IT CORPORATION

(Batch Steam Distillation and Metal Extraction)

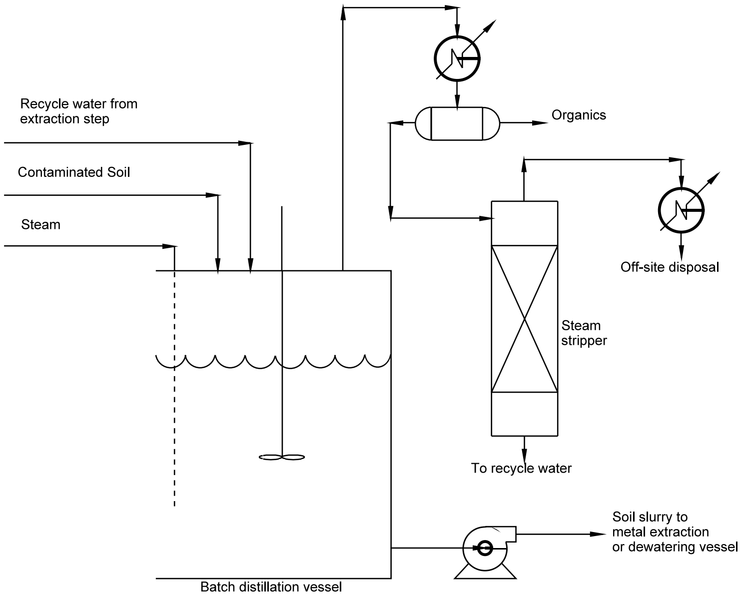
TECHNOLOGY DESCRIPTION:

The batch steam distillation and metal extraction treatment process is a two-stage system that treats soils contaminated with organics and inorganics. This system uses conventional, readily available process equipment and does not produce hazardous combustion products. Hazardous materials are separated from soils as concentrates, which can then be disposed of or recycled. The treated soil can be returned to the site.

During treatment, waste soil is slurried in water and heated to 100°C. This heat vaporizes volatile organic compounds (VOC) and produces an amount of steam equal to 5 to 10 percent of the slurry volume. Resulting vapors are condensed and decanted to separate organic contaminants from the aqueous phase. Condensed water from this step can be recycled through the system after soluble organics are removed. The soil is then transferred as a slurry to the metal extraction step.

In the metal extraction step, the soil slurry is washed with hydrochloric acid. Subsequent countercurrent batch washing with water removes residual acid from the soil. The solids are then separated from the final wash solution by gravimetric sedimentation. Most heavy metals are converted to chloride salts in this step. The acid extract stream is then routed to a batch steam distillation system, where excess hydrochloric acid is recovered (see figure below). Bottoms from the still, which contain heavy metals, are precipitated as hydroxide salts and drawn off as a sludge for off-site disposal or recovery.

As a batch process, this treatment technology is targeted at sites with less than 5,000 tons of soil requiring treatment. Processing time depends on equipment size and batch cycle times; about one batch of soil can be treated every 4 hours.



Batch Steam Distillation Step

WASTE APPLICABILITY:

This process may be applied to soils and sludges contaminated with organics, inorganics, and heavy metals.

STATUS:

The batch steam distillation and metal extraction process was accepted into the SITE Emerging Technology Program in January 1988. The evaluation was completed in 1992. The Emerging Technology Bulletin (EPA/540/F-95/509), which details results from the test, is available from EPA.

Under the program, three pilot-scale tests have been completed on three soils, for a total of nine tests. The removal rates for benzene, toluene, ethylbenzene, and xylene were greater than 99 percent. The removal rates for chlorinated solvents ranged from 97 percent to 99 percent. One acid extraction and two water washes resulted in a 95 percent removal rate for heavy metals. Toxicity characteristic leaching procedure tests on the treated soils showed that soils from eight of the nine tests met leachate criteria. Data were also collected on the recovery rate for excess acid and the removal rate for precipitation of heavy metals into a concentrate.

Estimated treatment costs per ton, including capital recovery, for the two treatment steps are as follows:

Batch Steam Distillation	
500-ton site	$299-393/ton
2,500-ton site	$266-350/ton
Metals Extraction (including acid recovery)	
500-ton site	$447-619/ton
2,500-ton site	$396-545/ton

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IT CORPORATION

(Chelation/Electrodeposition of Toxic Metals from Soils)

TECHNOLOGY DESCRIPTION:

IT Corporation has conducted laboratory-scale research on an innovative process that removes heavy metals from contaminated soils and sludges by forming a soluble chelate. The metals and the chelating agent are then separated from the soils and recovered.

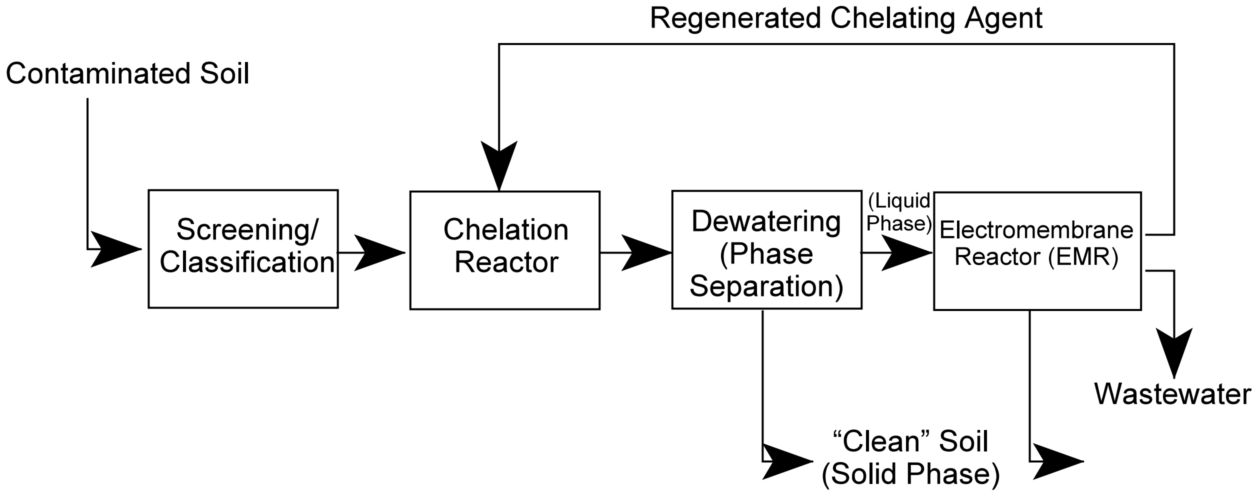
The treatment employs two key steps (see figure below): (1) a water-soluble chelating agent, such as ethylenediamine tetraacetic acid, bonds with heavy metals and forms a chelate; and (2) an electromembrane reactor (EMR) recovers the heavy metals from the chelate and regenerates the chelating agent.

Soils are screened before the chelation step to remove large particles such as wood, metal scrap, and large rocks.

The chelated soil is dewatered to separate the water-soluble chelating agent from the solid phase. The separated chelating agent, which contains heavy metals, is then treated in the EMR. The EMR consists of an electrolytic cell with a cation transfer membrane separating the cathode and anode chambers.

WASTE APPLICABILITY:

The technology is applicable to a wide variety of metal-contaminated hazardous wastes, including soils and sludges. To date, IT Corporation has demonstrated the technology's effectiveness in removing lead and cadmium from soils and sludges.



Simplified Process Flow Diagram of Treatment Process

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1994. The Jack's Creek site, located near Maitland, Pennsylvania, was selected as a site for technology evaluation. The site operated as a precious and nonprecious metal smelting and nonferrous metal recycling operation from 1958 to 1977. A portion of the property is currently operated as a scrap yard. Lead concentrations in the contaminated soil used for the evaluation was approximately 2 percent. Toxicity characteristic leaching procedure (TCLP) analysis on the contaminated soil showed lead levels of 7.7 milligrams per liter (mg/L), which exceeds the regulatory limit of 5 mg/L. During the project, IT Corporation established appropriate conditions for lead removal and recovery from the soil and reduced TCLP concentrations of lead in the soil to below regulatory levels.

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IT CORPORATION

(Mixed Waste Treatment Process)

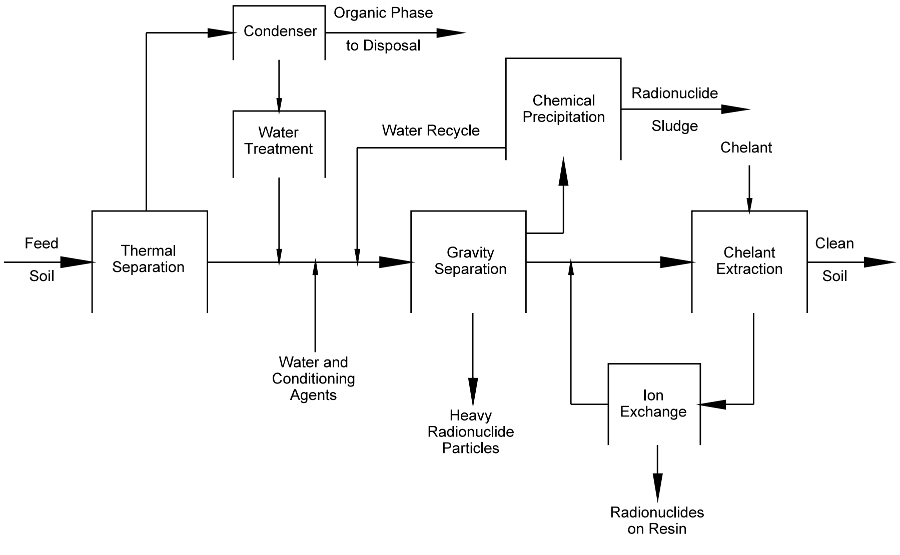
TECHNOLOGY DESCRIPTION:

IT Corporation's mixed waste treatment process integrates thermal desorption, gravity separation, water treatment, and chelant extraction technologies to treat soils contaminated with hazardous and radioactive constituents. The process separates these contaminants into distinct organic and inorganic phases that can then be further minimized, recycled, or destroyed at commercial disposal facilities. The decontaminated soil can be returned to the site. Each technology has been individually demonstrated on selected contaminated materials. The process flow diagram below shows how the technologies have been integrated to treat mixed waste streams.

During the initial treatment step, feed soil is prepared using standard techniques, such as screening, crushing, and grinding to remove oversized material and provide a consistent feed material.

Thermal treatment removes volatile and semi-volatile organics from the soil. Soil is indirectly heated in a rotating chamber, volatilizing the organic contaminants and any moisture in the soil. The soil passes through the chamber and is collected as a dry solid. The volatilized organics and water are condensed into separate liquid phases. The organic phase is decanted and removed for disposal. The contaminated aqueous phase is passed through activated carbon, which removes soluble organics before combining with the thermally treated soil.

Inorganic contaminants are removed by three physical and chemical separation techniques: (1) gravity separation of high density particles; (2) chemical precipitation of soluble metals; and (3) chelant extraction of chemically bound metals.



Mixed Waste Treatment Process

Gravity separation is used to separate higher density particles from common soil. Radionuclide contaminants are typically found inthis fraction. The gravity separation device (shaker table, jig, cone, or spiral) depends on contaminant distribution and the physical properties of the thermally treated soil.

Many radionuclides and other heavy metals are dissolved or suspended in the aqueous separation media. These contaminants are separated from the soils and are precipitated. A potassium ferrate formulation precipitates radionuclides. The resulting microcrystalline precipitant is removed, allowing the aqueous stream to be recycled.

Some insoluble radionuclides remain with the soil following the gravity separation process. These radionuclides are removed by chelant extraction. The chelant solution then passes through an ion-exchange resin to remove the radionuclides and is recycled to the chelant extraction step.

The contaminants are collected as concentrates from all waste process streams for recovery or off-site disposal at commercial hazardous waste or radiological waste facilities. The decontaminated soil can be returned to the site as clean fill.

WASTE APPLICABILITY:

This process treats soils contaminated with organic, inorganic, and radioactive material.

STATUS:

The mixed waste treatment process was selected for the SITE Emerging Technology Program in October 1991. Bench- and pilot-scale testing was completed in late 1995; a report detailing evaluation results was made available from EPA in 1997. Individual components of the treatment process have been demonstrated on various wastes from the U. S. Department of Energy,(DOE), the U.S. Department of Defense, and commercial sites. Thermal separation has removed and recovered polychlorinated biphenyls from soils contaminated with uranium and technetium. These soils were obtained from two separate DOE gaseous diffusion plants.

Gravity separation of radionuclides has been demonstrated at pilot scale on Johnston Atoll in the Pacific. Gravity separation successfully removed plutonium from native coral soils.

Water treatment using the potassium ferrate formulations has been demonstrated at several DOE facilities in laboratory and full-scale tests. This treatment approach reduced cadmium, copper, lead, nickel, plutonium, silver, uranium, and zinc to dischargeable levels.

Chelant extraction has successfully treated surface contamination in the nuclear industry for more than 20 years. Similar results are expected for subsurface contamination.

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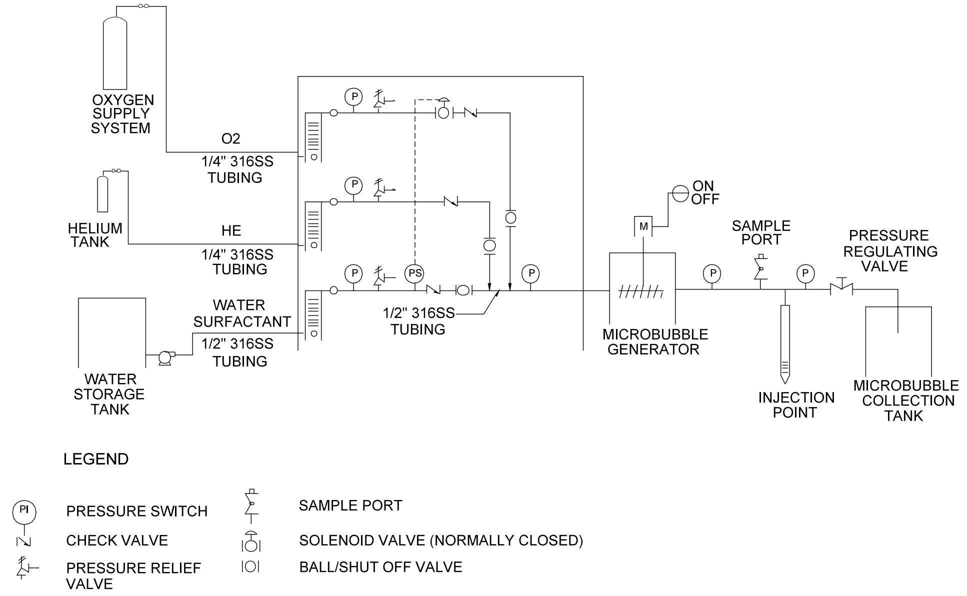
IT CORPORATION

(formerly OHM Remediation Services Corporation)
(Oxygen Microbubble In Situ Bioremediation)

TECHNOLOGY DESCRIPTION:

The application of in situ microbial degradation of petroleum hydrocarbons (PHC) has become a common and widespread practice. The most common factor limiting the rate of in situ biodegradation of PHCs is the amount of oxygen available in the saturated and unsaturated zones. Therefore, OHM Remediation Services Corporation (OHM) has focused on developing techniques for delivering oxygen to the subsurface to enhance in situ microbial degradation of PHCs. OHM has extensive experience with oxygen delivery techniques such as bioventing and biosparging to enhance microbial degradation. Injection of oxygen microbubbles is being investigated by OHM as an oxygen delivery system for the in situ biodegradation of PHCs in the unsaturated and saturated zones. OHM has conducted laboratory tests and field demonstrations of the oxygen microbubble technology in conjunction with the U.S. EPA and the U.S. Armstrong Laboratories .Oxygen microbubble technology (see figure below) uses a continuously generated stream of oxygen and water solution containing low concentrations of a surfactant. A water stream containing about 200 milligrams per liter of surfactant is mixed with oxygen under pressure. The resulting oxygen and water mixture is pumped through a microbubble generator that produces a zone of high-energy mixing. The result is a 60 to 80 percent by volume dispersion of bubbles, with a typical bubble diameter ranging from 50 to 100 microns. The microbubble dispersion is then pumped through an injection well into the treatment zone. The microbubbles deliver oxygen to contaminated groundwater, providing an oxygen source for aerobic biodegradation of the contaminant by the indigenous microflora.



Oxygen Microbubble In Situ Bioremediation

WASTE APPLICABILITY:

The process has successfully treated groundwater contaminated with a number of organic compounds including volatile organic compounds, semivolatile organic compounds, and petroleum hydrocarbons.

STATUS:

The Oxygen Microbubble In Situ Bioremediation process was accepted into the Emerging Technology Program in summer 1992. This process is being evaluated at a jet fuel spill site at Tyndall Air Force Base in Panama City, Florida.

The overall objective of this project is to evaluate the in situ application of the oxygen microbubble technology for bioremedation. The goals are to determine subsurface oxygen transfer to the groundwater, retention of the microbubble in the soil matrix, and biodegradation of the petroleum hydrocarbons present in the soil and groundwater.

A pilot test was performed at the site in 1995. The objective of the test was to determine the rate at which generated microbubbles could be injected into the surficial aquifer at the site. In addition, changes in the microbubbles and the aquifer during injection were monitored. Specific parameters monitored included the following:

- Microbubble quality, quantity, and stability
- Microbubble injection rate and pressure
- Lateral migration rates of microbubbles
- Lateral extent of migration of surfactant in the aquifer
- Lateral changes in dissolved oxygen concentration in the aquifer
- Rate of migration of tracer gas (helium) in the vadose zone
- Oxygen in the vadose zone

The pilot test verified that microbubbles can be injected into a shallow aquifer consisting of unconsolidated, fine-grained sediments. The study also verified that aquifer characteristics allowed the injection of the microbubble foam at rates of at least 1 gallon per minute. Continued injection of foam after about 45 minutes resulted in coalescence of the foam based on pressure measurements. The microbubble foam was observed to persist in the aquifer for long periods of time. This testing supported the use of oxygen microbubbles as an oxygen delivery system for in situ bioremediation.

The next testing phase at the site began in fall 1996. During this test, multiple injection points were used to determine the maximum rate of foam injection while maintaining foam stability. Oxygen was used as the gas for microbubble production. The rentention of oxygen microbubbles was compared to sparged air to determine oxygen delivery efficiency.

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IT CORPORATION

(Photolytic and Biological Soil Detoxification)

TECHNOLOGY DESCRIPTION:

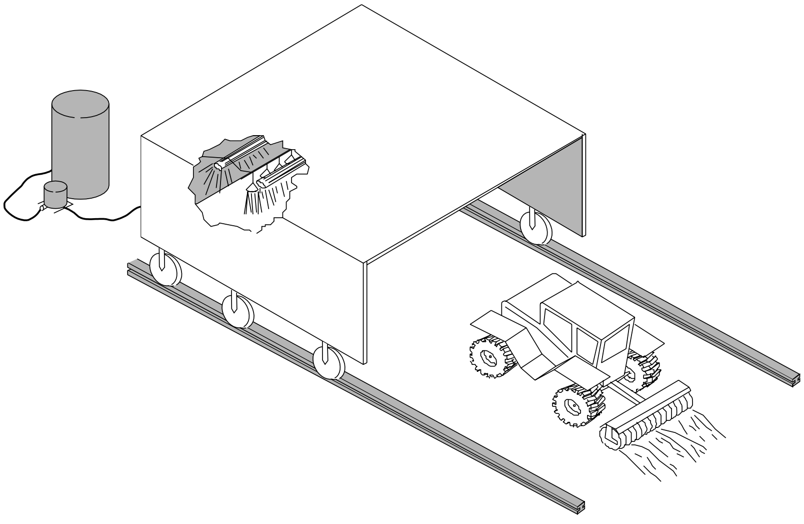
This technology is a two-stage, in situ photolytic and biological detoxification process for shallow soil contamination. The first step in the process degrades the organic contaminants with ultraviolet (UV) radiation. The photolytic degradation rate is several times faster with artificial UV light than with natural sunlight. The degradation process is enhanced by adding detergent-like chemicals (surfactants) to mobilize the contaminants. Photolysis of the contaminants converts them to more easily degraded compounds. Periodic sampling and analysis determines when photolysis is complete. Biodegradation, the second step, further destroys organic contaminants and detoxifies the soil.

When sunlight is used to treat shallow soil contamination, the soil is first tilled with a power tiller and sprayed with surfactant. The soil is tilled frequently to expose new surfaces and sprayed often. Water may also be added to maintain soil moisture.

When UV lights are used, parabolic reflectors suspended over the soil increase the amount of UV irradiation (see figure below). After photolysis is complete, biodegradation is enhanced by adding microorganisms and nutrients and further tilling the soil.

When these techniques are applied to soils with deep contamination, soil needs to be excavated and treated in a specially constructed shallow treatment basin that meets Resource Conservation and Recovery Act requirements. When soil contamination is shallow, photolysis and housing prevent contaminants from migrating to groundwater.

The only treatment residuals are soil contaminated with surfactants and the end metabolites of the biodegradation processes. The end metabolites depend on the original contaminants. The surfactants are common materials used in agricultural formulations. Therefore, the soils can be left on site.



Photolytic Degradation Process Using UV Lights

WASTE APPLICABILITY:

This photolytic and biological soil detoxification process destroys organics, particularly dioxins such as tetrachlorodibenzo-p-dioxin (TCDD), polychlorinated biphenyls (PCB), other polychlorinated aromatics, and polynuclear aromatic hydrocarbons.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1989; the evaluation was completed in 1992. The Emerging Technology Report (PB95-159992) is available for purchase from the National Technical Information Services. The Emerging Technology Bulletin (EPA/540/F-94/502) and Emerging Technology Summary (EPA/540/SR-94/531) are available from EPA.

Bench-scale tests conducted on dioxin-contaminated soil showed that the effectiveness of surface irradiation to degrade TCDDs or PCBs is strongly influenced by soil type. Early tests on sandy soils showed greater than 90 percent removals for both TCDDs and PCBs. Using a 450-watt mercury lamp, the irradiation time was more than 20 hours for greater than 90 percent destruction of TCDD and more than 4 hours for greater than 90 percent destruction of PCBs. However, a high humic content decreased the effectiveness of the UV photolysis. Soil contaminated with PCBs in the bench-scale tests had a high clay content. The highest removal rate for these soils was 30 percent, measured over a 16-hour irradiation time.

The bench-scale tests used a medium-pressure mercury UV lamp; sunlight was ineffective. No significant improvement in PCB destruction was achieved using a pulsed UV lamp.

The process was also tested with Fenton's reagent chemistry as an alternate method of degrading PCBs to more easily biodegraded compounds. PCB destruction ranged from nondetectable to 35 percent. Data indicates that no significant change in PCB chlorine level distribution occurred during treatment.

Other studies examined PCB biodegradability in (1) soil treated with a surfactant and UV radiation, (2) untreated soil, and (3) soil known to have PCB-degrading organisms. Study results were as follows:

- PCB removal in the UV-treated soil, untreated soil, and soil with known biological activity was higher when augmented with an isolated PCB degrader (microorganism).
- In the untreated soil, biphenyl was more efficient at inducing PCB degradation than 4-bromobiphenyl.
- For the treated soil, surfactant treatment may have inhibited microbial activity due to high total organic carbon and low pH.

Isolation and enrichment techniques have made it possible to isolate microorganisms capable of biodegrading PCBs in contaminated soil.

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IT CORPORATION

(Tekno Associates Bioslurry Reactor)

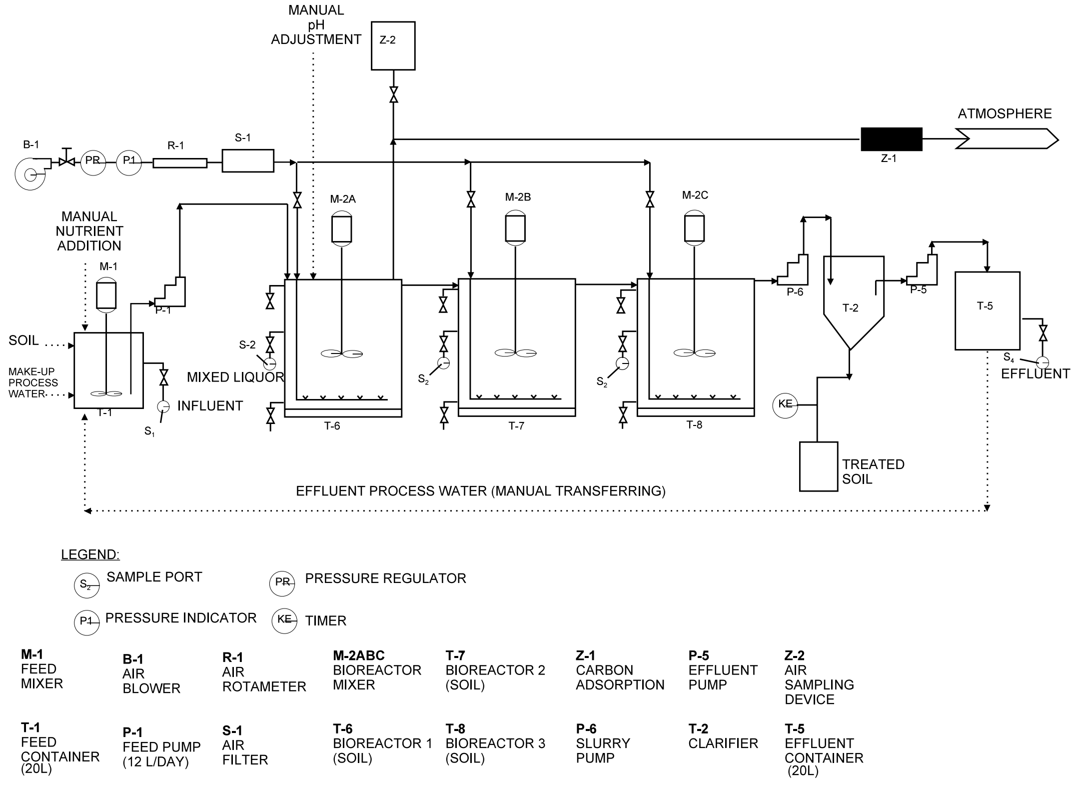
TECHNOLOGY DESCRIPTION:

IT Corporation (IT) has used the Bioslurry Reactor (developed by Tekno Associates, Salt Lake City, Utah) to treat polynuclear aromatic hydrocarbons (PAH) in soil. Traditional biological treatments, such as landfarming and in situ bioremediation, may not reduce PAHs in soil to target levels in a timely manner. Slurry reactors are more efficient for bioremediation and more economical than thermal desorption and incineration.

During the project, IT operated one 10-liter and two 60-liter bioslurry reactors (see figure below) in semicontinuous, plug-flow mode. The first 60-liter reactor received fresh feed daily and supplements of salicylate and succinate. alicylate induces the naphthalene degradation operon on PAH plasmids in the microorganisms. This system has been shown to degrade phenanthrene and anthracene. The naphthalene pathway may also play a role in carcinogenic PAH (CPAH) metabolism. Succinate is a by-product of naphthalene metabolism and serves as a general carbon source.

The first 60-liter reactor removed easily degradable carbon and increased biological activity against more recalcitrant PAHs (three-ring compounds and higher).

Effluent from the first reactor overflowed to the second 60-liter reactor in series, where Fenton's reagent (hydrogen peroxide and iron salts) was added to accelerate oxidation for four- to six-ring PAHs. Fenton's reagent produces a free radical that can oxidize multi-ring aromatic hydrocarbons.



Tekno Associates Bioslurry Reactor System

The T-8 reactor (third in a series) was used as a polishing reactor to remove any partially oxidized contaminants remaining after the Fenton's reagent treatment. Slurry was removed from this reactor and clarified using gravity settling techniques.

Operation of the reactors as described increased the rate and extent of PAH biodegradation, making bioslurry treatment of impacted soils and sludges a more effective and economical remediation option.

WASTE APPLICABILITY:

This technology is applicable to PAH-contaminated soils and sludges that can be readily excavated for slurry reactor treatment. Soils from coal gasification sites, wood-treating facilities, petrochemical facilities, and coke plants are typically contaminated with PAHs.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1993. Under this program, IT conducted a pilot-scale investigation of the three slurry reactors operating in series. A suitable soil for the pilot-scale test was obtained from a wood-treating facility in the southeastern U.S. About 4,000 pounds of PAH-impacted soil was screened and treated during summer 1994. CPAH and PAH removals were demonstrated at 84 and 95 percent, respectively. A final report is available from EPA.

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KSE, INC.

(Adsorption-Integrated-Reaction Process)

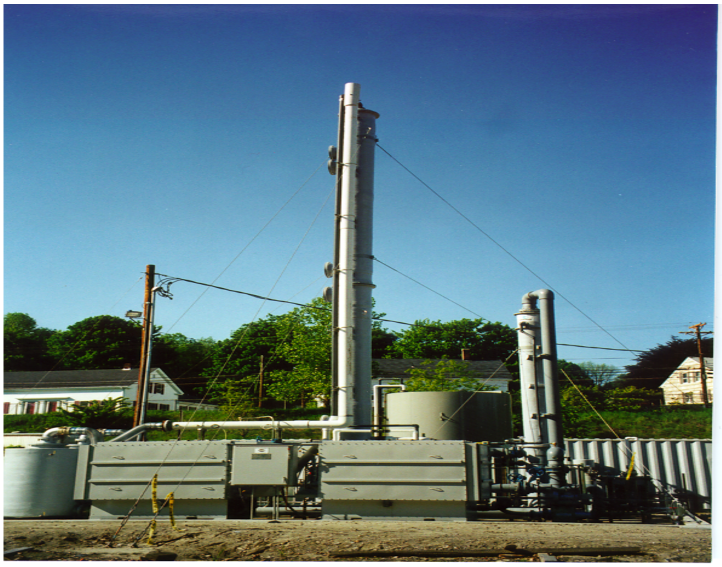
TECHNOLOGY DESCRIPTION:

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

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

The treated effluent air contains carbon dioxide and water, which are carried out in the air stream exiting the reactor. For chlorinated VOCs, the chlorine atoms are converted to hydrogen chloride with some chlorine gas. If needed, these gases can be removed from the air stream with conventional scrubbers and adsorbents. The AIR 2000 process offers advantages over other photocatalytic technologies because of the high activity, stability, and selectivity of the photocatalyst. The photocatalyst, which is not primarily titanium dioxide, contains a number of different semiconductors, which allows for rapid and economical treatment of VOCs in air. Previous results indicate that the photocatalyst is highly resistant to deactivation, even after thousands of hours of operation in the field.

The particulate-based photocatalyst allows for more freedom in reactor design and more economical scale-up than reactors with a catalyst film coated on a support medium. Packed beds, radial flow reactors, and monolithic reactors are all feasible reactor designs. Because the catalytic adsorbent is continuously regenerated, it does not require disposal or removal for regeneration, as traditional carbon adsorption typically does. The AIR 2000 process produces no residual wastes or by-products needing further treatment or disposal as hazardous waste. The treatment system is



AIR2000

self-contained and mobile, requires a small amount of space, and requires less energy than thermal incineration or catalytic oxidation. In addition, it has lower total system costs than these traditional technologies, and can be constructed of fiberglass reinforced plastic (FRP) due to the low operating temperatures.

WASTE APPLICABILITY:

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

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

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

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

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

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

DEMONSTRATION RESULTS:

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

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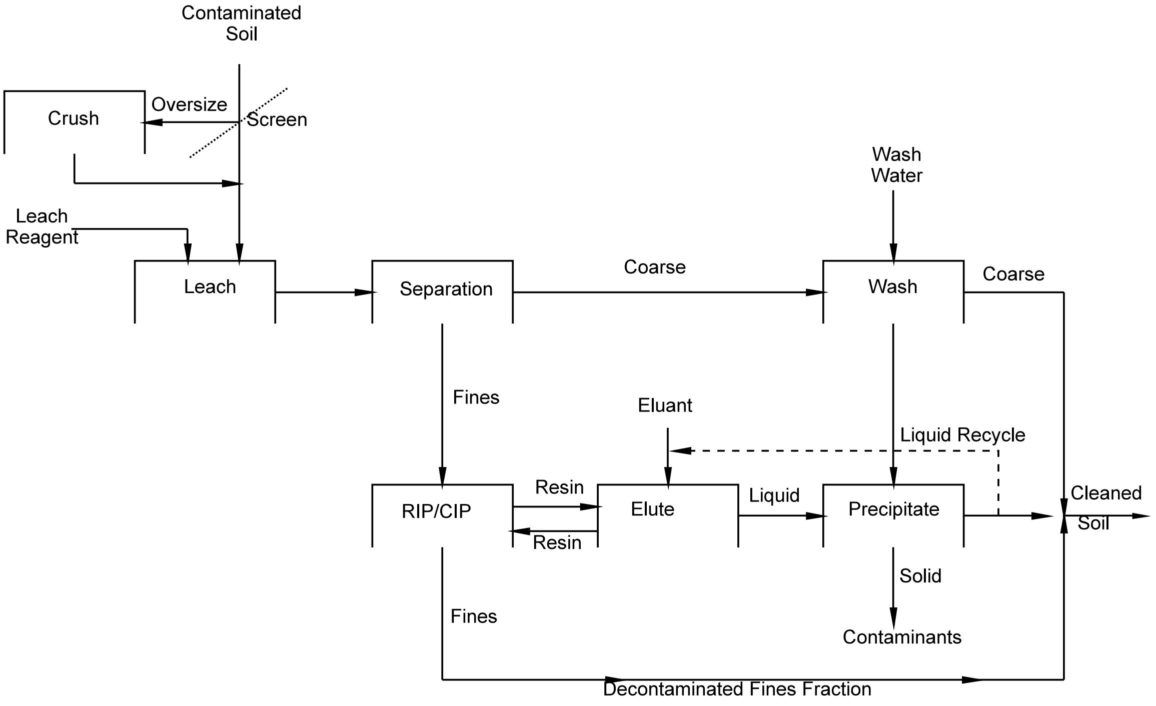
KVAERNER ENERGY & ENVIRONMENT
(formerly Davy International Environmental Division)
(Chemical Treatment)

TECHNOLOGY DESCRIPTION:

This treatment employs resin-in-pulp (RIP) or carbon-in-pulp (CIP) technologies to treat soils, sediments, dredgings, and solid residues contaminated with organic and inorganic material. These technologies are based on resin ion exchange and resin or carbon adsorption of contaminants from a leached soil-slurry mixture.

RIP and CIP processes are used on a commercial scale to recover metals from ores. The RIP process recovers uranium and uses anion exchange resins to adsorb uranium ions leached from ore. The CIP process recovers precious metals. In this process, activated carbon adsorbs gold and silver leached as cyanide complexes. The figure below illustrates a typical process for metals and other inorganically contaminated soils. Incoming material is screened, and over-sized material is crushed. The two fractions are then combined and leached in an agitated tank, where the contaminants are extracted. The leached solids are then passed to cyclones that separate coarse and fine material. The coarse material is washed free of contaminants, and the wash liquors containing the contaminants are passed to the contaminant recovery section. The leached fine fraction passes to the RIP or CIP contactor, where ion-exchange resins or activated carbon remove the contaminants. The difficult fines washing step is thereby eliminated.



Chemical Treatment Process

The resins and carbons are eluted and recycled in the extraction step, and the concentrated contaminants in the effluent pass to the recovery section. In the recovery section, precipitation recovers contaminants from the wash and eluate solutions. The precipitation yields a concentrated solid material and can be disposed of or treated to recover metals or other materials. The liquid effluent from the recovery section can be recycled to the process.

For organically contaminated feeds, the in-pulp or slurry process treats the whole leached solid. Organic contaminants eluted from the resin or carbon must be treated appropriately by a separate technology.

Both the RIP and CIP commercial scale processes operate in multistage, continuous, countercurrent contactors arranged horizontally.

WASTE APPLICABILITY:

This chemical treatment technology treats soils and other materials contaminated with inorganic and organic wastes. Inorganics include heavy metals such as copper, chromium, zinc, mercury, and arsenic. Treatment of materials containing organics such as chlorinated solvents, pesticides, and polychlorinated biphenyls requires appropriate extractant reagents and sorbent materials.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1991. Laboratory studies have been underway since January 1991. Bench-scale tests have successfully met targets for removal of several heavy metal contaminants.

Arsenic and mercury have proven more difficult to remove; however, laboratory tests have reduced arsenic to below 30 milligrams per kilogram (mg/kg) in soil and mercury to 0.5 mg/kg in soil in the major fraction of the soil. Due to the lack of demand for this technology in the European Market, Davy has decided to withdraw from the SITE Program.

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MATRIX PHOTOCATALYTIC INC.
(Photocatalytic Air Treatment)

TECHNOLOGY DESCRIPTION:

Matrix Photocatalytic Inc. is developing a titanium dioxide (TiO_2) 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_2 catalyst bed activated by ultraviolet (UV) light. Typically, organic contaminants are destroyed in fractions of a second.

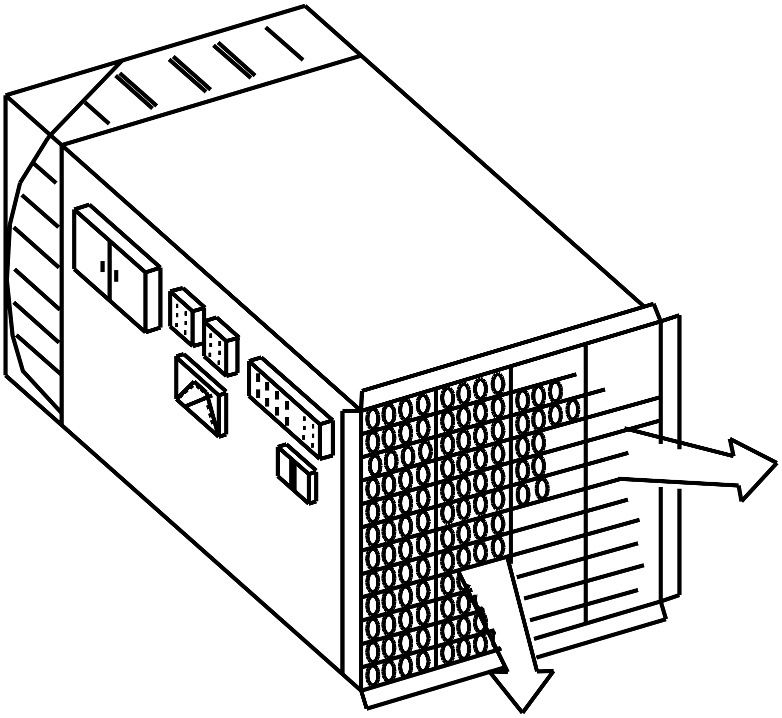
Technology advantages include the following:

- 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_2 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, stack gas treatment, soil venting, and manufacturing



Full-Scale Photocatalytic Air Treatment System 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_2 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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MATRIX PHOTOCATALYTIC INC.

(Photocatalytic Aqueous Phase Organic Destruction)

TECHNOLOGY DESCRIPTION:

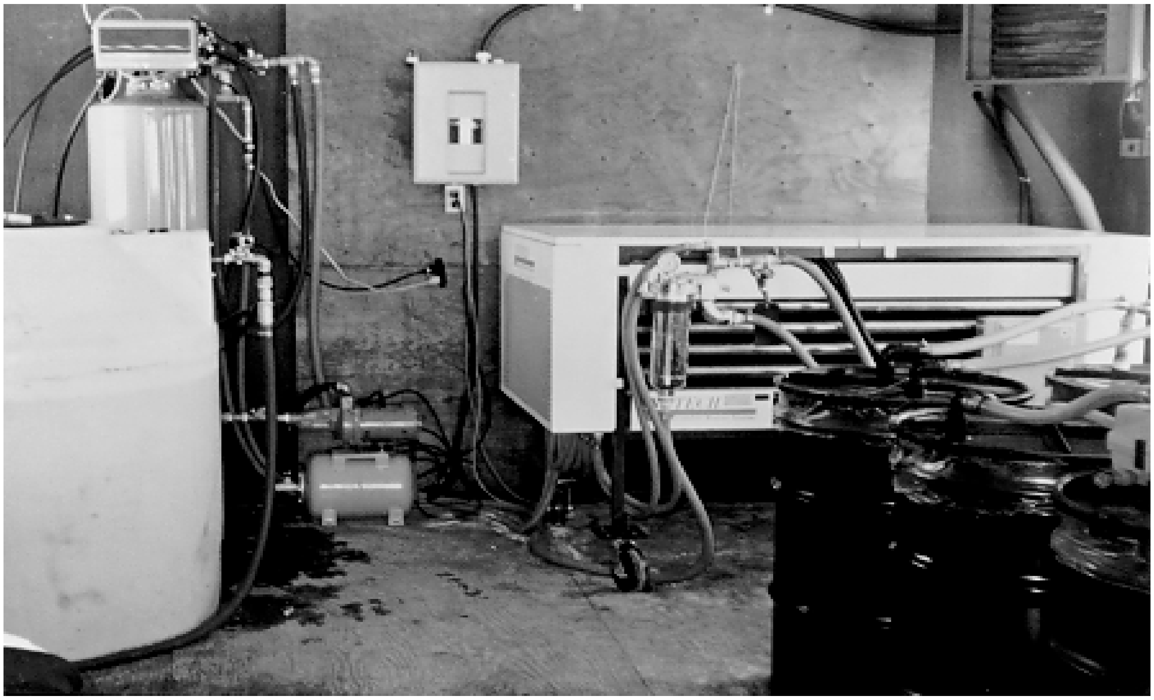
The Matrix Photocatalytic Inc. (Matrix) photocatalytic oxidation system, shown in the photograph below, removes dissolved organic contaminants from water and destroys them in a continuous flow process at ambient temperatures. When excited by light, the titanium dioxide (TiO_2) semiconductor catalyst generates hydroxyl radicals that oxidatively break the carbon bonds of hazardous organic compounds.

The Matrix system converts organics such as polychlorinated biphenyls (PCB); phenols; benzene, toluene, ethylbenzene, and xylene (BTEX); and others to carbon dioxide, halides, and water. Efficient destruction typically occurs between 30 seconds and 2 minutes actual exposure time. Total organic carbon removal takes longer, depending on the other organic molecules and their molecular weights.

The Matrix system was initially designed to destroy organic pollutants or to remove total organic carbon from drinking water, groundwater, and plant process water. The Matrix system also destroys organic pollutants such as PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, chlorinated alkenes, chlorinated phenols, chlorinated benzenes, alcohols, ketones, aldehydes, and amines. Inorganic pollutants such as cyanide, sulphite, and nitrite ions can be oxidized to cyanate ion, sulphate ion, and nitrate ion, respectively.

WASTE APPLICABILITY:

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



10-Gallon-Per-Minute TiO_2 Photocatalytic System Treating BTEX in Water

STATUS:

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

During August and September 1995, the Matrix system was demonstrated at the K-25 site at the Department of Energy's Oak Ridge Reservation in Oak Ridge, Tennessee. Reports detailing the results from the demonstration are available from EPA.

DEMONSTRATION RESULTS:

Results from the demonstration are detailed below:

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

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MEDIA & PROCESS TECHNOLOGY

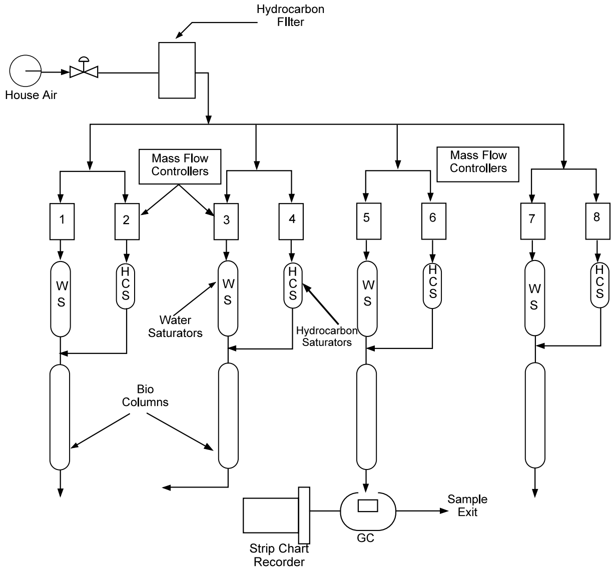
(formerly Aluminum Company of America and Alcoa Separation Technology, Inc.)

(Bioscrubber)

This bioscrubber technology digests hazardous organic emissions generated by soil, water, and air decontamination processes. The bioscrubber consists of a filter with an activated carbon medium that supports microbial growth. This unique medium, with increased microbial population and enhanced bioactivity, converts diluted organics into carbon dioxide, water, and other nonhazardous compounds. The filter removes biomass, supplies nutrients, and adds moisture. A pilot-scale unit with a 4-cubic-foot-per-minute capacity is being field-tested (see figure below).

In addition to efficient degradation, the bioscrubber provides an effective sink to mitigate feed fluctuations. During an 11-month bench-scale test, the bioscrubber consistently removed contaminants such as petroleum hydrocarbons, alcohols, ketones, and amines from the waste feed at levels ranging from less than 5 to 40 parts per million (ppm).

The bioscrubber provides several advantages over conventional activated carbon adsorbers. First, bioregeneration keeps the maximum adsorption capacity constantly available; thus, the mass transfer zone remains stationary and relatively short. The carbon does not require refrigeration, and the required bed length is greatly reduced, thereby reducing capital and operating expenses. Finally, the chromatographic effect (premature desorption) common in an adsorber is eliminated because the maximum capacity is available constantly. The bioscrubber's advantages are fully exploited when the off-gas contains weakly adsorbed contaminants, such as methylene chloride, or adsorbates competing with moisture in the stream. The bioscrubber may replace activated carbon in some applications.



Bioscrubber Pilot-Scale Unit

WASTE APPLICABILITY:

The bioscrubber technology removes organic contaminants in air streams from soil, water, or air decontamination processes. The technology is especially suited to treat streams containing aromatic solvents, such as benzene, toluene, and xylene, as well as alcohols, ketones, hydrocarbons, and others. The technology has several applications to Superfund sites, including (1) organic emission control for groundwater decontamination using air strippers, (2) emission control for biological treatment of ground and surface water, and (3) emission control for soil decontamination. These primary treatment processes have not been designed to prevent volatile organic compound discharges into the atmosphere. The bioscrubber is an ideal posttreatment component for these processes because it handles trace organic volatiles economically and effectively.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in July 1990. Bench-scale bioscrubbers operated continuously for more than 11 months to treat an air stream with trace concentrations of toluene at about 10 to 20 ppm. The bioscrubbers accomplished a removal efficiency of greater than 95 percent. The filter had a biodegradation efficiency 40 to 80 times greater than existing filters. The project was completed in June 1993. Based on results from the Emerging Technology Program, the bioscrubber technology was invited to participate in the SITE Demonstration Program.

Evaluation results have been published in the report "Bioscrubber for Removing Hazardous Organic Emissions from Soil, Water and Air Decontamination Processes" (EPA/540/R- 93/521). This report is available from the National Technical Information Service. The Emerging Technology Bulletin (EPA/540/F- 93/507) and the Emerging Technology Summary (EPA/540/SR-93/521) are available from EPA. An article on the technology was also published in the *Journal of Air and Waste Management*, Volume 44, March 1994, pp. 299-303.

The pilot-scale unit has also been tested on discharge from an air stripping tower at a flow rate of 2 standard cubic feet per minute. The discharge contained from less than 10 to 200 ppm toluene. The unit demonstrated the effectiveness, efficiency, and reliability of its design. Additional tests are underway to confirm results at higher flow rates and with other contaminants.

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MEMBRANE TECHNOLOGY AND RESEARCH, INC.

(VaporSep® Membrane Process)

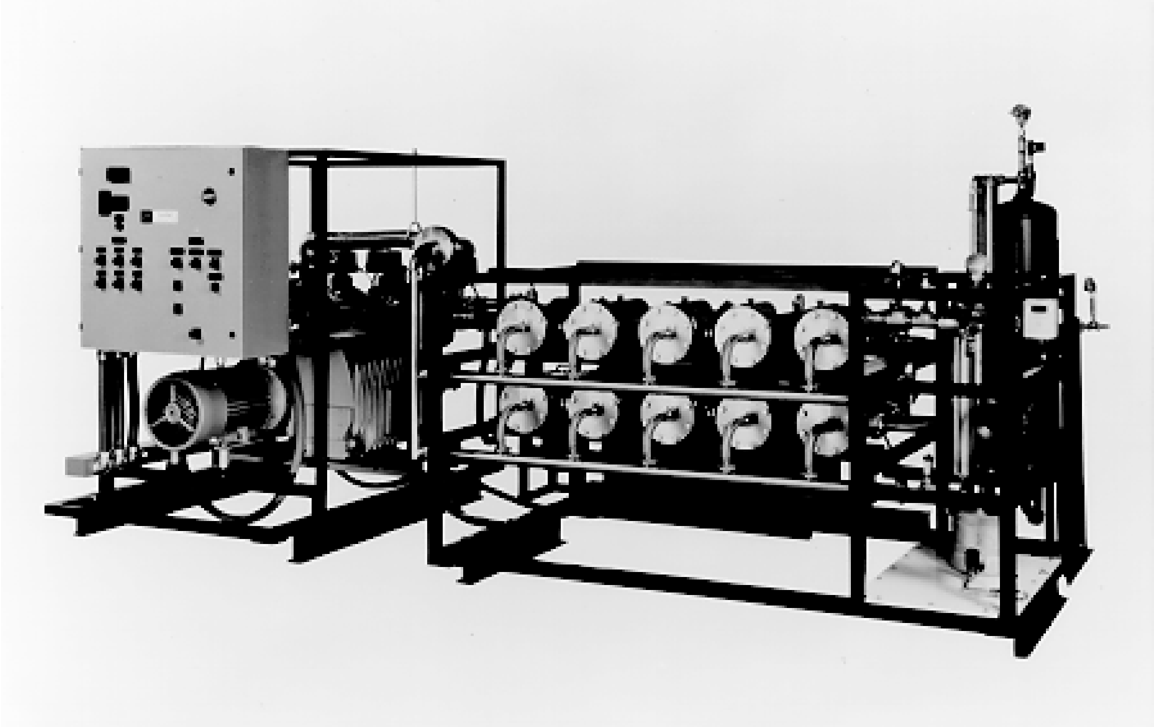
TECHNOLOGY DESCRIPTION:

The Membrane Technology and Research, Inc., VaporSep® system, shown in the figure below, uses synthetic polymer membranes to remove organic vapors from contaminated air streams. The process generates a clean air stream and a liquid organic stream.

Air laden with organic vapor contacts one side of a membrane that is 10 to 100 times more permeable to the organic compound than to air. The membrane separates the air into two streams: a permeate stream containing most of the organic vapor, and a clean residual air stream. The organic vapor is condensed and removed as a liquid; the purified air stream may be vented or recycled.

The VaporSep® system maintains a lower vapor pressure on the permeate side of the membrane to drive the permeation process. This pressure difference can be created by either compressing the feed stream or using a vacuum pump on the permeate stream.

The VaporSep® systems built to date range in capacity from 1 to 700 standard cubic feet per minute. The systems are significantly smaller than carbon adsorption systems of similar capacity and can be configured for a wide range of feed flow rates and compositions. The process has been tested on air streams contaminated with a wide range of organic compounds at concentrations of 100 to over 100,000 parts per million.



VaporSep® Membrane Organic Vapor Recovery System

The VaporSep® system removes between 90 and 99 percent of the organic vapor, depending on the class of organic compound and the system design. The system produces only a purified air stream and a small volume of organic condensate. The concentration of organics in the purified air stream is generally low enough for discharge to the atmosphere.

WASTE APPLICABILITY:

VaporSep® systems can treat most air streams containing flammable or nonflammable halogenated and nonhalogenated organic compounds, including chlorinated hydrocarbons, chlorofluorocarbons (CFC), and fuel hydrocarbons. Typical applications include the following:

- Reduction of process vent emissions, such as those regulated by EPA source performance standards for the synthetic organic chemical manufacturing industry.
- Treatment of air stripper exhaust before discharge to the atmosphere.
- Recovery of CFCs and hydrochlorofluorocarbons.
- Recovery of valuable organic feedstocks for recycling to the process.
- Recovery of gasoline vapors.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in 1989; the project was completed in 1991. The process, demonstrated at both the bench and pilot scales, achieved removal efficiencies of over 99.5 percent for selected organic compounds. The Emerging Technology Bulletin (EPA/540/ F-94/503) is available from EPA.

Almost 40 VaporSep® systems have been supplied to customers in the United States and overseas for applications such as the following:

- CFC and halocarbon recovery from process vents and transfer operations.
- CFC recovery from refrigeration systems.
- Vinyl chloride monomer recovery from polyvinyl chloride manufacturing operations.
- CFC-12/ethylene oxide recovery from sterilizer emissions.
- Recovery of monomers, other hydrocarbons, and nitrogen in polyolefin degassing processes.

A VaporSep® system successfully treated an air stream from a soil vacuum extraction operation at a U.S. Department of Energy site.

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METSO MINERALS INDUSTRIES, INC.
(formerly Svedala Industries, Inc.)
(PYROKILN THERMAL ENCAPSULATION Process)

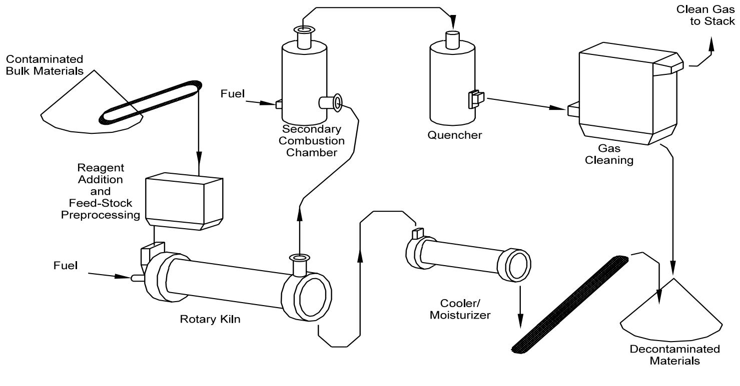
TECHNOLOGY DESCRIPTION:

The PYROKILN THERMAL ENCAPSULATION process is designed to improve conventional rotary kiln incineration of hazardous waste. The process introduces inorganic additives (fluxing agents) to the waste to promote incipient slagging or thermal encapsulating reactions near the kiln discharge. The thermal encapsulation is augmented using other additives in either the kiln or in the air pollution control (APC) baghouse to stabilize the metals in the fly ash. The process is designed to (1) immobilize the metals remaining in the kiln ash, (2) produce an easily handled nodular form of ash, and (3) stabilize metals in the fly ash, while avoiding the problems normally experienced with higher temperature "slagging kiln" operations.

The basis of this process is thermal encapsulation. Thermal encapsulation traps metals in a controlled melting process operating in the temperature range between slagging and nonslagging modes, producing ash nodules that are 0.25 to 0.75 inch in diameter.

The figure below illustrates the process. Wastes containing organic and metallic contaminants are incinerated in a rotary kiln. Metals (in particular, those with high melting points) are trapped in the bottom ash from the kiln through the use of fluxing agents that promote agglomeration with controlled nodulizing.

The PYROKILN THERMAL ENCAPSULATION process may reduce leaching of metals to levels below EPA Toxicity Characteristic Leaching Procedure (TCLP) limits for metals. Metals with low melting and vaporization temperatures, such as arsenic, lead, and zinc, are expected to partially volatilize, partitioning between the bottom ash and the fly ash. Metals concentrated in the fly ash may be stabilized, if necessary, by adding reagents to the kiln and to the APC system to reduce leaching to below TCLP limits. This process may also reduce the total dust load to the APC system and the amount of particulate emissions from the stack.



PYROKILN THERMAL ENCAPSULATION PROCESS

The use of fluxing reagents is a key element in this technology. The fluxing agents are introduced into the kiln in the proper amount and type to lower the ash's softening temperature. Proper kiln design is required to allow the kiln outlet to function as an ash agglomerator. Good temperature control is required to maintain the agglomerates at the correct particle size, yielding the desired 0.25- to 0.75-inch nodules. By producing nodules, rather than a molten slag, the process is expected to prevent operating problems such as ash quenching, overheating, and premature refractory failure. The process should also simplify cooling, handling, and conveyance of the ash.

The controlled nodulizing process should immobilize metals with high boiling points. Lead, zinc, and other metals with lower volatilization temperatures tend to exit the kiln as fine fumes. Reagents can be injected into the kiln, the APC devices, or a final solids mixer to aid in the collection of these metals from the gas stream.

WASTE APPLICABILITY:

The technology is intended for soils and sludges contaminated with organics and metals. As with other rotary kiln systems, the process is expected to destroy a broad range of organic species, including halogenated and nonhalogenated organics and petroleum products. Svedala Industries, Inc., claims that the following metals may be encapsulated or stabilized: antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, and zinc.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in March 1990. A final report has been prepared, and a technical paper summarizing the project was presented in 1994 at the Air and Waste Management Association 87th Annual Meeting and Exhibition in Cincinnati, Ohio. The final report was published in the July 1995 issue of the *Journal of the Air and Waste Management Association.*

A synthetic soil matrix was created for the batch rotary kiln tests. Feed preparation was a key element in nodule production. These tests yielded nodules with appropriate crush strength. Test results showed a decrease in TCLP metal leachate levels with increasing crush strength.

An analytical method involving microwave-aided digestion was used to evaluate samples produced in a second batch kiln test program. This method provided excellent, consistent results, indicating leachability below TCLP limits.

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MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

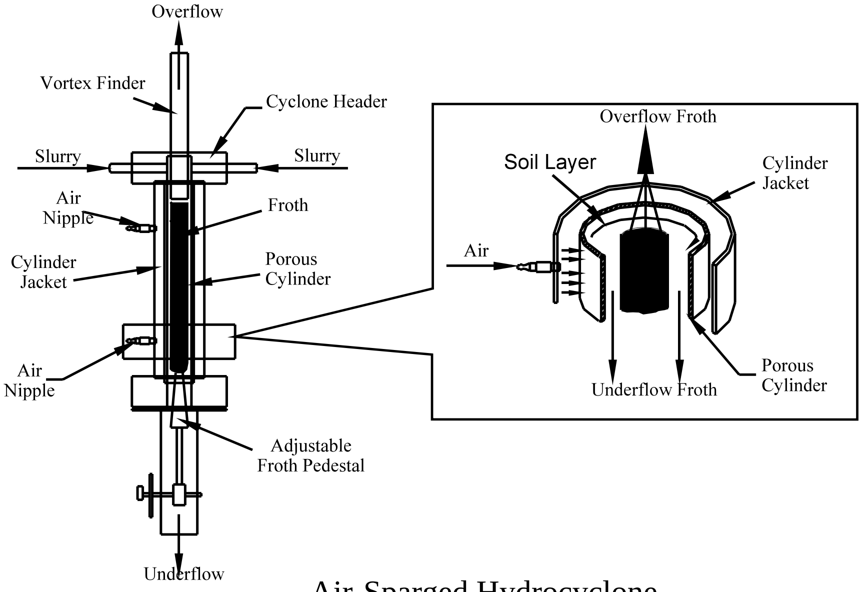
(Air-Sparged Hydrocyclone)

TECHNOLOGY DESCRIPTION:

The air-sparged hydrocyclone (ASH) was developed at the University of Utah during the early 1980s to achieve fast flotation of fine particles in a centrifugal field. The ASH consists of two concentric right-vertical tubes with a conventional cyclone header at the top and a froth pedestal at the bottom (see figure below). The inner tube is a porous tube through which air is sparged. The outer tube serves as an air jacket to evenly distribute air through the porous inner tube.

Slurry is fed tangentially through the conventional cyclone header to develop a swirl flow of a certain thickness in the radial direction (the swirl-layer thickness). The swirl is discharged through an annular opening between the porous tube wall and the froth pedestal. Air is sparged through the porous inner tube wall and is sheared into small bubbles. These bubbles are then radially transported, together with attached hydrophobic particles, into a froth phase that forms on the cyclone axis. The froth phase is stabilized and constrained by the froth pedestal at the underflow, moved toward the vortex finder of the cyclone header, and discharged as an overflow product. Water-wetted hydrophilic particles generally remain in the slurry phase and are discharged as an underflow product through the annulus created by the froth pedestal.

During the past decade, large mechanical flotation cells, such as aeration-stirred tank reactors, have been designed, installed, and operated for mineral processing. In addition, considerable effort has been made to develop column flotation technology in the United States and elsewhere; a number have been installed in industries. Nevertheless, for both mechanical and column cells, the specific flotation capacity is generally limited to 1 to 2 tons per day (tpd) per cubic foot of cell volume. In contrast, the ASH has a specific flotation capacity of at least 100 tpd per cubic foot of cell volume.



Air-Sparged Hydrocyclone

WASTE APPLICABILITY:

Conventional flotation techniques used in industrial mineral processing are effective ways of concentrating materials. However, metal value recovery is never complete. The valuable material escaping the milling process is frequently concentrated in the very fine particle fraction.

The ASH can remove fine mineral particles that are not normally amenable to the conventional froth flotation process. These particles are generally sulfide minerals, such as galena (lead sulfide), sphalerite (zinc sulfide) and chalcopyrite (copper- iron-sulfide). Finely divided mining wastes containing these minerals oxidize and release the metallic elements as dissolved sulfates into the groundwater. Particularly applicable are tailings from older operations conducted before the development of froth flotation. Earlier operations recovered minerals by gravity concentration, which did not effectively capture fine particles and left tailings with relatively large concentrations of the environmentally hazardous fine sulfide minerals.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in June 1990. The most recent pilot plant trials on tailings generated by gravity concentration have confirmed both the technology's ability to recover sulfide minerals and the high throughput capacity claimed by proponents of the ASH. However, results on the economics of ash processing were inconclusive. Studies under the SITE Program were completed in August 1994, and a journal article is pending. The pilot plant was dismantled after 4 years of operation.

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MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

(Campbell Centrifugal Jig)

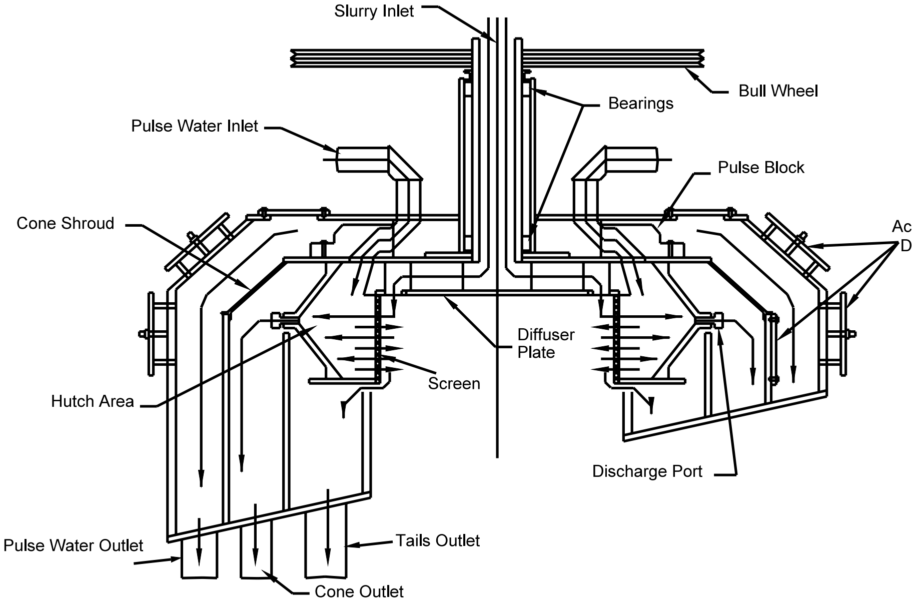
TECHNOLOGY DESCRIPTION:

The Campbell Centrifugal Jig (CCJ) is a mechanical device that uses centrifugal force to separate fine heavy mineral and metal particles from waste materials. The CCJ combines jigging and centrifuging to separate these particles from a fluid slurry. TransMar, Inc., owns the patents and rights to the CCJ technology.

Standard jigs separate solids of different specific gravities by differential settling in a pulsating bed and gravitational field. Jigs operating in this mode can recover solids larger than about 150 mesh (105 microns). Centrifuges are effective in separating solids from liquids but are not effective in separating solids from solids.

The CCJ, shown in the figure below, combines the continuous flow and pulsating bed of the standard jig with the enhanced acceleration forces of a centrifuge to segregate and concentrate heavy particles from the waste. The CCJ can recover particles ranging in size from 1 to about 500 microns, depending on whether the particles are sufficiently disaggregated from the host material. The disaggregated particle should have a specific gravity at least 50 percent greater than the waste material. The CCJ does not need chemicals to separate the solids.

Appropriately sized, slurried material is fed into the CCJ through a hollow shaft inlet at the top of the machine. The slurried material discharges from the shaft onto a diffuser plate, which has vanes that distribute the material radially to the jig bed. The jig bed's surface is composed of stainless-steel shot ragging that is slightly coarser than the screen aperture. The jig bed is pulsated by pressurized water admitted through a screen by four rotating pulse blocks. The pulsing water intermittently fluidizes the bed, causing heavier particles to move through the ragging and screen to the concentrate port, while lighter particles continue across the face of the jig bed to the tailings port.



Cambell Centrifugal Jig (CCJ)

The effectiveness of separation depends on how well the original solids are disaggregated from the waste material and the specific gravity of each solid. The slurried feed material may require grinding to ensure

disaggregation of the heavy metals. Operating parameters include pulse pressure, rotation speed or g-load, screen aperture, ragging type and size, weir height, and feed percent solids.

The CCJ produces heavy mineral or metal concentrates which, depending on the waste material, may be further processed for extraction or sale. A clean tailings stream may be returned to the environment.

WASTE APPLICABILITY:

The CCJ can separate and concentrate a wide variety of materials, ranging from base metals to fine coal ash and fine (1-micron) gold particles. Applications include (1) remediation of heavy metal-contaminated soils, tailings, or harbor areas containing spilled concentrates; (2) removal of pyritic sulfur and ash from fine coal; and (3) treatment of some sandblasting grit.

STATUS:

The CCJ was accepted into the SITE Emerging Technology Program in May 1992. The CCJ was evaluated at the Montana College of Mineral Science and Technology Research Center (Montana Tech). Montana Tech equipped a pilot plant to evaluate the Series 12 CCJ, which has a capacity of 1 to 3 tons per hour. Tests were completed in August 1994 on base-metal mine tailings from various locations in western Montana. A report on these tests is pending.

In addition, under the U.S. Department of Energy (DOE) Integrated Demonstration Program, the CCJ was tested on clean Nevada test site soil spiked with bismuth as a surrogate for plutonium oxide. These tests occurred at the University of Nevada, Reno, during August and September 1994. In the future, the CCJ will be tested for its ability to remove radioactive contamination from soils from several DOE sites.

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