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Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International

Atlanta, Georgia June 19-21, 1989

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FORUM ON INNOVATIVE HAZARDOUS WASTE TREATMENT TECHNOLOGIES: DOMESTIC AND INTERNATIONAL

Atlanta, Georgia, June 19 - 21, 1989

OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460
AND
RISK REDUCTION ENGINEERING LABORATORY
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

NOTICE

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The Forum programs and activities were planned by a committee consisting of the following members:

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The conference was coordinated by JACA Corp., Ft. Washington, PA 19034 under Contract No. 68-01-7481. The Project Officer was Thomas Pheiffer, Office of Program Management and Technology.

ABSTRACT

On June 19–21, 1989, the U.S. Environmental Protection Agency's Office of Program Management and Technology hosted an international conference in Atlanta, GA, to exchange solutions to hazardous waste treatment problems. This conference, the Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, was attended by approximately 530 representatives from the U.S. and seven foreign countries. During the conference, scientists and engineers representing government agencies, industry, and academia attended 30 presentations describing successful case studies of physical/chemical, biological, thermal, and stabilization treatment methods. In addition, domestic and international scientists and vendors presented over 40 posters explaining their treatment methods and results. This document contains abstracts of many of the presentations and posters from the conference.

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PHYSICAL/CHEMICAL TREATMENT METHODS

REMEDIATION AND TREATMENT OF RCRA HAZARDOUS WASTES BY FREEZE CRYSTALLIZATION

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Freeze crystallization is a general separation process used to remove pure components from solutions by crystallizing the materials to be removed. This process has been used for applications as diverse as organic chemical refining and fruit juice concentration, and is especially suited for treating hazardous wastes. This paper will illustrate how the process can be used in site remediation activities, including treated contaminated soils, where it can be used to recover valuable by-products from RCRA and other industrial waste streams, and the basis for its utility in mixed (hazardous and radioactive) wastes.

Freeze Technologies Corp. has built a mobile site remediation prototype commercial plant to demonstrate the field remediation aspects of this technology. The capacity of the units is nominally 10 gpm of ice production from a leachate or groundwater, at 90 percent water recovery. It is contained in two modules that are transported on standard low-boy trailers, and requires less than one week to set up.

Freeze crystallization has several advantages for remediation and waste recovery applications. It is a very efficient volume reduction process, producing a concentrate that has no additional chemicals added to it. If disposal in a hazardous waste landfill or incinerator destruction is required this will reduce these costs substantially. When a large fraction of the solvent (usually water) is removed from a waste, the remaining impurities often begin to crystallize as well. They are often sufficiently pure to have byproduct value for resale. Processing costs with freezing are generally low, ranging from $.03 to $.15 for 40 and 5 gpm plants, respectively.

PURIFICATION BY FROTH FLOTATION

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The purpose of this paper is to describe froth flotation and the guiding principles in the field of purification of contaminated soil and waste.

The Mosmans Method has been used for the decontamination of soil and waste in the Netherlands since 1983. This method is effected by well chosen mineral separation techniques which together result in a complete purification process. The most important, but also the most complex part of the Mosmans Method is the froth flotation technique.

To achieve a separation between the contaminants and soil in a soil-water mixture, the surfaces of the particles have to be adequately manipulated in such a way that the former will be hydrophobic and the latter hydrophybic. The manipulation is not related to changing the chemical structure of the particles, but to modifying the surfaces by selective adsorption. The hydrophobic particles glue themselves to air bubbles produced in the soil-water mixture.

SITE: EXTRACTION OF ORGANIC MATERIAL FROM SLUDGES, SOILS, AND LIQUIDS

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CF Systems Corporation manufactures solvent extraction equipment that is used to extract organics from liquids, sludges, and soils. The equipment is unique in that it uses a compressed gas or so-called critical fluid as the extracting solvent.

The company has three commercial units: one that is designed as a pretreatment for an incinerator; one that is a wastewater extraction unit owned by Clean Harbors, Inc. of Braintree, MA; and one that is a unit for the extraction of organics from sludges. The latter is in operation at the Texaco refinery in Port Arthur, TX.

The presentation dealt with a demonstration that CF Systems completed under the EPA's SITE Program at New Bedford Harbor in New Bedford, MA. The goal of the demonstration was to extract PCBs to an acceptable level from contaminated harbor bottom silts. The demonstration was an unqualified success and technical data and cost information were included in the presentation.

A video tape was prepared by the EPA concerning the demonstration and, in addition, a two-volume technical report was prepared by EPA's subcontractor, SAIC. Either one or both can be obtained by writing to: CF Systems Corporation, 140 Second Avenue, Waltham, MA 02154-1100, Attention: Mr. Thomas J. Cody, Jr., Vice President.

REVERSE OSMOSIS: ON-SITE TREATABILITY STUDY OF LANDFILL LEACHATE AT PAS SITE IN OSWEGO, NY

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Roy F. Weston, Inc.
Edison, NJ

Harry Whittaker
Environment Canada
Ottawa, Ontario, Canada

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U.S. EPA, ERT
Edison, NJ

In recent years, the development of new reverse osmosis (RO) membranes has opened the application of this technology to on-site treatment of hazardous wastes. Today's membranes offer better resistance to a wide pH range, higher treatment fluxes, and greater tolerance to organic solvents and oxidizing agents. Currently, RO is being explored as a waste volume reduction technique at hazardous waste sites. In a series of demonstrations at Canadian landfills, RO proved effective in concentrating not only inorganic species but volatile and semi-volatile organic compounds.

At the end of the summer of 1988, a study was undertaken to evaluate the capability of RO at the Pollution Abatement Services (PAS) site in Oswego, NY. The encapsulated site generates approximately 750,000 gal of leachate per year. This aqueous solution, contaminated with metals and solvents in the low parts per million level, is periodically collected and transported to an off-site treatment facility. The PAS study involved testing four different spiral-wound membrances in a single-stage RO system, under varying feed conditioning schemes.

Results showed that all test membranes rejected volatile organic compounds, semi-volatile organics, and metals with increasing levels of efficiency from one class of pollutants to another. Two contaminant characteristics which affected RO rejection were molecular size and polarity. In addition, membrane brand had a significant effect on performance. Results indicated that RO is a promising technology for on-site treatment of hazardous wastes.

ELECTRO-RECLAMATION IN THEORY AND PRACTICE

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During the last four years, Geokinetics has been developing a method to remove heavy metals and other contaminants from soil and groundwater.

The method is based on the electrokinetic phenomena of electro-osmosis, electrophoresis, and electrolysis, which occur when the soil is electrically charged by means of one or several electrode-arrays.

The most important applications of these phenomena with respect to the soil have been the dewatering of clays by electro-osmosis and experiments to desalinize arable lands (USA, 1958 and USSR, 1966–1975). Experiments on a very small scale to remove heavy metals from soils have been documented (UK, 1980, 1981, and 1982). Though promising, the author reported problems around the electrodes (precipitates).

Geokinetics has found a solution to these problems by developing an electrokinetic installation, which monitors and controls the chemical reaction environment around the electrodes. The core of such an installation consists of the electrode-series and their housings, which can be installed in principle at any depth, either horizontally or vertically. The housings are interconnected and form two separate (one for the cathode, one for the anode) circulation systems, filled with different chemical solutions. In these solutions the contaminants are captured and brought to a container-based water purification facility. The energy is supplied by a generating set or taken from the main.

Electro-reclamation can be applied both in situ (soils) and on- or off-site (excavated soil, scooped out river slush). The electrokinetic phenomena can also be used to fence off hazardous waste sites or potentially hazardous industrial sites.

The technique has been tested on the basis of numerous laboratory experiments, using different types of soil (clay, peat, argillaceous sand) and contaminants (As, Cd, Co, Cr, Cu, Hg, Ni, Mn, Mo, Pb, Sb, Zn). Two in situ field experiments (Cu, Pb, and Zn) have been finished and one in situ remediation project (As) has been successfully completed.

Reduction of individual heavy metal concentrations can be more than 90 percent, depending on the energy supply and time duration. Remediation costs are, therefore, directly related to these two factors. Costs range from less than $50 per ton, when relatively low energy is supplied over long periods (several months), to more than $400, when the time period is reduced to several weeks and the energy supply has to be increased accordingly. There is, however, a limit to the current strength which can be used. In practice, therefore, an optimum is calculated for energy supply and time duration.

PHYSICAL/CHEMICAL SOIL TREATMENT IN THE NETHERLANDS: A TECHNIQUE IN PROGRESS

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Dutch Association of Process-Based Soil Treatment Companies
The Netherlands

This technology is based on particle sizing and soil washing. After presieving (removal of parts > 4 to 8 mm) the main stream is intensively mixed with a process liquid. The aim of this mixing process is to disconnect the pollutants from the soil and transfer them into the water-phase. Next the cleaned soil fraction is separated from the polluted process liquid using separators or hydrocyclones (separation limit approximately 50 to 70 um). The waste water generated is treated in a water purification system. After the removal of residual fines (sedimentation), the water is treated by means of precipitation, neutralization, coagulation, and flocculation. Finally, the remaining organic substances are removed by active carbon filters.

The physical/chemical treatment process can be used to clean pollutated soil contaminated with:

- Mineral soils
- Heavy metals (Pb, Zn, Ni, Cr, As, Hg)
- Inorganic compounds (complex and free cyanides)
- Aromatic compounds (benzene, toluene)
- Polycyclic hydrocarbons
- Chlorinated hydrocarbons (PCBs)
- Pesticides, herbicides, and fungicides

Some treatment results:

	Input (ppm)	Output (ppm)
Complex cyanides	100 - 250	5 - 15
Polynuclear aromatics	100 - 150	15 - 20
Heavy metals	300	75 - 125

The operating costs of a physical/chemical treatment installation depend mainly on the quantity of fines/sludge (< 63 um), the addition of chemicals, and the type of the soil. The average costs vary between $60/ton and $90/ton. Disposal of contaminated fines range up to $125/ton.

VACUUM EXTRACTION TECHNOLOGY: SITE PROGRAM DEMONSTRATION AT GROVELAND WELLS SUPERFUND SITE

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Vacuum extraction is an in situ or ex situ treatment process for cleanup of soils and groundwater contaminated with volatile organic compounds (VOCs), liquid-phase hydrocarbons, or semi-volatile compounds. The process of removing VOCs from the vadose zone using vacuum extraction is a patented process. Demonstration of the Vacuum Extraction Technology was conducted under the EPA Superfund Innovative Technology Evaluation (SITE) Program at the Groveland Wells Superfund Site in Groveland, MA. The demonstration included an eight-week pilot test to remove VOCs (mostly TCE) from the underlying soil and groundwater.

The subsurface conditions included multi-layered glacial deposits consisting of sands, silty sands, and clays. Groundwater was 27 ft deep with a perched water table at about 10 ft. A multi-layered vacuum extraction and monitoring system was installed and operated in sub-zero weather in northern Massachusetts.

Objectives of the pilot program included testing of soils before, during, and after implementation of the vacuum extraction process. The effectiveness of the process was monitored by measuring subsurface vacuum, rates of flow, rates of VOC extraction, and adsorption on activated carbon. The system was designed to operate on the fringe of the contaminant plume and to quantify the level of cleanup that could be achieved by the process by using barrier wells to prevent the migration of contaminants from the primary source area into the demonstration area.

Results demonstrated the effectiveness of the vacuum extraction process to clean up contaminated soils. Data from the pilot test also demonstrated that the contaminant distributions were different than originally suspected from the Remedial Investigation (RI). In the area of the fringe of the contaminant plume, soil concentrations were reduced more than 95 percent to non-detectable levels. Accordingly, evaluation of the process dynamics and cleanup rates were adjusted to reflect the actual subsurface conditions. Additional data from subsequent cleanup work at the site is presented to further evaluate the demonstration program.

The objective of evaluating "How clean is clean?" is addressed with respect to the vacuum extraction process. Results from other sites where vacuum extraction has been applied are also presented. Results indicate that vacuum extraction technology is widely applicable for cleanup of soils and groundwater that are contaminated with VOCs.

IN SITU REMOVAL OF VOC FROM SOIL AND GROUNDWATER BY VAPOR EXTRACTION AND GROUNDWATER AERATION

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Data gained from more than a thousand cases in Europe confirm vapor extraction to be an efficient and cost-effective remedial technique for soils contaminated by volatile organic compounds (VOCs). Negative differential pressure is created in a vapor extraction well, generating a steady flow of soil gas towards the extraction well. This provides a flushing of the soil with air undersaturated in respect to the contaminant concentration. Contaminants will evaporate into the gaseous phase both from the liquid phase and from the soil.

Concentrations in the discharged air are high during an initial period of about 30 days. Subsequently, they stabilize at a relatively low level, eventually decreasing to background levels. The effective radius of a single vapor extraction well ranges typically from 20 ft to 150 ft under non-sealed surfaces and up to 300 ft under sealed surfaces.

As in any remedial action, efficient application is strongly dependent on a precise definition of the location and the extent of a contaminant source. Remediation by vapor extraction operates in situ, generates minimal amounts of waste due to the selective removal of volatile contaminants, and is not disruptive to ongoing production processes. Only a small space is required for the blower installation.

For the remediation of sufficiently permeable, contaminated aquifers, groundwater aeration in connection with vapor extraction can be applied as an alternative to or in combination with groundwater extraction. Oil-free air is injected into the aquifer at the bottom of the contamination, either continuously or in a pulsed manner. The air migrates upward along numerous pathways, taking up volatile contaminants from both the soil and the groundwater. Upon arrival in the unsaturated zone, the now contaminated air is drawn to a vertical vapor extraction well or a similar, horizontal installation. In coarse-grained sediments, groundwater aeration can be an alternative to pumping, thus avoiding the treatment of contaminated water.

IN SITU CADMIUM REMOVAL

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Due to the discharge of wastewater by a photo paper manufacturer, about 30,000 m^3 of soil was contaminated by cadmium.

TAUW Infra Consult developed an in situ remedial action technique under the direction of the government of the province of Utrecht. The in situ treatment method involves three aspects:

- Cd desorption of the contaminated soil
- Hydrological infiltration and withdrawal systems
- Purification of Cd–containing groundwater

The remedial action took place from June 1987 to October 1988. During the winter of 1987 to 88, temperatures dropped to −10° C, however no difficulties occurred because the water treatment plant was roofed and kept free of frost.

The desorption of cadmium from the soil was almost complete, with 90 percent of the soil samples containing Cd levels of < 1 ppm. Approximately 450 kg of Cd was recovered from the soil.

ULTROX® UV/OXIDATION OF ORGANIC CONTAMINANTS IN GROUND, WASTE, AND LEACHATE WATERS

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The removal of low levels of organic contaminants from groundwaters and industrial wastewaters presents a challenge to environmental professionals. Well–known and commonly used treatment processes such as granular activated carbon (GAC) and air–stripping transfer pollutants from one medium to another. With increasing public and regulatory concern over the final fate of pollutants, such transference technologies are not optimal.

Conventional chemical oxidation has been used in the treatment of various waters polluted by organic chemicals for a number of years. Potassium permanganate, chlorine, and chlorine dioxide have been used for treating organics such as phenol and its homologs in wastewaters. Hydrogen peroxide with a catalyst such as ferrous sulfate (Fenton's Reagent) has been used for oxidizing phenol and other benzene derivatives. Processes utilizing iron-catalyzed peroxides and chlorine compounds are attractive in that they utilize relatively low-cost treatment equipment. The disadvantages of these processes are that they can attack only a limited number of refractory organics. Ozone alone has been used to treat phenolic wastes, cyanides, and certain pesticides. Ozone treatment is a very clean process but is limited in the number of compounds which can be treated. These oxidation processes have been used and are continuing to be used in a number of situations.

The use of ultraviolet light catalyzed ozone plus hydrogen peroxide (UV/oxidation) as a water treatment technique is rapidly expanding. It offers a means of solving many of the problems created by the toxic water soluble chemicals that are found today in groundwater, wastewater, leachate, and drinking water supplies without many of the disadvantages of more conventional treatment techniques.

UV/oxidation, when used as a stand-alone treatment process, or in tandem with some of the above mentioned processes, can cost effectively destroy or render non-toxic the organic chemicals found on the EPA's priority pollutant list.

This paper describes the experience of Ultrox International in developing and applying the ULTROX UV/oxidation process to the full-scale treatment of organic chemicals in wastewaters, drinking waters, leachates, and groundwaters. The oxidants used in these applications are ozone and hydrogen peroxide. Ultrox International was issued a process patent in 1988 covering the application of UV light, ozone, and hydrogen peroxide to the treatment of a broad range of organic compounds in water. The process can successfully treat chlorinated solvents (such as TCE and vinyl chloride), BTX compounds, pesticides, PCBs, and explosives in water.

IN SITU STEAM/AIR STRIPPING

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This paper reports on work in progress on the use and development of a new in situ soil treatment technology. The technology treats soil by injecting steam and hot air into soil below the ground surface while vigorous mixing occurs using two 5-ft-diameter drills. Volatile organic compound (VOC) hydrocarbons are evaporated to the surface, captured in a containment vessel, and condensed for subsequent disposal. This technology is currently being applied to a chlorinated hydrocarbon contaminated site in California.

The test results to date have shown removal efficiencies from 96 to 99 percent VOC using EPA 8240 analytical methodology. Silty soils containing a broad mixture of VOC (up to 15 compounds) had their soil concentration reduced well below the target of 100 ppm (e.g., starting range 824 to 1,872 ppm, and after treatment range of 7 to 55 ppm). The results in moist clay soils containing tetrachloroethylene obtained similar efficiencies, 96 to 98 percent, but were not as successful in absolute removal (e.g., starting range of 2,305 to 5,838 ppm, and after treatment range of 53 to 203 ppm).

The process also removed significant quantities of semi-volatile compounds (SVCs) as listed in the EPA 8270 protocol. About 85 percent of the SVCs found on the site are phthalate esters of various aliphatic radicals (e.g., ethyl hexal). We believe that the phthalate esters hydrolyize to a phthalic acid salt and alcohol. The phthalate acid radical binds tightly to the clays and the alcohol appears to mostly dehydrate to olefins. The soil chemical analysis and recovered fluid chemical analysis support these ideas. SVC-like isophrone and phenol are quantitatively removed by distillation or vaporization.

The mass balance of recovered and remaining VOC is close to the starting calculated mass. The field chemical monitoring and the lab chemical data show little or no escape of VOC to the surroundings, either below the surface or to the atmosphere. We believe that for the volatile materials the process is quite effective in quickly remediating the soil. The treatment rates average about 6 to 8 yds/h. The process appears effective for some semi-volatile compounds, but the mechanism for this must clearly be evaluated on a compound-by-compound basis.

THE SIMPLEST WAY TO CLEAN CONTAMINATED WATER

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Great Falls, VA

Ralf F. Piepho Abwassertechnik GmbH has been in the waste water treatment business in Europe for over 10 years. The Corporation has developed a chemical-physical process for the treatment of contaminated water and has sold this treatment process to thousands of firms all over the world. The Piepho technology is well suited to deal with many of the remediation problems faced in the U.S. The Piepho system can be used not only to treat contaminated surface water or ground water, it can also clean contaminated soil in conjunction with a soil washing or soil flushing process. The system has three main advantages in the remediation market:

- Its cost – relatively inexpensive when compared with other methods of treatment.
- Easily transportable – can be installed or removed in less than a full day.
- Most important, the company has developed a reaction/ separation agent which removes the contaminants from the waste water, and at the same time it encapsulates these contaminants in a sludge that is resistant to leaching. In Germany, this has allowed the corporation to dispose of most of the concentrated waste on normal landfills, thus saving considerable expense.

BIOLOGICAL TREATMENT METHODS

REGIONAL BIOLOGICAL DECONTAMINATION CENTERS FOR THE CLEAN-UP OF CONTAMINATED SOIL, SLUDGES, AND INDUSTRIAL WASTE WATERS

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Due to a lack of landfill capacity, biological treatment of contaminated soils is becoming more and more important in West Germany. The Biodetox Company has developed and successfully applied various in situ and on-site technologies for the biological decontamination of mineral oil and related pollutants, light aromatics, and PAH.

An interesting technology which has found large attention lately is the Biodetox Bio-Pit Process. The polluted soil is excavated and brought to treatment pits specifically built for this purpose under government surveillance. Microbes and nutrients are added to the contaminated soil via a foamborne pre-inocculation and by regular distribution through a specially devised spraying system. Biodegradation takes place in the soil itself and in a submerged fixed-film bioreactor, assisted by specially selected and adapted naturally-occurring microorganisms. The dissolved soil pollutants are pumped into the bioreactor after having been washed out by the trickling water. The spraying system is also used to prevent the stripping of volatile pollutants.

With this proven process, more than 50,000 m^3 of contaminated soil were treated successfully, reaching the decontamination levels required by law within 6 to 12 weeks (average diesel fuel contamination before treatment: 30,000 ppm, after treatment: 500 ppm). The bio-process was approved by the German federal and state authorities. It is widely accepted by the public and does not present any hazard to the environment.

The Biodetox Company is presently building up a franchise network of regional biological decontamination centers where this specific technology is being applied. Presently, three biological decontamination centers are operating and seven are under construction in close cooperation with the regulatory authorities.

Regional biological decontamination centers are economically feasible with primary investment costs between $500,000 and $1.5 million. Very competitive treatment rates and consistently high quality performance nationwide are being ensured by the Biodetox franchise system.

BIOLOGICAL REMEDIATION OF CONTAMINATED GROUNDWATER AND SOIL – CONCEPTS OF REMEDIATION AND THEIR TECHNICAL APPLICATION

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In this paper different ways to develop biological processes for the remediation of contaminated soil and groundwater are discussed. With dichloromethane as an example, it is shown how elimination processes can be developed which are designed for a specific organic pollutant and specific bacteria. The fixed-bed reactor process presented here is able to achieve decomposition of dichloromethane from groundwaters of 4.2 kg/m^3 x d. These results could be maintained for more than six months. As in many contaminated sites, bacteria adapted to the organic pollutants already exist. The example of contamination with complex organic compounds will be used to show the activation of the microflora from the site to degrade the organic compounds and its technical application in remediation as another way to develop processes. From these investigations a concept of action was developed which permits statements about the possibility of biological remediation of a contaminated site and the processes which can be used, even with relatively few experiments. This concept facilitated the application of biological processes to different organic pollutants in all cases examined until now.

THE HOLZMANN SYSTEM OF IN SITU SOIL PURIFICATION

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Frankfurt, West Germany

In West Germany numerous sites of former gasworks and coking plants are contaminated with tar oils, polycyclic aromatic carbons, and cyanides.

On a former gaswork site in Bremen, a new method of in situ soil washing has been applied for the first time. The new method can be used economically under space limitations for high degrees of contamination, high contents of silt, and low permeabilities of the natural ground. The obtainable degrees of purification are very high.

The purification system with mobile plant components, using a high-pressure injection technique for the first purification step within an impermeable casing lowered into the ground, allows for simultaneous removal of organic and inorganic as well as soluble and insoluble pollutants down to great depths. No lowering of the groundwater table is necessary; the groundwater within the contaminated soil volume is also purified. Borings are brought down one by one, finally forming a pattern of overlapping borings with complete treatment of the contaminated soil.

The mixture of soil components, water, and pollutants produced by the high-pressure injection is pumped from the borehole and treated in a separator unit. The purified soil is returned to the open borehole after an exchange of contaminated against clean water. The original permeability of the ground is restored.

Water passing the separator unit is treated consequently to gain potable water suitable as process water and for re-infiltration through injection wells.

Sludge as a side-product of the purification process is treated microbiologically in composting piles.

SLURRY PHASE BIOLOGICAL TREATMENT OF HAZARDOUS WASTE

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This process involves the biological treatment of sludges and soils in a slurry form within a high energy environment. The process is referred to as Liquid/Solids Contact (LSC), and is carried out in a series of sequenced batch reactors on organic slurries containing less than 20 percent solids.

Remediation Technologies Inc. has a patent on the system and has completed a broad variety of bench- and pilot-scale studies as well as full-scale remediations. Examples of materials which have been tested include:

- Refinery sludges including API Separator Sludge, DAF Float, and wastewater lagoon sludges which contain aromatic and polynuclear aromatic hydrocarbons (PAH).
- Wood preserving sludges containing pentachlorophenol and PAH compounds.
- Petrochemical sludges containing halogenated aromatics and PAH compounds.

- Soils contaminated with a variety of petroleum and coal tar derived compounds.

The system has been used at over 10 sites for the closure of RCRA impoundments. The process is adapted for use in both tanks and impoundments. In the primary biostabilization step, volatiles are completely removed with residence times less than three days. Air emissions can be controlled by treating the off gas in a scrubber. Additional biostabilization steps are carried out for the degradation of recalcitrant compounds if needed. Over 90 percent destruction of PAH compounds has been achieved with residence times less than 30 days. The actual degradation rate is waste- and matrix-specific but in general, petroleum refining sludges are the most rapidly degraded of the substances tested.

The LSC process is an extention of conventional (aerobic) biological wastewater treatment technology. It offers the following advantages:

- It is applicable to a wide variety of contaminated soils and sludges.
- The process can be used in situ (e.g., in sludge impoundments) or in engineered containment systems.
- The reaction rates are 3 to 10 times faster than observed in the land treatment of similar materials.
- It provides for destruction of toxic chemicals at significantly lower costs than incineration or thermal treatment.

THERMAL TREATMENT METHODS

SITE: SHIRCO INFRARED INCINERATION

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The electric infrared incineration technology is a mobile thermal processing system which uses electrically powered silicon carbide rods to bring the organic waste to combustion temperatures and then, to incinerate any remaining combustibles in an afterburner. The mobile system is comprised of four components: the electric-powered infrared primary chamber, a gas-fired secondary combustion chamber, an emission control system, and a process management and monitoring control center.

Waste is fed into the primary chamber on a wire mesh conveyor belt and exposed (at temperatures of up to 1,850° F) to infrared radiant heat provided by the horizontal rows of electrically-powered silicon carbide rods above the belt. A blower provides air at selected locations along the belt and can be used to control the burning rate of the waste feed and its location while burning on the belt.

The ash material which drops off the belt in the primary chamber is quenched by water sprays utilizing scrubber effluent. The ash is held until the PCB content is determined to be less than 1 ppm.

Gaseous volatiles from the primary chamber are destroyed in the fired secondary chamber. Gases are ducted through the emissions control system, which consists of a venturi scrubber for particulate matter and a packed tower to neutralize acid vapor. An induced draft blower draws the cleaned gases from the scrubber into the free standing exhaust stack.

The scrubber liquid effluent then flows into a clarifier where scrubber sludge settles out for disposal. Finally, the scrubber effluent flows to an effluent tank, through an activated carbon filter for reuse, or to a POTW tank for disposal.

This technology is suitable for organic wastes contained in soils or sediments. Liquid organic wastes can also be handled once they are mixed with sand or soil.

Demonstration of the electric furnace was carried out at full-scale at an oil refinery site near Tampa, FL, from August 1 to 4, 1987. As part of the removal operation by EPA Region IV, a nominal 100-per-day Shirco Infrared System was set up at the site. The site was contaminated with nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. During the demonstration, the SITE Program evaluated the system for reliability of PCB destruction and to determine if the solubility of lead compounds could be reduced. A second demonstration of the system, at pilot-scale, took place at the Rose Township Dump Site in Michigan, from November 2 to 11, 1987. Organics, PCBs, and metals in soil were the target waste compounds to be destroyed or immobilized. The pilot-scale operation allowed the evaluation of several different operating conditions. Results of the two tests were similar:

- In both tests, at standard operating conditions, PCBs were reduced to less than 1 ppm in the ash with a DRE greater than 99.99 percent (based on detection limits).
- In the full-scale demonstration, the air pollution control system did not reduce particulate emissions to the regulatory level and several adjustments were needed to bring it into compliance with regulations.
- Lead was not immobilized; however, it remained in the ash and was not transferred to the scrubber water or emitted to the atmosphere.
- The pilot-scale unit demonstrated that blending fuel oil with the feed reduced the primary chamber temperature and thus lowered energy costs without decreasing performance.
- The unit requires a feed having a diameter of one inch or less, and care must be exercised in design and construction of material handling systems prior to feeding the material to the unit.

SEVEN YEARS' EXPERIENCE IN THERMAL SOIL TREATMENT

R.C. Reintjes and C. Schuler
Ecotechniek
Utrecht, The Netherlands

Ecotechniek, a Dutch company for environmental works, has used a thermal decontamination process for contaminated soil since 1981. Two plants are in full operation in the Netherlands and one is under construction in Germany.

The plants are based on a two-step process. In the first step the soil is heated to the temperature required to evaporate water and polluting substances (up to 350° C). The poisonous gases which develop are separated from the soil and destroyed in the second step, the incinerator. The heat developed in the incinerator in turn is used in the first step. Following treatment, the cleaned soil is cooled, moisturized with water, and fully re-used in sites.

The plants can process contaminated soil at a maximum rate of 50 tons/hour. At the present time, over 600,000 tons of soil have been decontaminated by this process.

CONTAMINATED SOIL REMEDIATION BY CIRCULATING BED COMBUSTION

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The Circulating Bed Combustor (CBC) is an advanced generation of incinerator that utilizes high velocity air to entrain circulating solids in a highly turbulent combustion loop. Because of its high thermal efficiency, the CBC is ideally suited to treat organic wastes with low heat content, including contaminated soil. This paper discussed the development of CBC contaminated soil treatment technology and its application to site remediation. The CBC process, pilot plant, and transportable field equipment units were described. In March of 1989, a Superfund Innovative Technology Evaluation (SITE) demonstration test burn of McColl Superfund Site soil was conducted in Ogden Environmental Services' (OES) Circulating Bed Combustion research facility. The results of the successful test were presented. The paper also reviewed the on-going site remediation activities in Alaska and California using OES designed, fabricated, and deployed transportable CBC units.

RESIDUES FROM HIGH-TEMPERATURE ROTARY KILNS AND THEIR LEACHABILITY

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W&E Umwelttechnik AG
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The characteristics of the residues generated by the combustion of hazardous waste obviously vary depending on where in the plant they were obtained. Since the largest portion of all residues are obtained in the form of slags, it is of great interest whether the composition of the slags allows for normal land disposal or recycling.Tests were carried out in cooperation with AVR-Chemie and our U.S. licensee, Combustion Engineering, in September 1988 in AVR Chemie's hazardous waste incineration plant at Rijnmond in the Netherlands. During all tests, the plant was operated under normal operating conditions and did not deviate from the usual, commercial operations.The leachability tests were carried out using the following three methods:

- Toxicity Test (EPA SW 846, Method 1310)
- Toxicity Characteristics Leaching Procedure (TCLP)
- Total Extractable Metals

The consideration of all tests revealed that 90 percent of the solids' input volume is discharged in the form of slags, whereas only 10 percent verge into other output flows.

The leachability tests according to the TCLP Method show that all values fall short of the threshold limits by at least a factor of 100.

The TCLP tests carried out on the slag samples obtained from a high temperature rotary kiln incineration system show that the leachability of heavy metals of this slag is considerably lower than the theshold limits for landfill disposal that are in force in the U.S. The fact that all these results were achieved with regular residues and under normal commercial plant operation conditions indicates that there is a probability that this slag may be delisted.

RECYCLING OF CONTAMINATED RIVER AND LAKE SEDIMENTS DEMONSTRATED BY THE EXAMPLE OF NECKAR SLUDGE

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The Neckar is 370–km–long tributary of the Rhine, its confluence with the same being not far downstream from Heidelberg. The river was made navigable over a length of 202 km during the decades following World War II (i.e., weirs with locks were constructed at 20–km intervals along the river to regulate the water–level). Primarily finegrained, suspended, and sedimentary materials are deposited in the storage ponds and necessitate river dredging.

The purposes of the dredging are:

- To keep the navigation lane open
- To maintain the required river cross–section for flood control
- To maintain water quality

The dredged material has become contaminated by heavy metals due to the expansion of industry in the area, cadmium being the prime contaminant. The sometimes high cadmium contamination precludes the use of the dredged materials for agricultural purposes. It was therefore initially proposed that the dredged sludge be dried and dumped at waste disposal sites. Since sites for waste disposal are rare and expensive to put into operation in the Federal Republic, economic means of recycling had to be sought.

Toward this end one of the largest civil engineering contractors in the FRG, Ed. Zublin AG of Stuttgart, has developed a process whereby dredged material is converted into spherical, porous, lightweight aggregate for the production of masonry blocks and lightweight concrete.

Ed Zublin AG has been awarded a contract to construct and operate a plant for the thermal treatment of 500,000 m^3 of sludge dredged out of the Neckar over a period of 10 years. In order to enable the thermal procedure involving temperatures of up to 1,150° C to be successfully put into service in an environment-friendly manner, a new concept for outlet-gas treatment had to be developed and tested.

SITE: OXYGEN ENHANCEMENT OF HAZARDOUS WASTE INCINERATION WITH THE PYRETRON THERMAL DESTRUCTION SYSTEM

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A SITE Program demonstration of the PYRETRON Thermal Destruction System (TDS) was conducted at the EPA's Combustion Research Facility (CRF). The PYRETRON TDS, developed by American Combustion, Inc. (ACI) of Norcross, GA, was installed on the pilot-scale rotary kiln incinerator. The demonstration tests were conducted using waste material from the Stringfellow Superfund Site near Riverside, CA. To increase test difficulty, the Stringfellow soil was combined with a high heating value decanter tank tar sludge waste from coking operations. The test objectives were to evaluate ACI's claims that the PYRETRON TDS is capable of achieving:

- Control of transient discharges of POHCs and PICs during operational upset conditions.
- Higher waste feedrates than conventional incineration.
- Economic system operation.

The demonstration test results showed that ACI's PYRETRON TDS achieved the RCRA 99.99 percent POHC DRE at a waste feedrate which was 100 percent greater than the maximum rate established under conventional incineration. Measured particulate emissions from the PYRETRON testing were significantly less than the required 180 mg per dscm corrected to 7 percent oxygen.

The PYRETRON TDS was also treated at the maximum conventional system feedrate but with a 60 percent increased mass charge size. During these tests the PYRETRON was capable of handling the increased charge mass without generating unacceptable levels of "puffs".

The concentration of POHCs in the ash residue was consistently below detection limits.

PROCESS DESCRIPTION AND INITIAL TEST RESULTS WITH THE PLASMA CENTRIFUGAL REACTOR

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During the last few years Retech, Inc. has developed the Plasma Centrifugal Reactor (PCR) to stabilize solid waste material while decomposing any toxic hydrocarbons into relatively innocuous, simple molecules. The PCR uses heat from an arc to melt and vitrify, thereby accomplishing the decomposition and stabilization of the waste. Plasmas can produce temperatures in excess of 10,000° C although the expected temperature to be produced in the molten glass is about 1,600° C.

The development of this furnace has been achieved through a three-stage program. Initial tests were performed at Ukiah in Retech's 100-kW lab-scale plasma furnace, followed by demonstrations on surrogate materials in a titanium production furnace located at Oregon Metallurgical Corporation, Albany, OR. This demonstration showed the effectiveness of a transferred-arc plasma to reduce the volume of simulated wastes. In stage two of this program, a quarter-scale PCR was designed, built, and tested at the Retech facility. During this phase, the first patent covering the plasma centrifugal furnace was issued (U.S. Patent 4,770,109). The final stage of this program will be to evaluate the performance of a full-size furnace (PCR-6). The preliminary tests of this reactor were conducted in cooperation with the U.S. Environmental Agency (EPA) on a Simulated Soil Matrix (SSM) at Ukiah. Further tests will be run at the U.S. Department of Energy (DOE) Magnetohydrodynamics (MHD) facility at Butte, MT, as part of EPA's Superfund Innovative Technology Evaluation (SITE) Program. Following the SITE Program, DOE plans to further test the capabilities of the PCR-6.

HAZARDOUS WASTE INCINERATION AND THERMAL DECONTAMINATION OF SOILS

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Incineration in a rotary kiln with a subsequent combustion chamber doubtlessly is the most technically and ecologically safe method for hazardous waste disposal, equally well suited for the treatment of liquid, pasty, and solid waste. Through its affiliate company, Ford, Bacon & Davis Inc., Deutsche Babcock Anlagen AG (DBA) so far has built 10 hazardous waste treatment plants based on this principle in the U.S. One of them serves exclusively for the disposal of 2 t/h of material containing PCBs, which are being destroyed at a high rate of efficiency.

Another kind of rotary kiln heating is being used in the DBA pyrolysis process for thermal decontamination of soils, which has already been applied in a technical-scale plant in the Federal Republic of Germany. Soils are being treated at the lowest possible temperatures (500 to 700° C) with long residence times in an indirectly heated rotary kiln. The resulting gaseous, organic compounds are being burnt in a subsequent combustion chamber at high temperatures (1,000 to 1,300° C). More than 20,000 m^3 of soils of a shut-down coke oven territory have been backfilled after successful decontamination in the DBA plant.

STABILIZATION TREATMENT METHODS

HAZCON, INC. SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION FINDINGS AND CONCLUSIONS

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In October 1987, the EPA initiated its first field test of a solidification/ stabilization (s/s) process under the Superfund Innovative Technology Evaluation (SITE) Program. The emerging technology demonstrated was developed by founders of HAZCON, Inc., based in Texas. The solidification technology was chosen for its potential to effectively stabilize and solidify highly organic waste streams using a cement-based process.

The author described the test criteria established jointly by the EPA and HAZCON, how the field test was conducted, actual test findings, and how these findings might impact the future of landfilling.

The test site was a former oil reprocessing facility located in Douglassville, PA. The site was placed on the NPL in 1985 due to the presence of high levels of organic and inorganic contaminants in site soils. Contaminants included PCBs, heavy metals, volatile and semi-volatile organics, base neutral acids, and other toxic materials.

Without knowing the organic content or chemistry of the soils to be tested, HAZCON received the materials from six locations on the site. Each batch was processed by HAZCON's Mobile Field Blending Unit (MFU), then extruded into forms for curing. The blocks were allowed to cure for 24 hours before being removed from the forms and buried on-site.

Samples were collected both before and after treatment. These samples were subjected to an extensive testing protocol, to include TCLP leachate analysis, permeability, weathering and strength tests, and micro-structural analysis. The results indicated that HAZCON's "Chloranan" treatment process effectively solidified both organics and inorganics. The heavy metals were immobilized, PCBs were not detectable in leachates, and the structural integrity of the mass was sound.

SITE: FIXATION OF ORGANIC AND INORGANIC WASTE/INTIMATE MIXING TECHNIQUE

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Solidification/Stabilization methods are increasingly being developed to physically/chemically fix and immobilize a wide range of industrial waste. These methods can include in situ techniques where the wastes are treated in-place without removal and intimate mixing techniques where the waste streams are removed and mixed with additives in specific proportions. The Soliditech process is an intimate mixing process whereby wastes, organic or inorganic, are mixed with pozzolanic material, URRICHEM, and other additives to form an immobilized mass with structural strength and low leaching potential. Data indicates unconfined compressive strength ranging between 400 and 850 psi, permeability between 10^{-8} and 10^{-9} cm/sec, no noticeable effect of wet-dry or freeze/thaw cycles, and significant reductions of organic and inorganic constituents in leachate.

POSTER PRESENTATIONS

AEROBIC DEGRADATION OF BENZENE, TOLUENE, AND THE ISOMERIC XYLENES BY MICROORGANISMS IMMOBILIZED ON GAS-PERMEABLE MEMBRANES

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Leachate recovered from the Georgswerder landfill in Hamburg contains significant amounts of volatile organics like benzene, toluene, and the isomeric xylenes. Preliminary tests confirmed that these substances are biodegradable under aerobic conditions. The question, however, was how to provide the microorganisms with oxygen without loosing the volatile substrates by stripping. In general, it is possible to transfer oxygen into water by means of gas permeable membranes which separate the biomass suspended in a liquid from an oxygen-containing gas phase. Silicone rubber appears to be an adequate material for that purpose. Experiments have been conducted which demonstrate a sufficient oxygen transfer capacity of silicone tubing oxygenation systems. Unfortunately, volatile organics dissolve readily in silicone rubber, and escape into the gas phase as the gas flows through the lumen of the silicone tubings. The loss of the potential substrates can be minimized by allowing microorganisms to colonize the membrane surface and form a biofilm "barrier" to the escaping volatile substances. The poster contains a summary of the results of experiments which have been conducted to quantify the transfer of benzene, toluene, and xylenes from an aqueous solution through the wall of silicone tubings into the gas phase. Growth of biofilms at the water-membrane interface as well as the resulting reduction of the overall mass transfer by the metabolic activity of the biofilm will be discussed. The proposed design of a membrane-biofilm reactor will be presented.

BENTONITE-CEMENT-FOIL CONTAINMENT SYSTEM

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In the period from 1948 to 1952 the insecticide HCH (Hexa chloro-cyclohexane) was produced in the southern area of the town of Hengelo. From 1948 to 1949 the total HCH-product was sold as an insecticide. From 1950 on only a part of the total product, the gamma-HCH, was sold as an insecticide and the residues (85 percent) were stored on the factory premises.

During the production of HCH, a contamination of the neighboring area took place via the chimney of the factory. From 1950 to 1970 HCH was illegally dumped at numerous waste disposal sites and sand and clay pits. It was also mixed with soil used as landfill material.

In 1977 the first soil contamination with HCH outside the area originally owned by the company was found. The largest contaminated areas were situated in the south of the town of Hengelo, in the northwestern part of the town of Enschede, and in Oldenzaal and Borne. The contamination was often found in combination with mercury contamination which was presumably produced during the chloro-alkaline process.

To enable future remedial actions, it was decided to erect a temporary storage site with a capacity of 125,000 m^3 until an adequate treatment method can be developed. During the selection of the location the objective was to find a site already contaminated with HCH, on which the storage site could be erected. The most favorable location was found to be an old refuse site on the southern border of the town of Hengelo near the village of Beckum.

In order to isolate the area it was decided to construct a bentonite-cement-foil wall. The wall was constructed by means of a hollow I-shaped beam which was brought down by a vibrator to the required depth. During withdrawal of the beam, the remaining hollow space was filled with a bentonite-cement mix. Then the HDPE-foil was attached to a large steel plate which was dropped into the bentonite-cement mix. The individual foil sheets were connected to each other by special locks. At a later stage the locks were cleaned up and filled with a special mix to ensure that they were watertight. Thus far about 8,000 m3 of the bentonite-cement-foil system have been completed.

THE 3-R PROCESS

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Future waste treatment plants shall certainly have to be equipped not only with efficient flue gas cleaning systems but also with treatment plants for the solid residues. These residues contain leachable heavy metals, salts, and — mainly in the case of flyash — halogenated aromates, which prohibit simple landfilling or recycling of this material.

In the 3-R Process developed by Deutsche Babcock Anlagen AG, the residues are treated thermally first, with 95 percent of the halogenated aromates being destroyed at temperatures of 400° C in the absence of air.

In a second phase, the mobile heavy metals and soluble salts are being separated from the residues by means of the acid solution produced in the flue gas treatment system.

MECHANICAL SEPARATION AND THERMAL TREATMENT OF DREDGED MATERIAL FROM HAMBURG HARBOR

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To be able to treat the 2 million m^3 of material that is dredged each year from its harbor basins, the Freie und Hansestadt Hamburg, through its dredging authority, has built a large-scale plant (1,200 m^3/h throughput) to extract the almost pollutant-free sand and dewater the remaining fine-grained fraction containing the pollutants. Large-scale experiments are carried out with this plant to test individual plant components like hydrocyclones, sieve belt presses, etc.; optimize the entire treatment process; and establish design data for the final industrial-scale plant. The start-up of the industrial-scale plant, which will process the total volume of dredged material produced, is planned for 1992 at the latest. With a view to the further treatment of the dewatered fine-grained fraction, the investigations conducted at the laboratories of Lurgi GmbH and Battelle-Institute e. V., in cooperation with Strom- und Hafenbau, the dredging authority in Hamburg, resulted in the development of a thermal treatment process. The dewatered fine-grained material is formed into pellets which are subjected to thermal treatment ($\approx$ 1,200° C) on a Lurgi travelling grate. The resultant products can be used as construction material (aggregates). The main advantages of the thermal treatment over alternative processes are: (1) organic pollutants are destroyed; (2) inorganic pollutants are immobilized; and (3) the products obtained satisfy building material standards. At present all the necessary ecological and technical investigations are under way to support the engineering work for the industrial-scale plant.

PACT® SYSTEM FOR GROUNDWATER, LEACHATES, AND PROCESS WASTEWATERS AND THE WET AIR OXIDATION SYSTEM FOR SLUDGE DESTRUCTION/STABILIZATION

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Two innovative waste treatment systems from Zimpro/Passavant Inc., the PACT® system using powdered activated carbon and the Wet Air Oxidation (WAO) system, have been selected by EPA for demonstration at the Syncon Resins Superfund Site in New Jersey.

The PACT system combines biodegradation and adsorption of organic contaminants by adding powdered activated carbon to biological treatment processes (in this case, the activated sludge process). PACT systems and WAO systems have effectively treated municipal and industrial wastewaters as well as groundwaters and leachates containing hazardous organic pollutants. Current installations have successfully treated wastewaters from the refinery, fuel, chemical, dye production, and pharmaceutical industries in addition to contaminated groundwater and mixed municipal/industrial wastewater.

PACT, when coupled with WAO, provides for the complete destruction of many toxic components and the reduction of solid residuals to a stable, sterile, inert ash. The insoluble ash separated from the effluent of the WAO process constitutes the only solid residue for disposal.

The PACT system and WAO system will be demonstrated together to treat groundwaters contaminated with various levels of organic chemicals. A trailer-mounted PACT system will decontaminate and remove adsorbable and biodegradable constituents from the groundwater. A skid-mounted WAO system will demonstrate destruction of adsorbed pollutants and bio-solids, while regenerating the powdered activated carbon for reuse in the PACT system. At higher temperatures, the WAO system will demonstrate conversion of sludges to a stabilized ash.

Bench-scale studies are currently underway at the Zimpro/ Passavant Inc. laboratory to determine operating parameters for the PACT system and WAO system during the on-site technology demonstration.

PYROPLASMA PROCESS FOR ORGANIC WASTE DESTRUCTION

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The Westinghouse Pyroplasma system destroys and recycles liquid organic materials by breaking the molecular bonds of chemical wastes and converting hazardous wastes into non-hazardous, potentially recoverable substances. The plasma process is capable of treating a wide spectrum of liquid organic wastes. Initially, emphasis was placed on the design of mobile units for site remediation. Present designs offer a modular system that can be utilized for a fixed-base system or a mobile configuration.

Throughput capacities are variable from 1 to 3 gpm single units to multi-stage units.

The destruction process is based on the concept of pyrolyzing waste molecules using a thermal plasma. The heart of the destruction system is a plasma torch which was designed by Westinghouse. Similar torches have been developed for practical applications ranging from blast furnaces and boiler ignition, to the testing of atmospheric reentry vehicle heat shields by the National Aeronautics and Space Administration (NASA).

The plasma torch in the current unit uses up to 850 kW of electric power across a colinear electrode assembly. This configuration produces an electric arc which ionizes an injected low pressure gas stream, forming a thermal plasma (or superheated gas) with temperatures in the 5,000 to 15,000° C range. Waste molecules are introduced into the superheated gas exiting the plasma torch. The molecules are dissociated into their basic elements because the thermal properties of the plasma enable it to break the bonds holding molecules together.

These atoms then recombine in the reaction chamber to form non-hazardous gases, typically carbon monoxide, nitrogen, and hydrogen, along with some lower molecular weight hydrocarbons (i.e., methane, ethane, etc.). Acid gas formed from the destruction of halogenated waste and the subsequent combination of hydrogen and halogen gases, is neutralized in a wet scrubber with sodium hydroxide to form a salt water effluent. Scrubbing also removes any particulate carbon produced. The product gas, which consists primarily of hydrogen and carbon monoxide, is drawn off by an induction fan and flared.

A process computer automatically controls the entire system through a series of temperature, pressure, electrical, and flow sensors. An experienced operator monitors and directs the unit's operation; however, pre-set parameters programmed into the computer logic have overriding control. There are numerous safety features built into the system, including the anticipation of a complete power failure, a worst case scenario. In addition, the process is monitored for various gases to keep the system operating efficiently and according to theoretical models.

The existing Pyroplasma unit is trailer-mounted and requires only power, water, inlet and discharge lines, and a flare stack. This present trailer unit is configured for processing primarily polychlorinated biphenyls (PCBs) and may not necessarily be the final configuration recommended for processing other organic waste materials.

Tests conducted in December 1988 of the mobile Pyroplasma system produced PCB destruction efficiencies well in excess of U.S. EPA requirements. The tests, conducted at the Westinghouse Environmental

Services' Waltz Mill facility in Madison, PA, were performed under a U.S. EPA Toxic Substances Control Act (TSCA) Research and Development Permit. During the tests, samples were taken for analysis by Entropy, a member of the U.S. EPA Contract Laboratory Program. Recently received test results showed destruction removal efficiencies (DRE) in the range of seven to eight "9s." Specific stack gas results are shown below:

	Test 1	Test 2	Test 3	EPA Criteria
DRE	99.999999	99.999999	99.999995	99.9999
HCl	0.941	0.0972	0.0343	4.0
Particulate	0.00837	0.00845	0.00441	0.08

DRE: (PCB in feed–PCB in gas) / (PCB in feed) x 100 (%)
HCl: Hydrogen Chloride in gas (pounds/hour)
Particulate: Particulate concentration (grains/dry standard cubic foot) @ 7% oxygen

In addition to the high PCB destruction efficiency, the hydrochloric acid concentrations to the stack gas were one and two orders of magnitude better than EPA standards. The gas particulate emissions were also an order of magnitude better than the EPA acceptance criteria. This test was conducted on 300 gal of transformer askerel fluid with a concentration of 70 to 80 percent PCBs by weight. The feed rate was 1 gpm. The system performed without problem during these tests. The tests were terminated when the PCB supply was depleted.

These tests have verified the efficiency and operability of this technology and constitute a major achievement in its commercialization for PCBs and other liquid organics. Also, the computer models which have been developed for predicting the operation of the system have been further refined and verified. Westinghouse Environmental Services has now verified that the Pyroplasma system is ready for commercial markets.

EPA SITE PROGRAM: SEPARATION AND RECOVERY SYSTEMS FIXATION TECHNOLOGY

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The SRS Chemical Stabilization and Solidification Technology provides lime-based chemical fixation of hazardous organic and inorganic sludges. Results are better than competing fixation processes because chemical reactions change and bind the hazardous constituents. The technology has been demonstrated at commercial sites and the company has contractually been responsible for total and permanent site cleanup at major sites on three continents.

The SRS technology is a lime-based process. The lime is specially prepared and contains proprietary non-toxic chemicals that catalyze and control the reactions between the lime and the waste. The sludge to be treated is removed from the waste pit by a swing line or crane and placed in a blending pit. Specially prepared lime and additives are added to the sludge in the blending pit using an excavator. The lime blend is then mixed with the sludge and the first step of neutralization takes place. At the completion of this step, black sludge is changed to a grey paste and any solid pieces have been dispersed.

After approximately 15 minutes, a second lime preparation is added to the sludge. This preparation is different from the first in both chemical form and composition. The lime is mixed over a 20-minute period in the blending pit. After this time, the reaction is about 80 percent complete.

After the second reaction step has been completed, the fixed product undergoes a QA/QC evaluation to determine if the fixation reactions are proceeding as planned. These tests include measurement of pH, unconfined compressive strength, liquid release, and moisture content. These tests have been designed to be conducted quickly in the field to ensure that the final fixed product will meet the required fixation criteria.

The treated material is then removed from the blending pit and placed on a product assembly line. The product is allowed to cure for several days. This time is very important because it allows the reactions to continue in a controlled environment. After the product has been sufficiently cured, it is placed in a storage area prior to being returned to the original pit for final compaction. Production rates are from 500 to 1,000 yd^3 per day.

B.E.S.T.® SOLVENT EXTRACTION SYSTEM

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Basic Extractive Sludge Treatment (B.E.S.T.®) is a chemical process which separates sludges and contaminated soils into three parts: oil, inert solids, and water. Because B.E.S.T. operates at such low temperatures, it has low energy requirements. B.E.S.T. achieves three objectives of hazardous waste management: waste minimization, detoxification, and resource recovery.

The B.E.S.T. process can be used to treat contaminated sediments in lake, river, and harbor bottoms. It can also process very thick but pumpable sludges. Most recently, RCC modified the process to treat soils, sand, or fine gravel.

At the heart of the process is triethylamine. Triethylamine is one of a family of aliphatic amines with the unusual property that it is miscible with oils and water at temperatures around 40° F and is essentially immiscible with oils and water at temperatures around 70° F. At about 170° F, triethylamine evaporates from oil and is recycled to the process.

Triethylamine smells like ammonia and has a flammability similar to gasoline. A caustic similar to household bleach, it is biodegradable in natural environments. Triethylamine is a commonly used chemical in the pharmaceutical, rubber, resin, and textile industries. RCC has patented the use of inversely miscible solvents such as triethylamine to remove water and oil from sludges and other mixtures of solids, water, and oil.

Unlike incineration, which is very energy intensive and destroys all the material, B.E.S.T. operates at low temperatures, conserves energy, and recovers valuable resources. The residual contaminated fraction is reduced to a very small quantity. When it is not suitable for reuse, it can be incinerated or chemically detoxified at a secure and protected location.

Because B.E.S.T. operates at moderate temperature and pressures, it uses standard process equipment and components. When processing the solids, the unit is equipped with a wash dryer, a heavy duty vessel commonly used in the food processing industry. In this vessel, steel paddles or plows agitate the material with chilled triethylamine. When the required number of "washes" have been accomplished, the oil, water, and solvent fractions are drained or pumped into a decanter. The solids portion remain in the vessel to be dried and discharged. The vessel is then prepared for the next cycle.

The decanted liquid portion is heated to 130° F and the triethylamine/oil fraction is separated from the water.

The oil and TEA portion is drawn off the top of the decanter and pumped into a TEA recovery system. The recovery system may be an evaporator alone or an evaporator combined with a finishing distillation column. Here the solvent is condensed and reused. The remaining oil can be used as a fuel or discarded. The water is drawn from the bottom of the decanter, and pumped to a stripping column where the remaining traces of solvent are recovered and reused.

The water portion, often much larger than the oil and equal to or larger than the solids, is disposed through standard wastewater or sewage treatment systems. In some cases, the water will be clean enough to require no further treatment.

Hazardous organic components such as polychlorinated biphenyls (PCBs) are isolated in the oil fraction. When PCBs are present, the oil can be treated with thermal or chemical processes. If PCBs are not present or are present at low levels, the oil may be recycled as fuel.

Heavy metals such as mercury, lead, zinc, chromium, or copper are found mostly in the solids. The B.E.S.T. process shifts the metals into a non-leachable state, thus allowing them to pass Environmental Protection Agency's EPTOX and TCLP tests. Detoxified solids are candidates for "delisting," or removal from the EPA list of hazardous substances.

In 1986, EPA tested B.E.S.T. at a Superfund Site near Savannah, GA, to determine its suitability as a transportable on-site technology. The test data proved the system was capable of separating oily sludges and producing a safe product. In addition, comparisons of RCC laboratory simulation data to field data indicate that laboratory-scale simulations can be useful in predicting system performance.

A 1987 study, funded by EPA and conducted by the Research Triangle Institute of North Carolina, rated B.E.S.T. number one out of eight for processing sediments contaminated with PCBs.

In 1988, EPA classified solvent extraction techniques such as B.E.S.T. as "Best Demonstrated Available Technology" (BDAT) for treating refinery wastes.

In May 1989, a B.E.S.T. Pilot Plant completed on-site demonstration tests at a large oil refinery.

In June 1989, numerous treatability studies were conducted in the RCC laboratory.

IN SITU VITRIFICATION TECHNOLOGY

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In Situ Vitrification (ISV) is a newly commercialized proprietary technology capable of satisfying SARA's mandate for permanent reduction of toxicity, mobility, and volume of organic and inorganic contaminants in soil, sediment, sludge, and/or tailings. The process involves the on-site and in situ electric melting of contaminated materials at temperatures typically exceeding 1,600° C. Organic contaminants are destroyed by pyrolysis; typical DRE is > 99.9999 percent (e.g., PCBs and dioxin). Typical inorganic contaminants (e.g., heavy metals) are chemically incorporated into the glassy residual product which is equivalent to natural obsidian and is capable of safe environmental exposure for geologic time periods. Typical volume reduction is 20 to 40 percent for most soils.

The ISV process is now offered on a commercial basis. It is applicable to all types of hazardous chemical, radioactive, and mixed wastes within site-specific application limits. It may be applied to fully saturated soils, but is subject to recharge limitations. Application costs are highly site-dependent; typical costs fall in the range of $250 to $350 per ton, not including treatability testing, permitting, or mobilization/demobilization.

The ISV process has been selected for use at several Superfund and private sites, and is being evaluated for potential use on many others.

MICROFILTRATION FOR REMOVAL OF HEAVY METALS AND SUSPENDED SOLIDS

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E.I. Du Pont de Nemours & Co., Inc.
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A unique microfiltration application for separating sub-micron particles is achieved using sub-denier fibers and a tortuosity structure of Tyvek® as filter media with the Oberlin Co. Automatic Pressure Filter (APF).

This filtration application has been capitalized by meeting the EPA effluent discharge limits in wastewaters containing heavy metals and suspended solids, groundwater leachate, basin leachate and runoff, and oily and radioactive wastes with solids concentrations ranging from 10 to 5,000 ppm and viscosities of waste as high as 16 cps.

The feed water preparation prior to treatment with the APF comprises chemical precipitation, polymer flocculation, and filter aid addition. The APF produces dry and non-leachable filter cake (40 to 60 percent solids) that is suitable for further treatment (i.e., landfilling, storage, incineration, and recycling).

This technology has been adopted in many Du Pont sites and several companies, and has been accepted by the EPA for the 1988 Superfund Innovation Technology Evaluation (SITE) Program.

BIOLOGICAL TREATMENT OF CHLOROPHENOL-CONTAMINATED GROUNDWATER

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BioTrol, Inc.
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BioTrol, Inc. has developed a system for the treatment of chlorinated phenols in wastewater streams. The compounds are degraded by microorganisms which are immobilized in a submerged, fixed-film bioreactor. An indigenous consortium of microorganisms is amended by inoculation of a specific bacterium with the capability to degrade pentachlorophenol (PCP) as well as tetra- and tri-chlorophenol. BioTrol has demonstrated treatment of groundwater containing up to 90 ppm PCP, and has achieved effluent concentrations as low as 100 to 200 ppb. The system is primarily applicable to groundwater; however, treatment of process and lagoon waters has also been demonstrated.

BIOTROL® SOIL WASHING SYSTEM

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BioTrol, Inc. has developed a soil washing system for the remediation of soils contaminated with organic chemicals. The system is based on a series of intensive scrubbing and physical separation steps using mineral processing technology. Water is used as a carrier for the soil and contaminants and is treated in a fixed film bioreactor using an amended bacterial consortium prior to recycle in the soil washing system. This poster presents the results of two years of pilot testing recently completed at a Superfund Site in Minnesota contaminated with wood preserving chemicals.

X*TRAX® – TRANSPORTABLE THERMAL SEPARATOR FOR ORGANIC CONTAMINATED SOLIDS

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Chemical Waste Management, Inc.
Oak Brook, IL 60601

The remediation of solids such as soils, filter cakes, and pond sludges that are contaminated with organic chemicals is a major problem for the environmental industry. Many of these wastes can be treated using a thermal separator; essentially, by drying them. Chemical Waste Management (CWM) has developed a patented system, trade marked X*TRAX®, that thermally separates organics from solids in an indirectly heated rotary dryer. The volatilized organics and water are carried to a gas handling system with an inert gas (nitrogen), where they are condensed and collected as a liquid. The carrier gas is reheated and recycled to the dryer in a closed loop. Only a small portion of the carrier gas is vented to the atmosphere through carbon adsorbers to control noncondensibles in the recirculation loop. CWM has constructed a full-scale transportable thermal separator with a nominal capacity of 100 to 125 tons per day. This unit is undergoing startup testing and will be available in the third quarter of 1989. CWM has been operating both a 5-tons-per-day pilot system and a 2 to 4 lb/hr lab-scale system since early 1988. The pilot unit is slated to undergo extensive testing on TSCA and RCRA wastes in mid-1989 at CWM's Kettleman Hills Facility in central California.

COMPUTERIZED ON-LINE SEARCH AND RETRIEVAL OF INFORMATION FROM EPA'S SITE PROGRAM APPLICATIONS ANALYSIS REPORTS

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The Applications Analysis Reports (AARs) may well be the most widely disseminated and influential output of EPA's Superfund Innovative Technology Evaluation (SITE) Program. They are basically executive digests of the more comprehensive Technical Reports from a SITE technology demonstration. They are meant to be a clear, concise statement to potential technology users. The AARs contain SITE technology information that is needed by individuals responsible for implementing remedial actions at hazardous waste sites.

To provide quick and easy access to this information, each approved SITE AAR is placed, in its entirety, on EPA's Technical Information Exchange (TIX) Computerized On-Line Information System (COLIS). The reports can be searched by entering keywords to locate those reports and sections pertinent to the user's needs.

TIX is maintained by the U.S. Environmental Protection Agency (EPA) in Edison, NJ. It disseminates technical information involving hazardous waste technologies and conducts a wide range of support services for the Risk Reduction Engineering Laboratory's (RREL's) research activities at Edison. It is operated by an on-site contractor under EPA sponsorship, and is managed by RREL's Releases Control Branch.

TIX provides immediate access to its collection and assists users in locating or obtaining materials from other sources (e.g., EPA's Center for Environmental Research Information). A library of commercial software is maintained so users may evaluate packages before purchasing additional copies.

TIX also pursues research studies of its own into the computerized retrieval and dissemination of information from its collections. In conjunction with EPA personnel, TIX helped to develop and now maintains COLIS, which is designed to meet the needs of several specific R&D efforts, such as accessing the SITE AARs. COLIS requires little or no prior computer experience and can be accessed remotely using a wide variety of computer equipment.

ATTIC: THE ALTERNATIVE TREATMENT TECHNOLOGY INFORMATION CENTER

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The Alternative Treatment Technology Information Center (ATTIC) is a comprehensive automated information retrieval system that integrates existing hazardous waste data sources into a unified, searchable resource. This system provides access to a wide variety of technical information sources at one central location and serves as a focal point to promote the exchange of technical information between members of the user community. The user community that will take advantage of the ATTIC system will include EPA staff at the Headquarters and Regional level, but more importantly, will also include the EPA contractors actively engaged in actual site cleanup and remediation. Expanding the targeted user community to include the various EPA contractors has allowed the overall scope of the ATTIC system to incorporate a greater variety of technical information on alternative treatment technologies, including international reports, bench- and pilot-scale data, and industrial applications. Through ATTIC, a user will be able to access a central resource to collect information on various hazardous waste treatment technologies. The center can provide searches of ATTIC resident data bases, comprehensive searches of on-line databases, and technical evaluations of collected data. As necessary, the center will also serve as an interface between the user community and the various EPA research laboratories.

THE SITE EMERGING TECHNOLOGY PROGRAM

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The SITE Emerging Technology Program, an integral part of the Superfund Innovative Technology Evaluation Program, was authorized by the Superfund Amendments and Reauthorization Act of 1986. The goal of the total program is to maximize the use of alternatives to land disposal in cleaning up Superfund sites. The Emerging Technology Program provides the framework to encourage further testing and evaluation, through pilot-scale, of technologies already proven at bench-scale. Partial funding is provided by EPA, through competitively awarded Cooperative Agreements, to assist technology developers with testing and evaluation of their technologies for application to hazardous waste cleanups. Seven technologies were funded from the first Emerging Technology Program solicitation. Included in the technologies now being evaluated are: removal of dissolved toxic metals by chemical treatment/ultrafiltration, electroacoustic soil decontamination, a "biological" ion-exchange resin for removal and recovery of metal ions from groundwater, constructed wetlands treatment for toxic metal removal, laser stimulated photochemical oxidation of toxic organics in water, solvent washing of contaminated soils, and contained recovery of oily wastes.

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION (SITE) DEMONSTRATION PROGRAM

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Under the Superfund Amendments and Reauthorization Act (SARA) of 1986, the Environmental Protection Agency was authorized to conduct a demonstration/evaluation program for assessing technologies applicable to hazardous waste cleanup. The aim of the program is to evaluate technologies that treat, recycle, and separate (e.g., permanent solutions), rather than to continue to select remedies that involve excavation/disposal and containment options (e.g., temporary solutions). This program is called the Superfund Innovative Technology Evaluation or SITE Program. The technology demonstrations carried out under this program focus on technologies at the pilot- or full-scale stage of development. Technology demonstrations are designed to be conducted on actual waste in the field, preferably at an actual Superfund site. The key to the program is conducting the technology demonstration in the field under actual conditions. This may include evaluating pre– and/or post–treatment options for the waste feed or residuals from the process.

While the SITE Program has developed a process for planning and conducting technology demonstrations in the field under the Superfund Program, this process is applicable and can provide guidance to develop a sound program to evaluate any technology in the field. The main objectives of any field demonstration program are to develop reliable performance and cost data on the technology being evaluated. This demonstration should provide detailed performance, cost effectiveness, and technology reliability data so that potential users have sufficient information to make sound judgments as to the applicability of the technology to a specific situation and to compare the evaluated technology to other available technology options. In the process of collecting and evaluating data, it is important to collect data of a known quality. Therefore, the processes of sampling and analysis, including quality assurance and quality control, are very important. In addition to these technical issues, government policy, regulatory requirements, and community involvement need to be addressed.

The technologies will be at the pilot– or full–scale. The main objectives of demonstration at the field–scale are development of reliable performance and cost data. Technology demonstrations provide performance, cost effectiveness, and reliability data so that potential technology users have sufficient information to make effective decisions as to the applicability of the technology to a specific situation. The demonstration and evaluation of a technology should be conducted with the purpose of characterizing performance, need for pre– and post–processing of the waste feed, waste type and constituents applicable to the technology, system throughput, problems and limitations of the technology, and operating and maintenance costs.

The demonstration/evaluation program will at a minimum address the following:

- Test plan development
- Sampling and analytical program
- QA/QC program
- Health and safety plan.