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Hazardous Waste Engineering
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Project Summary

Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste: Proceedings of the Thirteenth Annual Research Symposium

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Proceedings are summarized for Sessions A, B, and C of the U.S. Environmental Protection Agency's (EPA) Thirteenth Annual Research Symposium on Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste. The Symposium was held in Cincinnati, Ohio, May 6 through 8, 1987. Session A, Hazardous Waste Land Disposal, included 26 papers; Session B, Hazardous Waste Incineration and Treatment, included 26 papers; and Session C, HWERL posters, included 32 poster presentations. Research projects on which these papers and posters are based are sponsored by EPA's Land Pollution Control Division (LPCD), Cincinnati, Ohio, and Edison, New Jersey, and Alternative Technology Division (ATD), Cincinnati, of the Hazardous Waste Engineering Research Laboratory (HWERL). Land disposal subjects discussed include remedial action treatment and control technologies for soil and water, landfill liner and cover systems, geotechnical aspects of earthen barriers, leachate composition and migration, underground storage tanks and emergency response. Incineration and treatment subjects include thermal destruction of hazardous wastes, field evaluations of treatment methods, control of volatile emissions, waste minimization and emerging physical, chemical, and biological processes for hazardous waste destruction.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research projects that are fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Fifty-two papers and 32 posters outlining state-of-the-art findings from research funded by HWERL were presented at EPA's Thirteenth Annual Research Symposium on Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste. Papers are abstracted and posters are listed in this Project Summary. The Symposium was conducted in three concurrent sessions—one for Hazardous Waste Land Disposal (Session A), one for Hazardous Waste Incineration and Treatment (Session B), and one for HWERL poster presentations (Session C). The Symposium provided an effective means for presenting the latest significant research results of the LPCD's and ATD's research program to industry, State and Federal agencies, universities, environmental groups, and consultants.

Session A papers were grouped into eight sessions by these topics hazardous waste landfills, synthetic membranes and landfill liners; evaluations, hazardous waste management; data collection

techniques; underground storage tanks; control technology for Superfund sites; and releases control.

Session B papers were grouped into eight sessions by these topics: thermal destruction; innovative physical/chemical treatment; biotechnology; biosystems; alternative treatment technology; and characterization and control of volatile organic emissions.

Session C posters were presented on selected ongoing research topics.

Papers are abstracted here. The authors listed were the speakers and/or principal investigator for the project.

Session A
Land Disposal Research Papers

Technical Resource Documents and Technical Handbooks for Hazardous Wastes Management

Norbert B. Schomaker
U.S. Environmental
Protection Agency

The Environmental Protection Agency is preparing a series of Technical Resource Documents (TRD's) and Technical Handbooks to provide best engineering control technology to meet the needs of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), respectively. These documents and handbooks are basically compilations of research efforts of the Land Pollution Control Division (LPCD) to date. The specific areas of research being conducted under the RCRA land disposal program relate to laboratory, pilot and field validation studies in cover systems, waste leaching and solidification, liner systems and disposal facility evaluation. The specific areas of research being conducted under the CERCLA uncontrolled waste sites (Superfund) program relate to pilot and field validation studies in barriers, waste storage, waste treatment, modeling and postclosure evaluation. The technical resource documents are intended to assist both the regulated community and the permitting authorities, as well as support the RCRA Technical Guidance Documents prepared by EPA's Office of Solid Waste (OSW) The technical handbooks provide the EPA Program Offices and Regions, as well as the states and other interested parties, with the latest information relevant to remedial actions

Session A-1
Hazardous Waste Landfill

Implications of Current Soil Liner Permeability Research Results

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U.S. Environmental
Protection Agency

Since the 1970's hazardous waste legislation has specified soil liner permeability (hydraulic conductivity) as a major criterion for design of soil liners to contain hazardous wastes disposed on land. HWERL studies since 1972 have included over 30 individual projects investigating hydraulic features of compacted soils. Soil/permeant liquid compatibility, applicability of laboratory permeability tests; field permeability testing, effective porosity, and solute transit time have been investigated.

The type of test cell does not appreciably affect the value for permeability measured in the laboratory for water alone. When the permeant liquid contains high concentrations of solutes, rigid wall permeameters show greater increases in permeability (relative to water alone) than triaxial cells. Increasing the hydraulic gradient when using a triaxial cell results in lower permeability values. Triaxial cells and consolidation cells can simulate overburden loading stresses on a soil liner but no data are available to determine how well these laboratory values predict permeability of the soil liner after a landfill cell is completely filled. The compaction mold modified for permeability measurement is the most sensitive geotechnical laboratory method to measure liner/leachate compatibility.

Construction acceptance is being tested with infiltration test devices. Optimum size of infiltration test area versus the number of test sites is being studied. Collection lysimeters installed beneath soil liners offer the most practical means to reliably quantify seepage through the liner system. They also provide an opportunity to collect tracer compounds or leachates solutes for calculation of transit times through the liner.

Examination of soil liners in the field consistently shows heterogeneity in materials, fabric, moisture content, density, and texture Macrostructural units that provide preferential pathways for rapid flow of liquids are common, but the amount of liquids moving in these pathways is unknown.

Laboratory-measured values demo strate the lowest permeability that a s liner material can provide; these valu should be regarded as a goal that m be achieved in the field by skill personnel only under optimum con tions. The uncertainties about perme bility/compatibility testing and the effe of construction practice on permeabil of the completed liner dictate that s liners for hazardous waste facilities mu be designed, tested, and built with much higher degree of care than h been considered routine for civil work

The Behavior and Assimilatio of Organic and Inorganic Priority Pollutants Codisposed with Municipal Refuse—A Progress Report

Frederick G. Pohland
Georgia Institute of Technology

The behavior and possible assimilat of organic and inorganic priority pol tants codisposed with refuse are be investigated in 10 simulated lanc columns operated under single pa leaching or leachate recyle. The prio pollutants include selected orga compounds and three different load levels of heavy metals mixed w municipal refuse. After being brough indicated field capacity with wa additions, leachate and gas from the columns were analyzed for rout indicator parameters as well as selected priority pollutants.

Preliminary results indicate that presence of priority pollutants exhibi little apparent influence on the progr of refuse conversion into the acid mentation phase of stabilization. Tre indicative of assimilative capacity, p ticularly with respect to the inorga priority pollutants, are beginning to established as the various biological physical-chemical mechanisms of tenuation take effect. Microbial me tion of the chemical environment encouraged precipitation and comple tion or sorption of admixed species gas and leachate constituents are p titioned and released from the wa mass Moreover, leachate recycle te to regulate this process, contain various leached ingredients in a m homogeneous medium, provide gre saturation and contact opportunity, permit better inspection and operatic control of the overall mechanisms o *situ* assimilation.

Session A-2
Membranes as Landfill Liners

Field Verification of FMLS—Assessment of an Uncovered Unreinforced 60-Mil EPDM Liner after 18 Years of Exposure

Henry E. Haxo, Jr.
Matrecon, Inc.

Samples of a 60-mil vulcanized ethylene propylene rubber (EPDM) flexible membrane liner (FML) were recovered for analysis and physical testing from different locations within a basin that was being decommissioned after 18 years of service as an emergency pond for "red-water " Observations on the in-place uncovered liner, description of the sampling procedure and collection of the samples, and results of the laboratory testing of the samples are presented.

The properties of the liner samples varied significantly depending on the location in the basin from which they were taken. Samples taken from the liner on the dike slope facing south had less extractables (i.e , oily plasticizers) and generally had higher tensile strength and modulus than the reference FML The samples taken from the liner on the bottom of the basin had high extractables and properties comparable to those of the reference As no retained sample or analytical and physical test data on the original unexposed sheeting were available for comparison, data on a 1972 EPDM liner were used for reference

No failures were observed in the factory seams of the in-place liner. Most of the field seams on the slopes opened, resulting in sloughing of the liner Those field seams that were high on the slope showed an apparent increase in cross-links of the adhesive, however, the adhesive retained tack in most of the tested field seams, indicating low cure

Rodents had gnawed holes in the liner from the top surface in the upper slope areas There was no indication that the rodents had burrowed below the liner and gnawed from beneath the liner The design of the anchor trench using wooden planks was unsatisfactory, as many of the panels of sheeting pulled out

Geosynthetic Design Considerations for Double Liner Systems

Gregory N. Richardson
Soil & Material Engineers, Inc.

The "minimum technological requirements" of the Hazardous and Solid Waste Amendments of 1984 require a double liner system in most hazardous waste land disposal cells and surface impoundments. Ensuing guidance recommended the use of two flexible membrane liners (FML) Each FML in a landfill and the bottom FML in a surface impoundment is covered by a leachate collection/removal (LCR) system to aid in preventing leachate from standing on the FMLs. This paper reviews design considerations for the FML and LCR systems within the double liner system

Potential failure modes for geosynthetic FMLs and LCRs are described in this paper and design procedures are reviewed for each of the failure modes. Each design procedure calculates the actual service stress or flow conditions and compares this required performance to the limiting performance of the component itself. The limiting performance is typically obtained from laboratory testing. A Design Ratio (DR) is defined as the ratio of the laboratory limiting performance divided by the calculated service performance.

Inspection Procedures/Criteria for Installation of Flexible Membrane Liners

William M. Held
SCS Engineers

Inspection of flexible membrane liner (FML) installation is important in assuring required hazardous waste containment This paper outlines the procedures and criteria for inspecting the installation of the four most commonly used FMLs for land containment of hazardous wastes

- Polyvinyl chloride (PVC).
- Chlorosulfonated polyethylene (CSPE).
- High-density polyethylene (HDPE).
- Chlorinated polyethylene (CPE).

The FML installation steps for which inspection procedures are provided include

- Unloading and storage of FML.
- Preparation amd maintenance of the FML supporting surface (earth and other supporting surfaces are discussed).
- Placement of FML on supporting surface.
- FML seaming operations.
- FML anchoring and sealing including anchoring in earth and anchoring to concrete and other materials.
- FML testing including seam testing and testing of the integrity of the entire FML installation.
- FML cover operations.

The FML installer and inspector should be able to follow the guidelines developed by this study in preparing construction quality assurance plans, and in assuring that design plans and specifications are met.

Session A-3
Evaluations

An Assessment of Materials That Interfere with Stabilization/Solidification Processes

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Stabilization/solidification of hazardous waste involves mixing the waste with a binder material to enhance the physical properties of the waste and to immobilize contaminants that maybe detrimental to the environment. Many hazardous wastes contain materials that are known to inhibit the setting and strength development properties of commonly used stabilization/solidification binder materials. This paper describes the initial results of an evaluation into the effect of 10 interfering agents oil, grease, lead nitrate, copper nitrate, zinc nitrate, sodium hydroxide, sodium sulfite, phenol, trichloroethylene, and hexachlorobenzene on the setting and strength development properties of a metal hydroxide sludge stabilized/solidified with three binder materials (Portland

cement, lime/flyash, and cement/flyash).

The setting and strength development properties of the wastebinder-interfering agent mixture were evaluated using the unconfined compressive strength (UCS) test. UCS data indicated that relatively low levels (less than 8 percent) of phenols, lead nitrate, oil, and grease can result in an 80 percent reduction in the 28-day UCS developed by the wastebinder-interfering agent mixture as compared to control specimens. Trichloroethylene and hexachlorobenzene were shown to have little effect on strength development.

The results of this research confirm the need for waste-binder specific studies prior to the selection of a chemical stabilization/solidification process for the treatment of hazardous wastes.

Mine Waste/Overburden Analytical Techniques—Characterization and Simulation of Mine Tailings Weathering Environments

Frank T. Caruccio
University of South Carolina

The prediction of mine drainage quality is based on the chemical weathering attributes of the mine waste/overburden that is produced by the mining operation. These are generally assessed through overburden analyses, which fall into two broad categories, static or dynamic techniques. In the static tests, drainage quality projections are based on whole rock analyses. Alternatively, dynamic tests subject the samples to simulated weathering tests and monitor the quality of the effluent produced. Within these two categories several mine waste/overburden analytical techniques are available, each having advantages and disadvantages relative to the other. An extensive computer literature search identified the most popular analytical techniques and included column leaching tests, humidified cells, Soxhlet reactors, BCR initial and confirmed (bacteria) tests, and acid/base accounting. These analytical procedures were further structured to evaluate the effect of alkaline pore water, air lock, and interstitial sulfide reactivity.

In a preliminary study, several mine waste/overburden analytical techniques were evaluated to determine which one most closely approximates observed field conditions. Fractions of an acid producing pyrite rich ore found at a gold mine in South Carolina were contained in plastic tubs and exposed to the atmosphere. The volume and quality of the leachate produced after each rain event were related to the weight of the sample These field derived data provide the background against which the laboratory analyses of splits of the samples were compared and evaluated.

In the preliminary test, we found the finer the particle size, as prescribed by the particular test, the greater the amount of acidity produced. In essence, the acid production potential is an artifact of the particular test used and, to a lesser degree, the chemistry of the sample.

The Effects of Overburden Pressure and Hydraulic Gradient on the Performance of Model Soil-Bentonite Slurry Cutoff Walls

Richard M. McCandless
University of Cincinnati

Model soil-bentonite cutoff walls roughly 508 mm (20 inches) in diameter, 559 mm (22 inches) in height and 102 mm (4 inches) thick were constructed and tested in an instrumented tank. The effects of overburden pressure (vertical consolidation) and hydraulic gradient (horizontal consolidation) were investigated followed by tests to evaluate the potential for closure of artificial windows representing small pockets of entrapped bentonite slurry in the backfill

The average hydraulic conductivity of one model was measured for three hydraulic gradients under each of three applied overburden pressures. Decreases in conductivity were observed for incremental increases in both overburden pressure and hydraulic gradient as well as for their combined effect. The tests were interrupted on two occasions by hydrofracture near the base of the model. A reduction in effective stress with increased depth in the model wall was evidenced by unit weight, water content and vane shear strength data. By incrementally increasing overburden pressure it was possible to "heal" two slot-like windows in a subsequent wall suggesting that in situ consolidation of the backfill may serve to eliminate minor as-built or chemically-induced hydraulic defects in real slurry walls.

Session A-4
Hazardous Waste Managemer

Expert Systems to Assist in Decisions Concerning Land Disposal of Hazardous Waste

Daniel G. Greathouse
U.S. Environmental
Protection Agency

In FY'84 the Hazardous Waste Eng neering Research Laboratory succes fully developed a small proof-of-conce expert system to assist in interpretati of chemical immersion test (EPA Meth 9090) data for PVC liner materials. Th was the beginning of an orderly progre sion of efforts to assess the feasibil of using expert systems to assist permit reviews for hazardous waste la disposal sites. Permit review decisi areas amenable to expert system app cations have been identified and sever systems are in various stages of deve opment and testing. The rationale for th approach to provide decision support a for permit review include the complex of the required engineering evaluation availability of extensive releva research results and known subjec specific specialists (experts); concer that permit reviewers do not have all the required expertise and that they ha little, if any, access to subject specif specialists, concern that the reviewe do not have sufficient time to assimila all regulatory policy and research info mation; and concern that decisions m not be consistent among reviewers with EPA regulations and policies. Th decision areas selected for expert syste development and the progress on th ongoing development efforts will b presented.

Modeling Soil Water Movement in Minimum Technology Waste Management Facilities

David H. Gancarz
Radian Corporation

The hydrology of landfills, surfa impoundments, and waste piles is dor inated by unsaturated flow of soil wate Unsaturated conditions normally persi in the cover, solid waste, liner syster leachate collection and removal syster and in the soil below these systems. finite element model, UNSAT2D, deve oped as a generalized computer progra based on the two-dimensional equatio

of saturated/unsaturated flow, is described. This model can be used to simulate moisture movement through a two-dimensional vertical section of a facility.

Results from a series of simulations of alternative "minimum technology" designs are discussed, with emphasis on bottom liner design and leak detection. These data show that leak rates into leachate collection and removal (LCR) systems in excess of 100 gallons/acre-day are necessary for LCR system drains to flow when constructed over three-foot thick compacted soil bottom liners with a hydraulic conductivity of 10^{-7} cm/s. LCR systems built in conjunction with composite (flexible membrane over low-permeability soil) bottom liners are significantly more effective. Time to drain flow is reduced, minimum leak rate resulting in LCR system drain flow is reduced, and leachate collection efficiency increases.

Remediation of an Industrial Dump Site—A Case History, Part II

David S. Kosson
Rutgers University

The case history of the design and implementation of a remediation strategy for a hazardous waste disposal site is described. Sludges resulting from treatment of diverse chemical manufacturing effluents had been deposited in an unlined surface impoundment over several decades. "Remediation of an Industrial Dump Site—A Case History," presented at the 12th Annual Research Symposium, described laboratory and pilot-scale investigations of a proposed remedial strategy. The proposed process consists of *in-situ* alkaline sludge extraction coupled with on-site, sequential aerobic-anaerobic, soil-based microbial destruction of recovered organic contaminants. First year pilot plant results, presented previously, indicated rapid organic species extraction from sludges and greater than 95% destruction of recovered extract TOC. This paper will focus on results from second year pilot plant operation and analyses, which have been carried out on residuals present after extraction and treatment processes.

Capillarity and Anisotropy Effects on Ground-Water Flow to Excavation

Forest O. Mixon
Research Triangle Institute

In a hazardous waste disposal facility located in a saturated soil, the local water table and the capillary fringe zone are modified by the presence of the facility. In this paper, a conformal mapping solution to the accompanying ground-water flow is discussed. The flow net around an excavation is calculated and displayed in terms of the capillarity, local geometry and flow properties.

Capillarity can significantly influence net flow into an excavation, typical values can cause net flow to be 10 to 20 percent higher than predicted without capillarity. Anisotropic behavior can also be important. It is shown that anisotropy favoring horizontal flow can greatly alter the flow net and the total flow.

Session A-5
Data Collection Techniques

Pathways for the Removal of Volatile Organics from Surface Impoundments

Crowley Clark Allen
Research Triangle Institute

A series of surface impoundments have been investigated to determine the significance of biological oxidation as a major pathway for volatile organic removal. Measurements of the volatile organic concentrations, pH, and dissolved oxygen have been taken from active surface impoundments. Wastewater was removed from selected impoundments, and the rate of oxygen uptake and the compound specific fate of the volatiles was evaluated in the laboratory under both anaerobic and aerobic conditions. A biocide was used to evaluate the significance of biological activity relative to chemical reactions. The results indicated that biological activity is common in surface impoundments. The biological removal of specific components at one impoundment was low relative to the anticipated volatilization rates.

Composition of Leachates from Actual Hazardous Waste Sites

Glenn D. McNabb
Science Applications
International Corporation

This presentation addresses the analytical methodology used in a follow-on effort of a U.S. Environmental Protection Agency sponsored project. The project was initially undertaken to gather data on the composition of hazardous waste leachates and to support the development of multi-component synthetic leachate. These synthetic leachates will be used to evaluate the effectiveness of various liner materials used in landfills and other hazardous waste storage, treatment, and disposal facilities. As such, the formulated leachates should be representative of typical compositions of actual hazardous waste site leachates. During the initial study, the routine organic analyses of 13 leachates accounted for only approximately four percent of the overall Total Organic Carbon (TOC). As a result, a more rigorous and complex analytical method was developed and is presently being employed in the follow-on study to obtain a more comprehensive characterization. During the first phase of this study, a hazardous waste leachate sample was characterized by the new analytical procedure with the intent of maximizing the percent of TOC accountable by specific compounds or by functional groups. Overall, approximately 48% of the TOC was accounted for by the new method. This included approximately 20% attributed to individual components and 28% accounted for by functional groups. In order to obtain more information on the actual composition of hazardous waste leachate, a second phase of this study is employing the same new analytical method to characterize two additional leachate samples. Based on the results of these more thorough characterizations, recommendations will be made regarding the composition of representative synthetic leachates for linear compatibility testing.

Decontamination Techniques for Mobile Response Equipment Used at Waste Sites

Mary K. Stinson
U.S. Environmental
Protection Agency

Any cleanup equipment used at waste sites must be decontaminated after use.

This paper highlights a published EPA report on the state-of-the-art review of decontamination techniques for cleanup equipment and discusses field experience with decontaminating equipment presently in use.

For those who prepare decontamination plans for cleanup equipment at hazardous sites, the EPA report provides background material on decontamination methods, contamination assessment, and contamination avoidance. The EPA report particularly stresses the importance of contamination avoidance. Such measures as use of enclosures for equipment, safety features on equipment to prevent spills and leaks, and protective coatings on equipment surfaces reduce hazard, time, and cost of the final decontamination task.

Though chemical methods are being developed to degrade contaminants on equipment surfaces, use of physical removal methods prevails in the field. This will be shown in discussing decontamination procedures of equipment presently in use, such as the EPA Mobile Incineration System operating at the Denney Farm Site, Missouri, on dioxin-contaminated oils, sludges, and soils.

Session A-6
Underground Storage Tanks

Leak Prevention in Underground Storage Tanks: A State-of-the-Art Survey

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Enviresponse, Inc.

The objectives of this state-of-the-art survey were to examine the design and operational practices associated with underground storage tank (UST) systems and to identify areas for further research and development that would advance leak prevention technology.

Many standards, guidelines, and recommended practices for the design and operation of UST systems are currently promulgated by several professional and industrial organizations. However, many of these procedures have overlapping requirements and there is no way of confirming how widely they are understood or followed in the field. Consequently, there is a need for a cohesive and coordinated set of rules and standards that apply to various types of UST systems, including those that store chemicals, and for further work to assess and improve operating practices, including spill prevention and leak detection methods and devices.

A Preliminary Analysis of Underground Tanks Used for CERCLA Chemical Storage

Ihor Lysyj
Environmental Monitoring and Services, Inc.

The scope and severity of leaking underground storage tanks (USTs) containing chemicals have not been well defined. A study was undertaken for the U.S. Environmental Protection Agency (EPA) to collect and analyze data on USTs with the goals of (1) obtaining better information on the chemical UST population and (2) developing a strategy to rank underground tanks according to the hazard potential of their stored chemicals. The study addressed only Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) chemicals. Information sources included State surveys in California and New York and data from the Chemical Manufacturers Association (CMA). The analysis considered the nature (physical-chemical and toxicological properties) of the stored chemicals, tank population, size and age of tanks, materials of tank construction, and means of tank corrosion protection.

Solvents constitute the bulk (70-90%) of the organic CERCLA substances stored in USTs. As reported by CMA, the most prevalent organic solvents (acetone, methanol, toluene, methylene chloride, and xylene) constituted over 50% (both by number of tanks and volume stored) of all CERCLA substances in USTs. The average tank size reported by California and New York was 6,000 gallons, while that reported by the CMA was 15,000 gallons. The average tank age reported by CMA was 18 years. The majority are single walled, steel tanks that are protected against corrosion only by paint.

U.S. EPA Evaluation of Volumetric UST Leak Detection Methods

James W. Starr
Enviresponse, Inc.

This report summarizes the quantitative results through January 12, 1987 of the ongoing U.S. Environmental Protection Agency's (EPA) Hazardou Waste Engineering Research Laborato program to evaluate the performance commercially available, volumetric te methods for detecting leaks in unde ground petroleum storage tank system Volumetric methods (i.e., those operatir in or on the tank that yield a quantitati estimate of the leak rate) can be infl enced by a wide variety of environment factors, all of which can significant reduce the accuracy of the measur ment.

The first set of full-scale produ temperature experiments on a 30,285 (8,000 gal) tank were conducted assess the impact of thermally induc volume fluctuations on the testing overfilled tanks, the most common te condition. The initial data indicate fir that thermal effects are large when t temperature of the added product different from that of the *in situ* grou and stored product temperature, eve 24 h after product delivery, and secor that these effects can significantly impa a method's ability to detect small lea unless the thermally induced volun changes are compensated. When t vertical and horizontal distribution temperature was investigated, t results indicated that volume-weight temperature changes measured by single vertical thermistor array locat at the fillhole of the tank would adequate for compensation of thermall induced volume changes of the produ throughout the tank. The results al indicated that a 20 cm (8 in.) vertic separation of thermistors on the arr was adequate to characterize t temperature fluctuations that caus these volume changes.

An estimate of the technological lim of detecting leaks with volumetric te methods is also being made. The results can be used to assess t performance of existing test methods, well as new ones that might be develop in the future. The analysis suggests th with proper instrumentation and proc dures, a leak rate of 0.19 L/h (0.05 gal/ can be detected with a probability detection (PD) of 0.95 and a probabil of false alarm (PFA) of 0.001, providi no other sources of ambient noise a present (e.g., tank deformation, vap pocket).

Session A-7
Control Technology for Superfund Sites

NATO/CCMS Pilot Study on Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater

Donald E. Sanning
U.S. Environmental
Protection Agency

Groundwater and soil contamination by hazardous waste is a pervasive problem in industrialized countries. As scarce resources, water and land must be returned to productive use. Current cleanup efforts are hampered by limited technology options and high costs. It is desirable to build up the knowledge base so that more efficient, cost-effective remedial technologies can be developed. However, the urgent needs of society require that near-term solutions be found and applied to the most significant pollution problems. Consequently, promising new technology must be tested and demonstrated to determine its applicability and effectiveness for today's problems.

The U.S. Environmental Protection Agency has established a formal program to enhance the development and use of new or innovative technologies for mitigating the problems caused by releases of hazardous substances at uncontrolled hazardous waste sites. In the United States the program is called the Superfund Innovative Technology Evaluation or SITE Program.

In November 1986 the NATO-CCMS formally adopted a U.S. proposal for a new pilot study entitled "Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater." The following NATO countries opted to participate:

- Canada
- Denmark
- Federal Republic of Germany
- Greece
- Italy
- The Netherlands
- Norway
- Spain
- United States

Two non-NATO countries, Australia and Japan, have also expressed an interest in participating.

The purpose of this new study will be to field demonstrate and evaluate new technology and/or existing systems for remedial action at uncontrolled hazardous waste sites and is a logical international extension of the U.S. EPA, SITE program. This study will offer the potential to obtain a multiple data base on various remedial action unit processes, that is, microbial degradation, on site treatment/destruction, fixation, without any single country having to commit a disproportional amount of its internal resources to a specific research activity.

Simultaneously, along with the primary demonstration portion of the study, the opportunity for long-term technology transfer of environmental restoration technology development will be provided to participating countries.

Reactivity of Various Grouts to Hazardous Wastes and Leachates

Andrew Bodocsi
University of Cincinnati

A laboratory study was conducted to evaluate the potential of selected grouts for controlling the percolation of leachates from hazardous solid waste landfills or hazardous waste ponds. In the course of the study, seven different grouts were subjected to permeability tests and three of the grouts were tested for their reactivity by an immersion type test. Eight different chemicals, some with two concentrations, and two real-site wastes were used as permeants in the permeability tests, and as liquids for the immersion baths.

Of the seven grouts, the acrylate, cement-bentonite (mix 2), and urethane grouts had the lowest baseline permeabilities with water, ranging from 2.3 x 10^{-10} to 3.6 x 10^{-9} cm/sec.

During permeability testing with chemicals, the acrylate grout exhibited excellent resistance to the paint and refinery wastes, 25% acetone, 25% methanol, and sodium hydroxide, performed satisfactorily with cupric sulfate, ethylene glycol, and xylene, and was seriously damaged by aniline, 100% acetone, hydrochloric acid, and 100% methanol.

The permeability of the cement-bentonite (mix 2) grout was tested with acetone, aniline, cupric sulfate, hydrochloric acid, methanol, and sodium hydroxide. With every one of these chemicals the permeability of the grout improved, ultimately reaching a practically impervious state.

The urethane grout maintained its low permeability with acetone, aniline, ethylene glycol, methanol, paint waste, refinery waste, and hydrochloric acid and it performed marginally well with cupric sulfate. However, the urethane lost its low permeability with sodium hydroxide and xylene.

Based on the comparison of permeability and reactivity test results, a scheme was proposed to correlate the permeability changes of grouts to the weight and consistency changes that may occur during their reactivity testing.

Electro-Decontamination of Chrome-Contaminated Soils

Sunirmal Banerjee
University of Washington

A technique of *in-situ* treatment of inorganic waste-contaminated soils is being explored at a Superfund site in a current study. Transport of inorganic ions under an imposed electric field is essentially the basis of this technique. In this paper, the results of the laboratory experiments conducted on undisturbed soil samples obtained from the site and the initial results of preliminary field experiments are reported.

Generally, the laboratory results have shown that with appropriate combination of applied hydraulic and electric fields, it is possible to remove chromium at a faster rate by this approach than by hydraulic leaching alone. The preliminary field experiments also show that chromium concentrations can be altered by electro-kinetic treatment alone.

Current Status of the Designation and Adjustment of CERCLA Hazardous Substances and Their Associated Reportable Quantities

K. Jack Kooyoomjian
U.S. Environmental
Protection Agency

In this paper the U.S. Environmental Protection Agency (EPA) describes the technical methodology it has used to adjust reportable quantities (RQs) of CERCLA hazardous substances, which when released into the environment must be reported to the National Response Center (NRC), and the methodologies the Agency is considering for designation of additional CERCLA hazardous substances. In accordance with CERCLA Section 102, the EPA Administrator may promulgate regulations to establish the level of release of a hazardous substance which must be reported to the NRC. The methodology considers the intrinsic physical/chemical, toxicologic, and degradative properties of the hazardous substance. The Administrator issued Final Rules on April 4, 1985 and on September 29, 1986 which adjusted the statutory RQs of 442 of the 717 CERCLA hazardous substances Section 102(a) of CERCLA provides the Administrator with the authority to designate additional hazardous substances and adjust their RQs The options available to the Administrator for choosing those substances most appropriate for designation are also described

Session A-8
Releases Control

The EPA Personnel Protection Technology Research Program

Michael D. Royer
U.S. Environmental
Protection Agency

The Environmental Protection Agency's Personnel Protection Technology Research Program provides data, information and technology to enhance the Agency's capability to perform its mandated roles that require. (1) regulation of pesticides and toxic substance handling and use, and (2) operation of EPA and contractor personnel at chemical spills and uncontrolled hazardous waste sites. To meet this objective, the Program is developing, evaluating and improving chemical protection clothing and equipment, procedures to enhance the safety and cost-efficiency of working conditions, methods to predict the effectiveness of chemical protection clothing, and detection methods and devices that warn of imminent hazards to life and health.

Application Opportunities for Canine Olfaction: Equipment Decontamination and Leaking Tanks

Herbert S. Skovronek
New Jersey Institute of Technology

Rapid screening of heavy equipment used in site cleanup for residual contamination and scanning of underground storage tanks for leaks were identified as two promising environmental applications for canine olfaction.

In equipment decontamination, the objective was to demonstrate that a trained dog could detect and indicate extremely small residues of hazardous chemicals remaining on heavy equipment such as bulldozers, backhoes and front end loaders after washup. Using xylene and 1,1,1-trichloroethane as models of common hazardous chemicals, a trained dog reliably indicated hidden samples emitting as little as 0 5 μg/min. Gaussian dispersion models indicated that the dog is detecting 5-10 ppt or less at these emission rates Field tests on equipment indicated detection at emission rates as low as 1 ng/min.

From tests to evaluate the dog's ability to differentiate similar compounds, it was concluded that, at least in some compound families, the dog does respond to both the compound uses for training and its congeners. This capability may be useful in finding any members of such families at a site.

Gasoline was selected as the material of greatest importance when searching for underground leaks Water-washed gasoline, used to simulate underground leaks, did exhibit minor changes in composition However, possibly due to the training approach used, the dog was unable to differentiate the washed gas from unwashed gasoline Alternate approaches are delineated for future study

Nondestructive Testing (NDT) for Location of Containers Buried in Soil

Robert M. Koerner
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At the 12th Annual Hazardous Waste Research Symposium held at Cincinnati in 1986, the authors reported on their work concerning the nondestructive testing (NDT) for location of containers buried in the soil. An overall view was presented at that time. In this paper mor detail is given about certain aspects c the testing, which could not be include previously due to space limitations.

Experimental work is described wher seven techniques were reduced to fou for the majority of the testing. (Originall 17 techniques were considered—1 were eliminated during the literatur search.) The four techniques· meta detector (MD), electromagnetic inductio (EMI), magnetometer (MAG), and groun probing radar (GPR) were looked at i considerable detail In particular, result concerning the ability of each method t detect the container(s) when not trave ling directly over the container(s) (th lateral scan sensitivity) are given. Als detailed results, in the form of respons contour diagrams, are given in the cas of a "metal trash dump."

The effect of steel container buri orientation on the GPR is presente Water table depth determination (to 1 feet) with GPR is also demonstrate Under near perfect conditions of ve little interference (i.e., low electric conductivity, highly homogeneous, d soil and absence of power lines, met objects, etc.), it is possible to detect emp plastic drums to a depth of 3 feet wi EMI

Session B
Incineration and Treatment Research Papers

Session B-1
Hazardous Waste Thermal Destruction I

Thermodynamic Analysis of Post-Flame Reactions Applied to Waste Combustion

Daniel P. Y. Chang
University of California, Davis

The equilibrium compositions of pro uct gases resulting from the combusti of a few model waste/fuel mixtures ha been calculated. These include so chlorinated hydrocarbons (CHCs) a some high nitrogen-containing speci The calculations were carried out w the aid of an interactive, PC-compati version of a powerful equilibrium solv STANJAN. Examples are drawn from more interesting results in order demonstrate how the theoretical cal lations can be interpreted and used

provide insight into the occurrence of products of incomplete combustion (PICs) in incinerator effluents. Practical applications and extensions of the method are also discussed.

Influence of Atomization Parameters on Droplet Stream Trajectory and Incineration

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Protection Agency

In the incineration of liquid hazardous wastes, atomization quality may limit destruction efficiency. Large non-mean droplets in a fuel spray can pass through the flame zone prior to complete evaporation, and may subsequently fail to burn completely due to insufficient temperature and/or flame radicals. A study is ongoing to develop a predictive understanding of individual droplet trajectories in turbulent diffusion flames. Experiments in a cold quiescent flow environment, a laminar flow flat-flame burner, and a 100 kW swirling, turbulent combustor have been conducted to calibrate a model to predict three-dimensional trajectories of single monodisperse droplet streams.

Escape from the flame zone of large (> 200 μm diameter) fuel oil/xylene droplets has been observed as a function of initial droplet size, velocity, spacing, and injection angle. Incomplete incineration of these droplets was found to be related strongly to droplet penetration of the flame zone. Minimum model requirements to successfully predict droplet trajectories in turbulent diffusion flames include droplet spacing effects on drag; droplet/droplet interaction effects on evaporation; evaporation effects on drag; and turbulence effects on droplet ballistics.

Distribution of Volatile Trace Elements in Emissions and Residuals from Pilot-Scale Liquid Injection Incineration

Johannes W. Lee
Acurex Corporation

The EPA is currently developing regulations on trace element emissions from hazardous waste incineration. However, the data base to support these regulations is very sparse. Data on the effects of waste composition and incinerator operation on trace element emissions are particularly lacking. In response to these data needs, EPA is conducting several test series at the Combustion Research Facility (CRF), Jefferson, AR. The first series of tests was performed to investigate the fate of volatile elements in liquid injection incineration. In these tests, trace amounts of arsenic in the form of arsenic trioxide (As_2O_3) and antimony in the form of antimony trichloride ($SbCl_3$) were fired in a methanol base containing varying amounts of chlorobenzene and carbon tetrachloride. Test variables included incinerator temperature, excess air level, and feed chlorine content. As usually occurs in tests of this type, the data show a general inability to obtain mass balance closure for the trace elements. Both elements are found in the vapor phase at high temperatures, but they condense to particulate at scrubber exit temperatures. Other conclusions await further data reduction and evaluation.

Session B-2
Hazardous Waste Thermal Destruction II

Assessment of Residues from Incineration of RCRA Wastes

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Incineration is generally recognized as a well-demonstrated technology for the treatment of organic hazardous wastes including spent solvent wastes. Most studies of incineration have been concerned with the effectiveness of the process to destroy key organic constituents of a waste (destruction and removal efficiency, DRE) as measured by the relative quantity of those organics in the incinerator off-gas. In contrast, this paper focuses on characterization of the solid and liquid residues generated by incineration of RCRA wastes.

Two incineration systems are evaluated—one at a commercial treatment, storage and disposal facility (TSDF) accepting organic wastes from a variety of industrial generators (Facility A) and the other operated onsite at a chemical industry manufacturing plant (Facility B). Both systems generate two types of residue—ash and scrubber wastewater. Ash from both facilities is currently landfilled. Treatment of the scrubber wastewater at Facility A results in a metal sulfide sludge, which is also landfilled. At Facility B, scrubber wastewater is neutralized and injected into a deepwell on site.

All ash, sludge and wastewater samples collected at these facilities were analyzed for priority pollutant organics and metals. The ash and sludge samples were also subjected to the Toxicity Characteristic Leaching Procedure (TCLP). Ash from Facility A exhibited unacceptably high TCLP extract concentrations of two volatile organics—methylene chloride and tetrachloroethylene, indicating incomplete combustion of solvent wastes. Ash from Facility B passed the TCLP for both metals and organics, but both ash and extract levels of three on-TCLP metals—copper, nickel, and zinc—were high. Scrubber wastewater from both facilities had no significant concentrations of toxic organics. However, copper, lead, nickel and zinc were found at concentrations greater than 50 mg/l in the scrubber wastewater from Facility B. This paper presents and evaluates quantitative data describing the wastes incinerated and the resulting residues at both facilities.

Waste Characterization and the Generation of Transient Puffs in a Rotary Kiln Incinerator Simulator

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U.S. Environmental
Protection Agency

The batch introduction of waste-filled drums or containers into rotary kiln incinerators can lead to transient overcharging conditions, which are denoted as "puffs." This paper describes results of an in-house investigation at the U.S. EPA into the waste properties and kiln parameters that determine both the intensity and the magnitude of transient puffs leaving the kiln. The experimental apparatus utilized was a 73 kW (250,000 Btu/hr) laboratory rotary kiln simulator. Surrogate solid wastes in the form of plastic rods and surrogate liquid wastes on corncob sorbent in cardboard containers were investigated. Parametric studies were used to determine the extent to which waste and kiln variables (such as charge mass, charge surface area, charge composition, kiln temperature, and kiln rotation speed) affected the intensity (peak hydrocarbon emission) and magnitude (time-integrated hydrocarbon emission) of puffs.

Results demonstrate the relative ease with which failure conditions are

achieved, even at high excess air values and high kiln temperatures. Chemical analysis indicates that puffs arising from even innocuous surrogate wastes can contain numerous hazardous compounds even though adequate DREs (>99 99%) are achieved Increasing kiln temperature and rotation speed can adversely affect puff intensity, due to increased devolatilization and liquid evaporation rates. There are large effects of waste composition and, for solid wastes, waste surface area is a critical variable.

Stoichiometric oxygen requirement is an important variable distinguishing the transient behavior of different kinds of wastes. Thermogravimetric analyses may be useful in characterizing the propensity of solids to generate transient puffs, while liquid wastes may be best characterized by their normal boiling points and latent heats.

On-Line Monitoring of Organic Emissions with a Mobile Laboratory

Sharon L. Nolen
U.S. Environmental
Protection Agency

EPA's Hazardous Air Pollutants Mobile Laboratory (HAPML) was designed as an integrated sampling and analytical package for real-time monitoring of combustion sources. The HAPML is equipped with organic and inorganic analytical equipment and is completely housed in an 8-m long van.

The HAPML recently participated in a total mass emissions test at a full-scale rotary kiln incinerator The complete field test was conducted by EPA's Hazardous Waste Engineering Research Laboratory under the direction of Robert C. Thurnau and will be reported separately The HAPML collected continuous emission monitor (CEM), gas chromatograph/flame ionization detector (GC/FID), and GC/mass spectrometry (MS) data during steady state conditions and upsets which simulated conditions which might occur in normal operation. The GC/FID was used for on-line analysis of light hydrocarbons. The volatile organic sampling train (VOST) was used to collect samples for analysis by the GC/MS to identify other organic compounds in the stack gas. CO, CO_2, O_2, and NO_x data were collected with the CEMs.

This paper will discuss the data collected during the field test and other capabilities of the HA PML Future plans include exploring those other capabilities which include using the MS as a single ion monitor and testing the HCl monitor

Session B-3
Hazardous Waste Thermal Destruction III

Total Mass Emissions from a Hazardous Waste Incinerator

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Past studies of hazardous waste incinerators by the Hazardous Waste Engineering Research Laboratory have primarily examined the performance of combustion systems relative to the destruction and removal efficiency (DRE) for Resource Conservation and Recovery Act (RCRA) Appendix VIII compounds in the waste feed. These earlier studies demonstrated that in general most facilities performed quite well relative to the DRE. However, subsequent review by the U.S Environmental Protection Agency (EPA) Science Advisory Board raised questions about additional Appendix VIII or non-Appendix VIII constituents that were not identified in the earlier tests and might be emitted from hazardous waste combustion. This paper presents results of a characterization of incinerator effluents to the extent that the emitted compounds can be identified and quantified. Measurements were made of both Appendix VIII and non-Appendix VIII compounds in all effluents (stack, ash, water, etc.) from a full-scale incinerator A broad array of sampling and analysis techniques were used. Sampling methods included Modified Method 5, volatile organic sampling train (VOST), and specific techniques for compounds such as formaldehyde Analysis techniques included gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) Continuous measurements were also made for a variety of compounds including total hydrocarbons by flame ionization detector (FID).

Incineration of Cleanup Residues from the Bridgeport Rental and Oil Services Superfund Site

Larry W Waterland
Acurex Corporation

Several PCB-contaminated wastes will be generated through remedial actions at the Bridgeport Rental and Oil Services (BROSO) Superfund site in Bridgeport, New Jersey Among these are a lagoon surface oil, an underlying sludge, and contaminated soil Incinerability testing of these three wastes plus a combination of the soil and sludge was performed at the Environmental Protection Agency's (EPA) Combustion Research Facility (CFR) to determine whether thermal treatment via incineration was a viable treatment option for these wastes Tests under three incinerator operating conditions were performed in the CRF rotary kiln incineration system for each waste. Test variables included rotary kiln temperature and rotation speed (solids residence time) and afterburner temperature All wastes contained between 100 and 300 ppm polychlorinated biphenyls (PCBs) as Arochlor 1254. PCB destruction efficiency (DE) was in the 99.99 to 99 999 percent range for all tests. Al scrubber blowdown samples had nondetectable PCB levels (<1 ppb) and hazardous constituent trace element concentrations well below extraction procedure (E P) toxicity thresholds Kiln ash samples for the soil, sludge, and soil/sludge wastes were not PCB contaminated having nondetectable PCB levels (<0.4 ppm) The composite kiln ash for the lagoon surface oil tests contained 2.(ppm PCB. E P leachates of all kiln ash samples had hazardous constituent trace element concentrations well below E toxicity thresholds.

Pilot-Scale Testing of Nonsteady Boiler Waste Cofiring

Howard B. Mason
Acurex Corporation

Waste destruction efficiencies were measured for volatile and semivolatile chlorinated organic compounds cofired with gas, oil, and coal in a pilot-scale boiler simulator with a maximum capacity of 3 million Btu/hr. The tests were run to help interpret waste destruction data from 14 prior boiler cofiring field tests programs Specific issues addressed in the pilot-scale tests were: what is the background level of waste emissions due to residual deposition on boiler surfaces what operating conditions fail to yield acceptable destruction efficiency?; what waste products of incomplete combustion are formed, and in what quantities and what is the form and fate of trace metals contained in the waste? Operating parameters varied were excess O

atomization patterns; residence time; firing rate, wall cooling, and waste or fuel flow transients.

Session B-4
Innovative Physical/Chemical Treatment

Technical/Economic Assessment of Selected PCB Decontamination Processes

Ben H. Carpenter
Research Triangle Institute

Eleven emerging alternative treatments for polychlorinated biphenyl (PCB)-contaminated sediments have been compared and ranked using technical performance, status of development, test and evaluation data needs, and cost as factors. In ranking the processes, weights were assigned the factors to emphasize the extent of decontamination, the estimated cost of treatment, and the versatility of the process The emerging treatment processes are based on five different technologies one on low-temperature oxidation, two on chlorine removal, one on pyrolysis, four on removing and concentrating, and three on microorganisms Types of technologies not developed are chlorinolysis, stabilization, and enzymes On the basis of comparisons made, the treatment processes were ranked in the following order from highest to lowest KPEG, LARC, Acurex, Bio-Clean, Supercritical Water, Advanced Electric Reactor, Vitrification, OHM Extraction, Soilex, Composting, and Sybron Bi-Chem 1006 The first eight processes show potential for reduction of PCB concentrations to the desired background levels (1 to 5 ppm) or less, with minimum environmental impacts and low to moderate cost All the technologies except the advanced electric reactor required further development and testing

Mobile KPEG Destruction Unit for PCBs, Dioxins and Furans in Contaminated Waste

Charles J Rogers
U S Environmental
Protection Agency

The presence of highly toxic and persistent chemicals in liquids, soils, sediments, and sludges in abandoned waste sites poses a threat to both public health and the environment. Incineration is frequently used to destroy highly hazardous wastes, however, when operated under less than optimum combustion conditions, acutely hazardous products including polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can be formed and emitted in the combustion products. Various biological, chemical, and physical methods have been tested and have been demonstrated to be effective to varying degrees in destroying haloorganics.

The U S. Environmental Protection Agency (EPA) has supported research intramurally and extramurally since 1980, to develop an alternative method for *in-situ* or on-site destruction of halogenated pollutants. Chemical reagents prepared from polyethylene glycols and potassium hydroxide (KPEGs) have been demonstrated under mile conditions (25°-140°C) to dehalogenate PCDDs and PCDFs to less than 1 ppb of starting materials. The reaction mechanism is nucleophilic substitution at an aromatic carbon.

Toxicological tests have established that arylpolyglycol by-products from KPEG reactions are non-toxic. In July and August, 1986, a 2700-gallon KPEG reactor was used in Butte, Montana and Kent, Washington to successfully destroy PCDDs and PCDFs (120 ppb - 200 ppm) in 17,000 gallons of liquid waste to nondetectable levels. A new 2 cubic yard KPEG reactor designed to treat both liquids and soils will be field tested in 1987.

Supercritical Solvent Extraction

Charles A. Eckert
University of Illinois

Supercritical fluids are compressed gases at a temperature just above the vapor-liquid critical point, and have unique physical properties that can be used to develop novel separation schemes. There have already been numerous successful applications in a wide variety of areas ranging from the food industry (decaffeination of coffee), pharmaceuticals, and even energy (tertiary oil recovery). Significant opportunities exist to apply the same type of technology to problems in environmental control

This paper first discusses the technical advantages of supercritical fluid extraction and reviews the phase equilibrium methods for separation process design. It presents new results demonstrating the concept of "tailoring" solvents for specific separation applications, primarily by using mixed solvents or entrainers. These theoretical results have been applied to design detoxification plants and determine the technical and economic feasibility of this new processing method for the rapid and safe removal of contaminants from waste sites. Specifically, mobile units are proposed for an on-site removal of organic contaminants from soil and regeneration of granular activated carbon used for wastewater cleanup. Such an application of supercritical fluid technology would eliminate the need for transportation and burial, at costs significantly less than that for traditional methods.

Supercritical Fluid Extraction from Catalytic Oxidation of Toxic Organics from Soils

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Louisiana State University

Supercritical fluid (SCF) extraction is a promising new technique for the cleanup of soils, sediments, and sludges that are contaminated with hazardous wastes. In this investigation, supercritical carbon dioxide (SC-CO_2) has been used to extract PCBs, DDT, and toxaphene from contaminated topsoils and subsoils. An attactive feature of this process is that the CO_2, being virtually inert, leaves no solvent residue on the processed soil.

In our initial extraction studies, supercritical CO_2 at 100 atm and 40°C was continuously passed through a fixed bed of 10 g of soil. Approximately 70% of the DDT and 75% of the toxaphene could be leached from a topsoil (12.6% organic matter) contaminated with 1000 ppm DDT and 400 ppm toxaphene in under 10 minutes using SC-CO_2 at a rate of 0.7 g/s. The extraction of contaminated (with 1000 ppm Aroclor 1254) subsoil (0.74% organic matter) proved to be even more promising, because more than 90% of the PCBs could be extracted in under one minute at the same CO_2 rate.

Recently SC-CO_2 with a single entrainer,* either methanol or toluene,

*An entrainer is a volatile organic compound which, when added in low levels to supercritical CO_2, dramatically increases the solubilities of certain nonvolatile organics in the SCF

was compared to pure CO_2; comparison was made on the basis of extraction rate and the removal efficiency for DDT or PCBs from contaminated topsoils. The supercritical mixtures at 100 atm and 40°C were continuously passed through a fixed bed of 10 g of soil. The most effective solvent system, SC-CO_2 with 5 wt% methanol at a flowrate of 0.7 g/s, was able to leach 95% of the DDT from the soil in under 5 minutes, as compared to either pure CO_2 or CO_2 with 5 wt% toluene at the same conditions, which resulted in only 70% extraction in 10 minutes. This same extraction mixture (SC-CO_2 with 5 wt% methanol) was also applied to a highly contaminated spill site topsoil containing ca. 3500 ppm Aroclor 1260 and 2100 ppm Aroclor 1242. Over 98% extraction of the contaminants was realized in 10 minutes.

With the demonstrated ability to extract contaminants from soils using supercritical CO_2 with an entrainer, a logical further treatment would be the destruction of the wastes while they are in the supercritical phase. An evaluation of catalysts for the low temperature (below 350°C) oxidation of polycyclic aromatic hydrocarbons and chlorinated hydrocarbon wastes in the SCF phase will be presented.

Session B-5 Biotechnology

Microbial Degradation of Synthetic Chlorinated Compounds

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Pseudomonas cepacia strain AC1100 is a novel organism from the standpoint of being the product of a facilitated evolution process that has resulted in the formation of a unique metabolic pathway for the utilization of the herbicide 2,4,5-trichlorophenoxy-acetic acid. A review is presented of past research pertaining to this organism as well as features it possesses that make it a highly desirable subject for further investigation. Recent results of an on-going research program designed to isolate the genetic determinants responsible for 2,4,5-T metabolism by this organism are also presented. These include the isolation of a series of spontaneous mutants affected at several different 2,4,5-T degradation-specific loci, the construction of a genomic library of AC1100 DNA sequences of *Escherichia coli* and the use of this library in the complementation of a presumed transposon Tn5-induced mutant.

Bacterial Oxidation of Polychlorinated Biphenyls

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The University of Texas at Austin

The present studies represent a summary of the results obtained on the degradation of polychlorinated biphenyls by two strains of bacteria. The organisms, *Alcaligenes eutrophus* H850 and *Pseudomonas putida* LB400, are capable of metabolizing a wide range of PCB congeners. The initial reactions involved in the oxidation of 2,5,2', 5'-tetra-chlorobiphenyl by both organisms appears to involve oxidation at the unsubstituted 3,4-positions. The properties of the enzymes involved in these reactions and the regulation of their activities are being studied by modern molecular biological techniques. It is anticipated that the results obtained will lead to the construction of improved strains of bacteria than can efficiently degrade a wide range of PCB congeners.

Engineering P450 Genes in Yeast

John C. Loper
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College of Medicine

Cytochrome P450 systems catalyze the monooxygenation of a broad range of xenobiotic compounds. These systems are most extensively characterized in mammals, where for a given species a single form of NADPH-cytochrome P450 oxidoreductase (P450R) donates reducing power to any of 30-to-100 unique members of a P450 protein superfamily. We are interested in gene engineering P450 systems in yeast for the oxidative detoxication and biodegradation of environmentally stable organic pollutants. Two organisms, *Saccharomyces cerevisiae* (baker's yeast) and *Candida tropicalis* ATCC750, a yeast capable of n-alkane assimilation, have been used as models. *S. cerevisiae* is particularly useful in gene manipulation, *C. tropicalis* is of interest for its possible advantages for genetically engineering the uptake and catabolism of hydrophobic toxicants. The major proteins of interest in these model yeasts are: P450R; the P450 lanosterol 14α-demethylase, involved in sterol biosynthesis; and P450 n-alkane ω-hydroxylase.

Genes for these proteins have been isolated and determination of their DNA sequence has been completed or is in progress. Amino acid sequences deduced from these DNAs were compared to sequences reported for mammalian P450 system proteins. Our results indicate that the P450R protein is highly conserved among yeast and mammals. The yeast P450 proteins share patterns observed for mammalians P450s, with sequence similarity among enzymes of similar function and with wide sequence diversity between P450s of different substrate specificity. The yeast 450s for lanosterol demethylation and alkane n-hydroxylation belong to two new families in the P450 superfamily. Characterization of these genes forms a basis for the gene engineering of P450 expression in yeasts.

Session B-6 Biosystems

Biodegradation of Organopollutants by Phanerochaete chrysosporium*: Practical Considerations*

John A. Bumpus
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We previously reported that a wide variety of structurally diverse organopollutants are mineralized by the lignin degrading system of the white-rot fungus *Phanerochaete chrysosporium* (Science *228,* 1434, 1985). Current research is directed towards application of this technology for the biodegradation of environmental pollutants and hazardous wastes. The system is effective in both liquid and solid matrices. Bulking agents such as wood chips or corncobs can also serve as a carbon source for the fungus. Degradation of chemicals is supported by a carbon source for the fungus but readily available carbon sources such as glucose do not support sustained rates of degradation. Sustained rates were obtained with complex carbohydrates including natural sources. Rates of degradation increased with respect to the concentration of chemical. Degradation of mixtures often proceeded faster than the rate of degradation of pure chemicals. For example, the mineralization of pure 2,4,5,2,4,5-hexachlorobiphenyl proceeded much slower (1.1% in 30 days) than did the mineralization of Aroclor 1254 and 1242 (14.3% and 20.3%, respectively, in 30 days). Two percent of pure ^{14}C-naphthalene was present in coal-tar contaminated soil. Toxicity of

chemicals to the fungus was rare but could be circumvented. The fungus would grow in the presence of used motor oil or coal-tar contaminated soil. The toxicity of the fungicide pentachlorophenol (PCP) was reduced by starting with mature mycelia instead of fungal spores. Under these conditions, the fungus continued to mineralize substantial amounts of PCP at concentrations up to 100 ppm. For example, when the initial concentration of PCP was 100 ppm, greater than 20% of the PCP initially present was mineralized in 30 days. Furthermore, disappearance studies showed that approximately 95% of the PCP initially present had been metabolized

Growth of the White-Rot Fungus Phanerochaete chrysosporium *in Soil*

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Phanerochaete chrysosporium is a white-rot fungus with a demonstrated ability to degrade chlorinated organics in pure liquid culture to carbon dioxide. This ability suggests that the fungus may have potential as an *in situ* hazardous waste degrader However, no data exist regarding the ability of *P. chrysosporium* to survive and grow in soil. That information is required from an effective evaluation of the ability of the fungus to degrade organopollutants *in situ* The objective of this study was to investigate the influence of soil biotic and abiotic factors on survival and growth of the organism. This paper will summarize our research results to date on the effects of soil type, temperature, water potential and acidity on growth of the fungus in sterile soils.

Biological Treatment of Selected Aqueous Organic Hazardous Wastes

Richard J. Lesiecki
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This paper describes tests performed to evaluate the fate of aqueous organic hazardous waste compounds in the activated sludge process. Gas, liquid and waste solids samples were taken from acclimated activated sludge systems to determine amounts that were volatilized, biodegraded and associated with the wasted solids Results discussed here include two compounds, methyl ethyl ketone and 1,1,1-trichloroethane.

Session B-7 Alternative Treatment Technology

Assessment of Alternative Technologies for Treating Spent Electroplating Solutions and Sludges

Katherine Driscoll
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Off-site commercial hazardous waste treatment facilities were evaluated to generate support data for the U.S. Environmental Protection Agency's land disposal ban. Establishing treatment standards for electroplating wastewater and sludges is a high priority task with respect to the land disposal ban. One facility treated electroplating solutions with cyanide oxidation, hexavalent chromium reduction, a combination of lime and sulfide precipitation, and vacuum filtration. Electroplating sludges were stabilized with calcium hypochlorite, ferric sulfate or lime. Of particular interest is the use of waste streams as treatment reagents. This report summarizes data used to evaluate these treatment technologies for electroplating solutions and sludges.

Solvent Recovery Technologies

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U.S. Environmental Protection Agency

The increasing cost for disposal of hazardous wastes presents a favorable climate for recovery of materials and energy from hazardous wastes. In the case of waste solvents, the land disposal restrictions imposed by EPA on those materials on November 7, 1986, will make disposal much more difficult and costly

This paper describes approaches to recovery of solvent wastes: fuel blending, distillation, and steam stripping. The technologies are described and data are presented from EPA programs to evaluate these technologies.

Evaluation of Hazardous Waste Recycling Processes in the Printed Circuit Board Industry

Thomas J. Nunno
Alliance Technologies Corporation

In response to the 1984 RCRA Amendments, EPA's Hazardous Waste Engineering Research Laboratory (HWERL) initiated a program to develop case studies demonstrating waste minimization and recycling options for hazardous waste management. The program focused on solvent and metal waste streams from the semiconductor and printed circuit board industries, specifically: (1) waste solvents from resist stripping and developing operations; and (2) metal wastes from plating operations. Two case studies involved the use of solvent distillation units which achieved over 95 percent recovery of spent halogenated solvents. The results suggest that solvent recovery can be widely applied to printed circuit board manufacturing facilities. The other four case studies focused on technologies to reduce metal-plating wastes. Two of these, evaluating the use of sodium borohydride reduction as a substitute for lime/ferrous sulfate precipitation, found that the technology was a viable substitute in one case and was marginally acceptable in another. Another case study, involving carbon adsorption removal of organic contaminants from plating bath wastes, found that this technology significantly reduced both disposal costs and waste volume. A final case study of electrolytic recovery indicated that while acid copper electroplating rinses are amenable to electrolytic recovery, other metal-bearing rinses, such as those from solder (tin/lead) plating or etching are less appropriate.

The California Innovative Alternative Treatment and Recycling Demonstration Projects Program

Robert Ludwig
California Department of Health Services

The California Department of Health Services in cooperation with the U.S. Environmental Protection Agency is conducting, as part of its broad waste reduction program, demonstrations of alternative technologies and studies on hazardous waste management. The overall objective of the California Waste Reduction Program is to reduce the amount and eventually eliminate land disposal of untreated hazardous wastes. Alternative waste management strategies being studied include, in order of preference, (1) source reduction, (2) recycling, and (3) treatment.

This paper discusses state and federal statutory requirements and problems

encountered in the process of implementation of the elements of California's Waste Reduction Program. Specific studies described include (1) waste stream information collection, (2) assessment of extent of use of waste treatment in California, (3) waste audit programs, (4) waste management information transfer, and (5) discussion of preliminary results from demonstration projects.

Session B-8
Characterization and Control of Volatile Organic Emissions

Field Assessment of Steam Stripping Volatile Organics from Aqueous Waste Streams

Marvin Branscome
Research Triangle Institute

This paper discusses the removal of volatile organics (VO) from aqueous waste streams by steam stripping and summarizes the effectiveness of VO removal from the waste, the air emissions from the process, and the cost of the treatment process. Tests were conducted at two chemical plants that used continuous steam strippers to remove VO from the wastewater. The operation at Plant H, which produces ethylene dichloride and vinyl chloride monomer, treated about 852 liters per minute (L/min) or 225 gallons per minute (gal/min) of aqueous waste containing about 6 grams per liter (g/L) of VO. The operation at Plant I, which produces one-carbon chlorinated solvents, was smaller and treated 42 L/min (11 gal/min) of aqueous waste containing about 6 g/L of VO.

The test program evaluated the removal of VO from the water, which was about 99.8 to 99.999 percent at the two plants. At Plant H, the concentration of VO in the stripper bottoms ranged from 0.34 to 36 parts per million (ppm) with an average of 9.7 ppm. This wide range was caused by variations in the concentration of chloroform (the major constituent in the bottoms), which was apparently related to column fouling. This stripper processes wastewater containing about 1.4 g/L of filterable solids. At Plant I, the concentration of VO in the bottoms ranged from less than 0.005 to 0.13 ppm. Solids and an organic layer are removed in decanters at Plant I prior to steam stripping to provide a feed stream containing about 0.01 g/L of filterable solids. Emissions from VO from the decanter and storage tank vents at Plant I were estimated as 46 megagrams per year (Mg/yr). Significant vent rates of VO were also measured from the condensers at both sites. The condenser vent rate at Plant H averaged about 20 Mg/yr compared to 11 Mg/yr at Plant I. The condenser efficiency at Plant H ranged from an average of 6 percent for vinyl chloride to 99.5 percent for ethylene dichloride. At Plant I, the condenser efficiency ranged from 89 percent for chloromethane to 94 percent for chloroform.

Field Assessment of the Fate of Volatile Organics in Aerated Waste Treatment Systems

David Green
Research Triangle Institute

Aeration of wastewater containing volatile organic compounds in activated sludge systems effectively removes many of these compounds from the wastewater prior to discharge. Studies were conducted at full-scale treatment systems to determine the relative extent to which various compounds were destroyed biologically and stripped into the air. Direct measurements of air emissions were made through sampling and chemical analysis of off-gases from the aeration tank of an activated sludge unit. Indirect measurements were made by comparing compound specific biological oxidation rates obtained in closed bottles to total disappearances across the treatment units. Additional measurements were made to determine potential removal of organics in waste sludge streams. This paper describes these measurement techniques and results of the studies.

Pilot-Scale Evaluation of a Thin-Film Evaporator for Volatile Organic Removal from Land Treatment Sludges

Coleen M. Northeim
Research Triangle Institute

The U.S. Environmental Protection Agency's Office of Air Quality Planning and Standards is currently developing regulations to control air emissions from waste treatment, storage, and disposal facilities. In support of this regulatory development effort, the Research Triangle Institute has conducted a study of thin-film evaporators (TFE) for removing volatile organics (VO) from refinery wastes. Thin-film evaporators were studied to evaluate their use to remov and recover VO from waste petroleur sludges prior to land treatment. Thi would reduce the amount of VO availabl for release to the atmosphere during lan treatment of the sludges.

The treatment of two refinery sludge was investigated in a pilot-scale agitate TFE. The fraction of feed removed by th TFE ranged from 11 to 95.7 percent. A the greatest overhead fraction, mor than 99.9 percent of the VO and 7 percent of the semivolatile compound were removed from the sludge. At th lowest overhead fraction, greater tha 98.5 percent of the VO and 10 to 4 percent of the semivolatiles wer removed from the sludge. The sludg processed with the lowest overhea fraction contained water and maintaine suitable handling characteristics for lar treatment.

Session C
HWERL Research Posters

The posters presented at the Symp sium, and their primary authors, are a follows:

EPA/DOE Hazardous Waste Contr Technology Data Base
Cathy S. Fore
DOE Hazardous Waste Remedial Actio Program

Analysis of Samples from the Gatew National Recreation Area at Jamai Bay, New York
Dave Olsen
NUS Corp./Enviresponse Inc.

Case Evaluations of RD&D Perm Applications
Wyman Clark
EER Corp.

Update on Status of EPA Mobile Incineration System
A. C. Gangadharan
Enviresponse Inc.

Boiler Cofiring of Chlorinated Hydrocarbons
John W. Wasser
U.S. Environmental Protection Agency

Demonstration, Testing and Evaluati of Commercial Technologies Unc SITE Program
Seymour Rosenthal
Enviresponse Inc.

Conditions Which Enhance Biodegradation of Organic Compounds by White Rot Fungi
Steven Aust
Michigan State University

Demonstration and Evaluation of the EPA Mobile Carbon Regenerator
Patricia M Brown
Envireresponse Inc

Pretreatment of Land-Treated Wastes
Thomas C Ponder, Jr
PEI Associates, Inc

Geotechnical Analysis for Review of Dike Stability
Mark S Meyers
University of Cincinnati

Land Ban Data Needs
Ron Turner
U S Environmental Protection Agency

Demonstration of Computer Assisted Engineering Techniques for Remedial Action Assessment
Phillip R Cluxton
University of Cincinnati

Hazardous Waste Residuals Characterization
H Paul Warner
U S Environmental Protection Agency

Cost Engineering Models for Remedial Response Technologies
William Kemner
PEI Associates, Inc

Trial Burn Measurement Guidance
Roy Neulicht
Midwest Research Institute

Microscopic and Microchemical Analyses of Solidified Inorganic Wastes Containing Interference Compounds
Harvill C Easton
Louisiana State University

Vacuum-Assisted *In-Situ* Steam Stripping to Remove Pollutants from Contaminated Soil
Arthur E Lord, Jr
Drexel University

Use of Modified Clays for Adsorption and Catalytic Destruction of Contaminants
Steven A Boyd
Michigan State University

Stringfellow Leachate Treatment with Rotating Biological Contactor
Edward Opatken
U.S Environmental Protection Agency

Separation and Recovery of Hazardous Wastes
Paul R. Anderson
IIT Research Center

Treatment of Aqueous Metal and Cyanide Bearing Hazardous Wastes
Sardar Q. Hassan
University of Cincinnati

An Experimental Investigation of Single Droplet Combustion of Chlorinated Hydrocarbons
Nelson Sorbo
University of California, Davis

Catalytic Destruction of Halogenated Hazardous Waste
Howard Greene
University of Akron

Expert System Screening of Remedial Action Technologies for CERCLA Sites
Lewis Rossman
U S Environmental Protection Agency

Activities at Louisiana State University's Hazardous Waste Research Center
Louis Thibodeaux
Louisiana State University

Partitioning of PCDDs and PCDFs in Soils Containing Wood Preservative Fluid
Danny Jackson
Radian Corp

Technical Resource Documents
Norman Surprenant
Alliance Technologies Corp

Oxidation of Persistent Aromatic Pollutants by Lignin-Degrading Enzymes
John Glaser
U.S. Environmental Protection Agency

Laboratory Study of the Thermal Decomposition of Sulfur Hexafluoride
Philip H Taylor
University of Dayton Research Institute

The U S. EPA Combustion Research Facility
R. W. Ross
Acurex Corp.

Construction, Testing, and Skakedown of an Environmental Testing Chamber for Soil Reagent Testing
Michael Black
U.S Environmental Protection Agency

Earthen Liners: Prototype of a Field Study of Transit Time
Karen A. Albrecht
Illinois State Geological Survey

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This Project summary was prepared by staff of JACA Corporation, Fort Washington, PA 19034.
***Naomi P. Barkley** and **John F. Martin** are the EPA Project Officers (see below).*
The complete report, entitled "Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste: Proceedings of the Thirteenth Annual Research Symposium," (Order No. PB 87-233 151/AS; Cost: $42.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
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