THE USE OF GEOSYNTHETIC MATERIALS IN THE DESIGN OF LINED WASTE CONTAINMENT FACILITIES

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ABSTRACT

The paper examines how geosynthetic materials are incorporated into the design of lined waste containment facilities in order to protect valuable groundwater from pollution by the uncontrolled movement of leachate and liquid waste away from the containment area.

Waste containment facilities have progressed from being unregulated unlined excavations in the ground to systems which use a substantial amount of state-of-the-art technology in their design.

The interplay between design and functional requirements is examined given the current scenario of legislative options and trends when different waste types and volumes are considered for disposal.

A method for the construction of a verifiable leak detection system is also discussed.

INTRODUCTION

In the past landfill liners consisted primarily of recompacted clay barrier systems with typical permeabilities achievable in the laboratory of less than 1×10^{-7} cm/s but with the advent of the double ringed infiltrometer and other field testing devices, investigations indicate that actual field permeabilities are much greater than those reported in the laboratory. This does not compare well with flexible geomembrane linings such as High Density Polyethylene (HDPE) which has a consistent molecular structure and crystallinity resulting in guaranteed permeability ratings of the order of 3×10^{-13} cm/s.

As a consequence, solid waste landfills have progressed from being unregulated, unlined, excavations in the ground to sophisticated synthetic liner systems that incorporate the use of composite liners, drainage materials and soil reinforcing grids.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA)

The Environmental Protection Agency (EPA) does not believe that a compacted clay soil liner (min. 90cm) can ordinarily be constructed to meet by itself the requirement of no effluent migration during the active life and post-closure monitoring period for a surface impoundment. (Normally 30 to 50 years) (Ref. 4)

The EPA also believes that flexible geomembrane linings are the only effective means of preventing migration of chemicals for the same operating and post-closure periods. (Ref 4)

Oils or plasticizers are extractable materials which tend to leach out, causing stiffening and brittleness of the flexible membrane lining. This extraction process occurs in the presence of common household solvents. The embrittlement can then result in cracking of the liner e.g. PVC, EPDM. Also, plasticizers are known to be eaten or gnawed by rodents. HDPE on the other hand contains no plasticizers which can leach out and provides no nutrition for rodents.

It is now recognised that the most suitable synthetic material for use in conjunction with leachate producing landfills and toxic and hazardous waste landfills is HDPE. When designing the landfill, the engineer should consider the following physical and mechanical properties such as;

tensile strength
elongation
chemical resistance
dimensional stability
absorption
seaming
ultra violet resistance.

In the USA the ASTM Method 9090 - is recognised for waste/liner compatibility testing. The liner is immersed in the chemical solution for 120 days at ambient temperature (23°C +/- 2°C) and at elevated temperatures of (50°C +/- 2°C). Comparison of measurements of the membranes physical properties is taken periodically before and after contact with the waste fluid and is used to estimate the compatibility of the liner with the waste over time.

THE PRIMARY IMPORTANCE OF PERMEABILITY TESTING

A classification of the physical types of hazardous waste indicates that many contain organic fluids. Furthermore, the organic fluids in these wastes may, in the presence of overburden or hydraulic pressure gradients, permeate the liner of a disposal facility. Leachates generated by the organic fluids in hazardous wastes to fall into four major categories: acidic, basic, neutral polar, and neutral nonpolar organic fluids.

Permeability remains the primary criterion for evaluating the suitability of clay liners for the lining of hazardous and municipal waste disposal facilities. Permeability of clay liners has in the past been determined by using a standard aqueous leachate such as 0.01N $CaSO_4$. Since clay liners may be exposed to organic fluids, a testing procedure was developed to compare the effects of a standard leachate and organic fluids on the permeability of clay liners.

Evaluation of clay soils used in the construction liners shows that the predominant clay minerals in these so are smectite (montmorillonite), illite, and kaolinite. Four native clay soils that contain these clay minerals we selected for evaluation of the comparative permeability test methods. (Ref. 2)

All four of the clay soils used in this study, when evaluated by the traditional permeability test using wa ($0.01N\ CaSO_4$), would qualify for lining hazardous waste disposal facilities on the basis of their havi permeabilitites lower than 1×10^{-7} cm/sec. However, these same clay coils underwent large permeabil increases when permeated by basic, neutral polar, and neutral nonpolar organic fluids and showed the potenti for substantial permeability increases when exposed to concentrated organic acids.

MOLECULAR DIFFUSION

Chemicals can pass through soil liners by molecular diffusion, as well as by advective transport.

Calculations (Ref. 5) show that after 10 to 30 years, molecular diffusion begins to transport the first molecu of waste 90cm downwards through a compacted soil liner. Accordingly, even with a perfectly impermeable s liner with zero hydraulic conductivity, in 1 to 3 decades contaminants will begin to migrate through the soil lin due to molecular diffusion.

Investigations of existing sites indicated that clay liner systems were severely affected by the type of fluids th they came in contact with. With the advent of sub-title D (EPA) it has been determined that municipal landfi liner systems will consist of both compacted clays and synthetic geomembranes used in conjunction with on another.

EPA REGULATIONS PERTAINING TO MUNICIPAL SOLID WASTE LANDFILLS AND HAZARDOUS WASTE IMPOUNDMENTS

In October 1991, the Environmental Protection Agency issued new regulations for the design of landfills unde Subtitle D of the Resource Conservation and Recovery Act (RCRA). Under these regulations, most new landfi sites and lateral expansions of existing sites will be built with a composite liner and leachate collection system The composite liner must consist of both a geomembrane liner and a clay liner. The flexible membrane liner, as the upper component, must be at least 0,75mm thick, and the compacted clay, as bottom component, mus be at least 60cm thick and restrict permeability to 1×10^{-7} cm/sec.

On the other hand many hazardous materials fall into the category of special provision requiring the use of double-liner systems of geomembranes.

These special standards require two liners underlying the unit and a leak detection system between the two liners. The two liners must be constructed in such a way which prevents the migration of liquids into or out of the space between the liners.

The EPA specifies that, when using HDPE as the liner membrane, in hazardous waste impoundments it must be a minimum of 1,5mm thick.

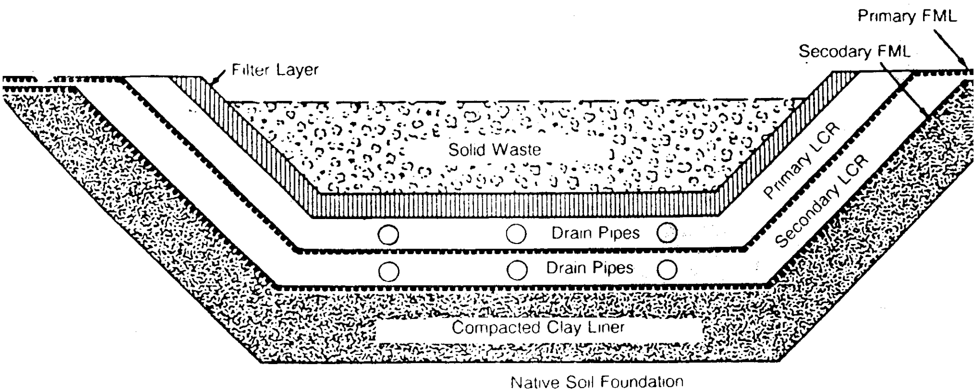


FIG. 1 - SYNTHETIC/COMPOSITE DOUBLE LINER SYSTEM

COMPARISON OF THE PROPOSED LEGISLATION IN SOUTH AFRICA

In South Africa, the waste stream is controlled by the Environment Conservation Act 73 (ECA) of 1982 as amended in 1989 and 1992.

This act stipulates i.a. that "no person shall establish, provide or operate any disposal site without a permit issued by the Minister of Water Affairs and Forestry".. It further states that any site which develops leachate or has the potential for damaging the environment should be lined.

At the time of writing the Department of Water Affairs and Forestry is in the process of producing minimum requirement documents for waste disposal facilities, which will include requirements for disposal site linings.

LEGISLATIVE TRENDS

In October 1989 the Department of Environmental Affairs commissioned a CSIR study to examine Hazardous Waste in South Africa.

The legislative options mentioned in Vol. IV of the report are summarised below :

1. **Classification and Hazard Rating**
   Inform industry on what waste types it intends to control.

2. **Polluter Pays Liability - Waste Avoidance**
   To directly or indirectly encourage and ultimately force waste producers to decrease the volume and effect of the waste they produce on the environment.

3. **Cradle to Grave Control**
   To control the waste from generation to disposal to prevent the uncontrolled dumping of waste in environmentally sensitive areas.

4. **Technological Standards**
   To establish a level of uniformity on the technological side of the waste industry.

5. **Registration and Permits**
   To ensure the ultimate safe disposal of waste none of which can be omitted from a successful waste strategy.

The ultimate aim of a properly integrated waste management strategy is the elimination of waste by means of a combination of avoidance, reduction and recycling policies and this can be achieved by :

* Permits issued in accordance with the ECA Act No. 73 of 1989 as amended March 1992.

* The Department of Water Affairs and Forestry regulations for minimum requirements for the permitting, operation and closure of general and hazardous waste landfills.

As the minimum requirement documents have not yet been issued in South Africa, waste operators and consultants can only follow the guidelines as set out above and use the regulations as implemented in say, USA or Europe as benchmarks for the design of their waste sites.

DESIGN PHILOSOPHY

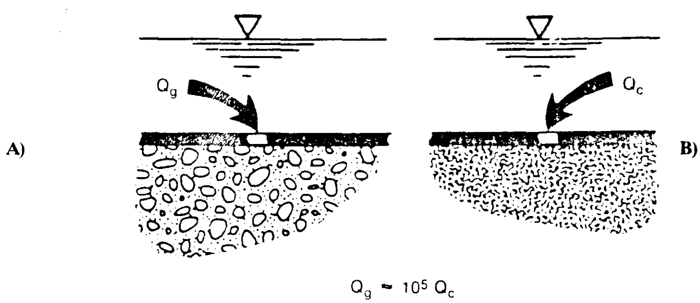
The following design philosophy will provide some useful pointers to the consultant when tackling a design for a lined wastefill site.

DRAINAGE LAYERS

In the early design of landfills, these drainage layers consisted of gravel and coarse sand. Since the availability of these materials in some locations is limited the drainage performance is inadequate, and valuable volume is taken up by the aggregate layer. Geosynthetic drainage media are effective equivalents in terms of drainage performance and consume less volume when compared with natural materials.

The theory behind the use of these drainage systems is to prevent the build-up of any leachate within the landfill, to remove liquid head and to monitor liner performance.

Under Subtitle D regulations, leachate collection/liner systems must be built to maintain less than 30cm (head) of leachate over the liner.



A) LINER/NATURAL SOIL B) LINER/COMPACTED CLAY

FIG. 2 - ADVANTAGE OF A COMPOSITE LINER (Q = PERMEABILITY)

GEONETS FOR LEACHATE DRAINAGE

According to ASTM D4716, a Darcy's law test for flow in porous media, transmissivities in a geosynthetic drainage layer may be measured for a given hydraulic gradient. Depending on conditions, flow rates can be two orders of magnitude higher than a 300mm thickness of sand by using a 20mm layer of geonet.

The philosophy as per reference 18 July 26th 1982 of the EPA is that for an HDPE synthetic membrane lining (composite or double lining). The leachate collection and removal system installed above the HDPE liner can achieve virtually a 100% removal efficiency. In contrast, if a clay liner is used some leachate will seep into the clay liner rather than be removed by the drainage layer. This leachate will remain in the soil after closure and will likely migrate in to the ground water at some future time by the process of molecular diffusion.

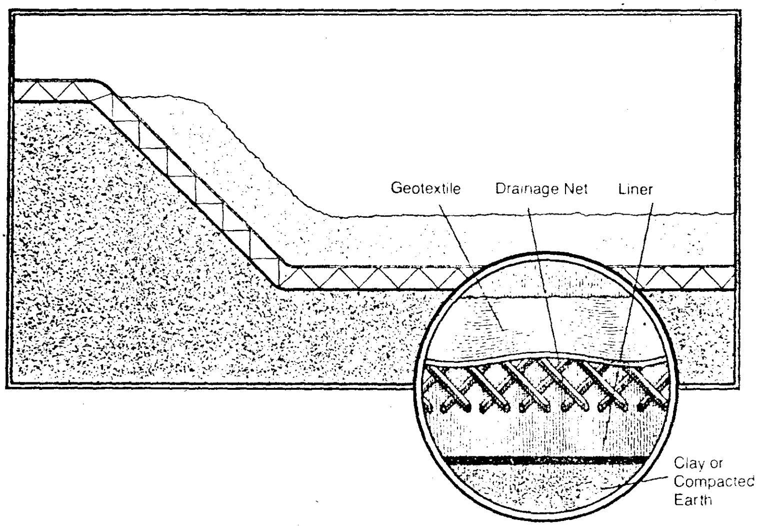


FIG. 3 TYPICAL HDPE COMPOSITE LINER COMPLETE WITH GEONET AND GEOTEXTILE

GEOFABRICS

The Geofabric materials used in landfill operations are generally of non-woven spunbonded polyester or polypropylene. Geofabrics act to cushion loads and prevent puncturing during construction and throughout the design life of the structure. It increases the frictional co-efficient between a liner and cover soils when used in conjunction with a textured surface liner on steepened slopes.

	FRICTION ANGLE (DEGREES)	
SLIDING SURFACE	PLAIN HDPE	TEXTURED HDPE
HDPE/H.R. Clay	16	24
HDPE/Ottawa Sand	17	26
HDPE/Geotextile (Non-Woven)	11	29

GEOGRIDS

These are primarily intended as earth reinforcement. Placed in soil, they interact with soil particles through friction, confinement and bearing to increase the load bearing capacity of the soil.

Very often a landfill site will overlay a region of poor quality foundation soils, having low bearing capacities. The height to which waste may be placed is severely reduced over such areas. However, alternating layers of soil and geogrids provides a reinforced foundation for the support of waste and allows for increased waste storage. Existing waste storage facilities inevitably and often rapidly approach their design capacities. Employing the use of geogrids allows for the vertical expansion of existing or closed facilities by the process of "Piggy Backing". By this method the geogrid provides the structural foundation for the expansion, and provides support against the unpredictable collapse and differential settlements within the existing waste cell below.

GEOSYNTHETICS IN FINAL COVERS

Geosynthetic materials are also used in landfill capping systems. According to Subtitle D rules, regulation cover caps must be designed to minimize water infiltration and cap erosion. The infiltration layer must be a minimum of 45cm thick, and have permeabilities no greater than 1 x 10^{-5} cm/sec. The cover must also be able to support vegetation.

Cover caps consist of three layers-Barrier, Drainage, and Protective. The barrier layer, which prevents water infiltration, usually comprises of a geomembrane liner such as HDPE or VLDPE, no less than 0,5mm thick, laid on top of the compacted supporting subgrade or alternatively a Gas Collecting layer.

Drainage material, placed on top of the barrier layer, is either gravel or synthetic geonet that transports water that has percolated through the protective and vegetation layers.

The protective layer is often a layer of soil, 60cm to 90cm deep, that protects the drainage and barrier layers from damage. A geotextile material can be used to supplement or replace soil in this protective layer.

THE SABS 1526-1991 GEOMEMBRANE QUALITY MARK

Once a specifier has chosen an HDPE liner membrane whose thickness is in keeping with either USA or European standards, does he then accept that a candidate liner complies with the requirements of SABS 1526-1991 or should he insist that the product actually carries the mark?

When a product complies with the requirements of SABS 1526-1991' all that the specifier is sure of is that a sample of the product submitted to the SABS met the requirements of the specification. (Which is no guarantee that what is laid on site will do so.)

When the product is authorised to carry the mark, the specifier is assured that all liners authorised to carry the mark are produced in a factory which is subject to random checking by the SABS to ensure that the product being manufactured does in fact at all times comply with the requirements of the specification.

Unless a specifier has firm reason to implicitly trust the company offering a product, his specification should simply require that all candidate products be authorised to carry the mark.

The only alternative to this is that every roll to be used is actually tested by the SABS for compliance. As the SABS weathering test has a duration of eight months this is hardly practical.

SABS 1526 consists of a material specification which lays down **minimum** standard such as tensile strength; puncture and tear resistance and retention of physical qualities after ageing, for polyolefin geomembranes.

It is however, not sufficient to specify that the geomembrane to be used must carry the SABS mark. The best liners available, if incorrectly installed, will probably fail in a short time. Accordingly a very important part of the SABS document is the appendices, which does not form part of the product specification.

AGGRESSIVE FLUIDS

Waste products that are aggressive in nature (acid, alkaline, corrosive, toxic, radioactive or have a high COD) should be neutralised or immobilised at source to avoid the possibility of containment leakage that can result in environmental pollution problems.

This ideal solution is not always practical and can be prohibitively expensive. It is thus the norm that such effluents are held in containment structures, prior to further treatment or for permanent containment.

VERIFIABLE LEAK DETECTION SYSTEM

Many engineers in search of liners that can be guaranteed not to leak have adopted the use of multiple liners with intermediate leakage detection layers e.g. Mossgas Waste Storage Facilities.

Conventional multiple liner systems provide a passive leak detection system, dependent upon the establishment of a hydrostatic head of leaking fluid within the leak detection media for flow of such leakage to a sump.

Evidence of leak in the leachate collection system provides a positive indication of a leak in the upper liner.

Absence of leack in the leachate collection system is however, not a guarantee that no leaks exist, only that the rate of entry through the upper liner must be equal to or less than the rate of loss through the lower liner.

The partial vacuum of the verifiable leak detection system establishes an inward hydraulic gradient through both geomembranes. The inward flow of air, or fluid causes vacuum pressure loss and/or liquid accumulated within the cell and indicates the presence of leaks. This can be monitored by measuring the vacuum pressure and volume of fluid colled.

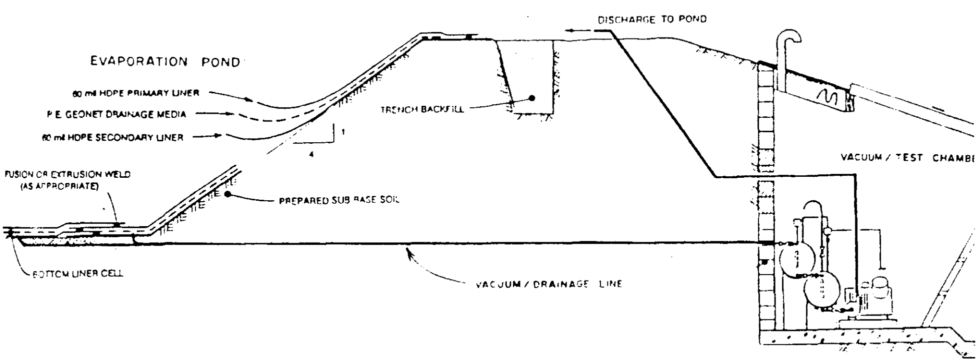


FIG. 4 - SCHEMATIC OF A TYPICAL VERIFIABLE LEAK DETECTED SYSTEM

Prior to contained fluid passing through any holes in the upper or lower membrane liners, any potential leaks will pass air which is immediately detected as a loss of vacuum. it is therefore possible to detect potential leak locations prior to filling of the impoundment with liquid or leachate.

CONCLUSION

A landfill site if correctly designed and managed should have minimal impact on the environment whether for visual, odour or groundwater pollution reasons.

HDPE, although one of the most recently developed geomembrane of those commercially available today, has because of its inherent high degree of crystallinity, natural flexibility and attendant excellent chemical resistance characteristics attained worldwide recognition as the most suitable material for the lining of Solid Municipal and Hazardous Waste sites.

'urther, due to the high degree of control which is achievable in the factory, constant quality is always uaranteed when geosynthetic materials are used to replace natural materials for lined waste facilities. This rovides the site owner with peace of mind in the knowledge that he has been proactive in the war against nvironmental pollution.

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