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Project Summary

Resistance of Flexible Membrane Liners to Chemicals and Wastes

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Qualitative and quantitative information on the chemical resistance of *flexible membrane liners (FMLs)* has been collected from vendors and technical publications. This information has been compiled in a computer data base comprising about 3,000 data fields on 23 liner materials and 549 chemicals. A printout of the information is included in the full report.

Criteria for assessing the information on a common basis were developed. Based on these criteria, normalized ratings of chemical resistance were developed for each chemical/material pair for which there were data. In all, 1,300 ratings were developed and have been summarized in a chemical resistance matrix. These ratings are intended to provide guidance to FML users, but they are not appropriate by themselves as a basis for selecting or rejecting a liner. Furthermore the pertinence of the criteria on which the ratings are based has not been substantiated by field experience.

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

Concern about the long-term integrity of waste containment systems (impoundments and landfills) has resulted in more stringent containment regulations. These regulations focus on the materials used to line and cap waste sites to prevent liquid escape and water entry. The materials used are principally clays and synthetic polymers. The latter include flexible membrane liners (FMLs), which are the subject of the full report.

FMLs are installed in the form of sheeting that is typically several feet wide and 0.02 to 0.1 in. (20 to 100 mils) thick. Sheets are seamed together at the site. Sheeting is presently fabricated from one of four primary or one of several secondary base polymeric materials, some of which are used alone and some of which are reinforced with fabric.

Selecting a liner for a given application involves defining the site requirements, the length of storage, and the waste to be contained. Leaks may occur from tears, punctures, cracking, faulty seams, or other physical occurrences, but they may also result from chemical attack of the liner. The resistance of a liner material to chemical attack and permeation are vital considerations in liner selection.

Liner materials vary widely in their resistance to any given chemical. Thus chemical resistance testing is conducted by the liner industry, by those contemplating installation of a waste impoundment facility, and by various government agencies. Though these groups have conducted considerable testing, their results have been difficult to compare because there have been no standard procedures for testing and reporting the results. Furthermore, the findings are scattered throughout the technical literature, government reports, vendors' brochures, and proprietary literature.

The objective of this study was to gather, analyze, and report all available

existing data on the resistance of polymeric FMLs to waste chemicals that may be stored in hazardous waste landfills and surface impoundments. The purpose of this compilation is to help liner manufacturers, vendors, purchasers, and reviewers of permit applications to select the most chemically resistant FML for a given waste site.

Materials

FMLs are compounded from mixtures of one or more base polymers with additives to improve processing, physical properties, and resistance to weather and soil exposure. Except for highly compounded FMLs such as polyvinyl chloride, the base polymer is the main determinant of the liner's ultimate chemical resistance. The chemical resistance of any polymer is principally a function of its chemical structure, molecular weight, crystallinity, and degree of crosslinking. The base polymers most commonly used for FMLs are as follows:

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

Most of the chemical resistance data presented in the full report are for these materials. Another group of base polymers is less widely used and has limited data available. They are also included in the full report.

Methods for Assessing Chemical Resistance

The chemical resistance of any material is related to its ability to perform any intended functions during and/or after contact with a chemical. If no change occurs in a liner's ability to function as designed after chemical exposure, it is said to be resistant to the chemical. Chemical resistance of an FML should be rated on the liner's ability to prevent the passage of waste and leachate or certain components of these liquids. The barrier can be breached by chemical interactions that reduce the physical properties of the FML to the point of failure, or it can be breached by permeation of the waste or its components through the FML. The latter may occur with little noticeable effect on the liner's physical properties.

Though no consensus yet exists on what characterizes a nonresistant liner, changes in the following physical characteristics generally indicate a lack of chemical resistance: weight, dimensions, tear strength, tensile strength, percent elongation at break, modulus of elongation, and hardness. In addition, semicrystalline polymers may also exhibit stress cracking as a sign of poor chemical resistance. Correlations between changes in these physical properties and changes in the barrier effectiveness of the FML have not been developed.

Information Sources

Chemical resistance information was solicited from the FML industry and from university and independent researchers. In addition, an extensive literature search was conducted. The principal sources of information were the vendors of liners and liner materials (who provide chemical resistance tables as part of their product literature) and government-sponsored research. The vendors' tables typically contain qualitative ratings of resistance upon exposure to neat chemicals. The criteria for these ratings were not usually available from the vendors, and test data were supplied in only a few cases. Most test data for liners exposed to neat chemicals and waste mixtures came from government-funded studies.

Computer Data Base

The information gathered was compiled in a computer data base comprising about 3,000 data fields on 23 liner materials and 549 chemicals.

The information in the data base consists of two types: quantitative and qualitative. The quantitative data consisted of specific test results. The qualitative information was provided by vendors and technical literature that described chemical resistance in subjective terms such as "excellent," "fair," or "poor." Since these terms are not consistent or comparable between sources, the ratings have been normalized to a common 5-grade scale of a, b, bc, c, and d, where "a" is the most chemically resistant liner and "d" is the least.

All essential information of the data base has been tabulated and is included as an appendix to the full report for those who may want to independently assess chemical resistance or for those who may be involved in research using chemical resistance data.

Chemical Resistance Matrix

After the data were compiled and entered into the data base, the data needed to be summarized on a common basis in a form that would serve various groups interested in the use of FMLs for waste containment. The format selected was a matrix in which chemical resistance was reduced to resistant and nonresistant ratings and could be shown on a chemical-by-chemical basis for each generic class (base polymer) of liner material. A scheme was devised to indicate chemical resistance as derived from either the qualitative ratings and/or from an evaluation of laboratory results.

The ratings in the chemical resistance matrix are intended to be used only as a general guide in assessing the potential performance of a liner. A favorable rating is no guarantee that the liner will perform successfully. Nor should an unfavorable rating be taken as an absolute indicator that the liner is unsuitable for a particular application. No known correlations have been made between the liner material performance in short-term laboratory tests and likely performance over decades in the field. Nevertheless, compiling and assessing available information will help users reach intelligent decisions regarding the installation of FMLs.

Information Handling

To facilitate the generation of the chemical resistance matrix for FML materials, the information was organized by means of a commercially available and widely used computer data base system known as FOCUS (Information Builders, Inc., New York, New York).*

The key field for each record was the Chemical Abstracts registry number for the chemical of concern. Mixtures of wastes were assigned numbers. The chemicals were also assigned to a chemical class (inorganic acids, amines, ketones, etc.), and each class was given a code number. Depending on the type of information available, the record also contained the type of liner, vendor's resistance rating, temperature for the rating, type of test performed, exposure conditions and time, test results, and fields for referencing information sources. Thus, once the data were compiled, they could be retrieved on the basis of the chemical, chemical class, liner material, test type, etc. The types of liner materials and tests for which published data were found are listed in Tables 1 and 2.

As described earlier, the qualitative ratings of chemical resistance were normalized to a common 5-grade scale from most to least resistant.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table 1. *Liner Materials*

Code*	Description
HDPE/EPDM	High-density polyethylene/ EPDM alloy
HDPE	High-density polyethylene
LDPE (Copol)	Low-density polyethylene copolymer
EVA (Copol)	Ethylene vinyl acetate copolymer
CSPE	Chlorosulfonated polyethylene
CR	Polychloroprene
EPDM	Ethylene-propylene-diene terpolymer
IIR	Isobutene-isoprene copolymer (butyl rubber)
CO	Polyepichlorohydrin
ECO	Epichlorohydrin-ethylene oxide copolymer
CPE	Chlorinated polyethylene
PVC	Polyvinyl chloride
Polyester	Polyester elastomer
AC	Asphalt concrete
HAC	Hydraulic asphalt concrete
SC	Soil cement—95 parts soil, 5 parts clay, 10 parts cement, 9 parts water
SA	Soil asphalt—7 parts asphalt, 100 parts soil
ASPH	Asphalt
ECB	Ethylene-bitumen copolymer
PVC-CPE	Polyvinyl chloride-chlorinated polyethylene blend
CPE/PE/CPE	Laminate of CPE and PE
XR-5	XR-5® (Seaman Corporation)

*As used in the chemical resistance matrix.

Table 2. *Chemical Resistance Tests*

Description	Data Reported As	Test Code*
Permeation	$g/m^2/hr$	1
Immersion followed by dimensional measurements	% swelling	2
Immersion followed by measurement of elongation at break	% change in elongation at break	3
Immersion followed by weighing	% weight change	5
Immersion followed by determination of tensile strength at break	% change in maximum strength	7
Immersion followed by determination of stress at 100% elongation	% change in 100% modulus	8
Hardness	Hardness points change	9
Immersion followed by determination of stress at 200% elongation	% change in 200% modulus	10
Soil permeability	cm/s	11

*As used in the appendix to the full report.

Data Limitations

The organization and consolidation of chemical resistance information required grouping liner materials by generic type. All information for a given base polymer was thus categorized together, regardless of liner formulation or supplier. This approach facilitated data handling, but it could also lead to false conclusions about the performance of a given brand of liner material. This problem may be particularly significant when only one source of information has been found for a single liner/chemical pair. If that information applies to a liner that was specially formulated for the specific waste or chemical, it may lead to false conclusions about other liners in the same generic class. But if the information indicated poor performance, it could wrongly deter the user from investigating the use of a generic material in an upgraded formulation.

Conclusions

The criteria for assessing the compiled data and developing chemical resistance ratings for the matrix are based on technical judgment and generally concur with similar attempts by other investigators. However, the criteria have not been proposed or adopted as standards by the U.S. Environmental Protection Agency (EPA) or any independent organization. The criteria represent a starting point for developing chemical resistance standards for liner materials. All information on which the ratings are based is presented in the appendix to the full report to facilitate other interpretations. As more information from the laboratory and field becomes available, the data base can be expanded and the criteria modified to reflect experience.

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The complete report, entitled "Resistance of Flexible Membrane Liners to Chemicals and Wastes," (Order No. PB 86-119 955/AS; Cost: $22.95, subject to change) will be available only from:
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