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**The Use of Geosynthetics in the Disposal and Treatment  
of Solid Waste.**

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# The Use of Geosynthetics in the Disposal and Treatment of Solid Waste.

**Matthew Eberle and Greg Farrell, Geofabrics Australasia Pty, Ltd.**

## *ABSTRACT:*

*Geosynthetic materials have gained broad acceptance in the greater engineering community in Australia by providing alternative construction materials for infrastructure (eg road construction), geotechnical works (retaining structures and foundations), coastal works (sand/rock armour filtration and erosion protection) and water-wastewater projects (liquids containment, filtration). The properties of Geosynthetic materials that make them cost effective alternatives in these applications can also be put to good effect in landfill practices. Some of the common uses in solid waste disposal for geosynthetics include; low leakage rate barriers for landfill base liners, filters and drains in leachate collection systems, reinforcement of cover soils on landfill caps, low infiltration landfill caps, groundwater / seepage interception drains around waste cells, reed bed lining for leachate polishing, and erosion control of rehabilitated landfill sites. Geosynthetics allow landfill space to be maximised in volume by steepening the cell slopes and reducing the thickness of hydraulic and leachate control layers. Many geosynthetics are now made from a high percentage of recycled materials (eg recycled PET and HDPE) so the use of virgin quarry gravels and clay resources can be minimised. Case histories from a number of Queensland projects highlighting the use of Geosynthetics in landfill construction are presented.*

## **1.0 The Anatomy of a Modern Landfill**

Modern landfills have progressed from the humble local “tip” or “dump” of years gone by. These past methods of ‘garbage’ disposal have given the practice of depositing non-recyclable solid wastes into an engineered waste cell a bad reputation. Today, landfilling philosophies have been developed to accommodate different climates, environments, geological and hydrogeological conditions, and energy recovery/re-use objectives. Often the design and implementation of these philosophies incorporates a high level of engineering, although it is sound engineering that will ensure that there is no significant impact from the facility on nearby use, and the (potential) contaminating lifespan of the waste body will be minimised where possible.

### *1.1 LANDFILL DESIGN PHILOSOPHIES*

The anatomy of modern landfill cells underwent major changes in the U.S. during the 1980’s with the introduction regulations that distinguished between hazardous and nonhazardous waste. These changes were in response a number of environmental incidents and growing concerns for public safety. Landfill operators in the U.S. now had a 30 year (post closure) liability to consider, and this often influenced the philosophy adopted in the engineering of the cell. Many landfills incorporated geosynthetics into the barrier and leachate collection systems to conform to the new regulations, and attention was not only focused on the stability and containment of the waste, but also to leachate management, and one of the goals was to create a dry, densely-packed waste “Tomb” such that leachate was not generated, and if it was, the mounding height above the lining system would be minimised - limiting the hydraulic head and potential advective flows of leachate out of the waste cell. Although this operational design or philosophy minimises the landfill operators risks during the 30 year (post closure) period, it does little to ensure minimise or reduce the potential contaminating lifespan of the facility. The waste may still be active in 30 or 1000 years, when the site is abandoned by the operators and leachate collection and monitoring is stopped, or some of the engineered systems start failing.

The waste in a “dry tomb” style cell (Figure 1) will not breakdown at the same rate as waste cells with higher infiltration rates, or with leachate recycling and injection, and is not as heavily compacted.

This leads to the concept of the “Bioreactor” – which is really nothing more than a well engineered landfill!

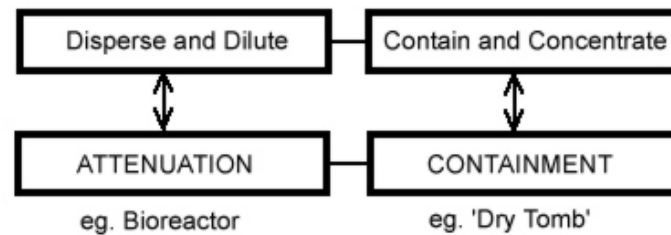


Figure 1: Landfill Design Philosophy.

The Bioreactor concept also includes energy recovery from the landfill gases that are generated, and the attenuation and accelerated breakdown of contaminants will enable operators to leave a site with a high level of confidence that the contaminating lifespan has been exceeded. The Bioreactor approach however creates a new set of challenges that must be overcome, and possibly new operations, including:-

- Greater handling of leachate, and additional leachate treatment operations – such as ammonia/nutrients removal.
- Greater volumes of (or earlier) gas generation that need to be managed and/or utilised
- Greater settlement of the waste body, due to the lighter compaction rates that are more conducive to gas generation/collection, and biodegradation - possibly requiring (an ultimately redundant) temporary cap.

A new range of landfill construction materials (in geosynthetics) have been developed (and in use) since the late 1970's to overcome the shortfalls of more traditional materials, such as compacted clay barriers, and granular soils for drainage (Figure 2). Some of the best available technologies used today are simply extensions to, or variations on widely used and accepted clay liner systems. One such technology is the Geosynthetic Clay Liner (or GCL), which combines a low permeability sodium bentonite clay, typically  $k \sim 1$  to  $5 \times 10^{-11}$  m/s, with geosynthetics for ease of placement and durability. Another advantage of using a GCL stems from the fact that it is essentially the same clay (or bentonite) used on every project. Historically the clay used to line a landfill cell was sourced locally, and the mineralogy and characteristics of the clayey barrier is never the same from one site to the next – often the clay used in the construction of any one cell at a single facility is not homogenous. Therefore, building up a knowledge database of the performance for a generic, project specific compacted clay liner (CCL) is both expensive and difficult and will not be at the same level as the knowledge available on the performance of a GCL.

## 2.0 Landfill Base Lining Systems

Landfill Base Lining Systems (Figure 2) are usually comprised of:-

1. *a leachate collection system* – commonly a blanket layer of single-sized aggregate with a grid of perforated HDPE collector pipes leading to a sump area. The leachate collection stone needs to be quite open (typically 16-32 mm grading) to avoid potential biological clogging. As a result of the open and porous structure of this layer, separation/filtration geotextiles are employed to prevent intrusion of waste and other solids into the stone (Figure 3), and to prevent the stone intrusion into the clay barrier. A thick, dense geotextile is often required to prevent damage to synthetic liners due to the aggregates angularity and hardness – comparative to the softness of some synthetic membrane liners. It is possible to source nonwoven geotextiles for separation, filtration, and puncture protection that are made from a high percentage of recycled material. For example, Bidim nonwoven geotextiles made by Geofabrics Australasia Pty Ltd contain approximately 85% recycled PET, and some of the

range of nonwoven geotextiles made by Soil Filters Australia Pty Ltd contain varying amounts of recycled PP and PET fibre.



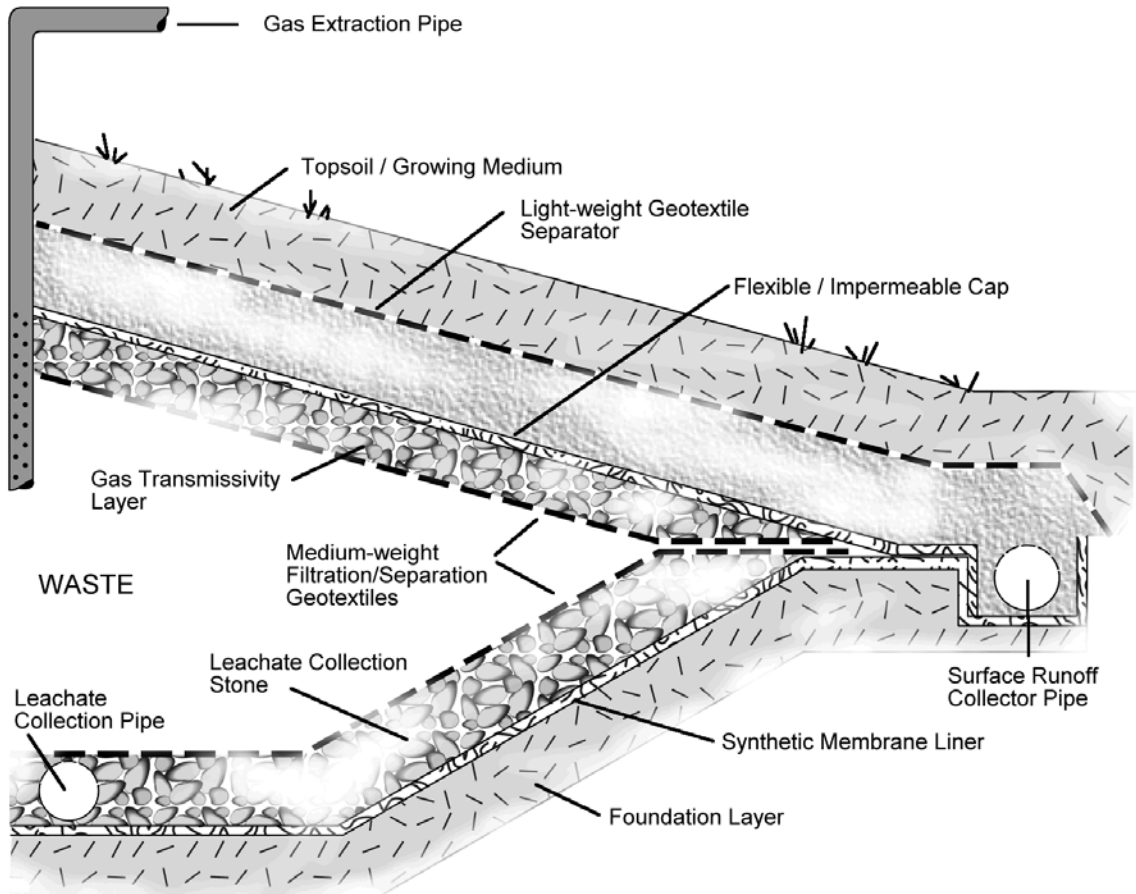


Figure 2: A typical general waste landfill cell construction.



Figure 3: Nonwoven geotextile filter/separator placement - between the leachate collection stone and the waste.

2. an impermeable barrier of compacted clay and/or geosynthetics - the selection of the impermeable barrier material will often depend on the regulatory requirements for the class of waste being contained. Theoretical leakage-rates for various barrier options were presented by

Giroud *et al* (1994). This comparison, shown in Table 1, illustrates the benefits to be gained by using low-permeability clay in direct contact with a geomembrane, where any holes or defects in the plastic membrane are effectively plugged by the clay component – especially if that clay has a swelling and self-sealing capacity, eg. sodium bentonite. Composite Liners, comprising a GCL and geomembrane (GM) in direct or “intimate” contact with each other, are often required to meet the barrier performance requirements for facilities to accept industrial and hazardous material. In terms of potential leakage rates, composite lining systems are considered as essentially “no-leak” systems.

Table 1. Leakage rate per unit area in litres per hectare per day (lphd) through various types of liners. (source: Giroud *et al*, 1994).

<b>Hydraulic Head (m)</b>	<b>~ 0.01</b>	<b>~ 0.3</b>
<b>Liner Type</b>	<b>Leakage Rate (lphd)</b>	
CCL, $k \sim 1 \times 10^{-8}$ m/s, $0.3 \text{ m} < \text{thickness (D)} < 0.9 \text{ m}$ .	9000	15000
CCL, $k \sim 1 \times 10^{-9}$ m/s	900	1500
GM, $k_{\text{soil}} \sim 1 \times 10^{-2}$ m/s	600	3000
GCL, $k \sim 1 \times 10^{-11}$ m/s, thickness (D) = 6mm	25	450
Composite Liner, GM/CCL, $k_{\text{CCL}} \sim 1 \times 10^{-9}$ m/s	0.05	1
Composite Liner, GM/GCL, $k_{\text{GCL}} \sim 1 \times 10^{-11}$ m/s	0.002	0.2

Although leakage rate is often used to benchmark lining systems, it is not the only performance indicator. Contaminant transport modelling and chemical compatibility testing (Eberle *et al*, 2000) can paint a more thorough picture, as the potential advective and diffusive flux for various contaminant species will vary depending on the characteristics of the barrier system used (eg. clay mineralogy or polymer chemistry). Rowe (1998) addresses the issue of equivalency and advective/diffusive transport through composite lining systems. Two composite barrier systems - one utilising a GM, thick CCL and sub-base attenuation layer, the other, a GM, thin GCL and attenuation layer - are shown to be equivalent in terms of contaminant transport of the species modelled, despite differences in the sorption or attenuation capacity of the primary clay component (CCL or GCL). This is due to the GCL-composite’s lower advective flux, combined with the in-situ soil’s inherent attenuation capacity. Thus, valuable landfill volume can be gained without loss of barrier system performance.

## 2.1 CASE HISTORY – BEDFORD St LANDFILL, TOOWOOMBA.

Toowoomba City Council has constructed new general waste cells at its Bedford Street facility in recent years. The landfill facility is situated to the north west of Toowoomba CBD. Toowoomba City Council constructed the base liner for the landfill cells using Bentofix® Geosynthetic Clay Liner in lieu of a 1.0m thick compacted clay liner. The floors of the waste cells utilised Bentofix® X1000 whilst Bentofix® X2000 was used in the walls.

The profile of the general waste cells were typically:-

- Floor slope - 2%
- Side slopes - 1V : 2H for vertical bund heights under 3m
- Side slopes - 1V : 3H for vertical bund heights over 3m

Prior to deployment, Toowoomba City Council employees were briefed by Geofabrics staff on aspects relating to the installation of the liner.

Bentofix® was placed directly upon the suitably prepared subgrade and the joints between rolls overlapped by 300mm. End overlaps were treated with bentonite paste. After laying Bentofix® on the cell floors, high crush strength Megaflo® drainage system was installed for the leachate collection, and the entire lining system was covered with a 300mm thick layer of selected soil to provide the confining pressure for the joints and spread any point loads from construction and waste placement.

Toowoomba City Council have installed approximately 66,000m<sup>2</sup> of Bentofix<sup>®</sup> as their primary base liner.



*Figure 4: GCL base liner being installed and covered.*

## 2.2 CASE HISTORY – SWANBANK LANDFILL, COMPOSITE LINER SYSTEM.

Thiess Environmental Services at Swanbank, near Ipswich, have constructed a number of cells of their general waste landfill. It serves as the landfill site for waste collections from the South East Corner of Queensland.

The existing clay available on site was generally of marginal quality with the permeability around  $1 \times 10^{-7}$  m/sec. EPA guidelines for these types of constructed landfills require 900mm of  $10^{-9}$  clay with a 1.5mm High Density Polyethylene geomembrane placed directly upon it. Because of the questionable quality of the clay, a Geosynthetic Clay Liner, Bentofix<sup>®</sup> X1000 has been utilized to provide the equivalency to the EPA requirements. The GCL has been placed directly upon the compacted clay with the 1.5mm HDPE geomembrane then placed directly upon the GCL. To complete the composite liner system a Bidim<sup>®</sup> geotextile is placed over the geomembrane to protect the thin plastic sheet from puncture damage from leachate collection stone, construction equipment, and waste.

In addition to providing the required permeability values, the Bentofix<sup>®</sup> GCL also protects the HDPE geomembrane from load induced puncture due to stones below. The GCL is very quickly installed without the constraints of moisture content and compaction control required with thick compacted clay liners.

The five cells constructed to date have ranged in size from approximately 25,000m<sup>2</sup> to 50,000m<sup>2</sup>.

## 3.0 Gas Emissions and Odour Control

Landfill cell gas emissions and odour control are now critical factors in siting considerations and gaining permits. As gas recovery and utilisation technology improves, landfill cap engineering will need to develop in tandem. GCLs offer many advantages over compacted clay in capping situations - such as greater strain tolerance, less potential for desiccation and cracking, and improved control of rainfall infiltration. Vangpaisal & Bouazza (2001) have extensively studied the performance of GCLs with nitrogen gas (a non-reactive gas), further improving predictability of performance (Figures 5 &

6). Note that the normal in-situ moisture content of a GCL in a capping barrier system will be in excess of 80% by weight, (Eberle & von Maubeuge, 1998).

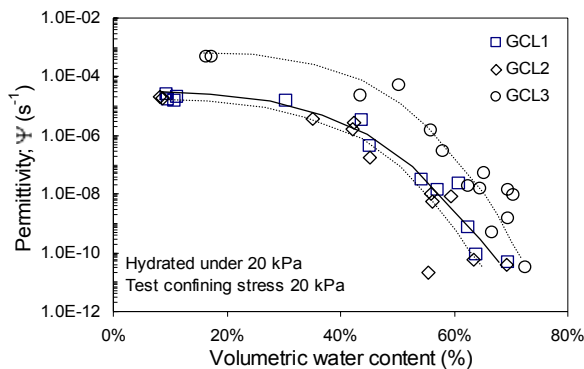


Figure 5: Variation of nitrogen gas permittivity with volumetric water content for confined hydration

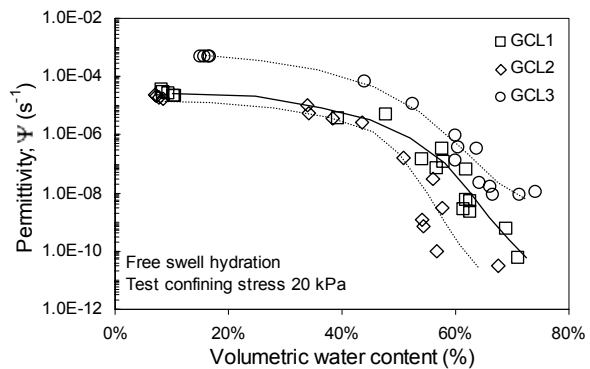


Figure 6: Variation of nitrogen gas permittivity with volumetric water content for free swell hydration

[Source: Vangpaisal & Bouazza (2001)]

### 3.1 CASE HISTORY – GORDONVALE LANDFILL CAP, CAIRNS.

Cairns Water, a business unit of Cairns City Council, were given the responsibility of controlling and managing all aspects of capping the Gordonvale landfill - approximately 20km south of Cairns. After consulting with landfill design specialists (Golder Associates) and reviewing the performance of the options available, they selected a Bentofix<sup>®</sup> Geosynthetic Clay Liner over a 400mm thick compacted clay liner (CCL). Along with the many advantages of using a GCL over a CCL included the recent successful installation of a Bentofix<sup>®</sup> GCL at Babinda Landfill nearby.

Bentofix<sup>®</sup> X2000 (a specialised capping grade of GCL) supplied by Geofabrics Australasia was used to cap the entire aerial extent of the landfill, with Geofabrics staff offering initial briefing and technical support to Cairns City Council employees who carried out the work in-house.

The GCL was laid directly onto a suitably prepared subgrade using an excavator and spreader bar supplied by Geofabrics. Rolls were run longitudinally from the base up the slope to the apex of the landfill. Adjacent roll had the standard 300mm overlap - no physical or mechanical joining is necessary. Transverse joints at the end of each roll also required a 300mm overlap, and were sealed with bentonite paste and protected from soil and foreign matter with geotextile cover strip (XROLL). Above the GCL barrier, a minimum of 400mm cover, a blended material comprised of approximately 50% shredded green waste and 50% sandy soil, was used as the confining cover soil layer.

The total project time required for complete installation of the 23,890m<sup>2</sup> of GCL was 6 weeks. Since the completion of capping works, Cairns Water staff have made comment on the significant reduction in leachate volume generated by rainfall infiltration into the waste body.



*Figures 7 and 8: Deployment of the Geosynthetic Clay Liner (GCL) cap, and sealing around a leachate collection manhole.*



*Figure 10: The finished Cap profile.*

#### **4.0 Conclusions**

The new philosophies and methods adopted at waste disposal facilities have seen purpose-made materials be employed to fulfil specific and multiple functions. These 'geosynthetic' materials provide a greater level of confidence that our waste facilities will not have a significant impact on current and future use of groundwater and natural resources adjacent to (or even at) the facility. Geosynthetic materials also offer the following advantages:-

- ease of use, and speed of deployment.
- a high level of manufacturing quality assurance – consistency and homogeneity.
- increase airspace in constructed cells.
- reduced requirement to quarry virgin gravels, clays and sands.
- reduced requirement to transport large volumes of gravels, clays and sands over urban, rural, or regional road systems.
- technically superior performance over many natural barrier and drainage materials when used alone.
- utilisation of recycled plastics that would otherwise occupy ‘dead’ space in a landfill cell.

#### ACKNOWLEDGEMENTS

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