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Second Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International

Philadelphia, Pennsylvania

May 15-17, 1990

EPA/540/2-90/009
September 1990

ABSTRACT PROCEEDINGS

SECOND FORUM ON INNOVATIVE HAZARDOUS WASTE TREATMENT TECHNOLOGIES: DOMESTIC AND INTERNATIONAL

Philadelphia, PA
May 15-17, 1990

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

ACKNOWLEDGMENTS

The Second Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International was sponsored by the U.S. Environmental Protection Agency's (EPA's) Technology Innovation Office – Walter Kovalick, Director.

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ABSTRACT

On May 15–17, 1990, the U.S. Environmental Protection Agency's Technology Innovation Office hosted an international conference in Philadelphia, PA, to exchange solutions to hazardous waste treatment problems. This conference, the Second Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, was attended by approximately 680 representatives from the U.S. and several foreign countries. During the conference, scientists and engineers representing government agencies, industry, and academia attended 35 presentations describing successful case studies of physical/chemical, biological, thermal, and stabilization treatment methods. In addition, case studies of applied technologies were presented by EPA's Superfund contractors. Domestic and international scientists and vendors presented over 50 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 SUPERFUND AND RCRA HAZARDOUS WASTES BY FREEZE CRYSTALLIZATION

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Freeze crystallization is a separation process used to remove pure components from solutions by crystallizing the materials to be removed. The technology has proven advantages that make it economically attractive as well as uniquely able to decontaminate many types of aqueous hazardous wastes. This presentation illustrates how the process can be used in site remediation activities, by-product recovery activities, and in the handling of mixed (radioactive and hazardous) wastes.

Freeze Technologies Corporation (FTC) has built a 10 gallon per minute (GPM) DirCon(TM) plant to demonstrate the freeze crystallization technology. The plant is contained in two modules that can be transported by truck and require less than one week to set up. The company's current demonstration project is scheduled for the Stringfellow site in Riverside, CA. Stringfellow is ranked high on the U.S. EPA's National Priority List (NPL) of Superfund sites targeted for remediation. The application is for a leachate from interception wells.

Applications for freeze crystallization processing of hazardous wastes are not limited to contaminated waters and wastewaters. The process has historically been developed and used for organic separations applications. Combinations of freezing with solvent extraction and soil washing also show great promise for minimizing the volume of contaminant removed from a waste/contaminated media.

Freeze crystallization has several advantages over competing technologies for remediation and waste recovery applications. First, it is an efficient volume reduction process, producing a concentrate that has no additional chemicals added to it. Volume reduction translates into reduced costs for wastes requiring destruction by incineration or disposal in a landfill. When a large fraction of the solvent (usually water) is removed from a waste, the remaining impurities often begin to crystallize as well. These components are often sufficiently pure to have by-product recovery value. Freeze crystallization has low processing costs generally ranging from $.03 to $.15 per gallon for 40 and 5 GPM plants, respectively.

ACR/EPRI PROCESS FOR CLEAN-UP OF CONTAMINATED SOIL

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The Alberta Research Council (Canada) in conjunction with the Electric Power Research Institute (USA) has developed a process for clean-up of soil contaminated with various oily and organic waste materials. The process that is applied for this purpose uses coal fines as a cleaning agent, and capitalizes on the drastic variations in the oleophilic properties between coal and mineral matter.

In principle, the process is based on specific oil agglomeration technique (Aglofloat) developed at the Council, with organic contaminants acting as the bridging liquid between coal particles. In the process, the contaminated soil is mixed with a coal-water slurry; the products, in form of contaminant wetted coal and cleaned soil, are separated by flotation. Both attrition, which takes place during mixing, and sorption capacity of the coal, have a major effect on process performance.

Bench-scale experiments have been conducted with samples contaminated with coal derived tar, heavy oil, and oil spills. The effectiveness of the cleaning procedure appeared to be dependent on the composition of the contaminated samples and also on the particle size distribution of solids. Both products, namely the processed soil as well as the oil-enriched coal, have been extensively tested in terms of their leachability and organic contents (soil) and handleability, leachability, and combustion characteristics (oil-enriched coal).

The process appears to be very well suited for treating oil waste materials originating from variety of coal/petroleum industries and it is now being tested in a 6 ton per day continuous facility in order to generate engineering data for further development. Conceptual engineering and economic analyses indicate that the commercialization of the process is feasible. The cost of treating one ton of contaminated soil varies from US $25–35 depending on the composition of the contaminated sample and plant capacity.

INSITU HOT AIR/STEAM EXTRACTION OF VOLATILE ORGANIC COMPOUNDS

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This paper presents results of using a new technology for the insitu removal of volatile organic compounds (VOCs) from soil. The technology injects hot air/steam into soil through two 5–ft–diameter counter rotating blades that are attached to drill stems. The soil is cleaned as the drill stems are advanced into and retracted from the ground. The evolved gases are trapped in a surface covering called a shroud, and contaminants are captured above ground via condensation and carbon absorption. The recovered contaminants can be reprocessed or destroyed.

The results of the initial use of the commercial prototype show 85 to 99 percent removals of chlorinated VOCs from clay soils. The technology was able to achieve its goal of less than 100 ppm over 80 percent of the time in three blind tests. The mass of material recovered in the condensate was conservative – approximately equal to the mass determined removed from the soil by chemical analysis and physical measurements (89 %). The technology also removed significant quantities (50%) of semi–volatile hydrocarbons (as quantified by EPA 8270). This was unexpected. Subsequent analysis has identified potential mechanisms for removal of semi–volatile components. Further testing is planned to evaluate these mechanisms.

The process has not been found to cause undesirable environmental emissions as a result of its operation. Noise and air emissions during operation are below the limits set by regional environmental regulations in southern California. Soil hydrocarbon emissions during treatment are not increased from background before treatment. Soil adjacent to the treatment has not been found to have increased VOCs after the process is operated. Environmental emissions caused by operational problems can generally be cured without shutdown.

EXTRACTION OF PCB FROM SOIL WITH EXTRAKSOL(TM)

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Polychlorinated biphenyls have been successfully extracted from clay-bearing soil, sand, and Fuller's earth, by the Extraksol(TM) process. The Extraksol(TM) process is a mobile decontamination technology which treats soil and sludges by solvent extraction. Treatment with Extraksol(TM) involves material washing, drying, and solvent regeneration. Contaminant removal is achieved through desorption/dissolution mechanisms. The treated material is dried and acceptable to be reinstalled in its original location.

The process provides a fast, efficient, and versatile alternative for treatment of PCB-contaminated soil and sludge. The contaminants extracted from the soil matrix are transferred to the extraction fluids. These are thereafter concentrated in the residues of distillation after solvent regeneration. Removal and concentration of the contaminants ensures an important waste volume reduction.

Extraksol(TM) is a flexible process designed to extract a variety of organic contaminants from unconsolidated solids. Polyaromatic hydrocarbons, oils, and pentachlorophenols have also been extracted from sludges, activated carbon, porous stones, and gravel, with high removal efficiencies.

TYVEK® MICROFILTRATION OF HAZARDOUS WASTEWATERS

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Du Pont has developed and recently commercialized a new filter media based on Tyvek® flash spinning technology. This new media has an asymmetric pore structure, a greater number of submicron pores, and a smaller average pore size (1–3). As a consequence, it has superior filtration properties, longer life, and in many instances can compete with microporous membranes, PTFE laminates, and various melt-blown media. When coupled with an automatic pressure filter (APF), it provides an automatic wastewater filtration process that is a dry-cake alternative to conventional crossflow microfilters and ultrafilters. This Tyvek® /APF process has proved extremely useful in filtering heavy metal and other hazardous wastewaters to meet strict EPA NPDES discharge limits. Specific examples and actual case histories were highlighted to illustrate its benefits. In addition, this Tyvek® /APF technology has recently been selected for EPA's SITE-3 program; this was also discussed.

CLEAN-UP OF CONTAMINATED SOIL BY OZONE TREATMENT

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A new technique which may be used to decontaminate soil containing different kinds of organic pollutants has been developed by our laboratory. The method is based on the treatment of the contaminated soil with ozone in the gas phase.

Ozone, the most powerful technically applied oxidizing agent, reacts with a lot of inorganic and organic compounds. We were able to show that it destroys both highly volatile aliphatic and aromatic hydrocarbons as well as polycylic aromatic hydrocarbons in soil derived from former industrial plants, coking plants, or gasoline stations. In the cleaning-up process, a gas stream enriched with ozone passes through the soil, thereby reducing the pollution up to 98 percent of the original concentration. The efficiency of the method depends on several parameters, e.g., nature of the contamination, condition of the soil and its permeability to gas, as well as the presence of accompanying substances.

This new clean-up procedure may be used insitu or on-site. Experiments have been carried out so far in laboratory and pilot-plant-scale. The first large scale insitu treatment will start soon.

In laboratory experiments the ratio of pollutant concentration and employed ozone quantity varied between 1:4 and 1:8. Organic compounds are transferred into substances which are highly biodegradable. There is no indication for the formation of toxic oxidation products.

Ozone treatment destroys soil microorganisms to a large extent, but we were able to show that the restoration of the soil micro flora can easily be achieved, for example, by addition of the effluent of a sewage plant.

BIOTROL® SOIL WASHING SYSTEM

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Soil washing is a process for treating excavated soils which are predominantly sand and gravel. In the process, contaminated soil is mixed with water and subjected to several stages of intensive scrubbing followed by classification. Several mechanisms can play a role in the treatment process, including separation of highly contaminated fine particles from the coarser sand and gravel, removal of surficial contamination from the coarse soil fraction through abrasive action, and dissolution of soluble contaminants in the aqueous phase. The washed, coarser soil components are then separated from the contaminated fine particles and process water, significantly reducing the volume of material requiring additional treatment.

A pilot-scale soil washing system with a treatment capacity of 500 to 1,000 pounds per hour was operated at a Superfund site in Minnesota contaminated with wood preserving wastes, including pentachlorophenol, polyaromatic hydrocarbons, copper, chromium, and arsenic. In general, contaminant levels in the washed soil were 90 to 95 percent lower than in the feed soil. Process water from the system was treated in a fixed film bioreactor and recycled. A three-stage slurry phase bioreactor was used to treat the contaminated fine solids. The results of this on-site pilot work were discussed, including preliminary results obtained during an EPA Superfund Innovative Technology Evaluation (SITE) demonstration. The results of bench-scale studies covering a wide variety of contaminants were presented, as well as the economics of full-scale treatment.

DEVELOPMENT AND DEMONSTRATION OF A PILOT-SCALE DEBRIS WASHING SYSTEM

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A large number of hazardous waste sites in the United States are littered with metallic, masonry, and other solid debris which may be contaminated with hazardous chemicals [e.g., polychlorinated biphenyls (PCBs), pesticides, lead, or other metals] and in some cases clean-up standards have been established (10μg PCBs/100 cm^2 for surfaces to which personnel may be frequently exposed). Although the majority of debris at Superfund sites does not possess the potential for reuse, the debris could, following decontamination, either be returned to the site as "clean fill" in lieu of transporting the debris offsite to a hazardous waste landfill or, in the case of metallic debris, be sold to a metal smelter.

During previous phases of this project we have developed a technology for performing on-site decontamination of debris. Both bench-scale and pilot-scale versions of a Debris Washing System (DWS) have been designed and constructed. The DWS utilizes an aqueous solution which is applied to the debris during a high pressure spray cycle followed by a turbulent wash cycle. The aqueous cleaning solution is recovered and reconditioned for use concurrently with the actual debris cleaning process; therefore the quantity of process water utilized to clean the debris is minimized.

The results obtained during a field demonstration of the DWS were presented. Data were presented which are indicative of the effectiveness of the system for removing PCBs from the surfaces of metallic debris, as well as the efficiency of the closed-loop solution reconditioning system, which is built into the DWS. The performance of the DWS under adverse (sub-freezing) temperature at a hazardous waste site located in Hopkinsville, Kentucky, was also discussed.

INTEGRATED SOIL–VAPOR/GROUNDWATER EXTRACTION CLEANING PROCESS

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An extraction process to remove VOCs from both groundwater and the vadose zone has been developed by Ed. Zublin. This process involves on-site regeneration of the carbon filter, eliminating periodic handling and replenishment. The system is designed to recover most solvents which can then be recycled or disposed. This feature is due to stringent air emission controls in West Germany.

Case studies continually show similar operating characteristics under different situations and varying contaminant concentrations. They demonstrate that this technology has developed into a proven and reliable remedial process.

The extraction process starts with a blower/vaccum pump creating a negative pressure causing the contaminated soil–vapor to flow toward the extraction well. Contaminated groundwater is pumped and stripped of its contaminants. Both air streams are treated by passing over an activated carbon filter to remove the contaminants.

All VES treatment processes involve three phases: a high concentration removal; a transitory phase; and an asymptotic phase. These phases can last up to several months or years. The performance of extraction systems is affected by several parameters.

Many Zublin installations combine the treatment of groundwater along with soil–vapor. The dual phase system maximizes removal of contaminants and minimizes the treatment period and pollution emissions. Cost efficiencies are enhanced by on–site regeneration of the carbon and recovery of the solvent.

A REVIEW OF ULTROX® UV/OXIDATION TECHNOLOGY AS APPLIED TO INDUSTRIAL GROUNDWATER, WASTEWATER, AND SUPERFUND SITES

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Ultrox International has demonstrated the efficacy of ultraviolet light-enhanced oxidation at industrial, Department of Defense, and Superfund sites. Waters containing halogenated solvents such as trichloroethylene, perchloroethylene, and other halogenated compounds have been successfully treated with ULTROX® 's patented UV/ozone/hydrogen peroxide process. Other contaminants such as aromatic solvents, hydrazines, phenols, chlorophenols, dioxanes, PCBs, and pesticides in wastewaters and groundwaters have also been treated to acceptable discharge standards. BOD and COD levels have also been reduced to meet the requirements of tougher effluent regulations. Summations of the above projects were presented, along with some of the technological basis of this process.

Commercial application of the technology is now growing rapidly. Design and cost data from operations at full-scale commercial installations were presented. The applications cover ultraviolet/oxidation systems treating wastewater in the wood treating industry and chemical industry; groundwater containing chlorinated solvents at automotive, aerospace, and electronics manufacturers; and municipal drinking water treatment.

A summary of test results from a demonstration of the ULTROX® process in the U.S. EPA Superfund Innovative Technology Evaluation (SITE) Program was also presented. Constraints and limitations of the technology in light of the above experience were discussed, as well as a comparison with other technologies.

THE LURGI–DECONTERRA PROCESS – WET MECHANICAL SITE REMEDIATION

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For wet mechanical remediation, Lurgi has developed the Deconterra process. This process is based on knowledge derived from processing of ores and salts as well as silt from flowing and standing water, and on the engineering experience Lurgi has accumulated in constructing many such plants. The special feature of the Lurgi–Deconterra Process is the wet mechanical attrition. The energy required can be matched to the type of soil and contamination. Energy of up to 16 kWhr/t can be transferred to the material.

Only water without any addition of detergents or solvents is used as scrubbing liquid. The contaminated soil or debris after reclaiming is classified, screened into different fractions, and crushed if necessary. Material discharged from the attritioner drum undergoes further screening, gravimetric sizing, sludge removal, froth flotation, and dewatering. The end products are cleaned soil and debris and a contaminated concentrate which is composed of the following materials separated in the process:

- light material from the gravimetric sizing (wood, tar, coal, coke)
- fine material from the hydrocyclone overflow
- froth from the flotation

Furthermore, treatment of the contaminated concentrate may include incineration in thermal treatment plants, solidification, pressure oxidation, or biological treatment.

Lurgi–Deconterra plants are designed as semi–mobile systems, enabling a quick move from one contaminated site to another. Material from all kinds of contaminated sites such as coking plants, old ammunition plants, various chemical industries, and railway repair shops have been treated in Lurgi–Deconterra plants with very good results. Following the Dutch reference all cleaning results are either reference category A or between A and B. Based on a Lurgi–Deconterra plant with a capacity of 25 t/hr throughput, the treatment fee per ton is in the range of US$ 80–90. Excluded from this amount are the costs for treatment of the highly contaminated residue.

THERMAL TREATMENT

DEVELOPMENTS AND OPERATING EXPERIENCE IN THERMAL SOIL CLEANING

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NBM developed an indirect heated thermal system using a dryer and a rotary tube–furnace. In indirect heating the soil does not come into direct contact with the gases from the heating system. Within the closed tube, the water vapor and the pollutants are released. Due to the small quantity of these gases a small incinerator can be used and dust problems can be handled easier. Finally, the flue gases from the burners remain clean and the heat content can be recovered. After laboratory experiments and a pilot plant phase, the first production plant was built in 1986. Up to November 1989, over 200,000 tons of soil, containing cyanides, aromatic hydrocarbons, and oily type pollutants were cleaned. Typical cleaning results are concentrations of less than 1 mg/kg total PAHs and less than 1 mg/kg total cyanide.

At the Technical University of Delft, laboratory work was done to determine the process conditions to bring the pollution levels below the accepted ("A" value, <0.1 mg organochlorine compound/kg) level and the process conditions for incineration. Special attention was paid to the formation of CDD and CDF. Based on the results of this laboratory work, NBM decided to carry out practical experiments to prove that it is possible to clean soil contaminated with halogenated hydrocarbons, and that safe incineration of the offgases is possible.

The practical experiments were carried out in two phases. First, in 1989, the incineration conditions were tested in the full-scale plant in Schiedam. While running the plant with an input of sand contaminated with fuel oil a known amount of a mixture of trichloroethene and tetrachloromethane was injected into the incinerator, and stack emissions were measured. The destruction efficiency was higher than 99.999 percent.

Further experiments were carried out in April 1990. About 700 tons of soil containing a.o. aldrin, dieldrin, and lindane were processed during a three–day test run. In these tests, the rest of the concentrations of contaminants were below the detection limit of 10 μg/kg dry solids.

REVOLVING FLUIDIZED BED TECHNOLOGY FOR THE TREATMENT OF HAZARDOUS MATERIALS

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The Revolving Fluidized Bed is a patented fluidized bed design which has very high combustion efficiency and can handle a wide range of materials including soils, industrial sludge, municipal waste, sewage sludge, rubber tires, and hazardous wastes. The material is burned very rapidly in a highly turbulent bed of red hot sand which churns in an elliptical pattern. This "revolving" action enhances the mixing in the combustion area and also moves large extraneous material to the edges of the furnace where it can be easily withdrawn. This is a patented feature and has many benefits to the combustion performance and the system's ability to handle a variety of wastes.

There are over 50 installations world wide using the revolving fluidized bed design. The systems range from small transportable units for soil cleaning to larger 400 T/day municipal waste disposal plants.

Superburn is currently constructing a 360 T/day revolving fluidized bed incineration plant in Sydney, Nova Scotia, Canada, for the Sydney Tar Pond Clean–Up Project, Canada's largest hazardous waste site clean–up. The total capital cost of the equipment is $16.5 million and will also produce up to 10 MW of power which will be sold.

The tar pond sludge is a coke oven residue containing hazardous organics which has accumulated to 700,000 tonnes in a small bay from the operation of a steel mill. The steel mill has now been converted to clean technology and the tarpond sludge will be disposed of in a Superburn plant.

Prior to contract award, Superburn conducted a series of trial burns on the sludge in a 6 M Btu/hr demonstration plant in Vancouver, BC. The objective of the trial burns was to confirm that stable operation could be achieved and the Principal Organic Hazardous Components, mainly PAHs could be destroyed with an efficiency of 99.99 percent. The revolving fluidized bed operated stably without support fuel on the coke oven residue and achieved DRE values on the POHCs of 99.99 percent to 99.9999 percent.

THERMAL GAS-PHASE REDUCTION OF ORGANIC HAZARDOUS WASTES IN AQUEOUS MATRICES

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Methods for the destruction of hazardous wastes containing chlorinated organic compounds such as PCBs have generally relied on some form of incineration. Potential problems that are associated with incineration include formation of small amounts of dioxins and furans, and the high cost of burning wastes which are mainly water, such as harbour sediments and landfill leachates.

Thermal gas-phase reduction of organic hazardous wastes in aqueous matrices is an alternative to incineration that eliminates both of these problems. The reaction is conducted in a hydrogen-rich reducing atmosphere with a complete absence of oxygen, resulting in virtually complete dechlorination of organic molecules and production of lighter recoverable hydrocarbons. After scrubbing the HCl from the gas stream, these hydrocarbons may be used as fuel in the boiler that preheats the waste. No chlorinated dioxins or furans are formed since the chlorine has been removed.

ELI Eco Technologies is currently building a mobile system based on its patented thermo-chemical process as a demonstration project for the Canadian Department of National Defense. The 2m diameter, 3m high reactor is designed to process 4 kg/min of aqueous waste contaminated with 10 percent PCBs. The demonstration project will take place during the summer of 1990.

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

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Chemical Waste Management (CWM) has developed a patented system, X*TRAX®, that thermally separates organics from solids, such as soils, pond sludges, and filter cakes, in an indirectly heated rotary dryer. Vaporized organics and water are transported with a nitrogen carrier gas to a gas treatment system where they are condensed and collected as a liquid. The gas is then reheated and recycled to the dryer. To control oxygen, a small portion of the carrier gas is vented to atmosphere through carbon adsorbers.

CWM has constructed a full-scale transportable X*TRAX® system that has been contracted for a PCB soils clean-up at a mid-size Superfund site in the Eastern U.S. The system is expected to mobilize in mid to late 1990 on that site. In an innovative combination, the condensed organic liquid will be chemically dechlorinated on site prior to off site disposal. A SITE demonstration test will be conducted at this site during the performance of the clean-up. Since early 1988, CWM has operated both a 5 ton/day pilot demonstration system, and a 2–4 lb/hr laboratory system for treatability studies. The pilot system has recently completed 10 tests using TSCA regulated PCB soils and is currently in preparation for an extensive testing program using RCRA regulated materials. In addition to a number of surrogate wastes, the laboratory system has processed over 19 RCRA and TSCA regulated waste materials.

ANAEROBIC PYROLYSIS FOR TREATMENT OF ORGANIC CONTAMINANTS IN SOLID WASTES AND SLUDGES – THE AOSTRA TACIUK PROCESS SYSTEM

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The AOSTRA Taciuk Process (ATP) is a thermal treatment technology which has been developed and proven effective for separating organic contaminants such as oils and petrochemicals from solid wastes, soils, and sludges. The process was developed jointly by the Alberta Oil Sands Technology and Research Authority and UMATAC Industrial Processes for producing bitumen from Alberta's oil sand deposits as distillate oil product, and for producing oil from oil shales. The extensive test work in these fields, and recent work directly with waste materials, are the background to the recent commercial application of the ATP System in waste treatment.

The ATP technology is a continuous flow pyrolysis system which achieves the separation of organic contaminants from host solids in the wastes, and offers the advantages of minimum air emissions, ability to recycle the organics, rapid treatment of waste volumes, and low cost. The ATP System has been extensively tested and its capability demonstrated for separating water and organic contaminants from soils and sludges.

The plant is a recycling facility for those constituents in the waste which are re-usable. It renders the solids free of the organic contaminant(s): the liquid products (water and oil) for reuse, secondary treatment, or disposal; and the air emissions meet regulatory criteria applicable to thermal remediation treatment of wastes.

The first commercial ATP treatment plant has a design capacity of 10 tph and was ready for service in September 1989. It will be employed in waste treatment, initially on a PCB separation soil treatment Superfund project in the U.S.A. The plant is portable and will be used on numerous job sites in North America. Other remediation projects and applications for the ATP technology and portable treatment plants of various sizes are being developed.

BIOLOGICAL TREATMENT

ALGASORB® : A NEW TECHNOLOGY FOR REMOVAL AND RECOVERY OF METAL IONS FROM GROUNDWATERS

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Bio-Recovery Systems has developed a new sorption process for removing toxic metal ions from water. This process is based upon the natural, very strong affinity of biological materials, such as the cell walls of plants and microorganisms, for heavy metal ions. Biological materials, primarily algae, have been immobilized in a polymer to produce a "biological" ion exchange resin, AlgaSORB®. The material has a remarkable affinity for heavy metal ions and is capable of concentrating these ions by a factor of many thousand-fold. Additionally, the bound metals can be stripped and recovered from the algal material in a manner similar to conventional resins.

This new technology has been demonstrated to be an extremely effective method for removing toxic metals from groundwaters. Metal concentrations can be produced to very low parts per billion (ppb) levels. An important characteristic of the binding material is that high concentrations of very common ions such as calcium, magnesium, sodium, potassium, chloride, and sulfate do not interfere with the binding of heavy metals. Waters containing a total dissolved solids (TDS) content of several thousand and a hardness of several hundred parts per million (ppm) can be successfully treated to remove and recover heavy metals. The process has been demonstrated under the Emerging Technology program of the SITE program for the effective removal of mercury from a contaminated groundwater.

BIOSORPTION – A POTENTIAL MECHANISM FOR THE REMOVAL OF RADIONUCLIDES FROM NUCLEAR EFFLUENT STREAMS

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Of the various stages involved in processing and reprocessing in the nuclear fuel industry, many produce aqueous effluent streams which contain both radioactive and non-active contaminants that can be considered hazardous to the environment. Currently, a variety of techniques are used to reduce the radionuclide loading of such effluents. These include filtration, ion exchange, and adsorption to mineral lattices. Many of the treatment processes currently in use demonstrate high efficiencies where substantial concentrations of radionuclides are present. However, where effluent metal concentrations lie in the lower range of 1 to 100 ppm, some of the classical treatments become less effective.

Biotreatment Limited is currently undertaking a laboratory research program to assess the potential of various forms of microbial biomass as matrices for the accumulation of metal cations that are of significance in nuclear reprocessing effluents. This study focuses on the biosorption of three of the cations most significant in nuclear effluent streams (strontium, ruthenium, and cobalt).

A selection of microorganisms, isolated from both natural and contaminated environments, were screened for their ability to tolerate various concentrations of the stable isotopes Sr, Ru, and Co. On the basis of this screening, organisms were selected for further testing in small-scale liquid culture media and model effluent streams constructed in the laboratory. Complete removal of Co and Sr from solution was demonstrated during 48h incubation at metal concentrations below 10 mg/l, using living cultures of Trichoderma viride and Penicillium expansum, although the composition of the liquid medium significantly affected biosorption. Biosorption was much less effective at metal concentrations between 30 and 200 mg/l. Some systems containing microbial necromass (dead cells) also showed cation removal from solution. Microbial biomass incorporated into a filter bed for the treatment of model effluent streams showed limited success in removing metal ions, although recirculation of the stream may offer a more effective system in the future.

BIOLOGICAL TREATMENT OF WASTEWATERS

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The Biological Aqueous Treatment System (BATS) was demonstrated for treatment of groundwater contaminated with pentachlorophenol (PCP). The system employs indigenous microorganisms; however, it is also amended with a specific PCP-degrading bacterium. Three flow rates were tested, corresponding to residence times of 9, 3, and 1.8 hours. PCP removal ranged from 97.6 to 99.8 percent, with average effluent PCP concentrations as low as 0.13 ppm. It was shown that biological degradation was the predominant removal mechanism while air stripping and bioaccumulation were negligible. Acute biomonitoring with minnows and water fleas showed complete removal of toxicity by the treatment system.

The BATS has also been shown to be highly effective for treatment of a variety of wastewaters, including process water and lagoon water, and for a wide range of contaminants. Results were presented on treatment of gasoline, phenolic, and solvent-contaminated wastewaters.

BIOTECHNICAL SOIL PURIFICATION OF SOIL POLLUTED BY OIL/CHEMICALS

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A/S Bioteknisk Jordrens has, during the three years of its existence, treated 110,000 tons of polluted soil, in 550 cases ranging from 600 kg to 11,000 tons. The pollutants have in most cases been light fuel oil, but soils polluted with the following have also been purified: gasoline, diesel, heavy fuel oil, acetone, MIBK, fish oil, turpentine, ethylene glycol, toluene, xylene, hydraulic oil, lubricating oil, ether, isopropanol, talates, and chlorobenzene.

The pollutants are microbiologically decomposed. The method is used in two different ways. In soil polluted with "non-volatile" pollutants such as light fuel oil, diesel/gasoline (which usually accompany each other), hydraulic oil, etc., these soil pollutants often consist of great volumes of relatively mildly polluted material. The soil is arranged in elongated stacks to separate one case from the other and facilitate treatment. Nutrients and bacteria are added and the soil is aerated. The microbiological decomposition of the pollutants is monitored by means of gas chromatography. The final content of oil before release for reuse is normally at a level where the content of oil cannot be detected, which means <10 ppm oil with the method of analysis applied.

In soil polluted with volatile and/or poisonous substances such as toluene, xylene, MIBK, acetone, chlorobenzene, etc., this soil may involve a risk as regards working environment. Purification takes place in a closed system where the pollutants are driven out of the soil by means of air via a bottom made of a specially developed perforated concrete clinker. The polluted soil is taken to a compost filter where bacteria decompose the pollutant. The method is also used in situ.

The basic price of soil purification of light components such as light fuel oil is DKK 160.00 per ton (USD 20). Heavy pollutants such as hydraulic oil require a relatively longer purification period and are therefore relatively more expensive. Soil purification of light fuel oil usually takes six months (= USD 20/t), and where heavy fuel oil is involved the period required for purification is one year (= USD 40/t).

IN SITU PHYSICAL AND BIOLOGICAL TREATMENT OF VOLATILE ORGANIC CONTAMINATION: A CASE STUDY THROUGH CLOSURE

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Organic contamination of soils and groundwater can present a long-term health and safety problem due to contamination of water supplies, and the migration and accumulation of vapors in structures. Treating organic contamination is a complex problem due to its complex phase distribution – free phase, adsorbed, dissolved, and vapor phase. No single remedial process is equally effective in dealing with all phases of contamination. Successful remediation requires the application of multiple techologies such as immiscible phase recovery, vapor extraction, and bioremediation. The case history presented in this paper demonstrates the successful application of this approach to the remediation of a site impacted by volatile petroleum hydrocarbons. The site treated was a retail gasoline station in suburban Montreal that had impacted an adjacent commercial establishment. Over a two and one-half year period the site was brought from severe contamination to closure. The technology utilized was a combined soil vent product recovery and bioreclamation system.

SOLIDIFICATION/STABILIZATION TREATMENT

THE GEODUR SOLIDIFICATION PROCESS

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During the last two years the Geodur solidification process has been developed and adapted to solidify/stabilize different hazardous chemicals in organic/inorganic soils and other solid waste materials. A pending patent has been taken on the Geodur concentrate/additive which is the main substance of the Geodur process. The additive is produced on a natural molecular basis and totally free of poisonous matter, harmless for workers and the environment.

The process consists of a mixing of the Geodur solution (Geodur concentrate in a ratio with water of 1:100) with the actual soil/solid waste, Portland cement, and water. As a result of this concrete is produced. The Geodur process activates chemically the natural bonding capabilities of the contaminated soil/solid waste by changing the surface tensions. This process of agglomeration produces an ultimate stabilizing effect on the solid waste product with high density and strength. The pH-factor of the soil/solid waste does not have any influence on the final strength of the concrete because it is controlled chemically by the Geodur solution.

The following kinds of soils and solid wastes have been solidified: Garden topsoil, clay and clayey humus, sand and sandy humus, silt, desert sand (salty), coast sand (salty), laterite, volcanic lava, mud (sediments with blue clay), municipal sludge (heavy metals), hazardous chemicals and oil contaminated soils, fly ashes, and stabilized and raw sulphite powder.

Apart from the leachability tests of contaminants, the chemical and ecotoxicological properties of the leachate are studied together with the mechanical strength and durability of the solidified materials. Petrographic analyses have also been carried out. It should be mentioned that a special ecotoxicological fouling test is carried out on different solidified materials exposed insitu in receiving waters. On the basis of the promising results with the process, Geodur now has the possibility for a full-scale mobile plant with a capacity up to approximately 120 tons per hour.

CHEMFIX – HEAVY METAL SOIL FIXATION

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In 1988, Chemfix Technologies, Inc. was chosen to participate in EPA's SITE Program at the Portable Equipment Salvage Company Superfund Site in Clakamas, Oregon. Among the goals of this demonstration were to show the viability of the CHEMSET™/CHEMFIX® process on heavy metal contaminated soil.

The treatment chemistry designed for the Program was waste specific and included the use of CHEMSET™ reagents. Specially designed high solids CHEMFIX® processing equipment was also employed.

Four individual areas were treated at the site, some with as much as 140,000 ppm of lead and 74,000 ppm of copper. The raw TCLP numbers were as high as 880 ppm for lead and 120 ppm for copper. A reduction of as much as 99+ percent in the TCLP mobility of these metals was demonstrated while producing a useable soil-like finished product (NATURFIL®).

AN EVALUATION OF THREE LEADING INNOVATIVE TECHNOLOGIES FOR POTENTIAL CLEAN-UP OF BASIN F MATERIALS AT ROCKY MOUNTAIN ARSENAL

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Our evaluation of innovative treatment technologies for the clean-up of Basin F at Rocky Mountain Arsenal (RMA) was conducted for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) from July 1986 to July 1988. The arsenal is located just northeast of Denver, and covers approximately 17,000 acres. On-site operations, which ran from 1942 to 1982, included chemical/incendiary manufacture and chemical munitions demilitarization (both military operations), as well as insecticide/pesticide manufacture by Shell Oil, which leased the facility from the Army in the early 1970s. Both military and industrial operations generated a variety of wastewaters that were disposed of in on-site lagoons, the best technology available at that time.

Three technologies were selected for laboratory or bench-scale evaluation testing; fluidized/circulating bed combustion, glassification, and soil washing. Fluidized/circulating bed combustion appeared promising and cost-competitive, but a major obstacle could not be overcome. Neither of the two existing vendor test facilities equipped with the appropriate FBC test equipment had the proper permits for operating with Basin F material. Soil Washing proved effective. After the soil from Basin F was washed through this process, we did a TCLP (Toxic Characteristic Leaching Procedure – an EPA-recommended test) to find out if the effluents should be classified as hazardous or nonhazardous. We found that while some target contaminants remained – that is, some pesticides and metals were detected – the levels were not measurable. Glassification process worked successfully on the Basin F material; organochlorine compounds were reduced by more than 99.9 percent, organophosphorus compounds were reduced by more than 99.7 percent, and organosulfur compounds were reduced by more than 99.6 percent. TCLP leachate from the glass product could be classified as nonhazardous since no target contaminants were detected.

As a result of this technology review and testing, we recommended that glassification should be the process pilot-tested on site at RMA. The cost for clean-up would be high – up to $200-300 million for treating Basin F material alone – but future government liability should be low because of the final vitrified, highly leach-resistant state of the residuals; in addition, the two-and-a-half-year time frame specified by the U.S. Army for Basin F Clean-up could be met.

SOIL VAPOR EXTRACTION AND TREATMENT OF VOCS AT A SUPERFUND SITE IN MICHIGAN

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The Verona Well Field supplies potable water to the City of Battle Creek, Michigan, three townships, and another small city. The combined service area equates to approximately 50,000 people. In 1981, the well field and surrounding area were found to be contaminated with chlorinated solvents and other volatile organic compounds (VOCs). The contaminant plume extended throughout an area approximately one mile by one-half mile. Two facilities operated by a local solvent wholesaler/distributor were identified as the primary sources of the contamination. VOC concentrations as high as 1,000 parts per million (ppm) were found in the groundwater and soil at the wholesaler's primary facility.

EPA selected enhanced volatilization of VOCs using soil vapor extraction (SVE) to clean up the contaminated soils. A pilot SVE system was installed in late 1987 and operated for about 69 hours. Approximately 3,000 pounds of VOCs were removed from the vadose zone during the pilot study. Using the results of the pilot phase, a full-scale SVE system was designed and installed in early 1988. The full-scale SVE system began operation in March 1988. It has since removed more than 40,000 pounds of VOCs.

From system startup until January 1990, extracted vapors containing VOCs were passed through vapor-phase activated carbon for treatment prior to discharge. In January 1990, the carbon system was replaced by a catalytic oxidation system capable of providing onsite destruction of VOCs. The catalytic oxidation system is expected to provide more continuous operation and a cost savings over the life of the project.

SLUDGE AND SOIL TREATABILITY STUDIES AT A LARGE SUPERFUND SITE

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The Bofors-Nobel (Bofors) Superfund Site, in Muskegon, Michigan, is under management by the Michigan Department of Natural Resources, Grand Rapids District, in cooperation with the United States Environmental Protection Agency, Region V. Ten sludge lagoons were used at the site for waste disposal from a chemical manufacturing facility. The sludge volume is approximately 120,000 cubic yards (yd^3). The volume of contaminated soils around the lagoons is approximately 748,000 yd^3.

Compounds of concern were selected during the baseline risk assessment:

- Aniline
- Azobenzene
- Benzene
- Benzidine
- 3,3' - Dichlorobenzidine (DCB)
- Methylene Chloride

These compounds are known, suspected, or potential human carcinogens. Clean-up standards for the sludges and soils were developed based on 10^{-4} and 10^{-6} excess cancer risks according to EPA guidelines.

Soil washing, low temperature thermal desorption (LTTD), and solidification/stabilization were selected for bench-scale treatability testing. Samples indicative of worst-case soil, worst-case sludge, average soil, average sludge, and average sludge and soil mixture were evaluated in the studies. Results of the treatability studies are summarized below:

- Soil Washing: This process was not effective in cleaning worst-case or average soil, specifically for DCB and azobenzene.
- LTTD: This process appears to be effective for cleaning worst-case soil and average sludge. LTTD was not effective for worst-case sludge and average sludge and soil.
- Solidification/Stabilization: Compounds of concern present in the prestabilized TCLP extract were generally still present in the stabilized TCLP extract in significant concentrations. Therefore, stabilization does not appear to be effective for this site.

CRITICAL FLUID SOLVENT EXTRACTION

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Solutions to today's environmental problems require the use of new technology or the application of existing technology in an innovative way. However, innovative applications of technology cannot be utilized in full-scale site remediations until they have been evaluated for environmental and economic effectiveness. The Superfund Innovative Technology Evaluation (SITE) program was established to evaluate innovative uses of technology in environmental clean-up operations. This paper presents the results of a pilot-scale testing for a critical fluid solvent extraction technology on creosote-contaminated soil at the United Creosoting Superfund Site in Conroe, Texas. This paper presents an independent pilot study to evaluate critical fluid extraction as a technical alternative.

The critical fluid extraction technology utilizes a solvent near its critical point, or state, to remove contaminants from various media. Under such conditions, the solvent's properties are enhanced to obtain high removal efficiencies and minimal residue is left in the media undergoing treatment. In the case of United Creosoting, contaminated soils consisted of compounds used in the former wood treating operations at the site: polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), and trace dioxins and furans. Propane gas was liquified by compression and used as the solvent in an onsite pilot-scale unit. The soil was mixed with water and fed into the extraction unit where the liquified propane dissolved the hydrocarbons from the soil slurry. The cleaned solids and water in the soil were allowed to settle, while the contaminant/propane solution was passed through a pressure reducing stage. The propane was vaporized in this stage, leaving concentrated hydrocarbons which can be incinerated.

Samples of untreated and treated soil were analyzed for priority pollutant organic compounds and dioxins. However, PAHs, PCP, and the dioxins were the contaminants of concern and are summarized in this paper. The onsite pilot testing of two 55-gallon drums at the United Creosoting site demonstrated removal efficiency for PCP was approximately 91 percent. Dioxins and furan removal efficiencies ranged from 66-83 percent.

SOLVENT EXTRACTION - A CASE STUDY - BENCH-SCALE TREATABILITY TESTING OF SOLVENT EXTRACTION FOR TREATMENT OF WASTES AT THE ARROWHEAD REFINERY SITE, MINNESOTA

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Solvent extraction is a separation technology that has demonstrated some applicability as a hazardous waste treatment technology. The technology has been applied to industrial wastewater, soil, and sludges contaminated with hydrocarbons, petroleum products, or heavy organic compounds. Basically, solvent extraction is a process that separates the waste feed stream into oil (organic), water, and solid phases. Rather than destroy the contaminants, the process yields products that may be more amenable to treatment, disposal, or in some cases, recycling.

The Arrowhead Refinery Superfund site in Hermantown, Minnesota, is a former waste oil recycling facility. Sludge bottoms and residual oils mixed with a clay filter cake were disposed of in a two-acre lagoon. The lagoon contains an acidic, metal laden, viscous oily sludge mixed with clay, fill material and the underlying peat. Adjacent surface soils throughout the site have also been contaminated with oil, and various organic and inorganic contaminants. The primary contaminants throughout the site are lead and polynuclear aromatic hydrocarbons.

A bench-scale solvent extraction treatability test was performed on wastes from the site by Resources Conservation Company (RCC) using their Basic Extractive Solvent Technology (B.E.S.T.™). Samples of the oily sludge, oily peat, and contaminated soil were tested individually. Samples of the untreated and treated wastes were analyzed through the TCLP to evaluate the performance of this solvent extraction process. The results of the bench-scale testing and a discussion of the performance of solvent extraction as a treatment technology for these wastes was presented.

CONCEPTUAL COST EVALUATION OF VOLATILE ORGANIC COMPOUND TREATMENT BY ADVANCED OXIDATION

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When VOCs were detected in the groundwaters of the San Gabriel Valley, the valley was listed as a Superfund site. In the course of the remedial investigation (RI), potable water treatment technologies were evaluated to determine effectiveness in reducing contamination levels below drinking water standards. Advanced Oxidation Processes (AOPs) are increasingly being considered as alternatives to more traditional air stripping and carbon adsorption processes. The effectiveness of ozone/hydrogen peroxide treatment (one of many variations on AOPs) of water is strongly dependent on local water chemistry (pH, alkalinity, hardness, total dissolved solids). A bench-scale treatability study was conducted to determine the effectiveness in treating trichloroethylene (TCE), tetrachloroethylene (PCE), carbon tetrachloride (CTC), and trans-1,2-dichloroethylene (t-1,2-DCE) in San

Gabriel Valley contaminated groundwaters. Results of the treatability study indicated the following:

- a hydrogen peroxide/ozone molar ratio of 0.5 yielded higher VOC oxidation rates and the most efficient use of oxidants compared to other ratios,
- higher ozone mass feed rate yielded higher oxidation rates,
- reaction rate constants were essentially independent of VOC concentrations,
- reaction rate constants for TCE and PCE were consistent with other studies,
- gas stripping was small or negligible for t-1,2-DCE, TCE, and PCE.

Using data obtained during the treatability study, a conceptual cost evaluation was prepared comparing the costs of air stripping with offgas treatment using vapor phase carbon adsorption, liquid phase carbon adsorption, and ozone/peroxide. Results of the feasibility study evaluation indicated the following relative costs for a facility capable of treating 15,000 gallons per minute contaminated with 75 ppb PCE, 15 ppb TCE, 20 ppb t-1,2-DCE, and 1.1 ppb CTC:

Ozone/peroxide treatment	$0.14/1,000 gallons
Air stripping with offgas treatment	$0.10/1,000 gallons
Carbon adsorption	$0.22/1,000 gallons

Ozone/peroxide treatment provides an added benefit of being a destructive technology which reduces the mobility and toxicity of contaminants in the treated waste stream. While ozone/peroxide treatment appears economical, additional pilot testing is required prior to actual application of the technology.

RECOVERY OF METALS FROM WATER USING ION EXCHANGE

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Ion exchange technology is being used to treat ground and storm waters at a wood treatment facility in California as part of a comprehensive site remediation program. Wood treating chemicals (inorganic metals) recovered from the site waters are reused in the wood treating operation. Offsite waste disposal is minimized and resource recovery is maximized.

Through past operation of the wood treatment facility, chromium has been released to the groundwater beneath the facility. Chromium and copper residues are present in storm water runoff which is captured on the site. Site investigations have determined the extent of groundwater contamination, and groundwater extraction and treatment remedial actions have been implemented.

In 1987, an ion exchange water treatment plant was put into operation at the facility. The ion exchange process captures hexavalent chromium from the groundwater which is being extracted from beneath the site. The process also captures copper and chromium which is in the storm water runoff on the site. The ion exchange resins are regenerated periodically to recover the captured wood treating metals in a concentrated form. The recovered metals are reused in the acid copper chromate (ACC) wood treating solution. To provide a regenerant stream suitable for reuse in the wood treating process, weak base and weak acid ion exchange resins were selected.

The water treatment plant has processed over 50 million gallons of water in over two years of operation and has consistently met the effluent quality limits. Operating problems encountered and overcome during the operating history were presented.

EVALUATION OF STABILIZATION/SOLIDIFICATION FOR CHROMIUM REDUCTION AND IMMOBILIZATION FOR THE MOUAT, MONTANA SITE

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In the late 1950s and early 1960s, Mouat Industries in Columbia, Montana, operated a processing plant that converted ore to high-grade sodium dichromate. During the process, a sodium sulfite waste containing substantial levels of sodium chromate and sodium dichromate was produced at the Mouat plant. The soil and groundwater at the site became contaminated with hexavalent chromium in the leachate from the waste sodium sulfite stockpiles. Analyses of soil and groundwater samples conducted by the Environmental Protection Agency and others in the 1980s led EPA to conclude that concentrations of toxic metals at the site were comparable to background levels of the area, with the exception of chromium. Chromium concentrations in the soil ranged from below 5 ppm to 3,100 ppm.

This report describes a treatability study in which the immobilization of chromium in soils from the Mouat site was assessed using acid washing, chemical reduction, and solidification. The relative effectiveness of an initial acid wash, and each of three reducing agents (sodium metabisulfite, ferrous sulfate, and standard slag), which converted Cr(VI) to Cr(III) in soil-cement matrices, were evaluated. Acid washing of the soil removed 93 percent of the Cr(VI) and 63 percent of the total chromium in the raw soil. The acid-washed soil and acid-washed soil-cement matrices yielded leachates (modified TCLP) which contained significantly less chromium than the raw soil-cement matrix. For soils that are not going to be solidified, acid washing of the soil and Cr(VI) reduction with ferrous sulfate proved to be the best treatment. The use of standard slag as a reducing agent was shown to be the best treatment for solidified, acid-washed soils. One advantage of using the standard slag for soils requiring solidification is that the slag exhibits cement-like properties, thus decreasing the total quantity of cement needed to stabilize the soil.

FIELD DEMONSTRATION OF A CIRCULATING BED COMBUSTOR (CBC) OPERATED BY OGDEN ENVIRONMENTAL SERVICES OF SAN DIEGO, CALIFORNIA

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This field program involved the remediation of polychlorinated biphenyl (PCB) contamination of the Swanson River Field, located on the Kenai Peninsula in southern Alaska. The Swanson River Field is located approximately 50 miles southwest of Anchorage in the Kenai National Wildlife Refuge.

Sampling and analysis of waste feed and effluent streams of the CBC during the Demonstration Test program was performed. Representative samples of waste feed (PCB-contaminated soil and gravel), spent bed material and fabric filter ash (combined sample), and stack gas effluent were collected. All sampled streams were analyzed for PCB concentration. Stack gas samples were collected to determine emission rates of PCB, chlorinated dibenzodioxins and dibenzofurans (PCDDs/PCDFs), particulate matter, volatile organics, and gaseous hydrogen chloride (HCl).

Continuous emission monitoring of stack gas to determine concentrations of oxygen, carbon dioxide, carbon monoxide, and oxides of nitrogen was performed. Grab sampling of soil feed and spent ash materials, and sampling for gaseous HCl on a rapid turnaround basis for potential modification of the sorbent (limestone) feed rate was conducted during the field test program.

The unit features a 30-inch internal diameter combustion zone measuring approximately 33.6 feet in height. Bed solids, consisting of sand, limestone, and feed material are purposely entrained and carried out the top of the combustor. Solids are then collected by a cyclone and continuously returned to the bottom of the incinerator. Gases exiting the combustor pass through a three-zone heat exchanger consisting of water cooling (Zone 1), preheating of ambient air for feeding into the combustor (Zone 2), and an air blast section using ambient air and discharging to atmosphere (Zone 3). Flue gas then flows to a fabric filter for particulate removal prior to exhaust to the atmosphere.

This program was closely monitored by OTS and by Alaskan agency personnel. In June of 1989, Ogden announced that they had been issued a nationwide federal permit for use of the CBC system for remediation of PCB-contaminated soils.

LOW TEMPERATURE THERMAL TREATMENT (LT3) OF SOILS CONTAMINATED WITH AVIATION FUEL AND CHLORINATED SOLVENTS

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Successful pilot study of low temperature thermal treatment (LT^3) (Patent No. 4,738,206) of soils contaminated with volatile organic compounds led to a full-scale demonstration to evaluate the use of this technology at DOD installations. The LT^3 process developed by Weston Services, Inc. under contract with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) was used in a test of remediating soils contaminated with aviation fuel (JP4) and trichloroethylene (TCE). Tinker Air Force Base, Oklahoma, was selected as the demonstration site. An abandoned landfill area had high concentrations of contamination in a clay soil, which was determined to be ideal for this test. The LT^3 process performed better than expected and achieved clean-up levels at lower temperatures, higher processing rates, and shorter residence times than previously thought possible. This directly translates into cost savings for future remediation sites. Test results indicative of the performance and potential application of this technology were presented.

POSTER PRESENTATIONS

TOXIC METAL REMOVAL FROM AQUEOUS WASTE STREAMS USING COMBINED CHEMICAL TREATMENT AND ULTRAFILTRATION

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The removal of selected soluble toxic metals from aqeuous solutions has been achieved using a combination of chemical treatment and ultrafiltration. Chemical treatment involves adjusting the alkalinity of the solution and adding polyelectrolyte at the parts–per–million level. Bench– and pilot–scale ultrafiltration experiments undertaken have realized removal efficiencies in excess of 34–55 percent for typically–found average concentrations of the toxic metals in groundwaters at Superfund sites. The program directed at the bench–scale investigated process limitations, while the tests conducted with the pilot–scale process equipment have provided data on longer–term process efficiencies, effective processing rates, and membrane fouling potential. Optimization of process variables, viz., solution pH, polyelectrolyte, polyelectrolyte concentration, and membrane material, has indicated what the operating range should be to remove soluble metal cations from water. The proposed technology has the potential to be applied successfully to the selected removal of toxic metals in groundwaters at Superfund sites. The final phase of the program involving a field demonstration at a uranium tailings site was outlined.

LEEP TECHNOLOGY SOIL REMEDIATION BY SOLVENT EXTRACTION

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LEEP (Low Energy Extraction Process) is a new solvent extraction process for the decontamination of earth materials containing organic pollutants. The contaminants are leached with a water miscible solvent and subsequently concentrated in a water immiscible solvent for ultimate off site disposal. The leaching solvent is recycled internally. LEEP is applicable to

various types of earth materials ranging from dry topsoil to very wet sediments, as well as to refinery sludges.

Among the compounds which LEEP can remove from earth materials, are some of the most prevalent pollutants, such as polychlorinated biphenyls (PCBs), dioxin, polyaromatic hydrocarbons, pesticides, wood preserving compounds, and petroleum products (e.g., heating oil and gasoline) to mention just a few. Results from bench-scale treatability studies conducted with different matrices show very high removal efficiencies. A number of compounds such as PCBs, polyaromatic hydrocarbons, and oil and grease in refinery sludges have been removed to levels below the detection limits.

The LEEP technology, which operates at ambient conditions, is built from simple, rugged pieces of equipment. Key process parameters can be adjusted to meet site specific requirements, which guarantees a complete and efficient clean-up of virtually every organic compound. The technology offers a cost effective way for on-site remediation of contaminated sites.

The development of the process concept and the early bench scale experiments were conducted at New York University under an EPA grant. ART International Inc. is currently building a trailer-mounted pilot plant. The work is supported by EPA under the SITE Emerging Technologies Program. ART International offers bench-scale treatability studies for the evaluation of the LEEP technology to remediate particular sites.

IN SITU ELECTROACOUSTIC SOIL DECONTAMINATION (ESD) PROCESS

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The technical feasibility of the electroacoustic soil decontamination (ESD) process through laboratory experiments clearly demonstrated the removal/concentration of heavy metals such as cadmium and zinc. Results of the decontaminated soils were, however, inconclusive.

The ESD process is based on the application of a d.c. electric field and acoustic field in the presence of a conventional hydraulic gradient to contaminated soils to enhance the transport of liquid and metal ions through the soils. Electrodes (one or more anodes and cathode) and an acoustic source are placed in contaminated soils to apply electric and acoustic fields to the soil. This process works especially well with clay-type soils having small pores or capillaries, where hydraulic permeability is very slight. The process is suitable for in situ soil washing.

The Phase I development program included a literature review, soil characterization, design and construction of the laboratory ESD unit, and lab-scale experiments with soils contaminated with decane, zinc, and cadmium. Evaluation of the experimental results showed that application of the field forces reduced zinc or cadmium metal concentration by more than 90 percent. A maximum of 97.4 percent concentration reduction in cadmium and 92.3 percent reduction in zinc were obtained. The results of the organic contamination (e.g., decane) were inconclusive as a result of the large discrepancy in the decane laboratory analysis.

EXXFLOW AND EXXPRESS MICROFILTRATION TECHNOLOGY

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EPOC manufactures microfiltration membrane separation systems using tubular woven textile modules. The process separates particles down to 0.01 micron and is used in a wide range of applications including soil detoxification, hazardous waste reduction, water purification, and materials recovery.

Both the EXXFLOW and EXXPRESS systems use a rugged flexible material which can be used with strong acids, strong bases, and can withstand operating temperatures to 180°F. Operational difficulties associated with other membrane separation processes have been virtually eliminated.

The EXXFLOW process removes heavy metals, pesticides, hardness, bacteria, and other impurities from water. EXXPRESS uses the same tubular membrane in the press mode which automatically dewaters soils, sludges, and aqueous wastes from toxic sites, industrial plants, food processes, and municipal water works.

EXXFLOW and EXXPRESS have been commercially applied to several industrial wastes including the removal of zinc and pesticides from pesticide wastes, and lead, zinc, and cadmium from ceramics industry waste.

For the EPA SITE program, EPOC will demonstrate the ability of the EXXFLOW/EXXPRESS system to successfully remove iron, copper, and zinc from acid mine drainage water at an iron mine in Northern California. The EXXFLOW unit will concentrate the precipitated heavy metals to a level where they will be dewatered by the EXXPRESS unit. The results are expected to be a semi-dry cake of 40–50 percent solids and a discharge water which will meet EPA discharge standards.

DIKLOR-S (CHLORINE DIOXIDE) TECHNOLOGY FOR WASTEWATER APPLICATIONS

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The technology used is based on the oxidation characteristics of chlorine dioxide and the unique way in which the EXXON CHEMICAL COMPANY - RIO LINDA CHEMICAL COMPANY process manufactures the oxidant and applies it to waste streams. Chlorine dioxide is manufactured in a patented generator that combines three separate chemical precursors. These precursors are 12.5 percent sodium hypochlorite, 15 percent hydrochloric acid, and 25 percent sodium chlorite.

The sodium hypochlorite and hydrochloric acid are combined in stoichiometric ratios to form chlorine gas. The resulting chlorine gas is aspirated into a chamber where it is combined with sodium chlorite. When these reactants come together in a reaction ratio of 1:2, one chlorine molecule oxidizes two chlorite anions, converting them to two molecules of chlorine dioxide. This reaction is instantaneous and can go to completion in a very small, compact reaction chamber. This reaction produces 95 to 98 percent pure chlorine dioxide. The critical aspect of the chemistry of this reaction is that molecular chlorine reacts with sodium chlorite faster than the hydrolyzation reaction of the chlorine with water.

Historically, chlorine dioxide treatment systems have been applied to drinking water disinfection, food processing sanitation, and as a biocide in industrial process waters. Since chlorine dioxide reacts via direct oxidation rather than substitution (as does chlorine), the process does not form undesirable trihalomethanes, an important feature when the chemical is applied to waste streams. This technology is applicable to aqueous wastes, soils, or any leachable solid media contaminated with organic compounds. It can also be applied to groundwater contaminated with pesticides or cyanide; sludges containing cyanide, sulfides, or other organics; and industrial wastewaters similar to refinery wastewater. It has been applied to remove phenols, mercaptans, thiosulfides, hydrogen sulfide, iron sulfide, and cyanide in a variety of industrial applications. Field application expertise and rugged, portable, compact equipment has been jointly developed by the two companies.

BIOREMEDIATION OF HAZARDOUS WASTES IN A SLURRY PHASE – THE EIMCO BIOLIFT(TM) REACTOR

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Bioremediation in the slurry phase offers distinct advantages over insitu treatment, land treatment, or composting: better control of environmental conditions, i.e., pH, temperature, aeration, nutrients, desorption of contaminants into aqueous phase, and thus, more rapid treatment of certain wastes. A closed reactor allows volatile emission control and operation in aerobic or anaerobic mode. Potentially, genetically engineered bacteria will first be used in closed reactor systems.

The EIMCO Biolift(TM) Reactor is a modified slurry agitator that uses a central airlift, bottom rakes, and an innovative diffuser design to achieve the basic objectives of mixing and aerating a slurry to sustain aerobic biodegradation processes. It can handle slurries of 25 – 50 wt% solids concentrations and provide mixing and aeration at a much lower energy consumption than conventional liquids/solids contact reactors. Biolift(TM) Reactors are supplied in four standard sizes ranging from 18,000 gallon to 300,000 gallon. Pilot equipment is available for treatability studies.

The Biolift(TM) Reactor is being used in several RCRA and Superfund applications. A wide mix of organic contaminants have been degraded in different soil and sludge matrices.

ALTERNATING CURRENT ELECTROCOAGULATION

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Hazardous constituents in wastewater may be suspended, emulsified, and/or completely or partially solubilized. In the traditional method of treating multi-phase wastes, chemicals are added to encourage flocculation and precipitation, as well as to enhance mechanical dewatering. A new technology using alternating current electrocoagulation (ACE) can effectively achieve phase separation of aqueous mixtures containing emulsified oils, suspended solids, and various dissolved pollutants. This unique approach is being developed by Electro-Pure Systems, Inc., a joint venture of Recra Environmental, Inc. and Co-Ag Technologies.

An alternating current electrocoagulator imposes an electric field on stable suspensions and emulsions and rearranges surface charges, which in turn facilitates particle flocculation and separation. Liquid/liquid and solid/liquid phase separations are achieved without the use of expensive poly-electrolytes. The process is also free of the excess waste solids attributed to chemical aids. This technology is used to break stable aqueous suspensions containing submicron-sized particles up to 5 percent total solids. It also breaks stable aqueous emulsions containing up to 5 percent oil.

The ACE technology can be applied to a variety of aqueous-based suspensions and emulsions typically generated as contaminated groundwater, surface run-off, landfill leachate, truck wash, incinerator scrubber solutions, treated effluents, and extract solutions. The suspensions include solids such as: inorganic and organic pigments, clays, metallic powders, metal ores, and natural colloidal matter. The emulsions include an array of organic solid and liquid contaminants including petroleum base byproducts. ACE has been used to remove fines from coal washwaters and colloidal clays from mine ponds in capacities up to 750 gpm. It has also been used to remove suspended solids and heavy metals from pond water and creosote-based contaminants from groundwater.

PHYSICAL/CHEMICAL TECHNOLOGIES FOR SOIL DECONTAMINATION

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IT Corporation is participating in the SITE Emerging Technologies Program (ETP) with two pilot demonstration projects featuring innovative technology combinations for soil decontamination. The first project, scheduled to be complete by the end of 1990, uses batch steam distillation followed by acid extraction to remove two common superfund site contaminants – volatile organic compounds (VOCs) and heavy metals. The separation of these contaminants from the soil is done batchwise in conventional equipment by slurrying the soil in water. Batch operation facilitates process adjustments to meet changing feed compositions. The treated soil can be returned to the site.

The second project has a duration of two years and will test the use of ultraviolet (UV) radiation to decompose polychlorinated biphenyls (PCBs) and polychlorinated dibenzo dioxins (PCDDs) on soil and make them less recalcitrant to biodegradation. The PCB photolysis residues will be further treated by biodegradation. Both sunlight and artificial UV light will be tested on test plots of contaminated soil. A photolysis–enhancing surfactant will be used to accelerate decomposition. Biodegradation tests will utilize indigenous microorganisms that have been enriched and propagated on PCB–type compounds. Results from this project will be available in 1992.

QUAD CHEMTACT™ MIST SCRUBBING TECHNOLOGY

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The patented QUAD Chemtact™ Mist Scrubbing Technology for removing gaseous contaminants has been in use for 15 years, with over 150 QUAD systems in a variety of industrial–sized applications. Major applications have been in odor removal for wastewater, rendering, paint resin, automotive plants, and landfill gases. Odor applications are extremely difficult because of the need to remove contaminants to levels of parts per billion.

Recent tests applied the Chemtact™ systems to treating VOC emissions. In an independent laboratory test, CH2M Hill reported high efficiencies of removal for a wide range of chemical compounds – usually in excess of 98 percent. Direct comparisons were made with packed column systems which showed only about 50 percent mass removals, and health risk measurements often showed increases in health risk.

The Chemtact™ system operates on different design principles from conventionally designed scrubbers (i.e., packed columns). There are four essential differences:

1. Scrubbing solution is atomized to extremely fine droplets (of approximately 10 microns), thus creating a dense fog;
2. Greater contact time between gas and liquid droplets;
3. Reactant chemical solution is once through, not recirculated;
4. Control instrumentation is used for rapid determinations and control of inlet reactant chemical feed concentrations.

All of these factors combine to make the QUAD mist scrubber function more effectively than conventional scrubber designs. Its benefits include higher efficiencies of removal, lower operating cost, lower maintenance, and lower quantities of liquid effluent to be treated.

VAPOR EXTRACTION SYSTEM

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The Vapor Extraction System (VES) uses a low-temperature, fluidized bed to remove organic and volatile inorganic compounds from soils, sediments, and sludges. Contaminated materials are fed into a co-current, fluidized bed, where they are well mixed with hot gas (about 320°F) from a gas-fired heater. Direct contact between the waste material and the hot gas forces water and contaminants from the waste into the gas stream, which flows out of the dryer to a gas treatment system.

The gas treatment system removes dust and organic vapors from the gas stream. A cyclone separator and baghouse remove most of the particulates in the gas stream from the dryer. Vapors from the cyclone separator are cooled in a venturi scrubber, counter-current washer, and chiller section before they are treated in a vapor-phase carbon adsorption system. The liquid residues from the system are clarified and passed through two activated carbon beds arranged in series. Clarified sludge is centrifuged, and the liquid residue is also passed through the carbon beds.

By-products from the VES treatment include: (1) 96 to 98 percent of solid waste feed as clean, dry dust; (2) a small quantity of pasty sludge containing organics; (3) a small quantity of spent adsorbent carbon; (4) wastewater that may need further treatment; and (5) small quantities of baghouse and cyclone dust.

This technology can remove volatile and semivolatile organics, including polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and pentachlorophenol (PCP), volatile organics, and some pesticides from soil, sludge, and sediment. In general, the process treats waste containing less than 5 percent total organic contaminants and 30 to 90 percent solids. Nonvolatile inorganic contaminants (such as metals) in the waste feed do not inhibit the process, but are not treated.

B.E.S.T. SOLVENT EXTRACTION PROCESS – TREATMENT OF TOXIC SLUDGE, SEDIMENT, AND SOIL

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B.E.S.T. treats toxic waste by extracting contaminants from soils, sediments, and sludges. Wastes containing PCBs, PNAs, pesticides, and petroleum hydrocarbons have been successfully treated with the B.E.S.T. solvent extraction process.

The process solvent, triethylamine (TEA), is unique. B.E.S.T. utilizes TEA's unusual ability to solvate both water and hydrocarbons. This multiple–miscibility characteristic of TEA allows removal of a broad array of contaminants in a variety of waste matrices. For high water content wastes, such as sludges and sediment, separation of clean water is as simple as increasing the temperature of the extract. At warmer temperatures TEA is insoluble in water, prompting the water to quickly settle into a distinct, separable phase.

B.E.S.T.'s solubilization of water and hydrocarbons removes contaminants from complex sludge emulsions and interstitial occlusions in soils. In this way, solids are cleaned and separated for disposal or backfilling. Water which is present in the waste feed will be carried through the process and then removed for discharge. The hydrocarbon contamination is extracted and concentrated reducing the overall volume of waste requiring regulated disposal and destruction.

Process steps include extraction of water and organic contaminants, solids separation and drying, and solvent recycle. TEA is 99.99 percent recycled within the process. Soils processing configurations perform the extraction and solids conditioning steps in a single vessel minimizing overall materials handling operations.

The B.E.S.T. process has been tested on bench–scale with over 50 different samples including soils, sediments, and sludges containing a multitude of analytes requiring removal. RCC has an analytical lab for testing and analysis. A pilot unit is also available for site demonstrations. The pilot unit is skid mounted for easy transport and set–up. Full–scale demonstration of the B.E.S.T. process occurred in 1987 at a Superfund site in Savannah, Georgia. RCC treated approximately 4,000 tons of oily sludge which was a viscous, acidic waste oil sludge containing heavy metals and PCBs.

INSITU SOLIDIFICATION/STABILIZATION - S.M.W.® TECHNIQUE

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The S.M.W.® Technique SITE Demonstration will involve insitu solidification/stabilization of contaminated soils at depth. Treatment will be accomplished using multi-axis overlapping hollow stem augers to inject and mix reagents with the soil. Any effective reagents that can be mixed in slurry form can be applied. The final product will be a monolith of treated soil.

A test section was installed in May 1989, in Hayward, California. The insitu mixing was performed in soils consisting of desiccated San Francisco Bay Mud underlain by silt, sandy silt, and silty sand. The results proved the capability and efficiency of a newly developed S.M.W. auger for mixing plastic silty clay.

The S.M.W.® Technique has a long history of successful geotechnical applications totalling 5 million cubic yards of soil-mixing work and including soil stabilization and construction of soil-cement mixed cutoff walls and diaphragm walls. The technique has only recently been considered for contaminated soil treatment. Compared to other insitu treatments, the S.M.W.® Technique is conducted in a well controlled and observable manner. Because it is an insitu technique, normal waste exhumation concerns such as air quality, excavation bracing, dewatering, and worker exposure are mitigated.

The mixing augers are mounted on a crawler base machine and fed by a computer-controlled mixing plant and flow control unit. Contaminated soils varying from clay to gravel and cobble may be successfully treated. Insitu treatment may be performed in both vadose and saturated soils.

CHEMICAL SOLIDIFICATION AND STABILIZATION

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The SRS Chemical Solidification and Stabilization (C.S.S.) process provides lime-based chemical fixation of hazardous organic and inorganic sludges. The SRS C.S.S. process has been used commercially for over 12 years at major sites on three continents. Over 500,000 cubic yards of hydrocarbon sludges and contaminated soils have been treated to environmental standards.

The sludge to be treated is removed from the waste pit and placed in a blending pit. Specially prepared lime reagents are added to the sludge in the blending pit using an excavator. The lime reagent is then mixed with the sludge and the first step of the neutralization process takes place. After approximately 15 minutes, a second lime preparation different from the first in both chemical form and types of chemicals is added and mixed over a 20-minute period. After this time, the reaction is about 80 percent complete. The treated material is then removed from the blending pit and placed on the product assembly line. The product is allowed to cure for approximately two days. After the product has been sufficiently cured, it is placed in a storage area prior to return to the original pit for final compaction.

The treated product is a soil-like material with very good structural properties and very low permeability. The process can treat a variety of wastes as well as contaminated debris. Volume increase is 10 to 25 percent in most waste compositions. Production rates are 300 to 900 cubic yards per production day. A QA/QC evaluation is performed on each day's production to assure that the material has been properly treated. For wastes that may pose air emission potential, an enclosed process system is available. Process costs range from $80.00 per cubic yard for the open system to $120.00 per cubic yard for the enclosed system.

STEAM INJECTION AND VACUUM EXTRACTION

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This is an insitu process for extracting volatile and semi-volatile contaminants from soil. Steam is injected down wells and into the soil, giving thermal and liquid-displacement enhancement to the vacuum extraction process. Contaminants in liquids and gases are pumped to the surface where they are treated by other processes (e.g., activated carbon). Groundwater may be pumped along with the other liquids to clean saturated soil zones and aquifers as well.

The process can be effectively applied to soils with high or low contaminant concentrations, so long as the contaminants mobilize, and are recovered, at a significantly higher rate under the steaming conditions than under the conditions of vacuum extraction alone. These requirements are met for most soils contaminated with industrial solvents, fuels, and other organic compounds.

This technology is currently being implemented at a State Superfund site in San Jose, CA, and has been accepted by the EPA SITE program.

VACUUM EXTRACTION TECHNOLOGY - SITE PROGRAM DEMONSTRATION AT GROVELAND WELLS SUPERFUND SITE, MASSACHUSETTS

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Vacuum extraction is an insitu or exsitu treatment process for cleanup of soils and groundwater contaminated with volatile organic compounds (VOCs), liquid-phase hydrocarbons, or semivolatile compounds. 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, Massachusetts.

The subsurface conditions included multilayered glacial deposits consisting of sands, silty sands, and clays. Groundwater was 27 feet deep with a perched water table at about 10 feet.

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.

Results demonstrated the effectiveness of the vacuum extraction process to clean up contaminated soils. In the area of the fringe of the contaminant plume, soil concentrations were reduced more than 95 percent to non-detectable levels. Additional data from subsequent clean-up work at the site is available in several EPA publications.

TECHNOLOGY SUPPORT CENTER

The Robert S. Kerr Environmental Research Laboratory
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The Superfund Amendment and Reauthorization Act (SARA) directs the U.S. Environmental Protection Agency (EPA) to conduct a program of research, evaluation, and demonstration of alternative and innovative technologies for remedial response actions that will achieve more permanent solutions. Individuals making decisions concerning remedial action options must select and/or approve effective remediation activities and technologies for each specific site that will be protective of human health and the environment.

The Robert S. Kerr Environmental Research Laboratory (RSKERL) is EPA's center of expertise for groundwater research, focusing its efforts on transport and fate of contaminants in the vadose and saturated zones of the subsurface and on subsurface processes for the treatment of hazardous waste. RSKERL has established a Technology Support Center (TSC) to support remedial action decisions of regional and state Superfund personnel by providing up-to-date subsurface fate, transport, and treatability information plus associated expert assistance required to effectively use this information. The TSC provides an avenue for exchange of the highly specialized subsurface remediation information between the research and user communities. Results from research and other investigative efforts plus the background and experience of RSKERL and other scientists and engineers are the basis of the information that is exchanged.

BIOLOGICAL SOIL REMEDIATION SYSTEMS FOR ORGANIC POLLUTANTS

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The regeneration of contaminated soil by microbial degradation depends on the ability of bacteria and fungi to utilize organic pollutants as sources of energy and nutrients. The biological degradation process depends on suitable conditions for the soil–microflora.

After the preparation of the soil by special machines for homogenization and mixing additives like organic material, mineral nutrients, and adapted bacteria, different systems could be used to maintain optimum conditions during the degradation process.

Depending on the kind of pollutants, time of degradation, and assigned reuse of the decontaminated soil, different remediation systems are applied. These systems are open–air degradation beds with a water circulation system and vegetation, heaps enclosed in tents or other mobile constructions, stationary plants with integrated soil–treatment machines, or totally closed bioreactors with installations for heating, watering, and pressure control of the atmosphere.

Results of each of the systems with different pollutants, especially hydrocarbons, were presented. Clean–up times range from three months up to two years depending on kind and concentration of the pollutant, degradation conditions, and pollutant–concentration of the cleaned soil.

APPLICATION OF WASTECH, INC.'S CHEMICAL FIXATION/STABILIZATION TECHNOLOGY

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For years we have used available technology to solidify different forms of liquid waste. Organic waste has always created a problem for final disposal of materials. The contribution of the vast volumes of organic waste come from all forms of industry. While the nuclear industry generates a minimum amount of organic waste in comparison with the non–nuclear industry, their waste characteristics have a two-fold problem. With the latest changes by the regulating bodies, these waste streams cannot be disposed of at a nuclear waste landfill because of the chemical toxicity. However, these waste streams cannot be disposed of at a hazardous waste landfill due to the radioactive materials content. The past practice of disposal of this waste in the liquid state, has proven to be unsatisfactory. Not only has this waste exhibited its ability to breach the integrity of the burial site, but it has proven to be an effective transport mechanism for moving other radioisotopes from the confines of the disposal site.

The non-nuclear industry has an equally restrictive situation. The generation of organic compounds grows into several millions of metric tons each year. The available disposal sites, which presently receive these materials, has decreased in numbers as well as received more restrictive governmental disposal criteria. This coupled with the ever increasing processing/disposal charges, has handicapped the small/medium-size business in competing for available revenue. Additional technology has been developed, and can be used by the industry to dispose of an array of organic materials effectively. The final end product may qualify for a reclassification of the material(s), due to the decrease in toxicity. The poster presented at this conference illustrated the effectiveness of this process and provided supportive laboratory data of the actual decrease of the toxicity of the raw material(s).

IN SITU PHYSICAL AND BIOLOGICAL TREATMENT OF COAL TAR CONTAMINATED SOIL

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Dense organic liquids such as coal tars, chlorinated hydrocarbons, and heavy petroleum products have contaminated groundwater at numerous domestic and international industrial sites. The Western Research Institute has developed a new in situ process to contain and recover oily wastes. The Contained Recovery of Oily Wastes (CROW©) process uses hot-water displacement to reduce concentrations of oily wastes in subsurface soils and underlying bedrock. In this process, the contaminated area is hydraulically isolated so that contamination is not spread into uncontaminated areas. The downward penetration of dense organic liquids is reversed by controlled heating of the subsurface to float oily wastes in water. The buoyant wastes are displaced to production wells by sweeping the subsurface with hot water. Waste flotation and vapor emissions are controlled by maintaining both temperature and concentration gradients near the ground surface. Reducing waste concentrations to residual saturation immobilizes the oily wastes. Following completion of the CROW© process, an in situ biological treatment process can be initiated for further treatment of the residual organic saturation.

Remediation Technologies Inc. is evaluating in situ bioremediation processes for remediating soils and groundwater contaminated with biodegradable contaminants by enhancing the growth and activity of aerobic bacteria. These microorganisms use the contaminants as a source of carbon and energy while converting them to carbon dioxide and water. The process involves installing a groundwater injection and extraction system that allows for the controlled transport of an oxygen source (typically hydrogen peroxide) and water soluble nutrients (typically nitrogen and phosphorus) between injection and extraction points. Oxygen and nurtrients are required to promote and sustain the microorganisms needed to effect the degradative process. In addition, in vessel biological treatment of CROW© process product water is also being evaluated.

A PERVAPORATION SYSTEM FOR VOLATILE ORGANIC COMPOUND REMOVAL

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The removal of volatile organic compounds (VOCs) from water has become an increasingly important environmental issue. About half of the 129 U.S. EPA priority pollutants are VOCs and are known to be toxic and/or carcinogenic. Pervaporation uses organophilic membranes to selectively remove VOCs from contaminated water, such as groundwater leachate. The organic compounds pass through the membrane, are drawn off by vacuum, and condensed. Unlike conventional treatment technologies (e.g., air stripping and granular activated carbon), pervaporation can recover valuable organic compounds from water for reuse, and can be run continuously without regeneration.

Preliminary tests indicated that the liquid film boundary layer, rather than the membrane itself, becomes rate controlling for most conventional pervaporation modules. Arising from the need for a hydrodynamically efficient pervaporation module, the Wastewater Technology Centre approached Zenon Environmental Inc. to develop the required module. Operating costs for the new module, at first projection, are competitive with air stripping using off-gas treatment by activated carbon. The new pervaporation module holds great potential for sufficiently dealing with VOC contaminated water.

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

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Two innovative treatment processes from Zimpro/Passavant, the PACT® system and Wet Air Oxidation (WAO), were selected for the SITE program in 1987 and tested at bench-scale in 1989 prior to full-scale demonstration on-site. The PACT® system combines biodegradation and adsorption of organic contaminants by adding powdered activated carbon to a biological treatment process. Current installations successfully treat refinery, fuels, chemical, dye production, and pharmaceutical wastewaters, leachates, contaminated groundwater, and combined municipal-industrial wastewater containing hazardous organic chemicals. PACT®, when coupled with WAO, provides complete destruction of many toxic components and reduces residuals to a stable, sterile, inert ash – the only solid residue for disposal.

As part of the SITE demonstration, contaminated groundwater from the Syncon Resins Site in Kearny, New Jersey, was treated at the Zimpro/Passavant Testing and Development facility (a permitted hazardous waste treatment, storage, and disposal facility, No. WID044393114) in Rothschild, Wisconsin. All 11 priority pollutants in the groundwater were reduced to below detection limits. COD of the groundwater was reduced by 85 percent, to less than 125 mg/l. BOD_5 was reduced by more than 93 percent to less than 10 mg/l. Unfortunately, the Syncon Resins Site was not available for the full-scale demonstration. EPA is continuing to search for a suitable site.

When EPA selects a site, the PACT® system and WAO will be demonstrated together to treat contaminated waters with various levels of organic chemicals. A skid-mounted PACT® system will treat contaminated waters. A skid-mounted WAO system will demonstrate destruction of adsorbed pollutants and bio-solids, while regenerating the powdered activated carbon for reuse. At higher operating temperatures, the WAO system will demonstrate conversion of sludges to a stabilized ash.

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