United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-83-046 Aug. 1983

EPA

Project Summary

Field Verification of Liners from Sanitary Landfills

Liner specimens from three existing landfill sites were collected and examined to determine the changes in their physical properties over time and to validate data being developed through laboratory research. Samples examined included a 15-mil PVC liner from a sludge lagoon in New England, a 30-mil PVC liner from a landfill in New York State, and four liners from a landfill test site in Boone County, Kentucky--chlorosulfonated polyethylene (CSPE), low-density polyethylene (LDPE), clay, and chlorinated polyethylene (CPE), low-density polyethylene (LDPE), clay, and chlorinated polyethylene (CPE).

The 15-mil PVC liner from the New England sludge lagoon lost plasticizers whether it was exposed to sludge only, weather only, or both. But the most severe loss of plasticizer and stiffening was exhibited by samples that had been exposed to weather only.

The 30-mil PVC liner from the New York landfill had stiffened and probably lost plasticizer after exposure to weather for 3 years. But the material was still extensive and had not become brittle, as is often the case with exposed PVC liners.

The remaining four liners from Boone County, Kentucky, came from two different test cells. The CSPE, LDPE, and clay liners were all from Test Cell 1. The CSPE liner was swollen and soft and had adsorbed considerable amounts of leachate after 9 years of exposure to attenuated leachate. Nonetheless, its properties were relatively normal for CSPE material. The LDPE liner appeared to be unaffected by its 9 years of exposure to full-strength leachate. These samples showed little swelling and normal properties for a 6- to 7-mil LDPE liner. The clay liner was shown to have contained the leachate effectively. No cracking, channeling, or unusual changes in texture or consistency were noted. The CPE liner from Test Cell 2 showed significant absorption of the leachate it had contained, but its properties were relatively good. CPE samples that had been exposed to weather only for 9 years showed significantly higher tensile strength, moduli, and puncture resistance than did the leachate-exposed samples.

This Project Summary was developed by EPA's Municipal Environmental 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

When municipal solid waste (MSW) is landfilled, ground and surface waters must be protected from leachates--liquid that has percolated through the waste and has become contaminated with extracted, dissolved, or suspended materials. The use of impervious barriers to intercept and control leachate offers a promising means of reducing or eliminating such pollution, and it is recommended by the U.S. Environmental Protection Agency (EPA) for consideration as a control mechanism.

Containment systems have traditionally been lined to prevent the excessive seepage of liquids into the ground. Clay, wood, concrete, asphalt, and metal linings were used in the past in a wide variety of applications. And in the last 30 years, synthetic impervious lining materials have been developed. Among these are polyethylene (PE), polyvinyl chloride (PVC), chlorosulfonated polyethylene (CSPE), butyl rubber, high density polyethylene (HDPE), and various asphalt cement mixtures.

A major concern with liners is the possibility of their degradation after prolonged exposure to leachate, which might chemically or physically attack liner materials. Unfortunately, no method of laboratory testing presently exists to predict the field service life of various liners. Strong circumstantial evidence indicates that liner life can exceed 20 years: Research to date shows only minimal physical changes in liner materials exposed to landfill leachate. More study is needed, however.

The primary objective of this project was to obtain specimens of liners from existing landfills to determine the changes in their physical properties as a function of age and to validate data being developed through laboratory research. Specifically, the program was to achieve the following goals:

1. Determine the nature, extent, and causes of any changes in the liners after prolonged exposure to the landfill environment.
2. Improve the ability to select liners by developing information on their strengths and weaknesses under a variety of conditions.
3. Assist regulatory agencies by providing information that could be used to develop site location and performance standards for waste disposal permit programs.

The project consisted of the following three tasks: (1) Obtaining liner samples and repairing the liner material after sample removal; (2) testing and evaluating the samples, and (3) comparing original liner material with the removed samples.

Methods and Materials

Site Selection

Thirty candidate sites were originally identified as possible choices for study. The criterion for the ideal test site was that it should have complete data and records available in the following categories:

1. Liner design and installation techniques
2. Methods of site operation
3. Type, age, and thickness of wastes in the landfill
4. Occurrence, quantity, and character of leachate
5. Soils, geology, and groundwater.

The original scope of work called for samples of several types of liners (clay, asphalt, and polyvinyl chloride) from at least four landfills. Unfortunately, however, most operators of the 30 selected sites declined to participate in the study because of legal considerations. The final field testing program was therefore restricted to liner materials obtained from three sites:

1. A New England sludge lagoon with a 15-mill PVC liner,
2. A landfill in New York State with a 30-mil PVC liner, and
3. An EPA field site in Boone County, Kentucky (BCFS), with a chlorosulfonated polyethylene (CSPE) liner, a low-density polyethylene (LDPE) liner, a clay liner, and a chlorinated polyethylene (CPE) liner.

Sampling

The sampling program was designed with three objectives: (1) To obtain samples of the various in-place liner materials, (2) to sample indigenous soils beneath the liner, and (3) to repair the liner to preclude escape of leachate as a result of the temporary interruption of liner integrity. Samples of similar soils beyond the influence of the landfill were also collected and analyzed for purposes of background comparisons.

Testing and Evaluation

The testing and evaluation methods selected were tailored to the two types of liner materials to be sampled--clayed and polymeric. Characteristics and properties of clay liners were to be compared with those for background soils to determine the nature of physical and mechanical changes at depth. Testing of polymeric materials included determinations of permeability, thickness, tensile strength and elongation at break, hardness, tear strength, creep, water absorption or extraction, puncture resistance, and density.

Chemical tests on soil samples beneath the liners included analyses for pH, Hg, Pb, Zn, Cd, Fe, Cl, COD, Na, NH_4, K, and Mg. This testing was designed to develop absorption data. Underlying soils were also subjected to physical tests for permeability, density and voids, water swell, and compressive strength.

Results and Procedures

New England Sludge Lagoon (SI)

The sludge lagoon at the solid waste disposal facility in New England covers approximaterly 1.25 ha (3.1 acres) and is 5 m (16 ft) at its deepest. The lagoon is completely lined with a 15-mil PVC liner. Sludge disposed of at the site consists of approximately 85 percent water and 15 percent syspended solids. A high pH of 10 to 11 is due to a high lime and ferric chloride content, which along with other toxic chemical conditioning agents, constitutes up to 40 percent of the total filter cake.

Samples were collected from weathered and sludge-exposed portions of the liner on two major site visits. Results for the weathered samples (Table 1) show a considerable variation in properties. Those portions that had been exposed to the weather showed a loss of plasticizer and a stiffening. One sample that was taken from a portion of the liner that had been stretched tightly across a boulder and exposed to the weather had a very low elongation (extending only 8 percent) and a thickness of only 11.5 mils (compared with the probable 15 mils of the original material). The extractables were still relatively high and might contain low-molecular-weight degradation products of the PVC. These data indicated strongly that a PVC liner should be covered and probably should be thicker than 15 mils if there is a possibility that the cover might be removed.

Samples of sludge-exposed liner were obtained from an area of the lagoon where sludge was being removed. None of the samples were taken from beneath the maximum depth of the sludge where anaerobic conditions were assured. Three of the samples had been covered with soil or with sludge, and the fourth was taken from the east berm and had been removed recently from the area where the sludge excavation was taking place. All of the samples were flexible, but to various degrees. Test results showed that only the weathered sample (from the berm) had lost considerable elongation. Elongations and extractables of the samples varied considerably and indicated that plasticizers were lost during exposure to the sludge even when the liner had not been exposed to the weather. A calcium carbonate deposit was found to be building up on the liner.

·Soil samples from beneath the lagoon liner were analyzed for chemical constituents indicative of leachate that might have penetrated the liner. Although the results showed elevated concentrations of nearly all constituents when compared with background sample data, the evidence is not sufficiently conclusive without additional testing.

New York State Landfill (SII)

The New York State landfill (SII) covers about 2.4 ha (6 acres) of rolling and wooded terrain in an area of predominantly clay and sandy soils with intermittent outcroppings of rocks. Precipitation averages 117 cm (46 in.) throughout the year.

Table 1. *Properties of 15-Mil PVC Liner Samples from Sludge Lagoon (SI)*

Property	Direction of test	Collected October 1979, southwest side				Collected June 1979 Berm		Collected June 9, 1980 Northeast corner			Collected June 9, 1980 East berm
		M1*	M2A	M2B	M3	M4A	M4B	1A	1B-Z	1C	X+
Analyses.‡											
Volatiles (2 hr at 105°C),%	---	0.9-7.1	0.65	0.26	3.41	0.28	0.25	5.44	8.15	3.13	8.46
Ash%	---	---	---	---	---	---	---	5.74	4.35	3.97	5.83
Specific gravity	---	---	---	---	---	---	---	1.27	1.31	1.25	1.32
Extractables, %	---	30.9-35.9	31.2	22.7	24.8	32.5	33.4	32.11	28.99	36.72	25.84
Physical properties											
Thickness, mils	---	12.4	14.7	14.8	11.6	15	15	16.5	15.0	16.0	16.0
Breaking factor, ppi	Machine	67.7	70.4	61.9	34.0	42.4	38.5	48.6	41.6	47.1	38.9
	Transverse	73.5	73.8	62.1	30.2	37.2	34.0	38.5	44.4	43.8	38.2
Elongation at break, %	Machine	335	275	310	8	310	300	290	225	350	170
	Transverse	295	285	325	5	300	300	270	225	400	175
Tensile set, %	Machine	88	127	110	2	92	87	83	86	86	101
	Transverse	63	180	127	1	97	95	54	114	109	91
S-100, ppi	Machine	36.2	60.0	40.9	---	28.4	25.5	29.7	33.8	22.9	36.1
	Transverse	43.9	58.0	39.7	---	25.9	22.7	26.0	35.5	19.1	34.9
S-200, ppi	Machine	45.2	68.3	50.4	---	34.1	32.1	38.6	41.4	32.1	---
	Transverse	53.4	65.8	49.7	---	31.2	27.7	33.8	42.3	26.4	---
Tear strength, Die C, lb	Machine	---	---	---	---	---	---	6.7	6.5	5.2	7.0
	Transverse	---	---	---	---	---	---	5.8	6.8	4.8	6.6
Hardness:											
Duro A:											
Instant reading	---	---	---	---	---	47.2	---	83	87	79	81
5-sec reading	---	---	---	---	---	36.8	---	81	86	75	81
Duro D:											
Instant reading	---	---	---	---	---	---	---	40	49	33	51
5-sec reading	---	---	---	---	---	---	---	33	44	27	46
Puncture strength:											
Thickness of specimen, mils	---	---	---	---	---	---	---	16.3	15.5	16.2	16.0
Stress, Kg (lb)	---	---	---	---	---	---	---	13 (28.9)	12.9 (28.3)	12.8 (28.2)	9.6 (21.1)
Elongation, cm (in.)	---	---	---	---	---	---	---	1.9 (0.76)	1.3 (0.51)	2.3 (0.93)	0.89 (0.35)

*Sample number.
+Taken from excavation dike at the northeast corner of the lagoon.
‡Solvent: $CH_3OH + CCl_4$

The method of landfilling was to place wastes in 3.1-m (10-ft) lifts covered with soil. No liquid or hazardous wastes were accepted for disposal between 1976 (when the landfilling commenced) and October 17, 1979, the date of the site visit.

During the site visit, a piece of the 30-mil PVC liner was collected from the surface near an exposed boulder. Results of tests run on this sample indicate that the sample had stiffened and probably lost plasticizer during its exposure to weather. The material was still extensible and had not become brittle, as is often the case with exposed PVC liner sheeting. Because no test data existed for the original liner material, no determination could be made of changes in properties that occurred during exposure.

Boone County Field Site (BCFS)

The BCFS is an experimental landfill operated by EPA to determine landfill performance. This 4-ha (10-acre) tract sits on top of a ridge 5 miles west of the City of Walton in Northern Kentucky. The site contains a field-scale landfill and four smaller test cells. This study examines clay and synthetic liners from the field-scale landfill (TC-1) and from one of the smaller test cells (TC-2D).

TC-1

From TC-1, samples were taken of a clay liner, a chlorosulfonated polyethylene liner (CSPE), and a low-density polyethylene liner (LDPE). Figure 1 shows the relative positions of these liners in the test cell.

The clay liner was composed of a slightly sandy moderately plastic clay containing limestone rock fragments up to 26 cm (10 in.) long. Liner thickness varied from 44 to 62 cm (17 to 24 in.). The clay was classified as a CL by the Unified Soil Classification System, with an average liquid limit of 42 and a plasticity index of 20. Rock fragments lay parallel to the liner surface. Average in-place dry density was 99 pcf, and average moisture content was 25 percent. Permeability ranged from 4 to 5 x 10^{-7} cm/sec for in-place tests; in laboratory tests, it was 2 x 10^{-8} cm/sec. The liner was light brown-gray to a depth of 31 to 36 cm (12 to 14 in.), where it abruptly changed to a more natural orange-tan for the remainder of its thickness. No visual signs of cracking, channeling, or unusual changes in texture or consistency were noted in any of the excavations.

Chemical analyses of the clay liner in TC-1 indicated that it provided effective leachate containment. Some leachate had collected below the clay liner, but this leakage resulted from a small perforation in the clay surface during cell preparation.

Four samples of synthetic liners were collected from TC-1--three CSPE and one LDPE sample. The unreinforced 0.75-mm (30-mil) CSPE sheeting had been in contact with a small amount of dilute leachate for 9 years, and the 0.15-mm (6-mil), unpigmented LDPE had been in contact with full-strength leachate for the same period.

The CSPE samples exposed to leachate had imprints of gravel and were swollen and soft. They had a small-scale rough appearance similar to that of a nervy compound after calendering. Seams had blisters filled with fluid that appeared to be essentially water. Substantial amounts of the dilute leachate were absorbed by the CSPE samples, with weights increased by as much as 28.4 percent and volumes by 57 percent. Ash values indicated a high inorganic filler content. Extractables (after the volatiles were removed) were relatively low, indicating either a relatively low plasticizer content in the exposed sheeting or a loss of plasticizer during exposure. Physical properties of the CSPE samples all appeared to be approximately the same.

Recovered samples were substantially thicker than were the original materials, partially because of swelling and probably as a result of the relaxing of the compound and the puckering of the liner material (which occurred because of the residual nerve in the sheeting). The values all appear to be relatively normal for the CSPE material. No significant differences were noted in the data among the different samples, indicating that sample location in the cell did not affect results and that the materials all came from the same lot.

The sample of LDPE film was clear after the surface stain was washed off, and it appeared to be unaffected by its 9 years of exposure to the unattenuated leachate. The sample showed little swelling and its properties were normal for a 6- to 7-mil LDPE. No puncture or tears of the material were observed during samle removal.

TC-2D

From TC-2D, six samples were taken of a 30-mil, unreinforced, chlorinated polyethylene (CPE) liner. Four of the samples were taken from the bottom of the cell, and two were collected above ground at the top of the cell (and had thus been exposed to the weather). Figure 2 shows the position of the CPE liner in relation to the other construction details of TC-2D.

The four leachate-exposed CPE samples from the bottom of TC-2D had been exposed to all the unattenuated leachate generated within the cell during the 9 years of operation. Chemical analyses of the layers of sand above and below the CPE liner indicated that it has contained the leachate within the cell. Samples were stiff and leathery. Though they showed significant absorption of leachate, their properties were relatively good. Volatile contents ranged from 16.7 to 18.8 percent. The latter value is equal to an increase of 23 percent by weight (based on the original), or a 31.7-percent increase by volume.

The two weather-exposed samples of CPE line that had been collected above the ground where the liner extended beyond the cell had not been exposed to any leachate. These samples were significantly higher in tensile strength, moduli, and puncture resistance compared with the leachate exposed samples. The lower values for the latter probably reflect the swelling by leachate, but crosslinking during exposure may contribute to the higher values of the weathered samples.

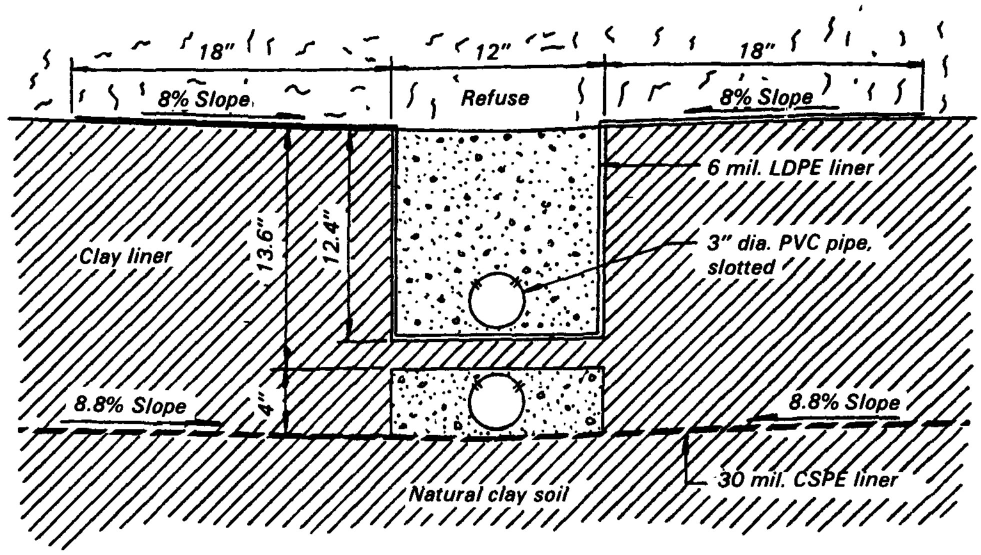

Figure 1. *Cross section of TC-1 at Observation Bulkhead.*

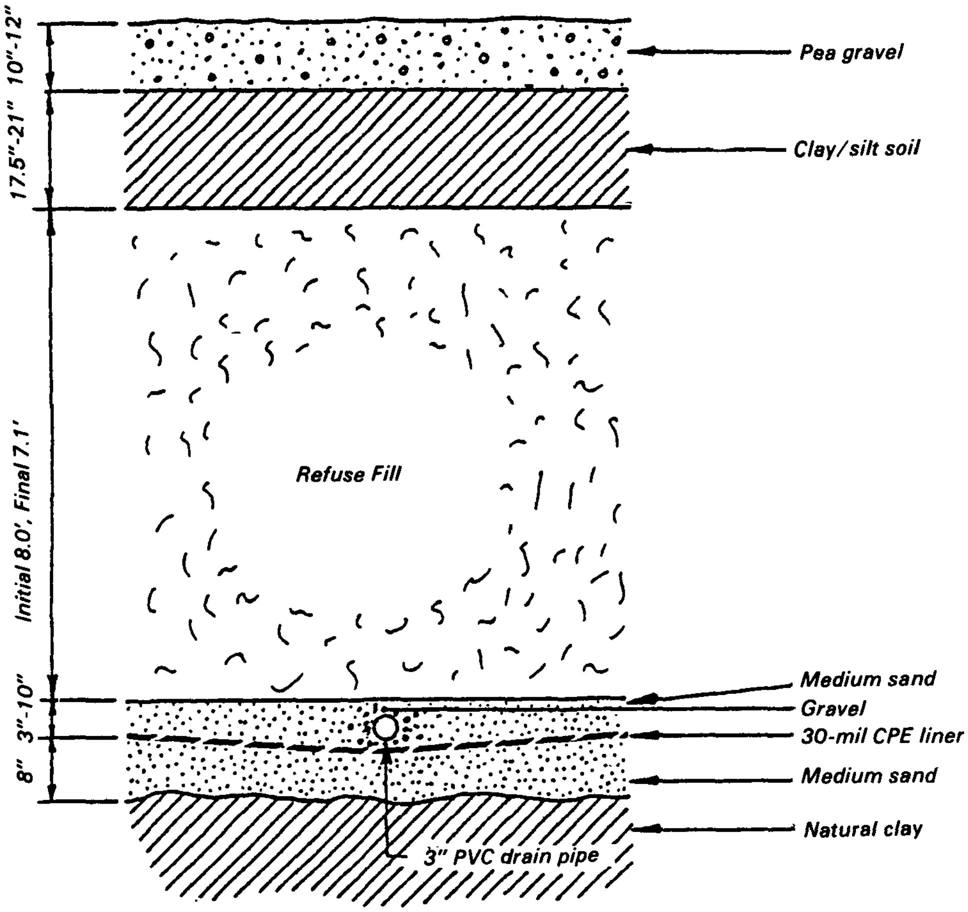

Figure 2. *Test cell construction details for TC-2D.*

An investigation of the subsoils in TC-2D revealed that the CPE liner was under an upward hydrostatic pressure from fluids in the underlying sand. Analyses showed, however, that the fluid did not contain leachate. The sand immediately below the CPE liner was a light tan except for a 1.3- to 1.9-cm (½ to ¾-in.) gray zone at the point of contact with the liner. The thick, natural clay section below the sand was a mottled gray-green in the upper 2.5 to 5.1 cm (1 to 2 in.). The remainder was a natural orange-tan.

Conclusions

All liners provided effective containment of leachate, even after considerable length of service and exposure. Though the polymeric liners experienced swelling and absorption of leachate, their physical properties remained relatively unaffected. Weathering of polymers caused stiffening and loss of plasticizer, suggesting that a protective soil cover is important for such liners. The clay liner experienced some leakage, but this problem was apparently the result of accidental puncture during test cell construction.

Investigations like this one are vital to determining whether or not liners are preventing damage to the environment. Most liners are installed with the assumption that they will function as protective barriers indefinitely. Such is not always the case, however, and actual sampling of such liners would establish their integrity, especially after the liner has been in contact with the leachate for some time.

Detecting liner failure and its causes is hampered greatly by the lack of records and data on site preparation, liner installation procedures, protection of completed liners, and landfill operations. Availability of such data is critical to predicting the containment capabilities of waste disposal sites.

Recommendations

1. Standards for testing liner materials should be established to determine longevity under various conditions and to guide the selection of liner materials.
2. Regulatory agencies should be encouraged to prepare guidance documents incorporating minimum design and construction standards and specifications for liner installation at various types of disposal facilities.
3. Surveillance, inspection, or certification procedures should be introduced to attest to correct liner selection and installation.
4. A more extensive liner testing and sampling data bank should be developed to ensure that the information is available both to regulatory agencies and to site designers, owners, and operators.
5. Site owners should be provided with assurances of anonymity and protection from certain legal liabilities in return for participation in investigations of this nature. Such assurances might require that financial support be given to site owners to correct problems discovered during sampling. The cost of insurance protection should be incorporated directly as a project cost.

The full report was submitted in fulfillment of Contract No. 68-03-2824 by EMCON Associates under the sponsorship of the U.S. Environmental Protection Agency.

This Project Summary was prepared by staff of EMCON Associates, San Jose, CA 95112.
***Robert Landreth** is the EPA Project Officer (see below).*
The complete report, entitled "Field Verification of Liners from Sanitary Landfills," (Order No. PB 83-217 810; Cost: $8.50, 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:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U. S. GOVERNMENT PRINTING OFFICE: 1983/659-095/0722

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300

RETURN POSTAGE GUARANTEED

[redacted]

PS 0000329
U S ENVIR PROTECTION AGENCY
REGION 5 LIBRARY
230 S DEARBORN STREET
CHICAGO IL 60604