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Use of Liner Materials for Land Disposal Facilities

EPA is charged by Congress to protect the Nation's land, air, and water systems. Under a mandate of national environmental laws focussed on air and water quality, solid waste management and the control of toxic substances, pesticides, noise and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

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USE OF LINER MATERIALS FOR LAND DISPOSAL FACILITIES

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The U.S. Environmental Protection Agency currently administers eight environmental laws, one of which is the Resource Conservation and Recovery Act of 1976 (RCRA). Among the several major objectives of RCRA is the elimination of improper land disposal practices, i.e., those disposal practices and sites identified as environmentally unacceptable according to EPA's proposed criteria issued pursuant to the Act. The criteria cover all forms of disposal of wastes on landfilling, landspreading, and impoundment or lagooning and apply to residential and commercial as well as industrial wastes.

Under RCRA's mandate, EPA has undertaken the research and development of environmentally safe practices for disposal of industrial residues. Industrial residues can be disposed of in an environmentally safe manner with carefully selected and designed secured landfills. Properly designed secured landfills can prevent excessive seepage of potential pollutants into the surrounding soils by use of liner materials. Desirable properties of liner materials for surface impoundments should be (1) impermeable to wastes; (2) durable; (3) resistant to chemical, biological, and mechanical damage, weathering, and deterioration; (4) low in cost; and (5) easy to install. The disposal of residuals in landfills requires

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an understanding of these factors, since not all candidate liner materials have these desirable properties.

The Solid and Hazardous Waste Research Division of the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, has developed research projects designed to answer questions for the user community and develop documents which will aid in the understanding of surface impoundment design. These research projects have been developed to assimilate or expand on existing data and generate new data. This data base will be used to establish evaluation criteria and test protocol for liner materials. The overall objectives of these research projects are to determine the effects of waste leachate on the physical properties of liner materials, to develop a data base from which the potential life of the material can be predicted, and to develop economic data on the materials and associated construction costs.

LINER CANDIDATE MATERIALS

Those materials that can be listed as potential liner candidates include natural clay soils; admixed materials (e.g., soil cement and asphaltic compounds); polymeric membranes; and sprayed-on materials. Each of these broad liner classifications have advantages and disadvantages when used as containment material. They are, however, being used to contain a wide variety of residuals. The liner materials being researched, excluding clays, are listed in Table 1. Clay materials are being evaluated in soil attenuation projects.

TABLE I

LINER MATERIALS EXPOSED TO LEACHATE FROM HAZARDOUS WASTE

MUNICIPAL REFUSE	HAZARDOUS WASTE	FGC SLUDGES
Polymeric Membranes	Polymeric Membranes	Polymeric Membranes
Polyethylene (PE)	Butyl rubber	Polyvinyl chloride
Polyvinyl chloride (PVC)	Chlorinated polyethylene (CPE)	Polyethylene
Butyl rubber	Chlorosulfonated polyethylene (Hypalon)	
Chlorosulfonated polyethylene (Hypalon) nylon scrim reinforced	Ethylene propylene rubber (EPDM)	Admixed Materials
Ethylene propylene rubber (EPDM)	Neopreme	Soil cements
Chlorinated polyethylene (CPE)	Polyvinyl chloride (PVC)	Lime stabilized soils
	3110 (a PVC-type material by DuPont)	Asphalt cements
		Emulsion asphalts
		Chemically stabilized SO_x sludge
Admixed Materials	Admixed Materials	Sprayed-on Materials
Paving asphalt concrete	Bentonite clay seal	
Hydraulic asphalt concrete	Emulsified asphalt (Petromat)	DCA 1295
Soil cement	Soil cement	Uniroyal
Soil asphalt	Hydraulic asphalt concrete	Dynatech
Bituminous seal	Compacted fine-grained soil	Plastics
Emulsion asphalt on fabric	Polymeric bentonite sealant	Asphalts
	Acid-resident concrete	Hot sulfur
	Hot sulfur	

Natural Soils

The natural clay soils have been used to contain a variety of industrial wastes. Clay liner designs are usually based upon permeability and sorption. Permeabilities of clays range from 10^{-5} cm/sec to 10^{-8} cm/sec. In layers of several feet thick, clays could offer only minimal seepage rates for several hundred years. Industrial waste ponds have clay liner thicknesses in the 2-70 ft range. Obviously, where a toxic waste is being contained, a greater depth of clay would be required.

Adsorption and ion exchange are two principle mechanisms where clays act as passive barriers. While these two principles are different, they are difficult to distinguish because each results in uptake and both can occur simultaneously. The literature on these mechanisms is extensive.[1] Data on the sorption of industrial waste and municipal sanitary landfill leachate are being generated in a series of controlled laboratory studies.

One effort[2] is examining the factors that attenuate contaminants (limit contaminant transport) in leachate from municipal solid waste landfills. These contaminants are: arsenic, beryllium, cadmium, chromium, copper, cyanide, iron, mercury, lead, nickel, selenium, vanadium, and zinc. The general approach is to pass municipal leachate, as a leaching fluid, through columns of well-characterized, whole soils maintained in a saturated anaerobic state. The typical municipal refuse leachate is spiked with high concentrations of metal salts to achieve a nominal concentration of 100 mg/l. The most significant factors in contaminant removal are then inferred from correlation of observed migration rates and known soil and contaminant characteristics. This effort will contribute to the development of a computer simulation model for predicting trace element attenuation in soils. Modeling efforts to date have been hindered by the complexity of soil-leachate chemistry.

The second effort[3] in this area is studying the removal of contaminants from landfill leachates by soil clay minerals. Columns are packed with mixtures of quartz sand and nearly pure clay minerals. The leaching fluid consists of typical municipal refuse leachate without metal salt additives. The general approach to this effort is similar to that described in the preceding effort except that (a) both sterilized and unsterilized leachates are utilized to examine the effect of microbial activity on hydraulic conductivity and (b) extensive batch studies are conducted of the sorption of metals from leachate by clay minerals.

A third effort relates to organic contaminant attenuation by soil. This is our initial effort in organic contaminant movement in soil. Much more is known about inorganic contaminant movement in soil because the analytical techniques for inorganic materials are well developed and relatively cheap compared to the time-consuming analytical techniques for organic materials. The problem is compounded by the fact that organic contaminants are more numerous and more are being synthesized all the time. PCB is the organic contaminant currently being investigated. As a part of the above-described effort, a gas chromatographic analytical procedure was developed that allowed improved quantitative measurement of PCB's in aqueous solutions.

Admixed Materials

Admixed materials, such as soil cements and asphaltic concrete, have also been used to line containment ponds, but to a lesser degree. While these materials do have application for containment based upon permeability, the potential chemical interaction limits the type of residuals that can be contained. W. S. Stewart[4] reported that the advantages of asphalt materials are their availability, versatility in available physical forms, and use for large-scale waterproof construction. Pure asphalt has also been used in a membrane form. The major disadvantage to the asphalt membrane was the subgrade requirement, weathering, aging and erosion from turblent water, and damage from mechanical equipment. Stewart developed a matrix based upon the chemistry of the liner and the waste stream (Table 2). This table should only be used as a starting point. Actual exposure tests should follow to determine specific compatibility.

Asphalt linings, compacted properly, have permeabilities in the range of 10^{-7} cm/sec. The Asphalt Institute (College Park, Maryland) has conducted tests in their laboratory[5] showing that properly designed mixes can be essentially impermeable to water (k=o). The chemical resistance of asphaltic materials should be checked first, by immersion tests or other test procedures. Charts have been developed which illustrate resistance of asphalt. Strength of waste streams and temperature

TABLE 2

COMPATIBILITY[a] OF LINER MATERIALS WITH VARIOUS INDUSTRIAL WASTES[b]

Name of liner	Short name	Vulcan-ized	Caustic petroleum sludge	Acidic steel pickling waste	Electro-plating sludge	Toxic pesticide formulation waste	Oil refinery sludge	Toxic pharma-ceutical waste	Waste water from rubber and plastics industry
POLYMERIC MEMBRANES									
Butyl rubber	IIR	Yes	Yes	Yes	Yes	?	No	?	?
Chlorinated polyethylene	CPE	No	Yes	?	?	?	No	?	?
Chlorosulfonated polyethylene	CSM Hypalon	No	Yes	Yes	Yes	?	No	?	Yes
Elasticized polyolefin	3110	No	?	?	Yes	Yes	?	Yes	Yes
Etnylene propylene rubber	EPDM	Yes	Yes	Yes	Yes	?	No	?	Yes
Neoprene rubber	CR	Yes	Yes	?	?	?	?	?	Yes
Polyethylene	PE	No	Yes	?	Yes	Yes	Yes	Yes	Yes
Polypropylene	PP	No	Yes	?	Yes	Yes	Yes	Yes	Yes
Polyvinyl chloride	PVC	No	?	?	?	Yes	Yes	Yes	Yes
ADMIX MATERIALS									
Asphalt concrete - hydraulic	HAC	-	Yes	No	No	?	No	?	?
Asphalt membrane	-	-	?	?	?	?	No	?	?
Soil asphalt	-	-	?	No	No	?	No	?	No
Soil cement	-	-	Yes	No	?	?	Yes	?	Yes
Compacted clay	-	-	No	No	No	?	Yes	?	Yes
Treated bentonite	-	-	No	No	No	?	Yes	?	Yes

[a]Chemical compatibility of lining materials with various industrial wastes. Indicates the potential suitability of a given type of lining material for confining types of wastes. For a given type of lining material compositions vary considerably as do the composition and concentration of the waste and environmental conditions under which they would be confined.

"Yes" = Lining material is probably suitable for confining a wide range of wastes of the type indicated, using a wide range of formulations.

"?" = Questionable. Suitability depends on the specific waste and the specific liner material. Immersion tests should be run.

"No" = The lining material would not or probably not be suitable for confining the type of waste shown.

[b]See reference 4.

may have an effect on the lining and deserves further laboratory testing before selection. In those admixes where stone/gravel are used, the chemical resistance of the stone/gravel should also be determined. Dissolution of the stone/gravel will seriously affect the integrity of the liner and could cause direct channeling through the liner.

Flexible Membrane Liners

Flexible membrane liners are becoming increasingly popular for containment devices. Their relative ease of installation and the chemical resistance to a wider variety of chemicals lend themselves to increased use by industry. EPA research efforts are underway where a range of generic type materials and thicknesses are being exposed to selected industrial wastes.

Two projects have been previously reported.[6] Data from the first year's exposure of municipal landfill leachate on flexible membranes and admixed materials resulted in relatively little change to the liners.[7] There was no apparent increase in permeability in any of the liner materials. There were losses in compressive strength of the admixed materials and in physical properties of some of the polymeric membranes and swelling of most membranes.

Due to the relative small change in the first year, the exposure time has been increased to a total exposure time of 56 months (July 1979). In addition to the longer exposure time, additional subtasks have been added to increase the overall data base.

A series of swelling tests[8] at room termperature and at 70°C indicate that membranes of neoprenes, chlorosulforated polyethylene, and chlorinated polyethylene continually swell in water, whereas the polyethylene, polybutylene, polyester, and elasticized polyolefin reach a plateau in the swell, as did polyvinyl chloride. In the permeability tests there was some indication that permeability increases with time, probably due to the swelling of the membranes by water. Since permeability tests take a long period of time, due to the extremely low coefficient of permeability, data are still being collected. Also, with the increased attention of landfill gas migrating away from the land disposal sites, gas permeability data are being collected. Data will be complete and reported on in a final report, scheduled for October 1979.

The second project was recently updated,[9] and a complete report is due in late 1978. The results of the study must still be considered preliminary at this point in the exposing testing, but it is quite apparent that some of the hazardous wastes can seriously affect the physical properties of the lining materials. The waste streams are being completely characterized to determine individual components which may be aggressive toward linings. Generally, organic constituents tend to have solvent effects upon the organic polymeric membranes and asphaltic materials. The effect will depend upon the specific component, strength, and liner material.

Spray-On Materials

A third effort[10] relates to the types of materials being tested for use as liners for sites receiving sludges generated by the removal of sulfur oxides (SO_x) from flue gases of coal-burning power plants. The volumes of SO_x sludge generated in any particular place will, typically, be much greater than those for other types of wastes, and therefore the disposal sites will be large. Consequently, methods of lining such disposal sites must have a low unit cost. It is desirable that the materials be easy to apply or install. Because of these considerations, the number of polymeric membranes included in the study have been reduced, whereas admixed and sprayed-on materials are being emphasized. A total of 18 materials are being tested, with two types of Flue Gas Desulfurization (FGD) sludges. The sludges are from an eastern coal-, line-, and limestone-scrubbed process.

CONSTRUCTION

The construction of a lined solid waste disposal facility requires the close attention of the field engineer. The best specification can be negated if the installation of the liner system is improperly monitored in the field. Three distinct phases of construction are necessary to complete the proper installation of a liner. Each phase requires attention if a successful containment is to be built. These three phases are discussed separately.

Subgrade Preparation

The liner, which is a relatively thin barrier, must rest on a firm, smooth foundation. Ideally, the subgrade would consist of 1 to 2 feet of compacted coarse-grained material, such as sand. The maximum grain size of the material is somewhat dependent upon the liner material to be used. If recompacted or imported clay is used or if the in-situ soil is to be amended by the addition of cement or montmorillonite, a larger grain size in the subgrade can be tolerated because the barrier will be thicker than polymeric membranes or asphaltic compositions. There are no specific recommendations for maximum grain size, but it would seem logical that a clay liner that is 12 to 18 inches thick could easily tolerate stones as large as 1 inch in diameter in the subgrade. Polymeric membranes should have a maximum grain size smaller than this, and specifications have been written which call for 100 percent of the subgrade to pass a no. 4 sieve.

In all cases, the subgrade should be free of roots, branches, and other similiar materials which could puncture the liner. Also, organic material can degrade and give off methane and other gases which could be trapped under the liner and could eventually rupture the barrier.

The subgrade should be smooth. The thin liner materials should not be required to bridge over tire tracks and other depressions. The subgrade can be rolled or dragged to achieve an acceptable subgrade texture.

The subgrade can be susceptible to differential settlement if not properly compacted. Obviously, the field inspection should include soil tests to ensure optimum compaction of the subgrade.

Liner Installation

Most liner materials require a unique installation technique. The exception is the polymeric materials which use essentially the same installation procedures. The following is a brief discussion of how to install paving asphalt, hot-sprayed asphalt, asphalt emulsion sprayed on polypropylene fabric, polymeric membranes, montmorillonite, and soil-cement liners. Standard specifications for the liner materials are available and give more detail on the proper installation procedures.

Paving asphalt is placed by a conventional paving machine. If a sealer coat is specified, it can be applied using a truck equipped with a spray bar or by using a hand-held sprayer. Since the integrity of this type of liner can be damaged by weeds growing through it, the use of a soil sterilant on the subgrade to prevent plant growth may be required.

Hot-sprayed asphalt membranes are constructed using a spray bar. The completed membrane will consist of 1 1/2 to 2 gallons of sprayed asphalt per square yard and can range in thickness from 1/4 to 3/4 of an inch. Three or four passes of the spray bar are used to build up this membrane. If fewer passes are used (higher application rate per pass), there is a tendency for bubbles to form. Leaks will develop when these bubbles rupture. Joints are formed by overlapping. The specified overlap varies from 1 to 12 inches.

There is a three-stage construction process for the asphalt emulsion sprayed on polypropylene fabric. First the fabric is spread on the ground. The fabric is in sheets 15 feet by 300 feet which are sewed together. A mixture of water, a wetting agent, asbestos, and an asphalt emulsion is then sprayed in two coats. The first coat is applied at a rate of 1 gallon per square yard. When this coat dries, the evaporation of the water causes pinholes to develop in the membrane. A second coat of the mixture is sprayed at a rate of 0.4 to 0.5 gallons per square yard. The final membrane is approximately 100 mils thick (one mil equals 0.001 inch). The manufacturer does not recommend placing this membrane when the temperature is below 40 degrees F.

Plastic and rubber membranes are delivered to the site in large sheets. These membranes range in thickness from 10 to over 60 mils. Typically, these sheets will have many factory splices in the material. In order to make the liner watertight, a number of field splices are required.

Anchoring the edges of plastic and rubber membranes is accomplished by burying the edge in a shallow trench.

The construction of a sanitary landfill liner using montmorillonite as an admixture to the native soil is accomplished using conventional farm and earth-moving equipment. Spreading the grayishwhite granular material can be accomplished with a fertilizer, pesticide, or manure spreader. Typical application rates range from 10 to 20 pounds per square yard. Some experimentation may be required to determine the proper setting to use for a particular spreader. After the material is spread, three to four passes with a disk are required to mix the montmorillonite to the appropriate depth, usually 6 inches. Flat steel-wheeled rollers or rubber-tired rollers are recommended for compaction. The use of sheepsfoot rollers are not recommended by the manufacturers because these devices tend to force the montmorillonite deeper into the subgrade than 6 inches. The material is not an effective liner if it is placed deeper than the design depth.

Soil-cement is a mixture of pulverized soil and measured amounts of portland cement and water, compacted to high density. Since no full-size sanitary landfill liner has been built using this material, no special construction techniques have been developed. In general, soil-cement pavements are built using the following steps:

(1) spread portland cement and mix, (2) apply water and mix, (3) compact the mixture, (4) perform final grading for drainage, and (5) cure the mixture. Depending upon the soil type encountered, cement is added at a rate of 3 to 20 percent of the weight of the soil. Spreading and mixing devices have been designed specifically for soil-cement pavement construction, but conventional earth-moving equipment can be used.

Liner Protection

No liner material should be used as a pavement. While some of these materials can easily support rubber-tired construction equipment, high-wheel loading could rupture some membranes. Equipment with crawler treads should not be allowed to operate directly on the liner. Manufacturers recommend protecting the liner with an earth cover 1 or 2 feet thick. This material should not contain jagged rocks or other sharp objects that could damage the liner. Similarly, the first lift of solid waste placed in the fill site should not contain items such as bulky wastes, pipe, or white goods that could puncture the liner during the filling operation. Such quality control is difficult to achieve, considering the heterogeneous nature of solid waste delivered in compactor trucks.

The above construction information is very general. In an attempt to be more specific about the actual placement of liner materials, a study is being undertaken to assess the best procedures and practices used by the liner industry. The study will encompass the site preparation and liner placement for a variety of clay, admixed, and polymeric liner materials.

Field Verification

Field verification studies for determining liner material performance require a substantial input of research dollars and time in order to obtain a long-term data base. The ideal field verification study would include 20 liner materials, 20 waste streams, exposure periods up to 5 years, and be located in four different geographic locations. Since studies like this are not feasible, based on a limited budget and time constraints, an alternative study has been selected.

A recently completed study[11] identified disposal sites where liner materials were installed. The survey obtained information relating to waste type, waste depth, waste age, type of liner material, owner, installer, and other pertinent information on the disposal site. Potential methods of liner recovery and the associated costs were discussed.

Although these data are still being evaluated, an approach is being developed where three to five selected lined sites will be investigated during the next year. Based upon the results of this effort and the interpretation of the data, additional sites may be sampled.

Liner Listing-NSF

In an attempt to alleviate the problem of continually reviewing material and performance specifications from several different companies for the same generic type polymeric material, the National Sanitation Foundation (NSF) has initiated an effort which will lead to a recognized listing of flexible membrane liner materials. The

NSF has gathered together representatives of Federal and State governments, industry, manufacturers, users, and the private community. The purpose[12] of the listing will be to:

> "*Establish the necessary performance requirements* for flexible membrane liners and covers for use in the retention and containment of substances so as to maintain and protect the environment. The flexible membrane liners covered under this standard are intended to retain waters and contain pollutants or chemicals".

The materials to be incorporated into this listing are thermoplastics, thermoplastic elastomers, and elastomers. Data are currently being reviewed by the advisory committees.

REGULATIONS

The U.S. Environmental Protection Agency, under authority of the Resource Conservation and Recovery Act of 1976 (Public Law 94-580), is developing recommendations, criteria, and regulations for the utilization of liner materials. These recommendations, criteria, and regulations are currently in various stages of review by industry, the private sector, and other government agencies.

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