Geosynthetics Asia'97, 26–29 November, Bangalore, India

THE USE OF GEOSYNTHETIC MATERIALS FOR WASTE CONTAINMENT

A.M. Scuero

CARPI Italia, Via Monte Bianco 5, 28041 Arona, Italy

ABSTRACT

The containment of solid and liquid waste materials represents one of the greatest societal problems that currently exists. It is very clear that improper disposal and/or improper containment of waste products represents a major threat to the world's groundwater and surface water suppliers. Fortunately, geosynthetics of every type play a key role in providing for safe and secure containment of such waste materials. Geomembranes, as the primary barrier, are augmented by various drainage materials such as geonets, geocomposites and geopipe. These in turn utilize geotextiles as protection, separators, gas drains and (along with geogrids) reinforcement materials. Geosynthetic clay liners are used to replace blankets of natural clays.

The paper reviews the use of the most common geosynthetic materials for waste containment and adresses some selected concerns about their use.

INTRODUCTION

While engineers, scientists and environmental have long cautioned against the dangers of ground water pollution caused by contaminated waste products, it is only recently that the political and public sectors have taken note and begun to act.

To be sure, the lay press has greatly emphasized the urgency of the situation to the point where the "environment" is as explosive of an issue as is national defense, budgetary items or other major political and societal topics. Thus it should come as no surprise that goverments of several industrialized countries have promulgated rules and regulations in this area in the form of "minimum technology guidance" that include geosynthetic materials. Indeed the very beginnings of the wide spread use of geomembranes for solid and liquid liners began in 1982 with the following statement contained in the United States Federal Register (U.S. EPA 1984):

"*Prevention (via geomembranes) , rather than minimization (via clay liners), of leachate migration similarly produces better environmental results in the case of surface impoundments used to dispose of hazardous wastes. A liner that prevents rather than minimizes leachate migration provides added assurance that environmental contamination will not occur*".

WASTE LANDFILL LINERS: TYPICAL DESIGNS

Bottom - Solid waste materials that are subsequently landfilled are subdivided into non hazardous and hazardous categories by virtue of chemical characteristics of the site-specific leachate. Leachate is the liquid contained in the waste and the subsequent rainfall and snowmelt that flows through it. Obviously, the leachate takes on the characteristics of the solid waste and is therefore always waste-specific, i.e. there is no typical leachate. The site-specific leachate is analyzed by conventional analytical techniques (usually TCLP sampling, then mass spectroscopy, and gas chromatography analysis) and if all of the listed priority pollutants (800+ in the USA, +600 in Italy) are less than stipulated official limits, the waste mass is considered non hazardous. In such a case, the most frequent design allows for:

- A leachate collection system should be located above the liner system
- The leachate collection system should be capable of maintaining a leachate head of less than 30 cm
- The liner system should be a *single composite liner* (i.e. it is not require to have a double liner system which leak detection capability as it is with hazardous waste materials)
- The single composite liner must be a geomembrane placed over a compacted clay liner
- The geomembrane, in case it is HDPE, must be 1,50 mm (USA) to 2,50 mm (Italy, Germany, etc.)
- The geomembrane must have "direct and uniform contact with the underlying compacted soil component". Furthermore, the term *intimate contact* is referenced in many regulations
- The compacted clay liner beneath the geomembrane must be 60 cm thick and of a permeability of 1×10^{-7} cm/s or less. (Note that permeability will be used in this chapter rather than the more accurate term of hydraulic conductivity)

If any one of the listed priority pollutants exceeds the stipulated official limits, the solid waste is considered hazardous. The most frequent design used for disposal of such a waste is shown in the cross section of Figure 1:

- The leachate collection system should be capable of maintaining a leachate head of less than 30 cm
- A *double liner system* which leak detection capability between them is to be located directly beneath the leachate collection system.
- A leak detection system should be located between the two liners.
- Both leachate collection and leak detection systems should have at least 30 cm granular layers that are chemically resistant to the waste and leachate, with a permeability not less than 1×10^{-2} cm/s, or an equivalent synthetic drainage material, e.g. , a geonet or geocomposite.
- The minimum bottom slope of the facility should be 0,5 %.
- The leachate collection system should have a granular filter or synthetic geotextile above the drainage layer to prevent clogging.
- Both collection systems, when made of natural soils, should have a network of interconnected perforated pipes to remove the leachate; the pipes should have sufficient strength and chemical resistance to perform under anticipated landfill loads.
- The geomembranes, if it is HDPE, must be 1,50 mm to 2,50 mm, according to the country regulations.
- The compacted clay liner beneath the secondary geomembrane must be 60 cm thick and of a permeability of 1×10^{-7} cm/s), or less.

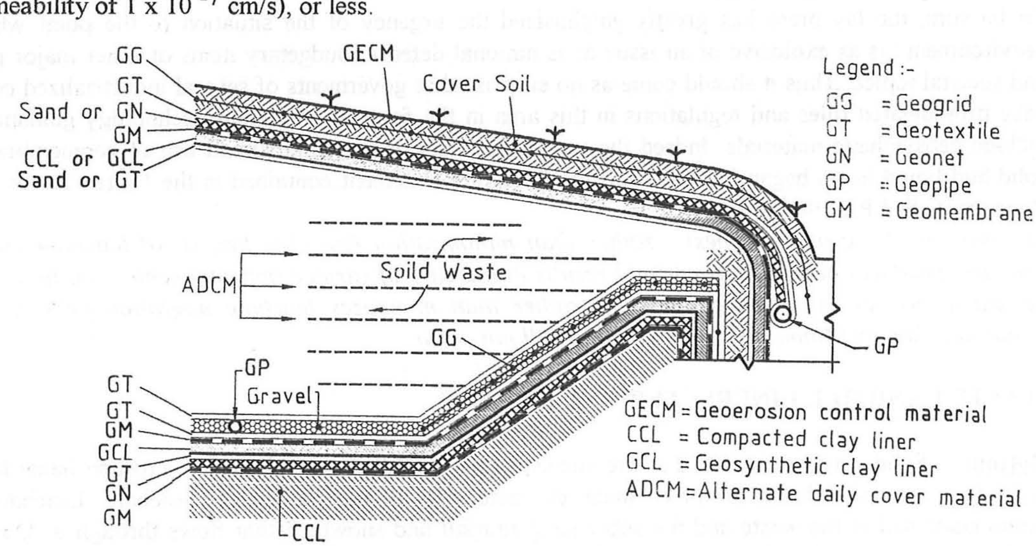

Figure 1: Various Components used in Double Liner Waste Containment System

Covers - Covers of waste landfill must perform one or several functions in additions to keeping water out of the contaminated material. They also raise ground surface elevations where necessary, minimize and control precipitation runoff and prevent out-migration of perched leachate. They separate the waste from plants and animals, discourage intrusion, intentional or accidental, and control gas release. The cover, or closure, of a landfill is critically important since its performance must be assured over an extremely long lifetime. Lifetimes well beyond the 30 years post closure care period are often considered. Within the cover system are the following elements which must be evaluated and designed according to site specific and waste specific considerations.

- vegetative cover and top soil
- cover soil
- surface water drainage system (unless arid climate)
- composite barrier system (geomembrane with clay liner or geomembrane with geosynthetic clay liner)
- gas venting layer (required for municipal solid waste)
- final compacted cover soil over the solid waste mass

Barrier Walls - The cut-off and/or containment of laterally flowing liquids from landfills and impoundment reservoirs generally utilize some type of vertical wall. The most common wall is constructed using a slurry supported trench, subsequently backfilled with soil-bentonite, soil-cement, cement-bentonite or soil-cement-bentonite. Concerns have arisen as to the installation, inspection and durability of such walls. A different, or complementary strategy uses a geomembrane by itself or in combination with any one of the standard backfill materials to provide the degree of completeness and environmental safety/security that most, if not all of these sites warrant.

Barrier walls containing a geomembrane can be useful in any application where the flow of water or other liquids is to be controlled. The use of a geomembrane in the wall is a way to ensure continuity of an extremely low permeability material. In the light of the numerous concerns found in conventional solutions, it is clear that barrier walls that include geomembranes provide an added factor of safety for almost any construction application.
The walls are generally installed by placing individual panels that are connected together. There are several different interlocking connections available and there are different ways to seal the connection. The geomembranes used for the panels have almost always been HDPE.

There are a variety of different applications where these walls have been proposed or used. Figure 2 shows a typical hazardous waste containment application. The barrier wall is installed at a depth that is either well below the plume of waste or keyed into the aquitard. The wall can also be welded to a cap geomembrane by overlapping either the wall or the cap. This type of sealed system can be monitored and can include a leachate collection system.
This solution (vertical barrier and capping) is frequently used to create a watertight barrier around an existing unlined landfill, when the flow of the watertable can disperse the leachate in the soil downstream.

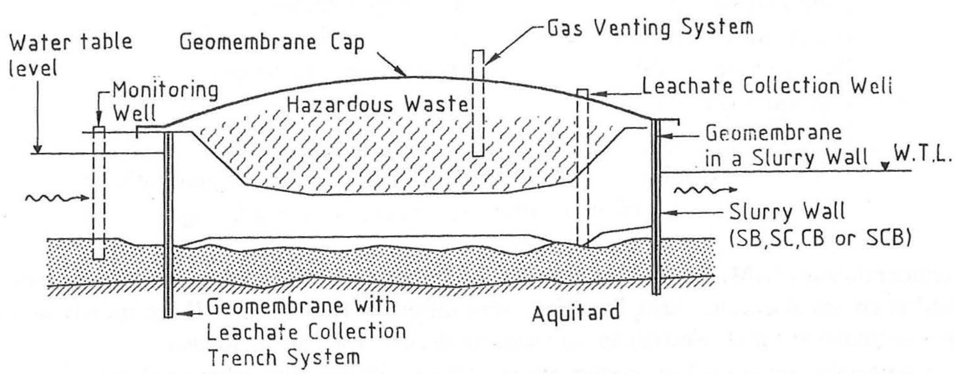

Figure 2: Confinment of Contaminated Soil. Geomembrane Vertical Wall System with Closure Cap (after GSE,1995)

GEOSYNTHETIC MATERIALS

Considering both the liner and cover systems shown in Figures 1, the geosynthetic alternatives to natural materials are as follows:

- geomembrane and geosynthetic clay liner versus clay soil
- geonet versus drainage gravel
- geocomposite versus drainage gravel
- geotextile versus filter sand
- geopipe versus concrete pipe

There is a large and ever growing body of technical information on geosynthetics; for example, see Koerner[2]. For geosynthetics used in the liner of a solid waste landifll, the most important types are described as follows:

- Geomembranes (GM) are very low permeability, polymeric membrane liners or barriers used to contain the generated leachate and to control fluid migration.
- Geotextiles (GT) are planar, permeable, polymeric materials comprised solely of textiles used for filtration, drainage, separation, or reinforcement.
- Geosynthetic clay liners (GCL) are factory-manufactured hydraulic barriers consisting of a layer of bentonite clay or other very low permeability material supported by geotextiles and/or geomembranes, being mechanically held together by adhesives, needling, or stitching.
- Geonets (GN) are net-like sets of interconnected polymer ribs used for the transmission of liquids in the plane of the structure.
- Geogrids (GG) are grid-like sets of interconnected polymer ribs used for reinforcement of soils or solid waste.
- Geopipes (GP) are polymeric pipes used to convey the leachate

Layer	Location	Geosynthetic	Primary Function
1	above waste	GT	Filtration (surface water)
2	above waste	GC	Drainage (surface water)
3	above waste	GM	Barrier (surface water entering; landfill gases leaving)
4		GT	Drainage (landfill gases)
5	below waste	GT	Filtration (leachate)
6	below waste	GN	Drainage on side slopes (leachate)
7	below waste	GT	Filtration for perforated pipes (leachate)
8	below waste	GT	Separation (protection)
9	below waste	GM	Barrier (leachate)
10	below waste	GT	Filtration and separation (leachate)
11	below waste	GN	Drainage (leachate)
12	below waste	GM	Barrier (leachate)
13	below waste	GTR	Separation (protection)
14	beyond waste	GG	Reinforcement

Table 1. - Use and primary funtion of various geosynthetic materials in the cross section shown in Fig. 1

Geomembranes (GM) - The geomembranes used for liners beneath the waste versus those geomembranes used in covers above the waste have four very different requirements. These greatly influence the overall geomembrane material selection and subsequent design. They are as follows:

- Geomembranes in the liner system are in contact with leachate, whereas those in the covers are only in contact with percolating water from rain and snow melt.

- Geomembranes in the liner system are under considerably higher compressive stresses that are those in covers.
- Geomembranes in the liner system should be subjected to large deformations of the subgrade , whereas geomembranes in covers generally undergo large subsidence of the underlying waste.
- Geomembranes in the liner system can only be removed at enormous expense of removing the waste whereas those in the covers are more accessible for maintenance and possible remediation.

As suggested above, the geomembranes of the line system beneath the waste must be chemical resistant to the leachate generated at the site. If aggressive leachates or an unknown synergism of chemical species is possible, an incubation and test protocol such as the EPA 9090 Method (U.S. EPA 1985), is necessary to select the proper polymer. Subsequent to the polymer material's selection, a number of index strength tests (on both the sheet and the seamed material) and several performance strength tests are necessary.
In this latter category, wide width tensile, friction and anchorage tests are usually necessary. To determinate the limit of hydraulic barrier that the geomembrane affords, water vapor transmission tests are sometimes required. More significant, however, would be solvent vapor transmission tests depending on the nature of the leachate. Numerous other tests such as soil burial, stress crack resistance for semi-crystalline polymers, plasticizer leaching, dimensional changes, ply adhesion of reinforced geommebranes, etc..., are required on a site specific basis and on a material specific basis. Geomembranes are usually made form HDPE (most frequently) and PVC.

For the geomembrane located above the waste, chemical resistance is usually not a major factor. Strength tests will include index tests and wide width rests addition to axisymmetric strength, via three dimensional out-of-plane loading. The latter test should be performed on both the sheet material and on the seamed material. Obviously geomembrane seam tests shear and peel will be required. Lastly, it may be necessary to evaluate the vapor transmission of the geomembrane which would generally be methane vapor transmission above the waste. Geomembranes are usually made from PVC (most frequently), LLDPE and PP.

Geotextiles (GT) - Geotextiles in waste containment are called on to serve as leachate and water filters, protection (as a separator) and as drains (for landfill gases) Depending upon their location in the facility numerous tests are required. For geotextiles placed beneath the waste, chemical resistance tests via a simulated immersion procedure must be performed. Various index strength tests are required as well as wide width strength and friction tests between the various interfaces involved. When the geotextiles serves as a filter, permittivity, opening size and clogging evaluations are necessary. In this latter case, both particulate and biological clogging should be considered. The geotextiles above the waste will require similar testing as just mentioned with the exception of the chemical resistance requirement and with the addition of methane transmissivity in the case of a geotextile used as a gas drainage layer. Geoetxtiles are usually made from PP, PP and PE.

Geonets (GN) - Clearly, a granular soil (sand or gravel) can be used for leak detection double liner systems, however, current practice generally utilizes a geonet. As shown in Figure 3, the reasons are as follows:
savings in air space, no perforated pipe system is necessary, the danger of damage to underlying geosynthetics is avoided, stability on side slopes can be achieved and construction is rapid and straightforward.
Geonets which are used as leak detection or primary leachate collection layers obviously must have adequate chemical resistance against the leachate that they transmit. Strengthwise, the compressive behavior against rib collapse or "lay-down" must be evaluated. Since long time frames are involved, compression creep is also a consideration. Most important, however, is the evaluation of the transmissivity or in-plane flow behavior under the site specific compressive stress and hydraulic gradient. Its evaluation should use the simulated cross-section of materials above and below the geonet. In this manner, intrusion of the overlying and underlying materials can be properly evaluated. If geonet joining is required, the seam strength must be assured. Furthermore, the manner of seaming must not restrict the in-plane flow

capabilities of the geonet. Friction testing of all interfaces must be performed. Geonets are usually made from HDPE or PP.

Geopipes (GP) - Perforated plastics pipes made from PVC or HDPE are commonly used as leachate collection systems. The interconnected system leads directly into down-gradient sump for removal and proper treatment of the leachate. Chemical resistance must be assured as well adequate compressive strength. As with other components beneath the waste, creep deformation must be kept within tolerable limits. Since the pipes are usually laid in a network pattern, numerous fittings and joints are required. These are important details and must be evaluated with the utmost care.

Geocomposites (GC) - Geocomposite drains used as surface water collectors above the waste require the same tests as the geonets below the waste, but generally do not require chemical resistance evaluation. Additionally, the compressive strenght requirements of these geocomposite drains are not as severe as they are for geonets placed beneath the waste. Frictional characteristics must be evaluated particularly when the closure side slopes become long and steep.

Geogrids (GG) - When used within the enclosed boundaries of the waste facility, as with vertical or horizontal extensions of an existing landfill, chemical resistance of geogrids must be assured. Strenght tests should include rib, junction and wide width tests of a short term nature, as well as creep strenght tests. Friction and anchorage tests are also necessary to perform. If connections are involved, the proposed joint method should be evaluated in tension, for both short and long-term (creep) behavior.
Geogrids outside of the waste enclosure (for example, for stabilization of ramps, berms and side slopes) require the same tests as just mentioned with the exception of chemical resistance. Also geogrid joint tests may be avoided since the geogrids are usually configurated so as to avoid connections. In addition, geogrid creep behavior is generally not critical, since stability problems are usually minimized after the waste is deposited and passive pressure is mobilized.

Geosynthetic clay liners (GCL) - They consist of factory-manufactured dry bentonite clay liners sandwiched between geotextiles or attached to a geomembrane. They can be constructed with lightweight equipment, minimizing the risk of damage to underlying components, and can easily be placed on side slopes. Also, the initially dry GLS does not yield consolidation water upon loading, unlike compacted clay liners. Consolidation water flows into the underlying drainage layer and is generally misinterpreted as liner leakage.

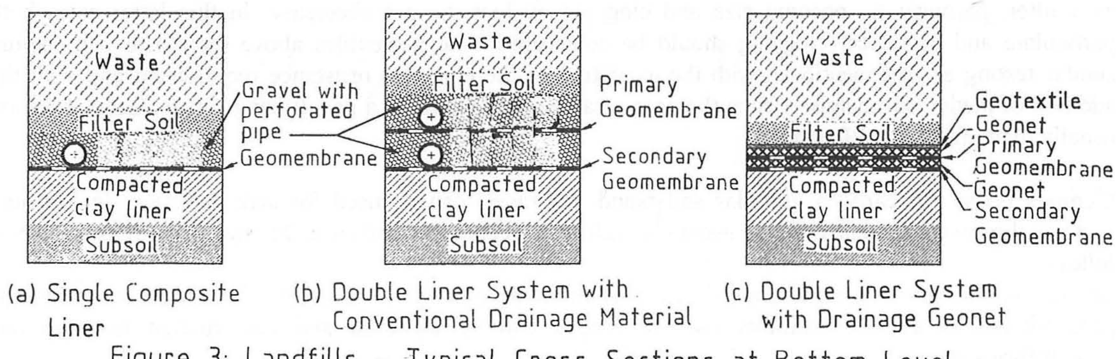

Figure 3: Landfills - Typical Cross Sections at Bottom Level

SOME SELECTED GEOSYNTHETIC CONCERNS

Clearly, the containment of our solid (and liquid) waste facilities is greatly dependent on the proper and long-term functioning of geosynthetic materials made from polymers.
With geosynthetic materias being used in applications having only a relatively short history of past experiences, many concerns are voiced and should certainly be adressed. This section presents some selected and more common concerns regarding geosynthetics used for waste containment applications.

Chemical Resistance - Whenever a polymeric material interfaces with leachate or other aggressive liquid, the chemical resistance of the resin or compound must be challenged. The heterogeneity of the leachate at any given time and the possible variations over the lifetime of the facility suggested the development of standards for uniform incubation and testing procedure for all types of geosynthetics. The most common is the U.S. EPA Method 9090 (1985).

Geosynthetic Seams - Clearly, the industry's ability to manufacture high quality rolls of geosynthetic materials in a factory setting far outstrips contractor's ability to seam the roll ends and edges together in the field. All seaming methods are based on heat sources softening or melting the geosynthetics to be welded together. Many destructive and nondestructive geomembrane seam testing methods are available.

Clogging of Filter and Drains - Among the various possible strategies that could be considered in light of geotextile filter clogging by particulates and bacteria in landfill leachates, today the most prudent approach seems to be a design which allows for some degree of access and continuos manteinance via backflushing through the system.

Long-Term Degradation - Geosynthetics are quite difficult to place, but their durability in a buried environment is far longer than ever suspected. When properly placed and seamed, the degradation of any geosynthetic material must come from molecular chain scission of the polymeric resin itself or bond breaking and reactions with the compounding material. Accelerated ageing tests at elevated temperatures are required. They were pioneered by the plastic pipe industry and cable shielding industry on high density polyethylene. Even exhumation of geosynthetics from old facilities have been conducted to better understand the potential problem. In these days, there are many geomembranes in excess of 30 years of successfull service. Sophisticated laboratory tests allow to predict a service life for the most common resins (and for the geosynthetic materials made of them) in excess of 100 years.

CONCLUSIONS

Use of geosynthetic materials for waste containment offers a vast potential. The quality of the products and of their installation must be verified at all times through a strict Quality Assurance and a Quality Control Plan. Only products from reputable, experienced manufactures shall be used. Installation plays a key role for the future correct performance of the facility therefore only contractors with previous experience in this business, with long records of successfull installations completed and with knowledgeable crews shall be used.

REFERENCES

- Landreth, R.E. (1997), Cover Systems for Waste Management Facilities in Municipal Solid Wastes: Problems and Solutions, Landreth, R.E. and Rebers, P.A., Eds., CRC Press, Boca Raton, FL.
- Koerner, R. M. (1994), Designing with Geosynthetics, 3rd Ed., Prentice-Hall Publ. Co., Englewood Cliffs, NJ.
- Daniel, D.E. (1987), Earthen Liners for Land Disposal Facilities, Proceedings Geotechnical Practice for Waste Disposal, Univ. of Michigan, ASCE, 21-39
- Daniel, D.E. and Koerner, R.M. (1997). Construction Quality Assurance/Quality Control for Landfills, in Municipal Solid Wastes: Problems and Solutions, Landreth, R.E. and Rebers, P.A. Eds., CRC Press, Boca Raton, Fl.
- Daniel, D.E. and Koerner, RM. (1993a), Cover Systems, in Geotechnical Practice for Waste Disposal, Daniel D.E., Ed., Chapman and Hall, New York, pp. 455-496.
- Daniel, D.E. and Koerner, R.M. (1993b), Quality Assurance and Quality Control for Waste Containment Facilities, U.S. Environmental Protection Agency, EPA/600/R-93/182
- Scuero, A.M., Nuzzo, G. and Salvemini A. (1990), "A continuos Barrier from Bottom to Crown in Hydraulic Earthfield Structures", Proc. 4th IGS Conference of Geosynthetics, den Hoedt, Ed., Balkema, pp 425-429