REPRODUCED AT GOVERNMENT EXPENSE

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

(TITLE): Proceedings of the Environmental Systems Symposium (13th) Held at Bethesda, Maryland on 20-22 March 1984.

(SOURCE): American Defense Preparedness Association, Washington, DC.

TO ORDER THE COMPLETE COMPILATION REPORT USE AD-A148 194.

THE COMPONENT PART IS PROVIDED HERE TO ALLOW USERS ACCESS TO INDIVIDUALLY AUTHORED SECTIONS OF PROCEEDINGS, ANNALS, SYMPOSIA, ETC. HOWEVER, THE COMPONENT SHOULD BE CONSIDERED WITHIN THE CONTEXT OF THE OVERALL COMPILATION REPORT AND NOT AS A STAND-ALONE TECHNICAL REPORT.

THE FOLLOWING COMPONENT PART NUMBERS COMPRISE THE COMPILATION REPORT:

AD#:	TITLE:
AD-P004 136	The Application of Emissions Trading to DoD Installations.
AD-P004 137	Compatable Goals: Defense and Environmental Protection.
AD-P004 138	Environmental and Energy Audits of Air Force Government Owned-Contractor Operated Installations.
AD-P004 139	Strategies for Preparing and Submitting A Part B Application for a DoD Facility.
AD-P004 140	Assessment of Environmental Costs at Ordnance Activities.
AD-P004 141	Remedial Action of Hazardous Waste, U.S. Corps of Engineers, Anniston, Alabama.
AD-P004 142	Incineration of Explosives Contaminated Soils.
AD-P004 143	Polymeric Liner Selection for Military Waste Impoundments.
AD-P004 144	Stabilization of Contaminated Soils by in situ Vitrification.
AD-P004 145	Applying an Innovative Approach to Field Investigations at a Remedial Action Site.
AD-P004 146	Treatment of Wastewater (Red Water) Resulting from TNT (Trinitrotoluene) Purification.
AD-P004 147	Location of Volatile Buried Wastes by Field Portable Instrumentation.
AD-P004 148	Practical Application of Earth Resistivity Methods in Phase II of the Installation Restoration Program.
AD-P004 149	The Hazardous Materials Technical Center.
AD-P004 150	Community Relations Activities at Department of Defense Sites.
AD-P004 151	Protocol for Aquifer Cleanup Decision Making at Military Installations.
AD-P004 152	Analysis of Geohydrologic Data by Kriging.

DTIC
DEC 5 1984

This document has been approved for public release and sale; its distribution is unlimited.

By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

AD-P004 143

POLYMERIC LINER SELECTION FOR MILITARY WASTE IMPOUNDMENTS

Jonathan W. Braswell, Gregory M. Gibbons, Timothy G. Shea, Ph.D.
Engineering-Science
10521 Rosehaven Street
Fairfax, Virginia 22030
(703) 591-7575

INTRODUCTION

The use of polymeric membrane liners to line or cap waste impoundments is receiving increasing attention. The liners are essentially impermeable to water and thus are assumed to be capable of providing complete containment of the waste fluids; however, while polymeric membrane liners have been used successfully for many years in water impoundments, little experience is presently available for the use of these liners with wastes. Of particular concern is the effect of the contained waste on the physical properties of the liner material - the compatibility of the liner with the waste. Moreover, the compatibility testing performed to date has utilized methodologies unique to each investigation, and published results tend to be general and inconclusive.

Until the last decade, lagooning was the accepted method of disposal of wastewaters from the manufacture of munitions. As a result, explosive compounds such as TNT and RDX are found in many of the lagoons that have been used by the Army for this purpose. Because these compounds have been defined as hazardous under RCRA, it may be necessary to remove, transport or dispose of the lagoon sediments or the residuals from the treatment of these sediments from many of the lagoons.

It was assumed that synthetic liners would be used in many of these clean-up operations, but synthetic membrane liners may or may not be compatible with the chemical compounds found in these sediments. Based on existing compatibility data, there is reason to believe that solvents such as TCE would be deleterious to the service life of commercially available synthetic membrane liners. The available information on the compatibility of synthetic liners with the explosives such as TNT and RDX is limited and contradictory.

The described work was performed for the United States Army Toxic and Hazardous Materials Agency as part of their In-Situ Treatment Technology Program. This work was done to provide initial polymeric liner compatibility data for selected explosives and solvents, in order to determine the applicability of polymeric liners for the cleanup and restoration of impoundments containing wastes from the manufacture of explosives.

MANUFACTURE OF POLYMERIC LINERS

The synthetic liner industry has a distinct three-step hierarchy, and a knowledge of the organization and flow of goods in the industry is necessary for the selection of candidate liners for compatibility testing. The three levels in the industry are:

1. Manufacture of resins;
2. Manufacture of roll goods; and
3. Fabrication of sheets.

A single company may perform more than one of these functions. Some roll good producers also fabricate sheeting or manufacture their own resin. In general, however, the manufacturing process follows the above sequence.

Synthetic liners are classified by the base polymer. In blends or alloys the main polymer is used for classification. Due to the specific formulation produced by each manufacturer, the properties of one manufacturer's resin may differ from the same type of resin produced by another manufacturer. Resin manufacturers produce the raw materials (polymers) that form the base of the membrane. To the basic polymer (e.g., polyvinyl chloride or chlorinated polyethylene), the resin manufacturers add compounding ingredients specific to their formulation. Compounding ingredients include plasticizers, crosslinking (vulcanizing) chemicals, carbon black, pigments, fillers, biocides and antidegradents. The resin is sold to a roll good producer or used internally.

Roll good manufacturers use the resin to produce rolls of liner material. The roll good manufacturer will add to the resin additional compounding ingredients specific to his formulation and then form this mixture into rolls of material. The material is either extruded or calendered (rolled) into panels four to six feet wide and of varying length. Roll goods (liners) are produced either with or without reinforcing. Unreinforced (unsupported) liners are calendered or extruded in varying thicknesses. Typical thicknesses for most commercial liners are 15, 30 and 45 mils. Thicker liners are made by plying sheets of material. Reinforced (supported) liners can only be made by calendering. A fabric (weave) is sandwiched between two layers of the membrane material. The normal thickness for a reinforced liner is 36 mils.

Each manufacturer of roll goods adds compounding ingredients for their specific formulation; therefore, the characteristics of liners in the same class may vary from one manufacturer to another. Additionally, the compatibility of different manufacturers' products may differ with a given chemical, temperature and exposure environment.

The final step in construction of most membrane liners is the fabrication of large sheets of material. A sheet fabricator seams rolls of liner material into large panels, often 70 to 100 feet wide and of varying length. The length is dependent on maximum total weight allowed for transport and for ease of installation. The panels are made as large as practical, utilizing as many factory seams and as few field seams as possible. Minimizing the number of field seams both facilitates installation, and factory seams are preferable to field seams because they are made under controlled conditions and thus are of better quality.

For high density polyethylene (HDPE), there is no production of roll goods and subsequent factory seaming to fabricate sheets. HDPE sheets are extruded directly at widths of 22-1/2 and 34 feet without seams. These sheets are then seamed in the field during installation.

The seams in a liner often are the weakest point. Seaming techniques vary with liner material, fabricator and installer preference. A brief definition of the five commonly used seaming techniques follows:

- o Thermal Weld - the process of joining thermoplastic sheets by the heating of areas in contact with each other to the temperature at which fusion occurs. The process is usually aided by a controlled pressure.

- o Dielectric Weld - a heat weld where the heating is induced within sheets by means of radio frequency waves.

- o Extrusion Weld - a heat weld where molten membrane material is injected into the seam. Extrusion welds are used with HDPE liners.

- o Solvent Weld - the process of joining sheets by applying a solution of the liner compound emulsified in a solvent to areas in contact with each other. The solvent evaporates leaving a homogenous weld of the liner material, usually aided by controlled pressure.

- o Adhesions - the process of joining sheets using specifically formulated flues to form a bond or seal, usually aided by controlled pressure.

LINER TYPES

Liners are classified by the main polymer utilized in their formulation. Table 1 is a description of the 10 liner types commercially available today and includes the abbreviation used for each. These liners are typically used for lining ponds and lagoons (except for

TABLE 1

DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Butyl Rubber	Co-polymer of isobutylene (97%) and small amounts of of isoprene. Usually vulcanized.	o High resistance to mineral acids o Good tensile strength o Ozone and weathering resistance o High tolerance to temperature extremes	o Highly swollen by hydrocarbons o Difficult to seam and repair; special vulcanizing adhesive required o Slightly affected by oxygenated solvents
Chlorinated polyethylene (CPE)	25 to 45% chlorine with 0 - 25% crystallinity. Usually unvulcanized.	o Resistant to many acids and alkalies o Good resistance to biological degradation o Ozone resistant o Often alloyed with PVC, PE and synthetic rubber	o Swells in high concentrations of aromatic hydrocarbons and oils
Chlorosulfonated polyethylene (Hypalon)	25 to 43% chlorine with 0 - 1.4% sulfur. Usually unvulcanized.	o Resistant to acids and alkalies o Ozone resistant o Resists molds and mildews	o Shrinks and hardens from exposure to UV light o Will soften at elevated temperatures o Low tensile strength o Poor resistance to oils o Swells in presence of aromatics

TABLE 1 (Continued) DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Ethylene propylene rubber (EPDM)	Terpolymer of ethylene, propylene and a minor amount of nonconjugated diene hydrocarbon. Usually vulcanized.	o Excellent ozone resistance o Tolerates extremes in temperature o Resistant to dilute solutions of acids, alkalies, silicates, phosphates and brine o Good abrasion resistance	o Not recommended for petroleum, aromatic or halogenated solvents o Special vulcanizing adhesives required for seaming and repair
Neoprene	Generic name of synthetic rubbers based on chloroprene. Vulcanized.	o Resistant to oils and acids o Mechanical properties similar to natural rubber with resistance to puncture and abrasion	o Vulcanizing cements required for seaming and repair
Polyethylene High density (HDPE)	Based on ethylene with 2-3% carbon black, density varies. Unvulcanized.	o Superior resistance to oils and solvents	o Special seaming tools required o Clear polyethylene readily degrades on outdoor exposure o Very stiff compared to other liner materials
Polyvinyl chloride (PVC)	Produced from vinyl chloride; 25-35% plasticizers, 1-5% chemical stabilizer, and microbiocide added. Un-vulcanized.	o Good resistance to many organic chemicals o Good tensile strength and elongation properties	o Affected by UV exposure o Heat of the sun can volatilize plasticizers o Susceptible to attack from hydrocarbcns, oils and solvents

TABLE 1 (Continued). DESCRIPTION OF POLYMERIC MEMBRANE LINERS CURRENTLY IN USE

TYPE	COMPOSITION	ADVANTAGES	DISADVANTAGES
Oil resistant polyvinyl chloride (PVC-OR)	Similar to PVC with additional oil resistant compounding ingredients.	o Good resistance to many organic chemicals o Good tensile strength and elongation properties o Good oil resistance	o Affected by UV exposure o Heat of the sun can volatilize plasticizers
Ethylene interpolymer alloy	Alloy of elasticized polyolefin.	o Resistant to many chemicals o Good oil resistance o Good temperature service o Good weathering	o Not recommended for organics, especially aromatic o Low temperature limitations
Polypropylene	Based on propylene with carbon black added. Unvulcanized.	o Resistant to many chemicals o Superior high temperature service o Good low temperature service o Good tensile strength	o Susceptible to UV and ozone attack o Difficult to seam in the field o Not recommended for oxidizing solvents

Sources: 1. Lining of Waste Impoundment and Disposal Facilities, SW-870, USEPA, Office of Water and Waste Management.

2. Engineering and Development Support of General Decon Technology for the DARCOM Installation Program, Task 7. Literature Search and Evaluation of Compatibility Testing of Waste Containment Barrier Materials.

polypropylene). The composition and relative advantages and disadvantages for each type of liner are also summarized in Table 1.

Table 2 is a listing of the roll good producers (and resin manufacturers) by type of liner. There are three main producers of roll goods for PVC, PVC-OR, Hypalon and CPE: Mainline; Pantasote; and B.F. Goodrich. Two resin manufacturers supply all the raw materials for Hypalon and CPE: Dow (CPE); and duPont (Hypalon will be made under a duPont patent until 1985). Ethylene interpolymer alloy (XR-5) is produced by only one firm, Shelter-Rite. XR-5 is a patented formulation of Shelter-Rite that reportedly has enhanced chemical resistance properties. EPDM is the only rubber liner material currently produced by more than one roll good manufacturer; namely, B.F. Goodrich and Carlisle. Rubber liner materials have been replaced in general usage by the more resistant plastic formulations. A single producer of polypropylene is included: General Tire using Hercules resin. Polypropylene is currently in the developmental stage for use in lining lagoons. It is widely used in tank lining because of its chemical resistance properties; however, it is not a feasible alternative for lining lagoons today.

EXISTING COMPATIBILITY DATA

Manufacturers are the primary source of liner compatibility data. Data is developed through manufacturers' specific testing, thus there is little agreement on "compatibility rating" criteria and ratings are often unsubstantiated with hard data. As detailed later in this paper, a standard, accepted test procedure has not been used in developing compatibility data, thus it is difficult to compare manufacturers' data bases.

General product material compatibility with specific compounds is useful in preliminary selection of liners for known wastes (with chemical breakdown of constituents). The Plastics Technical Evaluation Center (PLASTEC) of the U.S. Army Armament Research and Development Command (AARADCOM) located at Picatinny Arsenal in Dover, New Jersey has

TABLE 2

LINER TYPES AND MAJOR MANUFACTURERS

TYPE	ROLL GOOD PRODUCER	RESIN
PVC	B. F. Goodrich Mainline Pantasote	B. F. Goodrich B. F. Goodrich Pantasote
PVC-OR	B. F. Goodrich Mainline Pantasote	B. F. Goodrich B. F. Goodrich Pantasote
Hypalon (CSPE)	Stevens Pantasote B. F. Goodrich	duPont duPont duPont
CPE	Mainline Pantasote B. F. Goodrich	Dow Dow Dow
HDPE	Schlegel Gundle	Schlegel Phillips
Ethylene interpolymer alloy	Shelter-Rite	Hooker, Ferro
EPDM	Carlisle B. F. Goodrich	Proprietary
Butyl	Carlisle	Proprietary
Neoprene	Carlisle	duPont
Polypropylene	General Tire	Hercules

SOURCE: Telephone interviews and product brochures done extensive work in compiling compatibility data for polymers with energetics. Information has been gathered from reports and organized into a computer data base called COMPAT. Key words are used to retrieve the results of pertinent studies for a polymer material combination.

Table 3 is a summary of the results of a computer data base search performed by PLASTEC for polymer compatibility with TCE, TNT and RDX. Results of each study are listed by PLASTEC as being either compatible, marginally compatible, or incompatible. There were no data for TCE compatibility with the candidate liner types and data for TNT and RDX were limited to PVC, Hypalon, HDPE, EPDM and Neoprene. Hypalon and HDPE were noted as compatible for TNT in the studies; however, conflicting compatibility results were reported for TNT with PVC, EPDM, and Neoprene. EPDM and Neoprene were noted as compatible for RDX, while the results were conflicting for PVC and HDPE with RDX.

TEST SELECTION

Even when a polymeric liner has been properly installed, a failure of the liner can result from loss of liner integrity due to weathering or incompatibility of the liner with the chemical components of a waste. The selection of an appropriate liner must therefore focus on the degree to which the candidate liner can maintain its integrity over the projected life of the containment facility. Because liner performance data are limited, selections should be based in part on the results of exposure testing that simulates projected conditions.

An exposure test should be designed ideally as an accurate model of the intended application. The test should yield sufficient data that the results can be projected over the anticipated life of the facility, and the results should be useful for prediction of actual field performance. Unfortunately, because of the large number of variables that can affect liner integrity and the limited field data available on liner performance, no such liner exposure test has been developed. As a result, it is necessary to utilize a test procedure that best reflects a projected exposure condition and long-term liner performance. Moreover,

TABLE 3

PLASTEC COMPATIBILITY DATA SEARCH RESULTS

LINER TYPE	Chemical		
	TCE	TNT	RDX
PVC	No data	Conflicting data	Conflicting data
PVC-OR	No data	No data	No data
CPE	No data	No data	No data
Hypalon	No data	Compatible	No data
HDPE	No data	Compatible	Conflicting data
XR-5	No data	No data	No data
EPDM	No data	Conflicting data	Compatible
Neoprene	No data	Conflicting data	Compatible

SOURCE: PLASTEC, "A Compatibility Data Search, Plastic Materials vs. Energetics", 3 June 1982, ARRADCOM, Picatinny Arsenal the test procedure should be based upon accepted methods and have sufficient definition and control of test variables for reproducibility of results and comparison with results from other tests.

<u>Liner Exposure Methods</u>

Liner compatibility testing procedures focus on the method used to expose the liner samples to the test waste. Standard procedures for exposing liner samples to test wastes have only recently been developed. As a result, a wide variety of exposure methods and test variables are still being used. A majority of the liner exposure methods that have been used are adaptations of the American Society for Testing and Materials (ASTM) Method D-471 (Rubber Property Effect of Liquids), and ASTM Method D-543 (Resistance of Plastics to Chemical Reagents). These immersion tests, which are summarized in Table 4, have been used for both initial and long-term evaluation of liner compatibility.

In this type of test, specimens of a liner are immersed in the test waste and, after given exposure times, the liner specimens are removed and the changes in weight, dimensions and tensile properties are determined. Most immersion tests use the same immersion procedure; however, the test temperature, duration and evaluation criteria differ.

Most immersion tests are run at both ambient (23^{o}C) and elevated temperatures. The elevated temperature is intended to simulate adverse conditions and to accelerate any deleterious effects that the waste may have on the liner. Unfortunately there is no concensus as to what this elevated temperature should be. As a result, elevated test temperatures used vary from 50^{o}C to 100^{o}C for the identified tests. The ASTM methods recommend exposure of materials at higher temperatures if elevated temperatures are expected in service.

Each immersion test uses a different test duration. The exposure period for long-term tests tends to vary from one to four months; however, exposure periods of one year or longer have been used. In all cases liner specimens are tested several times during the test so that the effect of the waste on the liner can be determined as a function of time. This procedure allows one to determine if the liner stabilizes after a given length of time.

There are not consistent criteria for evaluating the test results, specifically with respect to what degree of change is acceptable. For example, while one supplier uses compatibility criteria of no more than 3-percent change in weight and 10-percent change in tensile properties, another will allow a change of approximately 20-percent in analysis properties (assuming that the analysis results have stabilized).

In addition to immersion tests, a number of other exposure methods have been developed and used in attempts to more closely simulate actual field conditions. These additional tests are listed in Table 4 and can be characterized as landfill simulation, weathering and permeability tests.

Landfill simulators permit the liner to be exposed to a stratified or solid waste and to a hydraulic head. Landfill simulators have been used for long-term, research-oriented studies of one year to three years. By their nature, landfill simulators do not permit temperature to be controlled and intermediate assessments of replicate systems are expensive.

Weathering tests are used to address what combined effect a waste and climatic variations has on a liner. One supplier uses a heat lamp on a laboratory scale to simulate the effect of waste stratification and ultra-violet light on a liner. On a larger scale outdoor waste tanks and an exposure period of four years have been used to evaluate weathering effects, and DSET Laboratories has developed a patented, ASTM-approved, accelerated weathering test (which does not include exposure to waste).

The only membrane liner waste permeability test reported in the literature was a pouch test. In this test, waste was sealed in a pouch

TABLE 4

ADDITIONAL EXPOSURE METHODS

Reference	Test	Test Duration	Primary Analysis	Comments
Haxo, Henry (Matrecon)	Simulation cells	To 1,200 days	Weight change, ultimate elongation, S-100 modulus, volatiles, extractibles	Landfill simulators
	Weathering tests	To 1,231 days	Ulitmate elongation, S-100 modulus, extractibles	Exposure of membrane to weather
	Tub tests	4 years	Visual	Weathering of waste air interface. Most severely attacked area
	Pouch tests	1,000 days	Weight of liner pouch, pH and conductivity of water	Attempts to compare relative permeabilities
J. P. Stevens Company	Exposure tests, uncovered - sunlamp	7, 14, 21 and 28 days	Visual, weight change	Causes stratification of waste & exposure of waste/air interface
	Exposure test, covered - sunlamp	7, 14, 21 and 28 days	Visual, weight change	Lamp acts as heater
Styron and Fry	Lagoon simulation	12 months	Breaking strength, ultimate elongation	Lagoon simulation, pressurized to create 9 meters of head
DSET Laboratories	EMMAQUA® Test method	Variable	Variable	Accelerated weathering test

SOURCES: (1) Haxo, ASTM 1982
(2) National Sanitation Foundation Proposed Standards
(3) Telephone interviews
(4) Desert Sunshine Exposure Tests, Inc.

made of a liner specimen and the pouch was immersed in de-ionized water. The flows of ions and water across the liner were then monitored.

TEST METHOD EVALUATION

Liner Exposure

Of the identified liner/waste exposure methods, only immersion tests and landfill simulator tests have been used extensively. Although weathering can have a significant effect on the long-term liner integrity, its impact is highly site-specific and difficult to simulate. Only the DSET Laboratories test is a fully documented and ASTM-approved procedure for measuring the effect of weathering, but it is only applicable to the simulation of weather effects and cannot be used to measure waste effects. Because of the inherent impermeability of polymeric liners, permeability is not considered to be a meaningful evaluation criteria (NSF). Additionally, no direct permeability test procedure is available. There are insufficient data on the pouch test to define what is measured by this procedure or its significance. Even though landfill simulators are designed so that leachate can be collected, permeability data from landfill simulators have yet to be published.

Immersion Tests

Immersion testing is the only widely-used procedure for determining the compatibility of polymeric liners with a test waste solution. This procedure evolved from standard ASTM test procedures for determining the compatibility of plastics and rubber with chemicals. A standard test protocol for liner compatibility with wastes has been recently proposed by the NSF. In addition to wide acceptance, the key advantages of immersion tests are the ability to fully define test parameters, limited exposure time and conclusive results. The key disadvantages are that field conditions cannot be fully simulated and solid or semi-solid wastes are difficult to test.

Because liner samples are exposed by immersing them in a test solution containing the waste, the area, equipment and waste quantity needed for immersion tests are small. As a result, it is feasible to expose multiple samples of a liner to a large number of variables such as waste concentration, exposure time, waste temperature and seam type.

Although exposure times of up to one year have been used for immersion tests, periods of one to four months are commonly used because any loss in liner integrity resulting from chemical reaction generally occurs within a short exposure time. Based on the compatibility data published by Exxon, the loss of integrity typically occurs within a month with concentrated chemicals. Additionally, accelerated exposure testing by increasing the temperature of the waste is used in both the initial ASTM procedures and in the proposed NSF test protocol.

Immersion tests, although widely used, do not simulate actual field conditions. In particular, the interface between the waste and atmosphere cannot be duplicated and the effect of waste concentration gradients on the liner cannot be investigated. As a result, some concern has been raised as to the degree that immersion test results can be projected to actual use. A second key disadvantage of immersion testing is the difficulty of using solid or semi-solid waste. Procedures for conducting immersion tests with solids or semi-solids have not been standardized, and it is unclear how well the test procedure can be adapted to solids.

<u>Landfill Simulator Tests</u>

Landfill simulation tests are used to simulate more closely actual field conditions and, as a result, to reflect more closely the actual effect of a waste on a liner. To date only a limited number of landfill simulator tests have been performed and a standardized or widely accepted landfill simulator procedure has not been developed. The key advantages of landfill simulator tests are the capabilities to simulate more closely field conditions and to use waste in a solid or semi-solid state. The disadvantages are that these units lack flexibility, are expensive and the validity of the results has not been demonstrated.

Unlike immersion tests where the liner specimens are simply suspended in a test waste solution, the liner specimen serves as the base of a simulated landfill in a landfill simulator. Factors such as exposure of the liner to a waste concentration gradient, a hydraulic head, and single side exposure can be simulated. It is assumed that such test results will more accurately reflect the interactions between the waste and the liner that occur in actual use and, thus, result in better predictions of long-term liner performance.

Because landfill simulators are constructed as tanks or columns with the liner specimen located at the base, the liner can be exposed to a solid waste without any special modification of the test procedure. Thus, test results from solids exposure should be comparable directly to liquid exposure results.

Although landfill simulators may better simulate actual field conditions, the volumes of material and waste required are large. Thus, fewer data points can be obtained and test variables are more difficult to control. Because each liner specimen must be installed in an individual test cell, a large number of test cells and large volumes of waste are required for a large scale test. As a result, fewer duplicate samples can be run and fewer variables investigated. Because only one side of the liner is exposed to the waste, longer exposure periods are required. In previous tests, exposure periods have been one year or greater. As a result, much less test data can be obtained within a given time and budget.

Of greater concern is the significance of the test results. Landfill simulators are still only an approximate model of actual service conditions. No standardized procedure has been developed and, until more field data are available, it will not be known how well landfill simulators actually reflect field conditions. Additionally, because of their size and long exposure times, it is difficult to closely control individual test variables during the test and, as indicated, fewer samples and variables can be run.

EXPERIENCE WITH THE NSF TEST PROTOCOL

The proposed NSF Test Protocol was selected for the liner compatibility testing with explosives and solvents. The NSF test has been proposed by the National Sanitation Foundation Joint Committee in their Draft Final Standards for Flexible Membrane Liners. The committee is composed of representatives of manufacturers, regulatory agencies, and users of liners. The standards represent a compilation of the views and ideas of many of the leading authorities on liners.

Immersion tests are the most widely used exposure method for liner compatibility studies and the only exposure method for which there is a standard procedure based on ASTM test methods. Immersion tests permit a large number of data points to be compiled, require a limited exposure period and permit close control over test conditions. The major drawback of immersion tests for the planned testing is the lack of past experience with the use of solid waste rather than a liquid waste; however, it would appear that immersion testing with solid waste would be feasible.

The proposed NSF liner compatibility test procedure was straightforward and no major problems were encountered during the testing period. The procedure permitted the screening of over 100 combinations of liners and test environments with good reproducibility of test results. Specific observations on the procedures used are presented below. The physical setup used to immerse the liner samples worked well and presented few problems. The immersion jars were easy to handle and allowed easy removal and replacement of test samples.

The most precise parameter used was weight change; however, it was not possible to obtain the precision implied in the NSF procedure for all liner/chemical combinations. The NSF procedure does not state a weighing precision but it does specify the use of a balance with a 1-mg precision. The liner samples immersed in water saturated TCE would lose weight while on the balance pan; thus it was not possible to obtain a steady weight to the third decimal point. This effect was also noted (to a much lesser degree) with the other samples.

Because of the changing weight, any variation in the time delay between drying and weighing would cause inconsistent weight readings. The NSF method calls for immediate weight readings because of this condition, and a standard procedure (as standard as possible) was used. Nonetheless, because it is impossible to reproduce exactly the drying-weighing procedure each time, the weights may deviate because of procedure as opposed to chemical effect. Even with the preceding considerations, the relative impact of weight changes during measurement was not significant.

Volume measurement was less precise than weight measurement because the method of measurement was not wholly satisfactory. The NSF proposed procedure specifies a dimensional measurement accuracy of 0.001 inches using a micrometer. A micrometer (caliper) is not suited for measurement of flexible material, especially to an accuracy of 0.001 inches. To measure length and width, the samples were held flat and every effort was made to not squeeze (and thus flex) the material; however, it was impossible to completely avoid flexing the liner sample. Also, the potential for flexing the samples increased after they softened in the water-saturated TCE solution. A second possible measurement error with the micrometer was not having it aligned perpendicular to the sample, thus altering the measurement.

LINER COMPATIBILITY

A projection of the potential compatibility of the five liner groups (PVC, CPE/Hypalon, XR-5, HDPE and EPDM/Neoprene) based on previously discussed results is presented below. The values are an assessment of the effect of the test chemicals on each liner based on the results of the screening test. A rating of one is used to indicate minimal effect and a rating of five to indicate failure of the liner.

HDPE appears to be potentially compatible with TNT and RDX, and may be compatible with TCE. The other four liner groups also appear to be potentially compatible with TNT and RDX; however, all four groups were found to be imcompatible with TCE.

SUMMARY OF THE INITIAL SCREENING TEST RESULTS

	Relative Effect of Test Chemical[1]		
Liner Group	TCE	TNT	RDX
PVC	4	3	3
CPE/Hypalon	5	3	2
XR-5	5	2	2
HDPE	3	1	1
EPDM/Neoprene	4	2	2

[1] Relative effects are ranked from 1 (minimal) to 5 (failure).