mid-Pacific from January 1992 until November 1999 under contract to the U.S. Defense Threat Reduction Agency to process coral soil contaminated with plutonium and americium. The mobile SGS used at Ashtabula has also been deployed under the Department of Energy, Accelerated Site Technology Demonstration Program at Sandia National Laboratories, Los Alamos National Laboratory, Pantex Plant, Nevada Test Site-Tonapah Test Range, Idaho National Engineering and Environmental Laboratory, and Brookhaven National Laboratory.

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ELECTROKINETICS, INC.

(In Situ Bioremediation by Electrokinetic Injection)

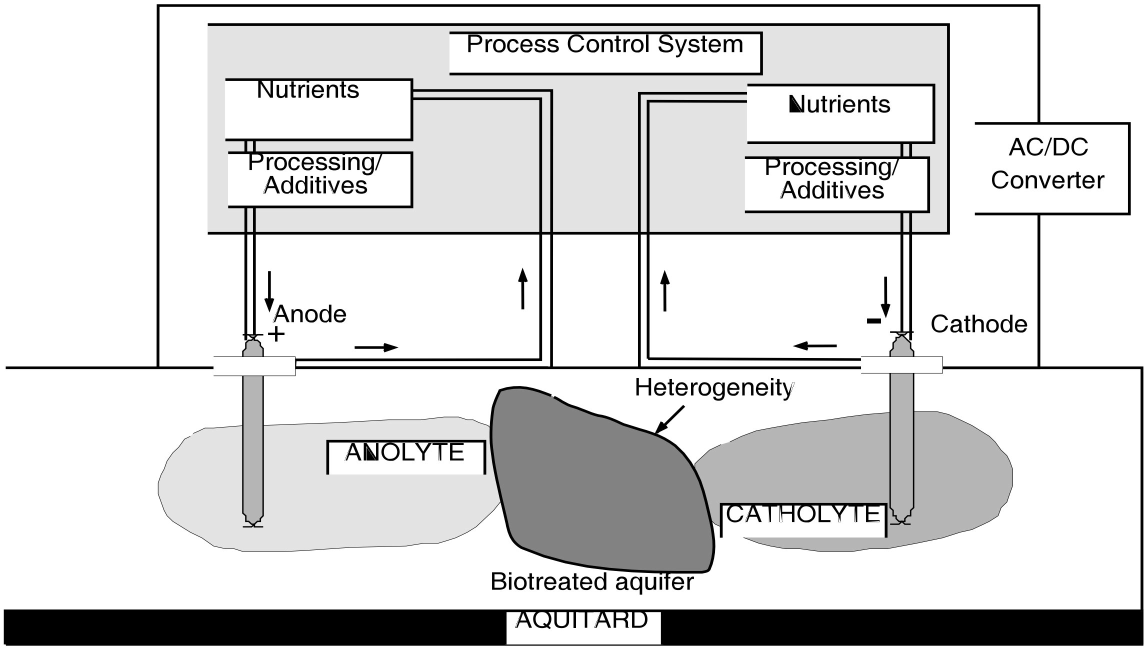
TECHNOLOGY DESCRIPTION:

In situ bioremediation is the process of introducing nutrients into biologically active zones (BAZ). The nutrients are usually introduced by pumping recirculated groundwater through the BAZ, relying on hydraulic gradients or the permeability of the BAZ. However, heterogeneous aquifers often hinder the introduction of the nutrients. For example, areas with higher permeability result in preferential flow paths, leading to incomplete biological treatment in other areas. The inability to uniformly introduce nutrients and other additives, such as surfactants and cometabolites, is recognized as a hindrance to successful implementation of in situ bioremediation.

Electrokinetics, Inc. (Electrokinetics), has developed an electrokinetic remediation technology that stimulates and sustains in situ bioremediation for the treatment of organics.

The technology involves applying to soil or groundwater a low-level direct current (DC) electrical potential difference or an electrical current using electrodes placed in an open or closed flow arrangement. Groundwater or an externally supplied processing fluid is used as the conductive medium. The low-level DC causes physical, chemical and hydrological changes in both the waste and the conductive medium, thereby enabling uniform transport of process additives and nutrients into the BAZ. The process is illustrated in the diagram below.

Electrokinetic soil processing technologies were designed to overcome problems associated with heterogeneous aquifers, especially those problems that result in incomplete biological treatment. For example, the rate of nutrient and additive transport under electrical gradients is at least one order of magnitude greater than that achieved under hydraulic gradients.



Schematic Diagram of In Situ Bioremediation by Electrokinetic Injection

WASTE APPLICABILITY:

In situ electrokinetic injection can be used for any waste that can be treated by conventional bioremediation techniques. The Electrokinetics, Inc. system facilitates in situ treatment of contaminated subsurface deposits, sediments, and sludges. The technology can also be engineered to remove inorganic compounds through electromigration and electroosmosis, while process additives and nutrients are added to the processing fluids to enhance bioremediation of organic compounds.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1995. Pilot-scale studies under the Emerging Technology Program will be used to develop operating parameters and to demonstrate the efficiency and cost-effectiveness of the technology during a full-scale application. The SITE evaluation may take place in 1999 at a military base or a U.S. Department of Energy (DOE) site.

In a Phase-I study conducted for DOE, Electrokinetics, Inc., demonstrated that nutrient and process additives could be transported in and across heterogeneous areas in aquifers at rates that could sustain in-situ bioremdiation. During the study, ion migration rates, which were on the order of 8 to 20 centimeters per day, exceeded the electroosmotic rate, even in a kaolinite clay. The ion migration also produced a reasonably uniform distribution of inorganic nitrogen, sulfur, and phosphorous additives across the soil mass boundaries. These results are significant and demonstrate that electrokinetic injection techniques may potentially be used for the injection of diverse nutrients in low permeability soils as well as heterogeneous media. Electrokinetics, Inc., recently completed bench- and pilot-scale tests, which determined the feasibility of enhancing the bioremediation of trichloroethylene and toluene by electrokinetic injection. The process of in situ bioremediation by electrokinetic injection was inspired by extensive research work conducted by Electrokinetics, Inc., using the electrochemical process to remediate soils contaminated with heavy metals and radionuclides. In 1994, Electrokinetics, Inc., was commissioned by the U.S. Department of Defense (DoD) to demonstrate its technology in a lead-contaminated creek bed at an inactive firing range in Fort Polk, Louisiana. The study was supported under the U.S. EPA SITE Demonstration Program. This pilot-scale field demonstration represents the first comprehensive scientific study worldwide for the application of electrokinetic separation technology applied to the remediation of heavy metals in soils. Electrokinetics, Inc., successfully removed up to 98 percent of the lead from the firing range soil and received the 1996 Small Business Innovation Research (SBIR) Phase II Quality Award from DoD for technical achievement.

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ELECTROKINETICS, INC.

(Electrokinetic Soil Processing)

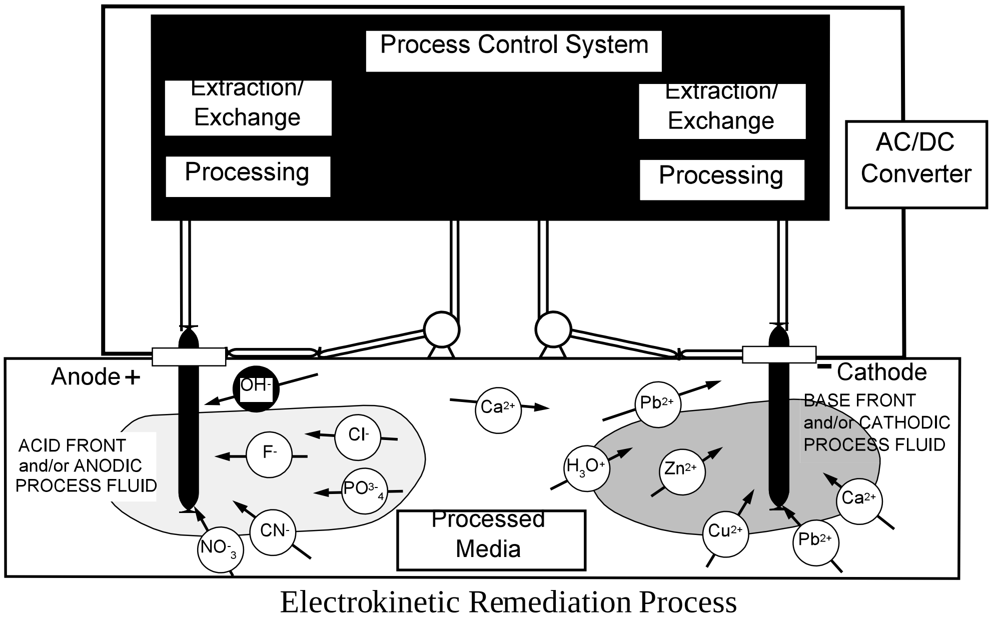
TECHNOLOGY DESCRIPTION:

Electrokinetics, Inc.'s, soil processes extract or remediate heavy metals and organic contaminants in soils. The process can be applied in situ or ex situ with suitable chemical agents to optimize the remediation. For example, conditioning fluids such as suitable acids may be used for electrode (cathode) depolarization to enhance the electrodeposition of certain heavy metals.

The figure below illustrates the field-processing scheme and the flow of ions to respective boreholes (or trenches). The mechanism of electrokinetic soil remediation for the removal of toxic metals involves the application of an electrical field across the soil mass. An in-situ generated acid causes the solubilization of metal salts into the pore fluid. The free ions are then transported through the soil by electrical migration towards the electrode of opposing charge. Metal species with a positive charge are collected at the cathode, while species with a negative charge are collected at the anode.

An acid front migrates towards the negative electrode (cathode), and contaminants are extracted through electroosmosis (EO) and electromigration (EM). The concurrent mobility of the ions and pore fluid decontaminates the soil mass. Electrokinetic remediation is extremely effective in fine-grained soils where other techniques such as pump and treat are not feasible. This is due to the fact that the contaminants are transported under charged electrical fields and not hydraulic gradients.

Bench-scale results show that the process works in both unsaturated and saturated soils. Pore fluid flow moves from the positive electrodes (anodes) to the cathodes under the effect of the EO and EM forces. Electrode selection is important, since many metal or carbon anodes rapidly dissolve after contact with strong oxidants. When the removal of a contaminant is not feasible, the metal can be stabilized in-situ by injecting stabilizing agents or creating an electrokinetic "fence" (reactive treatment wall) that reacts with and immobilizes the contaminants.



Electrokinetic Remediation Process

WASTE APPLICABILITY:

Electrokinetic soil processing extracts heavy metals, radionuclides, and other inorganic contaminants below their solubility limits. During bench-scale testing, the technology has removed arsenic, benzene, cadmium, chromi-um, copper, ethylbenzene, lead, mercury, nickel, phenol, trichloroethylene, toluene, xylene, and zinc from soils. Bench-scale studies under the SITE Emerging Technology Program demonstrated the feasibility of removing uranium and thorium from kaolinite.

Limited pilot-scale field tests resulted in lead and copper removal from clays and saturated and unsaturated sandy clay deposits. Treatment efficiency depended on the specific chemicals, their concentrations, and the buffering capacity of the soil. The technique proved 85 to 95 percent efficient when removing phenol at concentrations of 500 parts per million (ppm). In addition, removal efficiencies for lead, chromium, cadmium, and uranium at levels up to 2,000 micrograms per gram ranged between 75 and 98 percent.

STATUS:

Based on results from the Emerging Technology Program, the electrokinetic technology was invited in 1994 to participate in the SITE Demonstration Program. For further information on the pilot-scale system, refer to the Emerging Technology Bulletin (EPA/540/F-95/504), which is available from EPA.The SITE demonstration began in July 1995 at an inactive firing range at the Fort Polk Army Ammunition Reservation in Louisiana. The soil at the site is contaminated with lead, copper, and zinc, which have accumulated over several decades. Concentrations of lead in the sandy clay soil range from 1,000 to 5,000 ppm and are less than 100 ppm at a 3-foot depth. A 20-foot by 60-foot area was remediated to a depth of 3 feet. This demonstration represents the first comprehensive study in the United States of an in situ electrokinetic separation technology applied to heavy metals in soils. Electrokinetics Inc. received the 1996 SBIR Phase II Quality Award from the Department of Defense for its technical achievement on this project.

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ENERGIA, INC.

(Reductive Photo-Dechlorination Treatment)

TECHNOLOGY DESCRIPTION:

The Reductive Photo-Dechlorination (RPD) treatment uses ultraviolet (UV) light in a reducing atmosphere and at moderate temperatures to treat waste streams containing chlorinated hydrocarbons (CIHC). Because CIHCs are destroyed in a reducing environment, the only products are hydrocarbons and hydrogen chloride (HCl).

The RPD process is depicted in the figure below. The process consists of five main units: (1) input/mixer (2) photo-thermal chamber (3) HCl scrubber (4) separator and (5) products storage and recycling. Chlorinated wastes may be introduced into the process in one of three ways: vapor, liquid, or bound to an adsorbent, such as activated carbon.

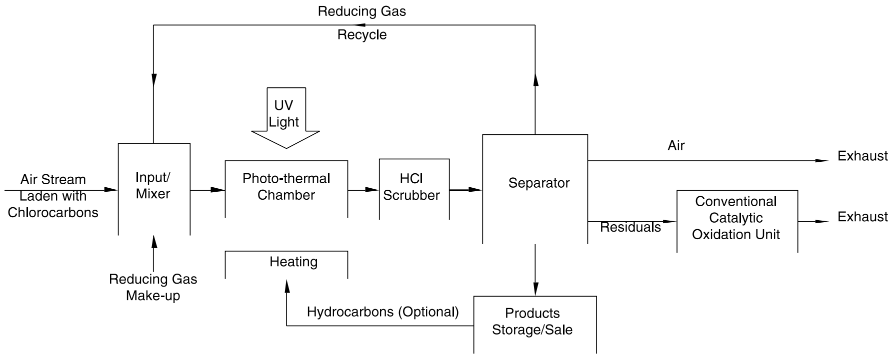
Air laden with chlorocarbon vapors is first passed through a condenser, which removes chlorinated materials as liquids. Chlorocarbon liquids are fed into a vaporizer, mixed with a reducing gas, and passed into the photo-thermal chamber. Chlorinated contaminants adsorbed onto activated carbon are purged with reducing gas and mildly heated to induce vaporization. The ensuing vapors are then fed into the photo-thermal chamber.

The photo-thermal chamber is the heart of the RPD process because all reactions central to the process occur in this chamber. Saturated, olefinic, or aromatic chlorocarbons with one or more carbon-chlorine bonds are exposed to UV light, heat, and a reducing atmosphere, such as hydrogen gas or methane. According to ENERGIA, Inc., carbon-chlorine bonds are broken, resulting in chain-propagating hydrocarbon reactions. Chlorine atoms are eventually stabilized as HCl, which is easily removed in a scrubber. Hydrocarbons may hold their original structures, rearrange, cleave, couple, or go through additional hydrogenation. Hydrocarbons produced from the dechlorination of wastes include ethane, acetylene, ethene, and methane. Valuable hydrocarbon products can be stored, sold, or recycled as auxiliary fuel to heat the photo-thermal chamber.

WASTE APPLICABILITY:

The RPD process is designed specifically to treat volatile chlorinated wastes in the liquid, gaseous, or adsorbed states. The RPD process was tested on methyl chloride, dichloromethane (DCM), chloroform, carbon tetrachloride, trichloroethane (TCA), dichloroethene (PCE), and trichloroethene (TCE).

Field applications include treatment of organic wastes discharged from soil vapor extraction operations, vented from industrial hoods and stacks, and adsorbed on activated carbon. The process can be used to (1) treat gas streams containing chlorinated hydrocarbons, and (2) pretreat gas streams entering catalytic oxidation systems by reducing chlorine content and protecting the catalyst against poisoning.In comparison to other photo-thermal processes (such as reductive photo-thermal oxidation [RPTO] and photo-



Reductive Photo-Dechlorination (RPD) Treatment thermal oxidation [PTO]), the RPD process is mostly applicable to streams without air and very high concentrations of contaminants (bulk down to greater than 1 percent). At very low concentrations (parts per million) and in the presence of air, the other photo-thermal processes may more cos- effective.

STATUS:

Bench-scale experiments were conducted on several contaminants (such as DCM, DCE, TCA, and TCE). Measurements of concentrations of parent compounds and products as a function of residence time were obtained at several test conditions. From these measurements, conversion and dechlorination efficiencies were determined at optimal operating conditions.

Experimental results on a representative chlorocarbon contaminant (TCA) are available in the Emerging Technology Bulletin (EPA/540/F-94/508). Greater than 99 percent conversion and dechlorination were demonstrated with high selectivity towards two saleable hydrocarbon products, ethane and methane. Similar favorable results were obtained for other saturated and unsaturated chlorocarbons treated by the RPD process.

Results of a cost analysis based on experimental data indicate that the RPD process is extremely cost competitive. For example, the cost of treating TCE concentrations of 1,000 ppm and 10,000 ppm is $1.10 and $0.25 per pound treated, respectively. The cost per 1,000 cubic feet of contaminated stream with 1,000 ppm is $0.38 and $0.88, respectively.

All technical data have been gathered and optimization has been completed. Design and assembly of a pilot-scale prototype are underway. The field demonstration may take place during 1999. The developer is seeking appropriate sites for field demonstration. After successful demonstration, the RPD process will be ready for full-scale commercialization.

The RPD technology has successfully completed the bench-scale developmental stage. Results are documented in the Emerging Technology Bulletin (EPA/540/F-94/508). Experimental results on a representative chlorocarbon contaminant (TCA) have demonstrated greater than 99% conversion and dechlorination, with high selectivity towards two saleable hydrocarbon products, ethane and methane. Similar favorable results have been obtained for other saturated and unsaturated chlorocarbons treated by the RPD process. Preliminary cost analysis shows that the process is extremely cost-competitive with other remedial processes; the estimated cost is less than $1 per pound of treated chlorocarbon. Based on the bench-scale results, a pilot-scale prototype unit has been designed and constructed. Currently, Energia is seeking funds to demonstrate the RPD technology with the pilot-scale system. After a successful pilot-scale demonstration the RPD technology will be available for commercialization.

These processes will be available for commercialization after the completion of the field demonstration.

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ENERGIA, INC.

(Reductive Thermal and Photo-Thermal Oxidation Processes for Enhanced Conversion of Chlorocarbons)

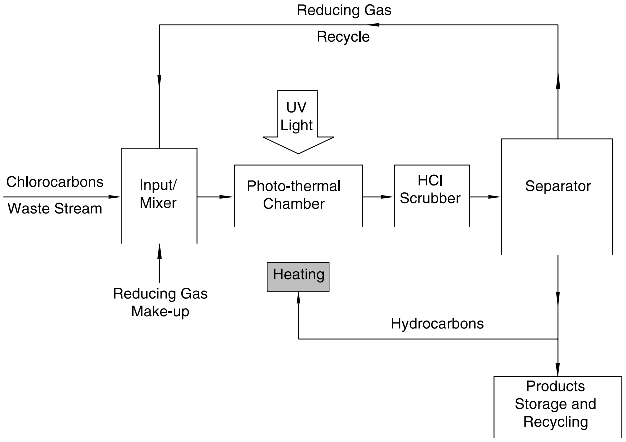
TECHNOLOGY DESCRIPTION:

Two innovative processes, Reductive Thermal Oxidation (RTO) and Reductive Photo-Thermal Oxidation (RPTO), are designed to safely and cost-effectively convert chlorinated hydrocarbons (ClHC) into environmentally benign and useful materials in the presence of a reducing atmosphere. Both processes have evolved from Energia, Inc.'s, Reductive Photo-Dechlorination (RPD) technology, which does not permit the presence of air (oxygen).

The RTO/RPTO processes treat air streams laden with ClHCs. RTO converts ClHCs at moderate temperatures by cleaving carbon-chlorine bonds in the absence of ultraviolet light. RPTO operates under similar conditions but in the presence of ultraviolet light. Subsequent reactions between ensuing radicals and the reducing gas result in chain-propagation reactions. The presence of air (oxygen) during the conversion process accelerates the overall reaction rate without significant oxidation. The final products are useful hydrocarbons (HC) and environmentally safe materials, including hydrogen chloride, carbon dioxide, and water.

The RTO/RPTO processes are shown in the figure below. The process consists of six main units: (1) input/mixer (2) photo-thermal chamber (3) scrubber (4) separator (5) product storage/sale and (6) conventional catalytic oxidation unit. Air laden with ClHCs is mixed with reducing gas and passed into a photo-thermal chamber, which is unique to the RTO/RPTO technology. In this chamber, the mixture is heated to moderate temperatures to sustain the radical chain reactions. Depending on the physical and chemical characteristics of the particular ClHCs being treated, conversion can take place in two ways: the RTO process is purely thermal, and the RPTO process is photo-thermal. After suitable residence time, HCl is removed by passing the stream through an aqueous scrubber. The stream can then be treated in an optional second stage, or it can be separated and sent to storage.

Excess reducing gas is recycled, and residual ClHCs, HCs, and CO_2 are either exhausted, or if needed, treated by catalytic oxidation. Volatile hydrocarbons can also be recycled as an energy source for process heating, if partial oxidation at the photo-thermal chamber does not generate enough heat.



Reductive Thermal Oxidation (RTO)
and Photo-Thermal Oxidation (RPTO) Process

WASTE APPLICABILITY:

This technology is designed to remove volatile hydrocarbons from air streams. Field applications include direct treatment of air streams contaminated with chlorocarbons, wastes discharged from soil vapor extraction or vented from industrial hoods and stacks, and those absorbed on granular activated carbon. M.L. ENERGIA, Inc., claims that the process can also be applicable for in situ treatment of sites containing contaminated surface waters and groundwaters. The process has not yet been tested on these sites.

STATUS

This technology was accepted into the SITE Emerging Technology Program in July 1994. Laboratory-scale tests were conducted on two saturated CIHCs (dichloromethane and trichloroethane) and on two representatives of unsaturated CIHCs (1,2-dichloroethene and trichloroethene). The RTO/RPTO processes have demonstrated 99% or more conversion/dechlorination with high selectivity towards saleable hydrocarbon products (methane and ethane). Based on these results, a pilot-scale prototype has been designed and constructed. Preliminary pilot-scale tests have been performed and the results are very encouraging. Currently, funds are sought for a comprehensive field demonstration with the pilot-scale system, followed by performance evaluation and cost analysis.

These processes will be available for commercialization after the completion of the field demonstration.

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ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION

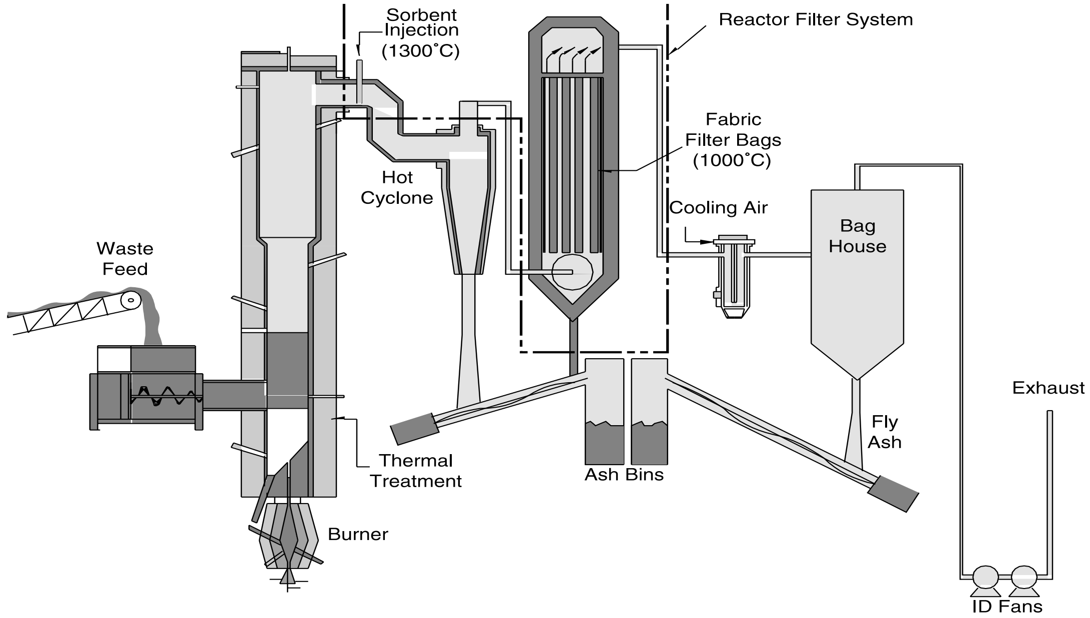
(Reactor Filter System)

TECHNOLOGY DESCRIPTION:

The Energy and Environmental Research Corporation (EER) Reactor Filter System (RFS) technology is designed to control gaseous and entrained particulate matter emissions from the primary thermal treatment of sludges, soils, and sediments. Most Superfund sites are contaminated with toxic organic chemicals and metals. Currently available thermal treatment systems for detoxifying these materials release products of incomplete combustion (PIC) and volatile toxic metals. Also, the large air pollution control devices (APCD) often required to control PICs and metals are generally not suitable for transport to remote Superfund sites. EER designed the RFS to avoid some of these logistical problems. The RFS uses a fabric filter installed immediately downstream of the thermal treatment process to control toxic metals, particulates, and unburned organic species.

The RFS involves the following three steps:

- First, solids are thermally treated with a primary thermal process, such as a rotary kiln, fluidized bed, or other system designed for thermal treatment.
- Next, a low-cost, aluminosilicate sorbent, such as kaolinite, is injected into the flue gases at temperatures near 1,300°C (2,370°F). The sorbent reacts with volatile metal species such as lead, cadmium, and arsenic in the gas stream and chemically adsorbs onto the surfaces of the sorbent particles. This adsorbtion forms insoluble, nonleachable alumino-silicate complexes similar to cementitious species.
- Finally, high-temperature fabric filtration, operating at temperatures up to 1,000°C (1,830°F), provides additional residence time for the sorbent/metal reaction to produce nonleachable



Example Application of RFS Equipment

by-products. This step also provides additional time for destruction of organic compounds associated with particulate matter, reducing ash toxicity. Because of the established link between PIC formation and gas-particle chemistry, this process can virtually eliminate potential polychlorinated dioxin formation.

The RFS may improve the performance of existing thermal treatment systems for Superfund wastes containing metals and organics. During incineration, hazardous organics are often attached to the particulate matter that escapes burning in the primary zone. The RFS provides sufficient residence time at sufficiently high temperatures to destroy such organics. Also, by increasing gas-solid contact parameters, the system can decrease metal emissions by preventing the release of metals as vapors or retained on entrained particles.

The figure on the previous page shows the RFS installed immediately downstream of the primary thermal treatment zone at EER's Spouted Bed Combustion Facility. Because the spouted bed generates a highly particulate-laden gas stream, a high-temperature cyclone is used to remove coarse particulate matter upstream of the RFS. Sorbent is injected into the flue gas upstream of the high temperature fabric filter. A conventional baghouse is available for comparison with RFS performance during the demonstration. However, the baghouse is not needed in typical RFS applications since the high-temperature filtration medium has shown similar performance to conventional fabric filtration media.

WASTE APPLICABILITY:

The RFS is designed to remove entrained particulates, volatile toxic metals, and condensed-phase organics present in high-temperature (800 to 1,000°C) gas streams generated from the thermal treatment of contaminated soils, sludges, and sediments. Many conventional treatments can be combined with the RFS technology. Process residuals will consist of nonleachable particulates that are essentially free of organic compounds, thus reducing toxicity, handling risks, and landfill disposal.

STATUS:

The RFS was accepted into the Emerging Technology Program in 1993. EER developed the pilot-scale process through a series of bench-scale screening studies, which were completed in September 1994. These screening studies guided the sorbent selection and operating conditions for the pilot-scale demonstration. The tests were completed in June 1996.

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ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION

(Hybrid Fluidized Bed System)

TECHNOLOGY DESCRIPTION:

The Hybrid Fluidized Bed (HFB) system treats contaminated solids and sludges by incinerating organic compounds and extracting and detoxifying volatile metals. The system consists of three stages: a spouted bed, a fluidized afterburner, and a high-temperature particulate soil extraction system.

First, the spouted bed rapidly heats solids and sludges to allow extraction of volatile organic and inorganic compounds. The spouted bed retains larger soil clumps until they are reduced in size but allows fine material to quickly pass through. This segregation process is beneficial because organic contaminants in fine particles vaporize rapidly. The decontamination time for large particles is longer due to heat and mass transfer limitations.

The central spouting region is operated with an inlet gas velocity of greater than 150 feet per second. This velocity creates an abrasion and grinding action, rapidly reducing the size of the feed materials through attrition. The spouted bed operates between 1,500 and 1,700°F under oxidizing conditions.

Organic vapors, volatile metals, and fine soil particles are carried from the spouted bed through an open-hole type distributor, which forms the bottom of the second stage, the fluidized bed afterburner. The afterburner provides sufficient retention time and mixing to incinerate the organic compounds that escape the spouted bed, resulting in a destruction and removal efficiency of greater than 99.99 percent. In addition, the afterburner contains bed materials that absorb metal vapors, capture fine particles, and promote formation of insoluble metal silicates. The bed materials are typically made of silica-supported bauxite, kaolinite, or lime.

In the third stage, the high-temperature particulate soil extraction system removes clean processed soil from the effluent gas stream with one or two hot cyclones. The clean soil is extracted hot to prevent unreacted volatile metal species from condensing in the soil. Off-gases are then quenched and passed through a conventional baghouse to capture the condensed metal vapors.

Generally, material handling problems create major operational difficulties for soil cleanup devices. The HFB system uses a specially designed auger feed system. Solids and sludges are dropped through a lock hopper system into an auger shredder, which is a rugged, low-revolutions-per-minute, feeding-grinding device. Standard augers are simple and reliable, but are susceptible to clogging from feed compression in the auger. In the HFB system, the auger shredder is close coupled to the spouted bed to reduce compression and clump formation during feeding. The close-couple arrangement locates the tip of the auger screw several inches from the internal surface of the spouted bed, preventing soil plug formation.

WASTE APPLICABILITY:

This technology is applicable to soils and sludges contaminated with organic and volatile inorganic contaminants. Nonvolatile inorganics are not affected.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in January 1990. Design and construction of the commercial prototype HFB system and a limited shakedown are complete. The Emerging Technology Bulletin (EPA/540/F- 93/508) is available from EPA.

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ENVIRONMENTAL BIOTECHNOLOGIES, INC.

(Microbial Composting Process)

TECHNOLOGY DESCRIPTION:

Polycyclic aromatic hydrocarbons (PAH) are widespread pollutants found at creosote wood treatment sites and at manufacturing gas plants (MGP). Environments contaminated with these compounds are considered hazardous due to the potential carcinogenic effects of specific PAHs.

Environmental BioTechnologies, Inc. (EBT), investigated the bioremediation of contaminants associated with former MGP sites in a program cosponsored by the Electric Power Research Institute and the EPA. Initially, EBT screened over 500 fungal cultures (mostly brown and white rot fungi) for their ability to degrade PAHs and other organic pollutants. A group of 30 cultures were more intensely examined and several cultures were optimized for use in a soil composting process.

EBT conducted bench-scale treatability studies to assess the feasibility of PAH degradation in soil using a fungal augmented system designed to enhance the natural bioprocess. Results of one study are shown in the figure below. Concentrations of 10 PAHs were determined over a 59-day treatment period.

Some states have a soil treatment standard of 100 parts per million for total PAHs. EBT's fungal treatment process was able to reach this cleanup standard within a 5- to 6-week treatment period for one PAH-contaminated soil, as shown in the figure on the next page.

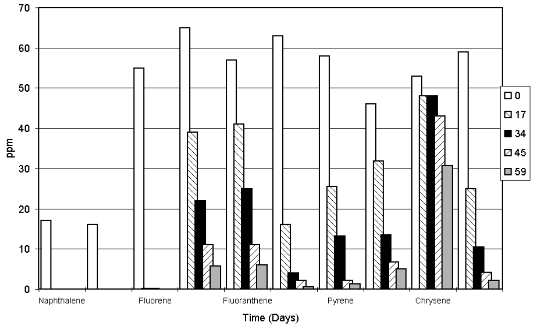
WASTE APPLICABILITY:

One intended environmental application for this technology is the treatment of soil and sediment contaminated with coal tar wastes from former MGP sites. Soils at these sites are contaminated with PAHs and are difficult to remediate cost-effectively. EBT's fungal soil treatment process is projected to cost $66 to $80 per ton, which is more cost-effective than other technical approaches such as coburning in utility burners, thermal desorption, and incineration that are being considered by utility companies.

STATUS:

EBT was accepted into the SITE Emerging Technology Program in 1993 and began laboratory studies in 1994. The project was completed in 1996. The overall project objectives were to (1) identify fungal and bacterial cultures that efficiently degrade coal tar wastes, and (2) develop and demonstrate a pilot-scale process that can be commercialized for utility industry applications.

EBT initially worked with PAH-spiked water and soils. EBT then tested, under optimized conditions, selected soil cultures from several MGP sites identified by New England Electric Services, a utility company sponsor. Testing identified several possibly superior fungal cultures to degrade PAHs. These cultures exhibited degradative preferences for either lower molecular weight or higher molecular weight PAHs, suggesting a consortia as a possible best



Fungal Degradation of Five PAHs in Soil Over A 59-Day Period approach. These cultures were then examined in nutrient-supplemented systems to determine optimal PAH degradation rates.

A bench-scale composter system was used to determine optimal moisture content, soil amendment requirements, and inoculation procedures for accelerating degradation of PAHs. During the second year, small (less than 1 cubic yard) plots of MGP-site soil were used to test the optimized process in laboratory studies before a field demonstration is conducted. Results from the evaluation were published by EPA in 1997.

EBT has also conducted a bench-scale treatability study for a company in France to determine the feasibility of fungal PAH degradation in MGP soil. Results demonstrated an increased rate of biodegradation in the fungal-augmented system for all of the measured individual PAH compounds in the 80-day treatment period, compared with the natural, unamended system.

EBT conducted another lab study on oil refinery wastes which contained PAHs. the fungal composting process was able to remove 90% of the PAHs in an 18 week period. Based on the results obtained during the Emerging Technology Program stage, EBT's fungal technology has been accepted into the U.S. EPA SITE Demonstration Program.

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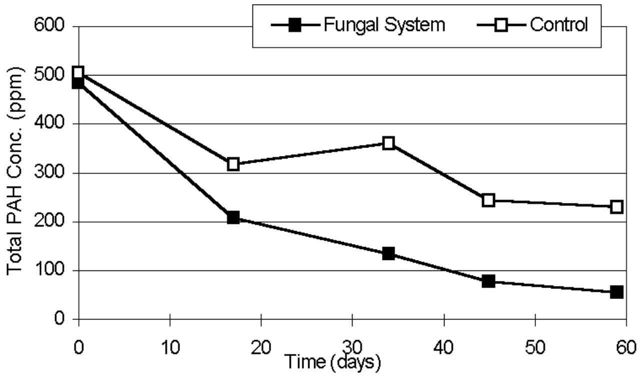


Degradation of Total PAHs In Soil

FERRO CORPORATION

(Waste Vitrification Through Electric Melting)

TECHNOLOGY DESCRIPTION:

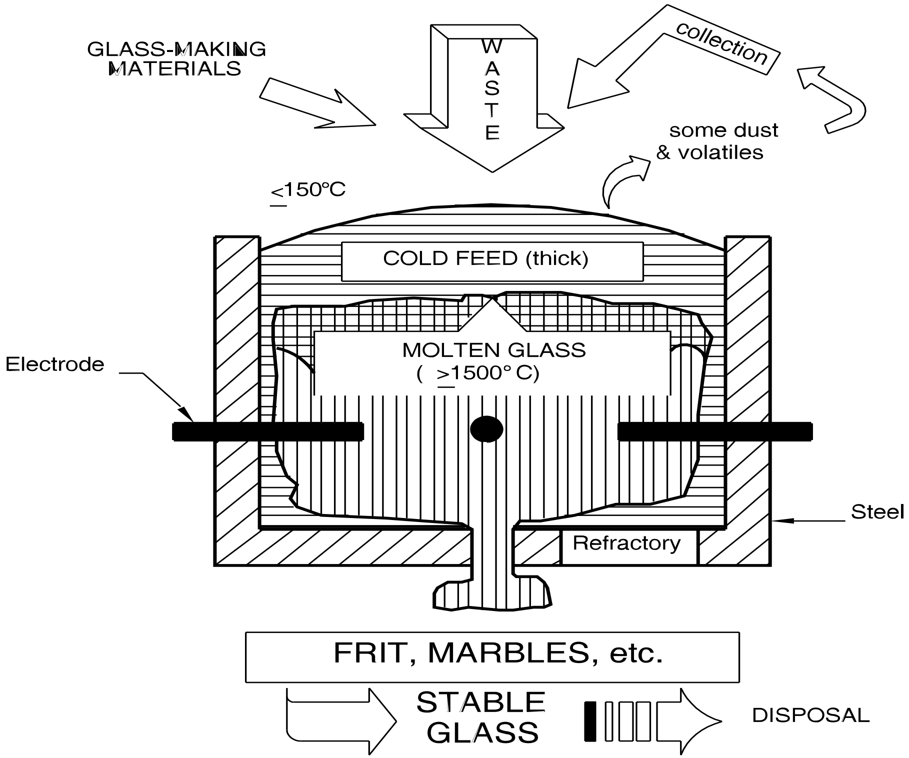
Vitrification technology converts contaminated soils, sediments, and sludges into oxide glasses, chemically rendering them nontoxic and suitable for landfilling as nonhazardous materials. Successful vitrification of soils, sediments, and sludges requires (1) development of glass compositions tailored to a specific waste, and (2) glass melting technology that can convert the waste and additives into a stable glass without producing toxic emissions.

In an electric melter, glass — an ionic conductor of relatively high electrical resistivity — stays molten with joule heating. Such melters process waste under a relatively thick blanket of feed material, which forms a counterflow scrubber that limits volatile emissions (see figure below).

Commercial electric melters have significantly reduced the loss of inorganic volatile constituents such as boric anhydride (B_2O_3) or lead oxide (PbO). Because of its low emission rate and small volume of exhaust gases, electric melting is a promising technology for incorporating waste into a stable glass matrix.

WASTE APPLICABILITY:

Vitrification stabilizes inorganic components found in hazardous waste. In addition, the high temperature involved in glass production (about 1,500 °C) decomposes organics such as anthracene, bis(2-ethylhexyl phthalate), and pentachlorophenol in the waste. The decomposition products can easily be removed from the low volume of melter off-gas.



Electric Furnace Vitrification

STATUS:

Under the Emerging Technology Program, synthetic soil matrix IV (SSM-IV) has been developed and subjected to toxicity characteristic leaching procedure (TCLP) testing.

Ten independent replicates of the preferred composition produced the following results:

	TCLP analyte concentration, parts per million	
Metal	Remediation Limit	Mean of Glass Replicates
As	5	<0.100
Cd	1	<0.010
Cr	5	0.019
Cu	5	0.355
Pb	5	0.130
Ni	5	<0.010
Zn	5	0.293

SSM-IV and additives (sand, soda ash, and other minerals) required to convert SSM-IV to the preferred glass composition have been processed in a laboratory-scale electric melter. Three separate campaigns have produced glass at 17 pounds per hour at a fill of 67 percent SSM-IV and 33 percent glass-making additives. The TCLP mean analyte concentrations were less than 10 percent of the remediation limit at a statistical confidence of 95 percent. Ferro Corporation's experience indicates that this melting rate would produce an equivalent rate of 1 ton per hour in an electric melter used to treat wastes at a Superfund site. The Emerging Technology Bulletin (EPA/540/F-95/503) is available from EPA.

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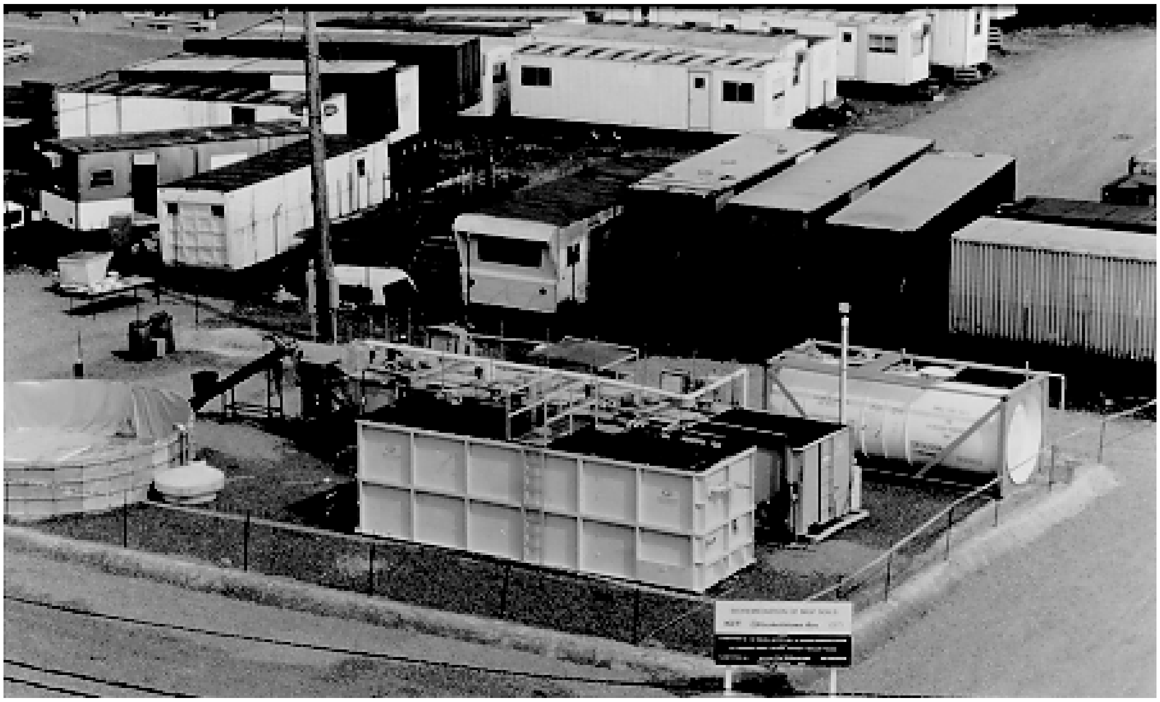
GAS TECHNOLOGY INSTITUTE
(Chemical and Biological Treatment)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology (IGT) chemical and biological treatment (CBT) process remediates sludges, soils, groundwater, and surface water contaminated with organic pollutants, such as polynuclear aromatic hydrocarbons (PAH) and polychlorinated biphenyls (see photograph below). The treatment system combines two remedial techniques: (1) chemical oxidation as pretreatment, and (2) biological treatment using aerobic and anaerobic biosystems in sequence or alone, depending on the waste. The CBT process uses mild chemical treatment to produce intermediates that are biologically degraded, reducing the cost and risk associated with a more severe treatment process such as incineration.

During the pretreatment stage, the contaminated material is treated with a chemical reagent that degrades the organics to carbon dioxide, water, and partially oxidized intermediates. In the second stage of the CBT process, biological systems degrade the hazardous residual materials and the partially oxidized intermediates from the first stage. Chemically treated wastes are subjected to cycles of aerobic and anaerobic degradation if aerobic or anaerobic treatment alone is not sufficient. Several cycles of chemical and biological treatment are also used for extremely recalcitrant contaminants.



Chemical and Biological Treatment Process

WASTE APPLICABILITY:

The CBT process can be applied to soils, sludges, groundwater, and surface water containing (1) high waste concentrations that would typically inhibit bioremediation, or (2) low waste concentrations for which bioremediation alone is too slow. The process is not adversely affected by radionuclides or heavy metals. Depending on the types of heavy metals present, these metals will bioaccumulate in the biomass, complex with organic or inorganic material in the soil slurries, or solubilize in the recycled water.

The CBT process can be applied to a wide range of organic pollutants, including alkenes, chlorinated alkenes, aromatics, substituted aromatics, and complex aromatics.

STATUS:

IGT evaluated the CBT process for 2 years under the SITE Emerging Technology Program. The Emerging Technology Bulletin (EPA/540/F-94/540), which details results from the evaluation, is available from EPA. Based on results from the Emerging Technology Program, this technology was invited to participate in the SITE Demonstration Program.

Under the SITE Demonstration Program, IGT plans to conduct a full-scale demonstration of the CBT process on sediments containing PAHs. Different operating scenarios will be used to demonstrate how effectively the CBT process treats sediments in a bioslurry reactor. Several sites are being considered for the demonstration.

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GAS TECHNOLOGY INSTITUTE
(Fluid Extraction-Biological Degradation Process)

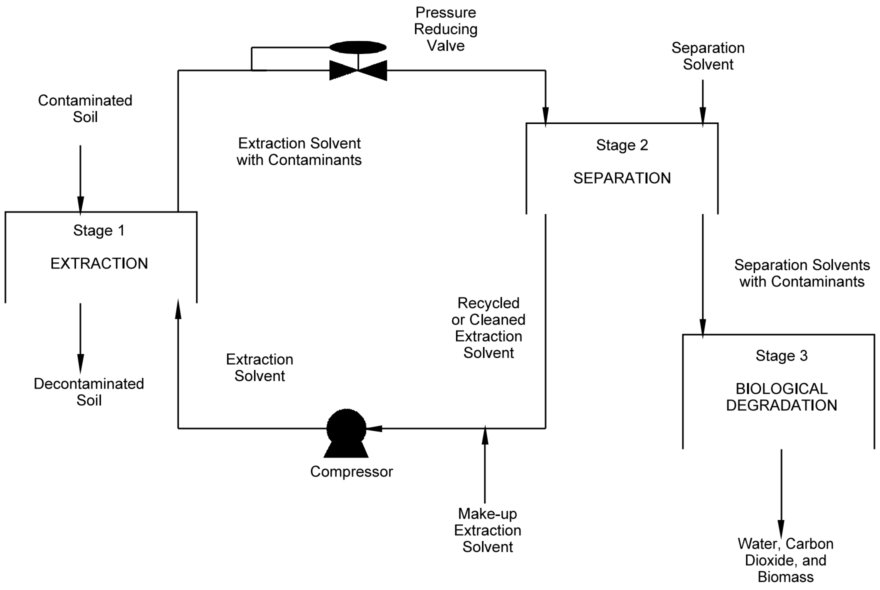
TECHNOLOGY DESCRIPTION:

The three-step fluid extraction-biological degradation (FEBD) process removes organic contaminants from soil (see figure below). The process combines three distinct technologies: (1) fluid extraction, which removes the organics from contaminated solids; (2) separation, which transfers the pollutants from the extract to a biologically compatible solvent or activated carbon carrier; and (3) biological degradation, which destroys the pollutants and leaves innocuous end-products.

In the fluid extraction step, excavated soils are placed in a pressure vessel and extracted with a recirculated stream of supercritical or near-supercritical carbon dioxide. An extraction cosolvent may be added to enhance the removal of additional contaminants.

During separation, organic contaminants are transferred to a biologically compatible separation solvent such as water or a water-methanol mixture. The separation solvent is then sent to the final stage of the process, where bacteria degrade the waste to carbon dioxide and water. Clean extraction solvent is then recycled for use in the extraction stage.

Organic contaminants are biodegraded in aboveground aerobic bioreactors, using mixtures of bacterial cultures capable of degrading the contaminants. Selection of cultures is based on site contaminant characteristics. For example, if a site is mainly contaminated with polynuclear aromatic hydrocarbons (PAH), cultures able to metabolize or cometabolize these hydrocarbons are used. The bioreactors can be configured to enhance the rate and extent of biodegradation.



Fluid Extraction-Biological Degradation Process

Research continues on using bound activated carbon in a carrier system during the separation step. Bound activated carbon should allow high- pressure conditions to be maintained in the fluid extraction step, enhancing extraction efficiency and decreasing extraction time. Bound activated carbon should also limit the loss of carbon dioxide, thereby decreasing costs. The activated carbon containing the bound PAHs could then be treated in the biodegradation step by converting the carrier system to a biofilm reactor. These activated carbon carrier systems could then be recycled into the high-pressure system of the extraction and separation steps.

WASTE APPLICABILITY:

This technology removes organic compounds from contaminated solids. It is more effective on some classes of organics, such as hydrocarbons (for example, gasoline and fuel oils) than on others, such as halogenated solvents and polychlorinated biphenyls. The process has also been effective in treating nonhalogenated aliphatic hydrocarbons and PAHs.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in June 1990. The Institute of Gas Technology has evaluated all three stages of the technology with soils from a Superfund site and from three town gas sites. These soils exhibited a variety of physical and chemical characteristics. Approximately 85 to 99 percent of detectable PAHs, including two- to six-ring compounds, were removed from the soils.

The measurable PAHs were biologically converted in both batch-fed and continuously fed, constantly stirred tank reactors. The conversion rate and removal efficiency were high in all systems. The PAHs were biologically removed or transformed at short hydraulic retention times. All PAHs, including four- to six-ring compounds, were susceptible to biological removal.

Results from this project were published in the Emerging Technology Bulletin (EPA/540/F-94/501), which is available from EPA. An article was submitted to the *Journal of Air and Waste Management*.

Potential users of this technology have expressed interest in continuing research. This technology has been invited to participate in the SITE Demonstration Program. The technology would be able to remediate town gas sites, wood treatment sites, and other contaminated soils and sediments.

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GAS TECHNOLOGY INSTITUTE

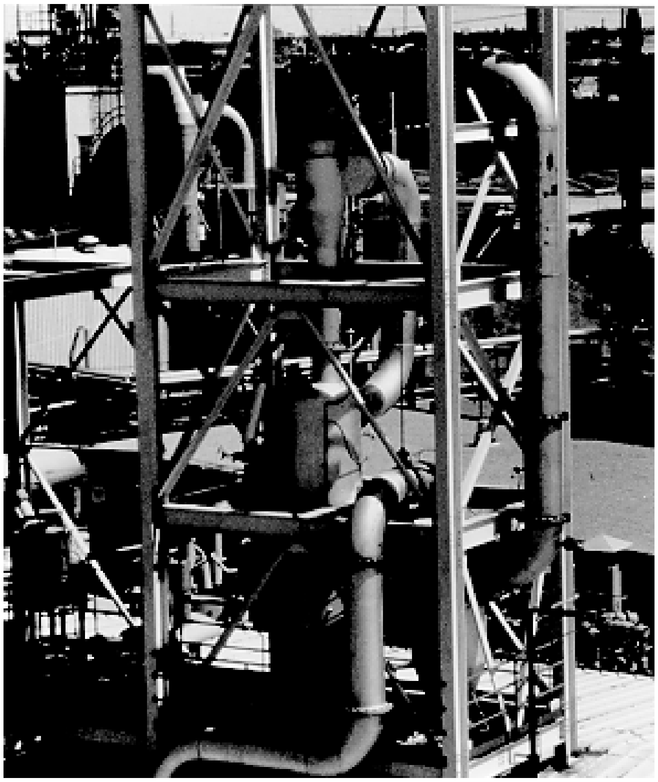
(Fluidized-Bed/Cyclonic Agglomerating Combustor)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology (IGT) has developed a two-stage, fluidized-bed/cyclonic agglomerating combustor (AGGCOM) based on a combination of IGT technologies. In the combined system, solid, liquid, and gaseous organic wastes can be efficiently destroyed. Solid, nonvolatile, inorganic contaminants are combined within a glassy matrix consisting of discrete pebble-sized agglomerates that are suitable for disposal in a landfill or use as an aggregate.

The first stage of the combustor is an agglomerating fluidized-bed reactor, which can operate under substoichiometric conditions or with excess air. This system can operate from low temperature (desorption) to high temperature (agglomeration). This system canalso gasify materials with high calorific values (for example, municipal solid wastes). With a unique fuel and air distribution, most of the fluidized bed is maintained at 1,500° to 2,000°F, while the central hot zone temperature can be varied between 2,000° and 3,000°F.

When contaminated soils and sludges are fed into the fluidized bed, the combustible fraction of the waste is rapidly gasified and combusted. The solid fraction, containing inorganic and metallic contaminants, undergoes a chemical transformation in the hot zone and is agglomerated into glassy pellets. These pellets are essentially nonleachable under the conditions of the toxicity characteristic leaching procedure (TCLP). The product gas from the fluidized bed may contain unburned hydrocarbons, furans, dioxins, and carbon monoxide, as well as carbon dioxide and water, the products of complete combustion.



AGGCOM Pilot Plant

The product gas from the fluidized bed is fed into the second stage of the combustor, where it is further combusted at a temperature of 1,800° to 2,400°F. The second stage is a high-intensity cyclonic combustor and separator that provides sufficient residence time (0.25 second) to oxidize carbon monoxide and organic compounds to carbon dioxide and water vapor. This stage has a combined destruction and removal efficiency of greater than 99.99 percent. Volatilized metals are collected downstream in the flue gas scrubber condensate.

The two-stage AGGCOM process is based on IGT's experience with other fluidized-bed and cyclonic combustion systems. The patented sloping-grid design and ash discharge port in this process were initially developed for IGT's U-GAS coal gasification process. The cyclonic combustor and separator is a modification of IGT's low-emissions combustor.

WASTE APPLICABILITY:

The two-stage AGGCOM process can destroy organic contaminants in gaseous, liquid, and solid wastes, including soils and sludges. Gaseous wastes can be fired directly into the cyclonic combustor. Liquid, sludge, and solid wastes can be co-fired directly into the fluidized bed. Solid particles must be less than about 6 millimeters to support fluidized bed operation; therefore, certain wastes may require grinding or pulverization prior to remediation.

Because the solid components in the waste are heated above fusion temperature during the agglomeration process, metals and other inorganic materials are encapsulated and immobilized within the glassy matrix.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Tests conducted in the batch, 6-inch-diameter fluidized bed have demonstrated that agglomerates can be formed from the soil. The agglomerates, produced at several different operating conditions from soil spiked with lead and chromium compounds, passed the TCLP test for leachability.

A pilot-scale combustor with a capacity of 6 tons per day has been constructed (see photograph on previous page), and testing has produced samples of agglomerated soil. Future testing will focus on sustained and continuous operation of the pilot-scale plant using different types of soil, as well as other feedstocks. Tests with organic and inorganic hazardous waste surrogates admixed with the feed soil will also be conducted. A final report on the project has been submitted to EPA.

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GAS TECHNOLOGY INSTITUTE

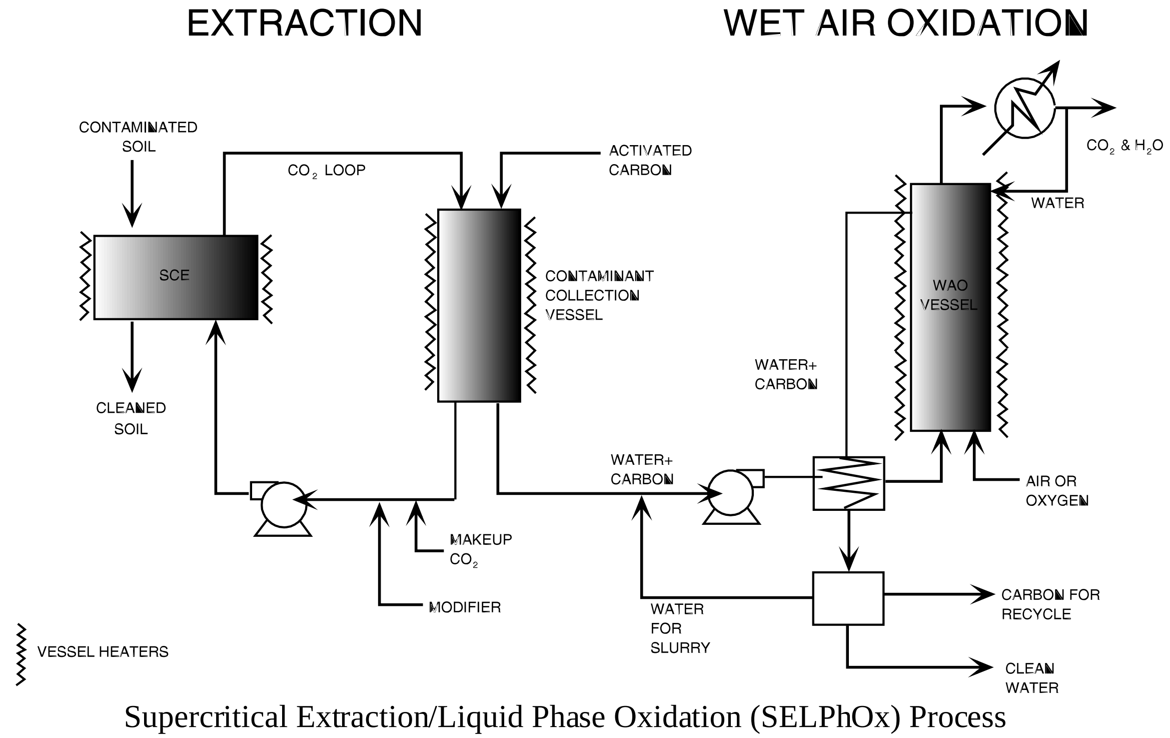
(Supercritical Extraction/Liquid Phase Oxidation)

TECHNOLOGY DESCRIPTION:

The Institute of Gas Technology's (IGT) Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) process (see figure below) removes organic contaminants from soils and sludges and destroys them. SELPhOx combines two processing steps: (1) supercritical extraction (SCE) of organic contaminants, and (2) wet air oxidation (WAO) of the extracted contaminants. The two-step process, linked by a contaminant collection stage, offers great flexibility for removing and destroying both high and low concentrations of organic contaminants.

Combining SCE and WAO in a single two-step process allows development of a highly efficient and economical process for remediating contaminated soils. Supercritical extraction with carbon dioxide (CO_2) removes organic contaminants from the soil while leaving much of the original soil organic matrix in place. The contaminants are collected on activated carbon in a contaminant collection vessel. The activated carbon with sorbed contaminants is then transported in an aqueous stream to a WAO reactor for destruction. Concentrating the organic contaminants on activated carbon in water provides a suitable matrix for the WAO feed stream and improves process economics by decreasing WAO reactor size. The activated carbon is regenerated in the WAO reactor with minimal carbon loss and can be recycled to the contaminant collection vessel.

The SELPhOx process requires only water, air, makeup activated carbon, and the extractant (CO_2). Primary treatment products include cleaned soil, water, nitrogen (from the air fed to the WAO step), and CO_2. Organic sulfur, nitrogen, and chloride compounds that may be present in the original soil or sludge matrix are



Supercritical Extraction/Liquid Phase Oxidation (SELPhOx) Process transformed to relatively innocuous compounds in the product water. These compounds include sulfuric acid and hydrogen chloride, or their salts. The treated soil can be returned to the original site, and the water can be safely discharged after thermal energy recovery and minor secondary treatment. The gas can be depressurized by a turbo expander for energy recovery and then vented through a filter.

WASTE APPLICABILITY:

The SELPhOx process removes organic contaminants from soils and sludges, including chlorinated and nonchlorinated polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls, and other organic contaminants. The process is targeted toward sites that are contaminated with high levels of these organics (hot spots).

The SELPhOx process was accepted into the SITE Emerging Technology Program in July 1994. The primary objectives of the project are to (1) evaluate SCE's contaminant removal efficiency, (2) determine the potential for CO_2 recovery and reuse, and (3) determine destruction efficiencies of extracted contaminants in the WAO process. Analytical results from the project will provide the necessary information for the full-scale process design.

Laboratory-scale SCE tests have been completed using soils contaminated with PAHs. Operating conditions for the SCE stage and the activated carbon adsorption stage have been selected. A transportable field test unit was constructed and tested with PAH-contaminated soil. The final report has been submitted by the developer.

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GENERAL ATOMICS,
NUCLEAR REMEDIATION TECHNOLOGIES DIVISION
(Acoustic Barrier Particulate Separator)

TECHNOLOGY DESCRIPTION:

The acoustic barrier separates particulates in a high temperature gas flow. The separator produces an acoustic waveform directed against the gas flow, causing particulates to move opposite the flow. The particulates drift to the wall of the separator, where they aggregate with other particulates and precipitate into a collection hopper. The acoustic barrier particulate separator differs from other separators by combining both high efficiency and high temperature capabilities.

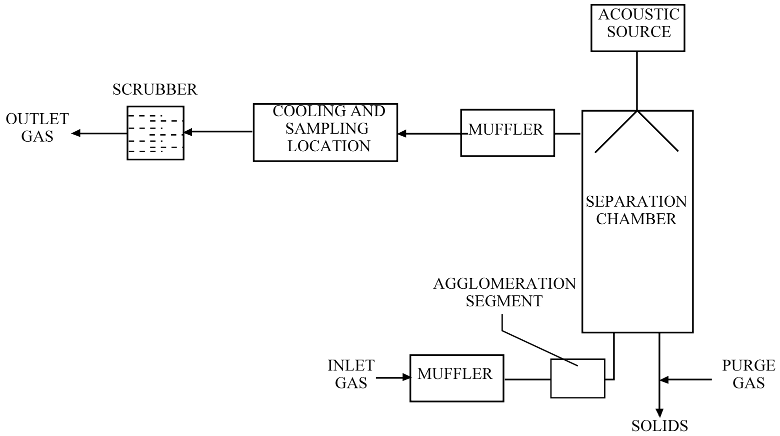
The figure below presents a conceptual design. High temperature inlet gas flows through a muffler chamber and an agglomeration segment before entering the separation chamber. In the separation chamber, particulates stagnate due to the acoustic force and then drift to the chamber wall, where they collect as a dust cake that falls into a collection hopper. The solids are transported from the collection hopper by a screw-type conveyor against a clean purge gas counterflow. The purge gas cools the solids and guards against contamination of particulates by inlet-gas volatiles in the process stream.

The gas flows past the acoustic source and leaves the separation chamber through an exit port. The gas then passes through another muffler chamber and flows through sections where it is allowed to cool and any remaining gas-borne particulate samples are collected. Finally, the gas is further scrubbed or filtered as necessary before it is discharged.

The separator can remove the entire range of particle sizes; it has a removal efficiency of greater than 90 percent for submicron particles and an overall removal efficiency of greater than 99 percent. Due to the large diameter of the separator, the system is not prone to fouling.

WASTE APPLICABILITY:

This technology can treat off-gas streams from thermal desorption, pyrolysis, and incineration of soil, sediment, sludges, other solid wastes, and liquid wastes. The acoustic barrier particulate separator is a high-temperature, high-throughput process with a high removal efficiency for fine dust and fly ash. It is particularly suited for thermal processes where high temperatures must be maintained to prevent



Acoustic Barrier Particulate Separator

condensation onto particulates. Applications include removal of gas-borne solids during thermal treatment of semivolatile organics, such as polychlorinated biphenyls, and gas-phase separation of radioactive particles from condensible hazardous materials.

STATUS:

The acoustic barrier particulate separator was accepted into the SITE Emerging Technology Program in 1993. The principal objective of this project will be to design, construct, and test a pilot-scale acoustic barrier particulate separator that is suitable for parallel arrangement into larger systems. The separator will be designed for a flow of 300 cubic feet per minute and will be tested using a simulated flue gas composed of heated gas and injected dust.

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GEO-MICROBIAL TECHNOLOGIES, INC.

(Metals Release and Removal from Wastes)

TECHNOLOGY DESCRIPTION:

Geo-Microbial Technologies, Inc., has developed an anaerobic biotreatment technology to release metals from liquefaction catalyst wastes. Such wastes are derived from spent coal and are also contaminated with complex organic compounds. The anaerobic metals release (AMR) technology may be adapted to treat other wastes contaminated with metals.

Current biohydrometallurgy systems use aerobic acidophilic bacteria, which oxidize mineral sulfides while making metals soluble and forming large amounts of acid. This aerobic process can result in acidic drainage from natural sources of metal sulfides. For example, acidophilic bacteria convert the pyrite and iron-containing minerals in coal into oxidized iron and sulfuric acid. The acid then makes the pyrite and other sulfide minerals more soluble resulting in stream and lake contamination due to acidification and an increase in soluble heavy metals.

The AMR technology operates anaerobically and at a near-neutral pH, employing anaerobic *Thiobacillus* cultures in conjunction with heterotrophic denitrifying bacterial cultures. The diverse culture of denitrifying bacteria consumes and treats multiple carbon sources, including some organic pollutants.

The anaerobic environment can be adjusted by introducing low levels of nitrate salts that function as an electron acceptor in the absence of oxygen. The nitrate salts provide an alternate electron acceptor and selectively enhance the remineralization process of the inherent denitrifying microflora. This process increases the population of the denitrifying bacterial population that releases the metals. Soils containing the released metals are then flooded with the dilute nitrate solutions. The improved anaerobic leaching solutions permeate the soils, allowing the microbial activity to make the metals soluble in the leachate. The nitrate concentration is adjusted so that the effluent is free of nitrate and the nitrate concentration is monitored so that the process operation can be closely controlled. Soluble metals in the leachate are easily recaptured, and the metal-free effluent is recycled within the process. The nitrate-based ecology of the process also has the added advantage of decreasing levels of sulfate-reducing bacteria and sulfide generation.

The versatility and low operating constraints of the AMR technology offer multiple process options. The technology can be adapted for in situ flooding or modified to flood a waste pile in a heap-leaching operation. The elimination of any aeration requirement also allows the process to be designed and considered for bioslurry applications. As a result, the technology offers a greater range of treatment applications for environmental waste situations that are often considered difficult to treat.

WASTE APPLICABILITY:

The AMR technology targets toxic metal-contaminated soils, sludges, and sediments, which can also be contaminated with other wastes, including hydrocarbons and organic pollutants. While metals are the primary pollutant treated, the biological system is also designed to degrade and remove associated organic contaminants.

STATUS:

The technology was accepted into the SITE Emerging Technology Program in July 1994. Studies under the Emerging Technology Program will evaluate how effectively the AMR technology removes metals from soil.

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HARDING ESE, A MACTEC COMPANY

(formerly ABB Environmental Services, Inc.)

(Two-Zone, Plume Interception, In Situ Treatment Strategy)

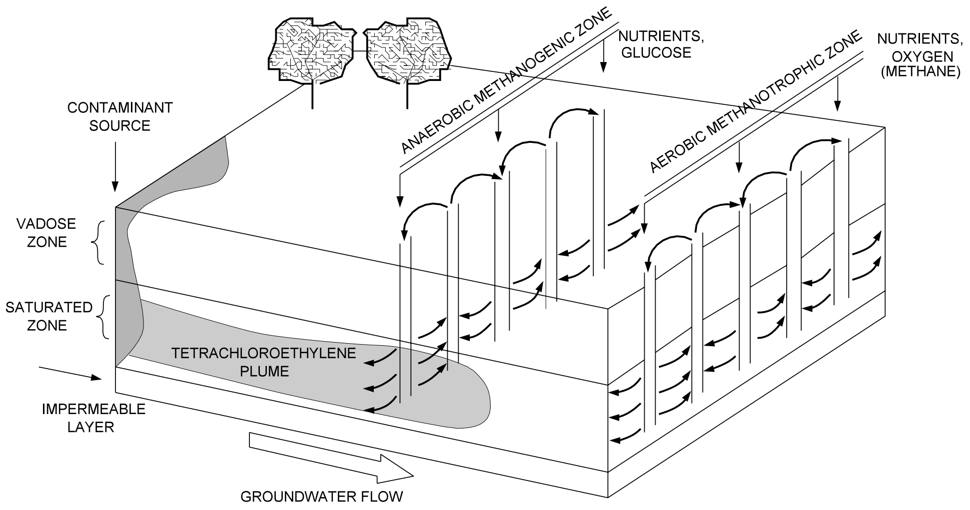
TECHNOLOGY DESCRIPTION:

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, isdesigned 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 (if an insufficient supply of methane results from the upstream, 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.



Two-Zone, Plume Interception, In Situ Treatment Strategy

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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HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.

(High-Energy Electron Beam Irradiation)

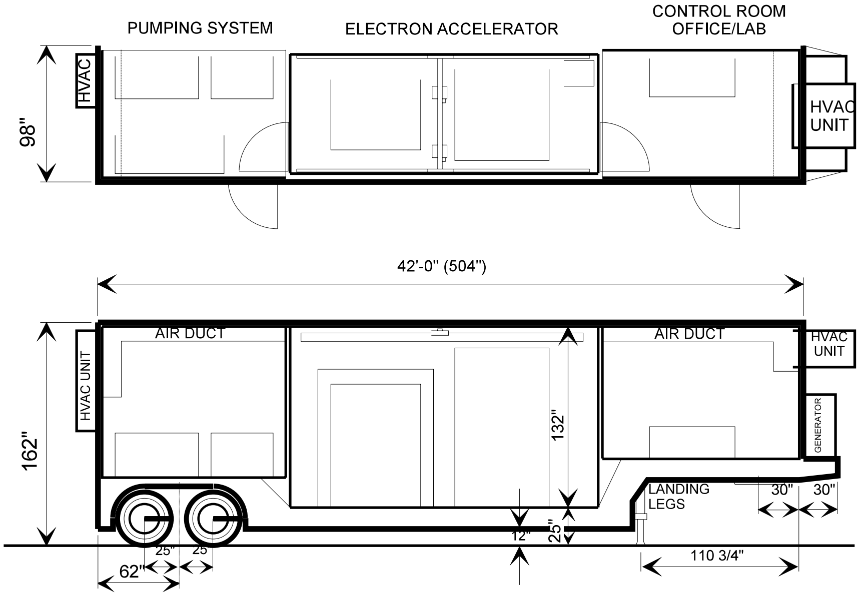
TECHNOLOGY DESCRIPTION:

The high-energy electron beam irradiation technology is a low-temperature method for destroying complex mixtures of hazardous organic chemicals in hazardous wastes. These wastes include slurried soils, river or harbor sediments, and sludges. The technology can also treat contaminated soils and groundwater.

The figure below illustrates the mobile electron beam treatment system. The system consists of a computer-automated, portable electron beam accelerator and a delivery system. The 500-kilovolt electron accelerator produces a continuously variable beam current from 0 to 40 milliamperes. At full power, the system is rated at 20 kilowatts. The waste feed rate and beam current can be varied to obtain doses of up to 2,000 kilorads in a one-pass, flow-through mode.

The system is trailer-mounted and is completely self-contained, including a 100-kilowatt generator for remote locations or line connectors where power is available. The system requires only a mixing tank to slurry the treatable solids. The system also includes all necessary safety checks.

The computerized control system continuously monitors the waste feed rate, absorbed dose, accelerator potential, beam current, and all safety shutdown features. The feed rate is monitored with a calibrated flow valve. The absorbed dose is estimated based on the difference in the temperature of the waste stream before and after irradiation. The system is equipped with monitoring devices that measure the waste stream temperature before and after irradiation. Both the accelerating potential and the beam current



Mobile Electron Beam Treatment System

are obtained directly from the transformer. Except for slurrying, this technology does not require any pretreatment of wastes.

WASTE APPLICABILITY:

This technology treats a variety of organic compounds, including wood-treating chemicals, pesticides, insecticides, petroleum residues, and polychlorinated biphenyls (PCB) in slurried soils, sediments, and sludges.

STATUS:

High Voltage Environmental Applications, Inc. (HVEA), was accepted into the SITE Emerging Technology Program in 1993. Under this program, HVEA will demonstrate its mobile pilot plant on soils, sediments, or sludges at various hazardous waste sites. Candidate sites are being identified. On-site studies will last up to 2 months.

Initial studies by HVEA have shown that electron beam irradiation effectively removes 2,4,6-trinitrotoluene from soil slurries.

As part of the Emerging Technology Program, HVEA has identified 350 tons of soil contaminated with an average Aroclor 1260 concentration of about 1,000 milligrams per kilogram. A small 1-ton feasibility study was conducted in August 1995. After results are available from the 1-ton study, HVEA plans to make its mobile unit available for full-scale remediations.

In a recent bench-scale study, a multisource hazardous waste leachate containing 1 percent dense nonaqueous phase liquid was successfully treated. In another bench-scale study, a leachate containing a light nonaqueous phase liquid contaminated with PCBs was treated to F039 standards.

FOR FURTHER INFORMATION:

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