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Hazardous Waste Engineering
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Project Summary

Land Disposal of Hazardous Waste: Proceedings of the Eleventh Annual Research Symposium

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Proceedings are summarized for Session A of the U.S. Environmental Protection Agency's (EPA's) Eleventh Annual Research Symposium - Land Disposal, Remedial Action, Incineration, and Treatment of Hazardous Waste. The symposium was held in Cincinnati, Ohio April 29 through May 1, 1985. Session A, Hazardous Waste Land Disposal, included 35 papers; and Session C included 20 poster presentations about the status of research projects sponsored by EPA's Land Pollution Control Division (LPCD) of the Hazardous Waste Engineering Research Laboratory (HWERL). Land Disposal papers are presented in the areas of remedial action, pollutant assessment, and pollutant control. They discuss the generation, movement, control, and treatment of pollutants in landfills, surface impoundments, air, underground mines, and uncontrolled remedial action hazardous waste sites. Session B, Hazardous Waste Incineration and Treatment, will be published as a separate document.

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

Introduction

The 35 papers and 20 poster presentations presented in Sessions A and C of EPA's Eleventh Annual Research Symposium - Land Disposal, Remedial Action, Incineration, and Treatment of Hazardous Waste are abstracted here. The symposium provided an effective means for presenting the latest significant research results of the LPCD's research program to industry, state and federal agencies, universities, environmental groups, and consultants. The symposium provided an effective means for presenting the latest significant research results of the LPCD's research program.

The symposium was conducted with simultaneous sessions - one for Hazardous Waste Land Disposal (Session A), one for Hazardous Waste Incineration and Treatment (Session B), and one for poster presentations (Session C).

Presented in the proceedings are twelve papers and four posters on uncontrolled sites and remedial actions. The topics include assessment of current technologies, verification of techniques for remedial action, *in-situ* treatment, site design and analysis, and site reuse.

Thirteen papers and ten posters address the pollutant assessment area. Topics discussed include soil permeability, column and batch leachate methods, air emissions, and surface impoundment technology.

Pollutant control research is discussed in nine papers and six posters. Subjects covered are containment and fixation, landfill and cover design, underground mine disposal, construction quality assurance and permeability of membrane liners.

Land Disposal Research Overview

Technical Resource Documents for Hazardous Wastes

Norbert B. Schomaker
U.S. Environmental Protection Agency

The EPA is preparing documents to assist permit applicants and permit writers responsible for hazardous waste landfills, surface impoundments, land treatment facilities and waste piles. These Technical Resource Documents (TRDs) describe current technologies and methods for evaluating the performance of the applicant's design in the area of liners, leachate management systems, covers, and other aspects of the containment facilities. These documents are basically compilations of research efforts of the Land Pollution Control Division (LPCD) to date in these areas and are developed and published to assist in the implementation of the RCRA regulations concerning hazardous waste disposal facilities. The TRDs support RCRA Technical Guidance Documents prepared by EPA's Office of Solid Waste (OSW). The Guidance Documents provide details of design and operating procedures that contribute to the satisfactory performance of a facility.

Sessions A-1 through A-3 Remedial Action

Evaluation of Chemical Grout Injection Techniques for Hazardous Waste Containment

Philip G. Malone
USAE Waterways Experiment Station

Field tests were conducted to determine if a continuous impermeable seal could be developed by injecting two chemical grouts into coarse-grained soils. Acrylate and sodium silicate grouts were injected into separate 2 × 4 meter test beds of coarse sand at a 30-50-cm depth using a maximum hole spacing of 40 cm (center-to-center) to produce a pan-like layer of grout. While some silicate grout bulbs coalesced, there were significant gaps in the grout layer and grout shrinkage produced non-uniform cementing. The acrylate grout flowed to the bottom of the sand bed and did not produce grout bulbs.

In a large field test, 30% sodium silicate was injected at 2.44 meters depth in fine sand using injection holes on 1.52 meter centers. Significant problems were noted when the pods were excavated. The pods were asymmetrical and ungrouted areas were present. Pockets of coarse sand in the finer sand were not cemented although they had been filled with grout. Root and rootlet holes in the cemented sand were not sealed.

Conventional injection of chemical grouts did not produce an impervious seal. More unusual techniques, such as jet grouting, may be needed to obtain a useful seal.

Permeable Materials for the Removal of Pollutants from Hazardous Waste Leachates

James Park
University of Cincinnati

Four readily available, low-cost permeable materials—limestone, coal, fly ash, and a soil containing clay—were tested to determine their ability to remove organic pollutants from two simulated hazardous waste leachates. Various sequentially ordered layers of these materials were evaluated for their ability to retain total organic carbon (TOC) and 12 selected priority pollutants. The most effective ordering of materials was found to be a layer of fly ash, followed by a layer of coal, followed by a layer of limestone.

Mechanisms of Contaminant Migration Through a Clay Barrier - Case Study, Wilsonville, Illinois

Robert Griffin
Illinois State Geological Survey

Routine monitoring of a hazardous waste disposal facility at Wilsonville, Illinois revealed that organic contaminants were migrating 100-1000 times faster than predicted based on laboratory measured hydraulic conductivity values. A detailed hydrogeologic investigation of the site revealed that the local ground-water flow and gradient were dominated by a 45-ft high coal mine refuse pile which caused radial flow from the pile through the trenches. Measurements of hydraulic head indicated that the vertical gradient was much less significant than the lateral component of ground-water flow. The distribution of contamination in the ground water was clearly related to the flow patterns. Time series sampling o monitoring wells in slowly recharging formations showed that concentrations of volatile organics varied widely through the recovery period.

Laboratory methods for measuring hydraulic conductivity included recompacted and undisturbed samples. Field methods included both vertical and 45 angle open hole slug tests and recovery tests on monitoring wells in each of the major geologic units. Angle holes yielded higher hydraulic conductivities by as much as one order-of-magnitude compared to corresponding vertical holes. Angle holes were interpreted a intersecting more of the predominantly vertical fractures present in the till tha the vertical holes.

The hydraulic conductivity tests and geologic investigation revealed tha some of the till units beneath th trenches were highly fractured an jointed and lead to the conclusion tha the higher than predicted migratio rates could be accounted for by the di ferences between laboratory and fiel measured hydraulic conductivities These differences appear to be largel due to the inability of small laborator specimens, whether undisturbed or re compacted, to simulate the flo through cracks, joints, and fracture present in the natural materials.

Reclamation and Redevelopment of Uncontrolled Hazardous Waste Sites

Garrie Kingsbury
Research Triangle Institute

Uncontrolled dumping and industri spills have contaminated properti with hazardous materials (now mo than 18,000 sites inventoried by U. EPA). Since many of these properti are in prime urban locations, issues su rounding the reclamation and redev opment of contaminated properti have assumed national importance. Th principal objective of this study h been to document with case studies r lationships between site remediati methods, cleanness criteria, and rec velopment land uses.

After extensive interviews with fe eral and state officials, 12 uncontroll hazardous waste sites were selected f detailed study. For each of these sit remedial actions have been undertak with some upgraded redevelopment

the property in mind. Redevelopment includes single- and multi-family residential, recreational, commercial, institutional, and light industrial land uses.

Two distinct types of redevelopment efforts were encountered—*public-initiated* projects and *developer-initiated* projects. In the case of public-initiated projects (for example, most Superfund sites), immediate concerns for community health are paramount, and site reuse, if any, tends to be incidental to site cleanup.

Remedial Action Modeling of the Western Processing and Occidental-Lathrop Sites

Stuart Brown
CH_2M Hill

Data from the Western Processing and Occidental-Lathrop hazardous waste sites, were used to demonstrate and, to the extent possible, confirm the utilization of numerical computer models for the evaluation of remedial actions at hazardous waste sites. Groundwater flow and contaminant transport models of the sites were developed and calibrated against existing data.

The Western Processing model was used to assess and rank possible remedial actions for the site. Of six potential actions, pump and treat produced the most favorable results. Of the passive actions, the highest degree of cleanup was achieved by the source removal action.

The Occidental model was used to evaluate the effectiveness of an installed ground-water extraction, treatment, reinjection system. The model under-predicted plume reduction and the concentration of contaminant at the extraction wells during a one-year period after startup. This under-prediction was attributed to a conceptual model that could not represent transport of contaminant through sand and gravel preferred pathways. Long-term model predictions show a stagnation of the plume that may require relocation of extraction wells for complete plume cleanup.

Model results helped to confirm the use of numerical models for the evaluation of hazardous waste sites. More specifically, simulation of the sites helped to: 1) identify data deficiencies and help improve the understanding of contaminant transport at the site; 2) rank remedial action alternatives at the Western Processing Site; and 3) show the importance of recalibration and reevaluation of the conceptual model as more data become available.

Demonstration of a Geographic information System for Hazardous Waste Site Analyses

Margrit von Braun
University of Idaho

This paper investigates the applicability of a Geographic Information System (GIS) to the study of a hazardous waste site. Existing data including aerial photographs, maps, and site study reports were digitized to create a spatial data base for an active Superfund site. These computer maps were then analyzed by cartographic modeling techniques to assess current site conditions and prospective remedial actions. Existing site drainage basins were identified and characterized in terms of stormwaters ran off-site or infiltrated on-site. Wastes were inventoried within each basin, and stormwater/waste-contact budgets were developed for each drainage stream. Additional computer maps were then constructed to represent various remedial action scenarios. Stormwater/waste-contact budgets were developed for various combinations of berms, dikes, and asphalt covers. These alternatives were evaluated according to the estimated reductions in waste contacted runoff and infiltration. Excavation volume estimates were developed for the several above-grade waste types and successive estimates were accomplished for removing contaminated soils down to the ground-water table.

Field Determination of Hydraulic Conductivity and Bentonite Content During Slurry Wall Construction

Matthew J. Barvenik
Goldberg, Zoino & Associates, Inc.

Soil/bentonite backfilled cutoff walls (slurry walls) have been used over the past several years to contain and isolate hazardous wastes. Although many slurry walls have been installed, their effectiveness and construction quality have not been studied or documented to any extent. This paper reports on the first phase of testing at the Gibson Road Site at Nashua, New Hampshire. The objective of this phase is to evaluate quality control measures for bentonite content and hydraulic conductivity determinations. This paper specifically addresses the methylene blue titration for bentonite content determination and the API fixed ring permeameter for hydraulic conductivity determination. This paper discusses the applicability and practicability of these tests for field and quality control.

Control of Fugitive Dust Emissions at Hazardous Waste Cleanup Sites

Keith D. Rosbury
PEI Associates, Inc.

Three field studies were performed to determine the effectiveness of dust control strategies at hazardous waste sites. Twelve dust suppressants were tested to determine the effectiveness of fugitive dust control against wind erosion from exposed areas. Based on a tracer sampling protocol, the suppressants were totally effective for 1 to 4 weeks after application, with declining control efficiencies thereafter. The second wind erosion field study was an evaluation of the effectiveness of windscreens and windscreen/dust suppressant combinations in controlling fugitive dust from storage piles. Based on 82 tests, the windscreen showed no consistent significant level of control of particles $\leq$10 micrometers. The wind erosion emission rate of particles $\leq$10 micrometers is fairly constant at windspeeds above a threshold of about a 7 mph average. The windscreen may control larger particles more effectively, but these particles are less of a threat because they exceed the inhalable size and are not carried long distances in the wind. Chemical stabilizers were superior in performance to the windscreen. The third field study, investigating active cleanup emissions, consisted of testing fugitive dust control measures applicable to the use of a front-end loader to load dirt into a truck. Control efficiencies of 41 to 77 percent were measured for area spraying and spray curtains. In general, chemical dust suppressants are often wastes or by-products themselves. Before applying a dust suppressant, the user should analyze the dust suppressant for toxic substances and test for reactivity between the dust suppressant and the contaminated soil.

Practical Methods for Decontaminating Buildings, Structures and Equipment at Superfund Sites

M. P. Esposito
PEI Associates, Inc.

Practical methods for decontaminating buildings, structures, and equipment at Superfund sites are described in a new EPA handbook. Techniques presented include: asbestos abatement, absorption, demolition, dismantling, dusting/vacuuming/wiping, encapsulation/enclosure, gritblasting, hydroblasting/waterwashing, painting/coating, K-20, scarification, RadKleen, solvent washing, steam cleaning, vapor-phase solvent extraction, acid etching, bleaching, flaming, drilling and spalling, microbial degradation, and photochemical degradation. Method descriptions include a general discussion of the procedure, advantages, disadvantages, applicability, effectiveness, engineering considerations (including building preparation, process description, and equipment needs), safety requirements, waste disposal, and costs. Potential decontamination techniques for a given contaminant/structural material combination are identified in a matrix. Other information presented in the manual includes stepwise guidance for developing a cost-effective decontamination strategy, case studies illustrating the actual application of many decontamination methods, cost analyses for the application of each method of a model building, a discussion of worker health and safety precautions, and a summary of available sampling techniques.

In-Situ Treatment of Contaminated Groundwater and Soils

Roger Wetzel
JRB Associates

In-situ biological degradation has been selected for field demonstration at a waste disposal site at Kelly Air Force Base, Texas. The *in-situ* biodegradation treatment of this site will involve the introduction of oxygen to the subsurface and the circulation of water by an extraction/infiltration system. Extensive investigation has been necessary to characterize the site, demonstrate the effectiveness of the biological treatment in the laboratory, and determine the modifications of site conditions required to approach the optimum for treatment. The four elements of the project necessary to provide the information required for the design and implementation of the field demonstration are 1) geological investigation and site characterization, 2) determination of the contaminant profile, 3) microbiological investigation, and 4) laboratory biodegradation investigation. The results of each element of the project are summarized, and recommendations for design and implementation of the field demonstration are made based on these results.

Case Study Investigations of Remedial Response Programs at Uncontrolled Hazardous Waste Sites

Claudia Furman
JRB Associates

Section 105(7) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) requires that USEPA establish means of ensuring that remedial actions are cost-effective over the period of potential exposure to hazardous substances or contaminated materials. In partial support of this objective, USEPA has been directing the preparation of detailed case studies on remedial responses at uncontrolled hazardous waste sites. Detailed information has been collected on cost, institutional, and technical issues related to the implementation and effectiveness of remedial actions at these sites. Compiled into a succinct case study, this historical information can then be used in planning, selecting, designing, and cost analyzing future remedial actions.

The project discussed here is a continuation of earlier case study activities where 23 case studies were published (USEPA[a], 1984). The focus of this more recent series of eight case studies (USEPA[c]), however, was on fund-financed or enforcement actions, as opposed to the earlier studies which focused on private- and State-lead actions. Within this report, the eight case studies are briefly described in table format, followed by a more comprehensive discussion of four of the eight remedial case studies.

Effect of Freezing on the Level of Contaminants in Uncontrolled Hazardous Waste Sites Part 1: Concepts and Literature Review

Iskandar K. Iskandar
U.S. Army Corps of Engineers

A literature search indicated that na
ural freezing may have detrimental e
fects at uncontrolled hazardous was
sites in the cold dominated areas b
cause of frost action on buried materia
and ion movement in soils. Natural ar
artificial freezing, however, can be use
beneficially to concentrate effluents ar
to dewater sludges, contaminated sec
ment and soils. The process of artifici
ground freezing can also be used as a
alternative to temporarily immobili
contaminant transport and, potentiall
for decontaminating soils, sedimen
and sludges. A cost and economic ana
ysis procedure was developed and use
to evaluate ground freezing.

Sessions A-4 through A-6- Pollutant Assessment

VOC Emission Reductions fro Surface Impoundments by us of Wind Fences and Wind Bar riers

Louis Thibodeaux
Louisiana State University

Quantities of hazardous waste mate
als in liquid, sludge or solid form can
disposed on or near the soil surface.
common disposal operations uses s
face impoundments for aqueous was
Proper design and operation pro
dures can result in significantly reduc
emissions of hazardous volatile spec
to the surrounding air.

Surface impoundments usually c
sist of shallow earthen basins. Aqueo
and non-aqueous wastes are placed
these open-top basins for treatment
selected waste or for storage. Volati
may escape to the air boundary lay
but significant reduction in emission
possible by using perimeter and n
work fences. Desorption data were
tained on a pilot scale apparatus usi
ethyl ether as the model chemical. Fo
percent reduction in emission of et
ether was achieved with this liqu
phase controlled volatile chemi
using solid perimeter fences. Sever
eight percent reduction was achie
with solid fence networks.

Investigation of Floating Immiscible Liquids to Control Volatile Organic Chemical Emissions from Surface Impoundments

Charles Springer
University of Arkansas

Floating immiscible liquids were investigated as a control option for volatile organic chemical emissions from a laboratory scale waste water impoundment. Three different immiscible organic liquids were used—mineral oil, octanol and lauryl alcohol. A three phase resistance-in-series model was proposed. Experiments with complete surface coverage and thick mineral oil layer showed a considerable decrease in the emission rates only for those compounds with low oil solubility. On the other hand, the emission rate was less significantly reduced for chemicals with high oil solubility.

Leaching Potential of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Contaminated Soils

Danny Jackson
Battelle Columbus Laboratory

Ten soils contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) between 1968 and 1971 were collected from locations in Missouri and New Jersey. Partition coefficients (K_p and K_{oc}) for 2,3,7,8-TCDD were determined for the group of soils based on 2,3,7,8-TCDD concentrations in soil and soil leachate. Mean log K_{oc} values obtained from three different leaching methods (7.15, 7.34, and 7.35) were within one standard deviation of a predicted value of 6.95. Soil physical and chemical properties were determined as explanatory variables to account for observed variability in K_p values and 2,3,7,8-TCDD concentrations in soil leachate. Solvent extractable chlorinated organic carbon content of soils was found to greatly influence the partitioning of 2,3,7,8-TCDD between the soil solid-phase and soil leachate. An analytical solution of a solute transport equation and a retardation equation were used to predict mobility of 2,3,7,8-TCDD in soils. Predicted 2,3,7,8-TCDD movement rates for convection and dispersion in soil pore fluids were extremely slow. A number of other processes may cause actual movement rates to be greater or smaller than predicted.

Development of Standardized Batch Adsorption Procedures: Experimental Considerations

William R. Roy
Illinois State Geological Survey

A Technical Resource Document (TRD) is being developed to provide information on the use of batch procedures for determining the adsorption capacity of soils for solutes in waste leachates. The TRD will be part of the technical basis for guidance by the Office of Solid Waste on design and evaluation of compacted soil liners for waste storage and disposal facilities. In developing the batch procedures for the TRD it was found that the method of mixing the solute-soil mixtures influenced their adsorption by soil; more vigorous shaking resulted in greater adsorption. To obtain better reproducibility, a National Bureau of Standards rotating tumbler was adopted as the method of choice. A mixing interval of 24 hours appears to be a valid operational definition of equilibrium for these types of batch procedures. Changes in solution concentration of arsenic and cadmium were negligible after 10 hours when exposed to different soil materials. Solution ratios for inorganic solutes must be found empirically, but suitable ratios for hydrophobic organic solutes can be estimated from the solubility of the compound in water and the organic carbon content of the soil.

Clay Liner Systems: Current Design and Construction Practices

Leonard J. Goldman
Research Triangle Institute

Information is presented on selected aspects of hazardous waste facility clay liner design and construction. The information has been gathered as part of the effort associated with the production of the Technical Resource Document: *Design, Construction, Maintenance and Evaluation of Clay Liners for Hazardous Waste Facilities* (EPA Contract No. 68-03-3149-1-2). The sources of information were the published literature and interviews with approximately 30 geotechnical engineers and engineering geologists in the fields of liner design, liner construction, waste management, and governmental oversight of hazardous waste disposal activities. Collectively, these professionals had experience with clay lined facilities located in nearly all parts of North America.

Effects of Inorganic Leachates on Clay Soil Permeability

J. Jeffrey Pierce
Duke University

Hydraulic conductivity laboratory test results for three clay soils exposed to two inorganic chemicals are documented, the potential usefulness of five additional laboratory tests for predicting clay/chemical compatability is discussed, and an extensive literature review is summarized. Researchers have studied the effects of organic solvents on the hydraulic conductivity of compacted clays, and results indicate many of these solvents cause increases in hydraulic conductivities. Limited information, however, is available in the literature concerning the effects of inorganic chemicals on the hydraulic conductivities of clays.

In this research project, the hydraulic conductivities of three field clays—White Store, Hoytville, and Faceville—permeated with ferric chloride (500 mg/l) and nickel nitrate (50 mg/l and 300,000 mg/l) were determined using both fixed and flexible-wall permeameters. Results indicate that at the concentrations tested, neither chemical significantly altered the hydraulic conductivities of the three clay soils. The predictive test results are seen to be inconclusive because, as indicated, no changes in hydraulic conductivities were observed.

Effective Porosity of Geologic Materials

James P. Gibb
Illinois State Water Survey

The understanding of effective porosity and the development of a method for measuring the effective porosity of geological materials is essential to predict the rates of ground-water solute movement through those materials. This project is designed to explore the phenomenon of effective porosity as a dynamic soil/solute parameter. Modern chromatographic techniques are being adapted for measuring the effective or dynamic porosity of unweathered, unoxidized clay soils at three sites. Preliminary work has isolated some problems

associated with collecting undisturbed soil samples and conducting tracer experiments on low hydraulic conductivity soils in laboratory columns.

Solubility Parameters for Predicting Membrane-Waste Liquid Compatibility

Henry Haxo
Matrecon, Inc.

Swelling of a polymeric membrane liner by adsorption of waste liquids can result in softening, loss of mechanical strength and elongation, an increase in permeability, an increased tendency to creep under load, and greater susceptibility to polymer degradation. The significant factors involved in the swelling of a polymeric composition in a liquid are:

- Solubility parameter or cohesive energy density of the polymer relative to that of the liquid.
- Crosslinking of the polymer.
- Crystallinity of the polymer.
- Filler, plasticizer, and soluble constituents in the total compound.

Of these, solubility is probably the most significant factor and the subject of this new research project.

Most organic waste constituents have solubility parameters in the range of 9-10, which is in the same range as polymers used in the manufacture of the membranes. This indicates the need for selecting liner materials that have solubility parameters differing from the organic components of the wastes to be impounded.

This paper presents an analysis of data from the literature with respect to the solubility parameters of waste liquids and of polymeric materials; it also presents the results of laboratory testing of selected commercial lining materials in various organic solvents having different solubility parameters.

Analysis of Leachate Production in Closed Hazardous Waste Landfills

Randy R. Kirkham
Battelle Northwest Laboratories

Hazardous wastes disposed of in landfill sites may continue to drain for several years after site closure. Leachate sources include waste fluids as well as meteoric water trapped in the landfill during construction and operation. Waste fluid may be released through barrel degradation, and interstitial fluid may be released during subsidence or compression of waste materials. Water may also continue to enter the landfill through structural faults. Predictions of rates and amounts of leachate production can be developed if the hydraulic parameters or specific-yield values for the hazardous waste and backfill materials are known. A literature search showed that limited hydraulic parameters and specific-yield information is available. Unit-gradient and specific-yield modeling approaches were evaluated for use at hazardous waste landfills. Specific yield was determined for two data sets: one collected by a commercial hazardous waste site operator and provided to us by the state regulatory agency and the other collected by the authors at a hazardous waste site located in New York State. Specific-yield values of approximately 10 to 16% were calculated for the first data set. These values are within the range of reported values for similarly designed municipal waste landfills. A specific yield of 25% was calculated for recent hourly leachate level data collected by the authors at the New York State site.

Precision and Reliability of Laboratory Permeability Measurements

John L. Bryant
University of Cincinnati

Preliminary laboratory permeability test data were gathered from nine sources to create a data bank suitable for statistical analysis. The collected data also yielded a survey of the most commonly used permeameters and testing methods for clay liner permeabilities.

This paper describes the methods used to collect and organize the data. Tentative findings are discussed. Consideration is given to the degree of variability found in replicated permeability tests, the question of sample equilibration, parameters of sample preparation which may lead to sizable errors in permeability determinations, and the amount of variability of permeabilities that may be found in location-to-location sampling from within a source of liner material.

Simulating Landfill Cover Subsidence

Harry Sterling
Daniel Engineering

The subsidence response of the clay layer of a landfill was modeled using a geotechnical centrifuge. Data were collected to determine the effects of cavity width, clay moisture content, time to failure (cracking or collapse) when the critical cavity diameter was reached, and qualitative descriptions of the failure mechanisms. The prototype structures for the clay model layers were the multi-layered covers being tested as part of an EPA-sponsored investigation of hydrologic isolation. These structures consisted of three 2 ft. (0.61 m) layers, with a compacted clay layer at the bottom, covered by sand, and finally top soil. The clay layer was modeled in the laboratory at 1/48, 1/32, 1/24, and 1/16 scales, and was surcharged with lead shot to simulate the overburden due to the other two layers. The scope of the work was limited to clay layers subjected to slump, a type of subsidence characterized by localized void spaces beneath the covers.

Clay layer behavior was dependent upon both the moisture content and cavity width. Field cavity widths of 4 ft. (1.2 m) were successfully bridged by all models tested at that width, but failures and extensive cracking occurred for many models simulating both 8 ft. (2.4 m) and 12 ft. (3.7 m) field cavities. Collapse of the samples at the 8 ft. width occurred at optimum moisture content (which also was the plastic limit of the clay soil), while sample collapse at the 12 ft. width occurred at moisture contents 3 percent below optimum. Qualitatively, soil cracking features were similar to those reported at field sites investigated by other workers.

The centrifuge modeling procedure has promise as an investigative tool to determine the physical mechanisms of subsidence and may be used to test a variety of different configurations for subsidence response in order to determine optimum landfill cover designs.

Leachate Collection Systems—Summarizing The State-of-the-Art

Jeffrey M. Bass
A.D. Little, Inc.

A manual has been prepared to summarize the state-of-the-art in leachate

collection system design, construction, inspection, maintenance and repair as it pertains to system failure. Leachate collection system failure mechanisms, as well as design, construction, inspection, maintenance and repair practices which may reduce the likelihood of failure are reviewed.

Verification of Leachate Collection Efficiency with Physical Models

Paul Schroeder
USAE Waterways Experiment Station

Two large-scale physical models of landfill/liner/drain systems were constructed to examine the effects of length, slope and hydraulic conductivity of the drain layer and the depth of saturation above the liner on the subsurface lateral drainage rate. The models have two different lengths and adjustable slopes. They were filled with a 3-foot sand drain layer overlying a 1-foot clay liner. A 2-inch layer of gravel was placed under the liner to collect seepage from the clay liner. The design, construction, instrumentation and preparation are described in detail.

Several drainage tests were run on each configuration of the models by applying water as rainfall to the surface of the sand layer and then measuring the water table along the length of the models and the drainage rate as a function of time. The experimental design and test procedures are presented along with some descriptive results.

Sessions A-8 through A-9 Pollutant Control

Waste-Liner Compatibility Studies

Warren B. Lyman
A.D. Little, Inc.

Three different programs of study were undertaken focusing on the compatibility of synthetic liners (principally flexible membrane liners (FML) with hazardous wastes. In Study I, qualitative and quantitative information on the chemical resistance of FML materials was collected from vendor and technical publications. This information was compiled into a computer data base comprising about 3,000 data fields on 23 liner materials and over 500 chemicals. Criteria for assessing this information on a common basis were developed, with separate guidelines established for olefinic and non-olefinic liner materials. On the basis of these criteria, normalized ratings of chemical resistance were developed for each chemical/material pair for which there were data. The Study report contains these ratings (over 1,300) as well as a listing of the raw data from which they were derived.

In Study II, a search was made for laboratory test methods that were or could be used to ascertain the compatibility of flexible membrane liners with hazardous wastes. Twenty-seven identified methods, from the United States and foreign countries were examined and compared. Each pertinent test is described in the Study report. The report also discusses the basis for these tests and the extent to which they can realistically be expected to reflect short- and long-term liner performance.

In Study III, research was undertaken to evaluate routes to estimating chemical/liner compatibility. Proven estimation techniques might be used, for example, in prescreening FML materials to be tested for compatibility with a waste, or estimating the resistance of an existing FML liner to a new chemical in the waste. This study showed that one approach using solubility parameters can provide useful information in many situations. Solubility parameters were shown to be useful in three different ways, in solubility parameter maps, statistical correlations, and with the use of the exchange energy density parameter.

Recovery and Testing of a Synthetic Liner from a Waste Lagoon after Long-Term Exposure

Henry Haxo
Matrecon, Inc.

Samples of a 100-mil high-density polyethylene (HDPE) liner were recovered from a waste lagoon in the northeastern United States after 4.75 years of exposure at different depths and tested to determine the effects of the exposure on physical properties. The recovery was performed during removal of the lagoon in a Superfund Remedial Action. The impounded waste liquid was predominantly aqueous and contained significant amounts of organics, particularly chlorinated hydrocarbons, the concentration of which increased with depth.

Overall, the liner appeared to be in satisfactory condition. There was no evidence to indicate that it had cracked or failed, but it did show considerable waviness and distortion on the berm and slopes.

Liner samples were analyzed and tested. Samples of the HDPE liner from the bottom of the lagoon had absorbed about 2% waste and showed a 10% loss in tensile at yield and similar losses in modulus. The samples taken from the slopes of the lagoon showed essentially no change in properties. The use of construction equipment in attempting to remove the waste without damaging the liner was unsuccessful, and the liner on the bottom of the lagoon was destroyed during the cleanup operations.

Strength and Durability of Flexible Membrane Liner Seams After Short-Term Exposure to Selected Chemical Solutions

Ronald Frobel
U.S. Bureau of Reclamation

In March 1983, the United States Environmental Protection Agency (USEPA) began research with the United States Bureau of Reclamation (USBR) to evaluate flexible membrane liner (FML) seams exposed to selected environmental conditions over short periods. A total of 37 combinations of reinforced and nonreinforced FML materials joined by various seaming methods have been subjected to six chemical solutions, brine, tap water, and accelerated outdoor aging by ultraviolet light. Evaluation of the effects of these types of environmental conditions included destructive and nondestructive testing. The destructive tests performed before and after exposure were dynamic load, shear and peel at room temperature, and static dead load at 50°C. The nondestructive tests performed on unexposed samples only were acoustic methods, air lance, vacuum chamber, double seam pressurization, and mechanical point stress.

To date, tests have been completed on unexposed seams and seams that have been exposed for 3 months. Exposures for six and 12 months are currently underway. The results and evaluation of the nondestructive tests and the

3-month chemical exposures are presented in this paper.

Chemical Mass Transport Measurements to Determine Flexible Membrane Liner (FML) Lifetime

Arthur Lord
Drexel University

The prediction of the service life of flexible membrane liners (FMLs) when exposed to chemicals has usually the result of testing for physical or mechanical property changes after periodic incubations. This paper presents an alternative that makes use of four different diffusion-related measurements of the incubated FML. These tests are water vapor transmission (WVT) radioactive tracer transmission (RT), water absorption (WA) and water vapor absorption (WVA).

This approach was tested for up to 6-month exposure times. The FMLs used were PVC, EPDM and CPE. The chemicals used were 10% NaOH (in water), 10% H_2SO_4 (in water), 10% phenol (in water) and 100% xylene. The WVT and RT were found to be quite reliable test methods, whereas significant problems occurred with the WA and WVA. Various transport coefficients showed all the expected behaviors with chemical exposure:

- constancy (acids and bases on all FMLs)
- decrease (plasticizers leaching from FMLs)
- increase (Phenol-treated CPE and EPDM in H_2SO_4)

The WVT and RT results were generally comparable in all but one situation, that of CPE-phenol. Here WVT showed about a fourfold increase in permeability, whereas RT showed essentially no change in diffusivity.

Although it is preliminary, the work reported here lends credence to the use of mass transport measurements to determine structural change in FMLs and hence a prediction of their lifetime.

A Technique for Retrofitting Impoundments with Geomembranes

David Shultz
Southwest Research Institute

This paper presents the results of a project to investigate techniques for retrofitting existing surface fluid impoundments with a flexible membrane liner or geomembrane. The project was performed as three separate studies. The first was conducted to examine various retrofit concepts. The most promising concepts were then tested using a small physical scale model.

The most practical and successful concept was the pull-through technique, in which the geomembrane is pulled along the sides and bottom of an impoundment. Large-scale demonstration of this technique was carried out at a one-acre fluid impoundment constructed at Southwest Research Institute.

The Role of Impoundment Size in Controlling Environmental Risk at Hazardous Waste Surface Impoundments

Gordon B. Evans, Jr.
K.W. Brown & Associates

The environmental damage due to a hazardous waste surface impoundment failure is greatly affected by the impoundment size (volume). This research determined if multiple-small impoundments, designed to contain the same waste volume as one large impoundment, would present less environmental risk than the large impoundment. Three surface impoundment design scenarios (large, small-attached, small-unattached) were compared based on the environmental damage that would result from two failure situations: surface (catastrophic) and subsurface (long-term). The reduced risk from using smaller impoundments was then compared to the increase in construction cost due to constructing more than one impoundment. It was concluded that there are no real advantages to limiting the size of surface impoundments. Several design features are suggested which should greatly reduce the risks associated with surface impoundment failures.

Update: Storage of Hazardous Waste in Mined Space

Ronald B. Stone
Fenix & Scisson, Inc.

This report presents the results of the assessment of the use of mined space for long-term retention of non-radioactive hazardous waste. The report updates previous studies conducted from 1974-1977, and examines recent literature, recent project activities, involvement of government agencies, regulatory and permitting requirements, selection of existing mines for a demonstration project and presents a new approach proposed by industry, the use of solution-mined space for retention of hazardous waste in salt.

Factors Affecting Stabilization/Solidification of Hazardous Waste

Jerry N. Jones
USAE Waterways Experiment Station

The stabilization/solidification of toxic wastes involves a series of chemical and/or physical treatment procedures. The waste is normally treated so as to complex or bind the toxic elements in a stable, insoluble form or to entrap the waste material in a crystalline matrix. A hazardous waste may contain many constituents that could interfere with the binding process. This recently initiated project identifies possible interfering mechanisms between particular compounds and waste binding systems.

A synthetic sludge was produced containing parts per million concentrations of cadmium, chromium, mercury, and nickel. The sludge was mixed with increasing concentrations of interfering compounds and then with selected waste binders. Various waste mixtures are being evaluated to determine the particular interfering effects on stabilization/solidification processes. This paper is an interim report on the progress of the study.

Construction Quality Assurance for Hazardous Waste Disposal Facilities

Coleen Northeim
Research Triangle Institute

This paper describes the specific elements of a Construction Quality Assurance (CQA) Plan for the structural components of a hazardous waste land disposal facility, e.g., clay liner, dike, flexible membrane liner, leachate collection system, and cover system. The paper refers to EPA's draft technical guidance entitled "Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments—Design, Construction, and Operation" (MTG). This paper discusses the specific CQA components listed in the MTG which are: (1) responsibility

and authority, (2) personnel qualifications, (3) observation and tests, (4) design of a sampling program, and (5) documentation. A table identifying the facility structural components and the important factors to be controlled during their installation is also presented.

Session C

Land Pollution Control Division Posters

Poster Presentations

The posters presented at the Eleventh Annual Research Symposium are listed with their authors, as follows:

1. Computer Analysis of Hazardous Waste Dikes
   Andrew Bodosci
   University of Cincinnati
   Cincinnati, OH

2. Two Automated Systems for On-Scene Coordinators
   Richard Hildreth
   JRB Associates
   McLean, VA

3. Field Verification of Landfill Cover System Construction to Provide Hydrologic Isolation
   Richard Warner
   University of Kentucky
   Lexington, KY

4. Operation of the Center Hill Pilot Plant and Soils Laboratory for Superfund and RCRA Research Projects
   Gerard Roberto
   University of Cincinnati
   Cincinnati, OH

5. Evaluation of Stabilized Dioxin Contaminated Soils
   William Vick
   JRB Associates
   McLean, VA

6. Reclamation and Reuse of Contaminated Land in the United States, England and Wales
   Tayler Bingham
   Research Triangle Institute
   Research Triangle Park, NC

7. Maintenance Free Vegetative Systems for Landfill Covers
   John C. Rodgers
   Los Alamos National Laboratory
   Los Alamos, NM

8. Chemical Resistance of Flexible Membrane Liners Immersed in Selected Aqueous Solutions
   Gordon Bellen
   National Sanitation Foundation
   Ann Arbor, MI

9. Relationship of Laboratory and Field Determined Hydraulic Conductivity in Compacted Clay Soils
   Andrew S. Rogowski
   USDA-ARS
   University Park, PA

10. Critical Review and Summary of Gas and Leachate Production from Landfills
    Fred Pohland
    Georgia Tech
    Atlanta, GA

11. Hydraulic Conductivity of Two Prototype Clay Liners
    David E. Daniel
    University of Texas
    Austin, TX

12. Clay Chemical Compatibility and Permeability Testing: A Review
    R.S. Truesdale
    Research Triangle Institute
    Research Triangle Park, NC

13. Clay Liner Transit Time Prediction Methods and Effects of Leachate Composition on Liner Infiltration
    Ashok S. Damle
    Research Triangle Institute
    Research Triangle Park, NC

14. Effective Porosity of Compacted Clay Soils Permeated with Organic Chemicals
    Janice W. Green
    Arthur D. Little, Inc.
    Cambridge, MA

15. Influence of Concentrations of Organic Chemicals on the Colloidal Structure and Hydraulic Conductivity of Clay Soils
    K.W. Brown
    Texas A&M University
    College Station, TX

16. Assessment of Synthetic Membrane Successes and Failures at Waste Storage and Disposal Sites
    Jeffrey M. Bass
    A.D. Little, Inc.
    Cambridge, MA

17. An Electrical Technique for Detecting Leaks in Membrane Liners
    David W. Shultz
    Southwest Research Institute
    San Antonio, TX

18. Laboratory Determination of Dielectric Constant and Surface Tension as Measures of Liner/Leachate Compatibility
    Charles Mashni
    LPCD/CB, U.S. Environmntal Protection Agency
    Cincinnati, OH

19. Quick Indicator Tests to Characterize Bentonite Types
    Richard M. McCandless
    University of Cincinnati
    Cincinnati, OH

20. Estimating Transit Times of Noninteracting Pollutants Through Compacted Soil Materials
    Robert Horton
    Iowa State University
    Ames, IO

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The complete report, entitled "Land Disposal of Hazardous Waste: Proceedings of the Eleventh Annual Research Symposium at Cincinnati, Ohio, April 29-May 1, 1985," (Order No. PB 85-196 376/AS; Cost: $29.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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