The use of Geosynthetic Clay Liners (GCL's) in containment applications - an Australian perspective

P. Phillips and M. Eberle
Geofabrics Australasia Pty Ltd, Australia

Abstract: Geosynthetic Clay Liners are regularly used in Australia in solid and liquid waste containment applications. GCL's have been accepted worldwide as a component of what is considered a "best practice" primary lining system design - ie a composite geomembrane/GCL. The performance of composite liners and GCL's has been reported through the monitoring of many such installations. This paper highlights some of the field monitoring of these installations, and discusses the testing that has been performed on Geosynthetic Clay Liners on both a general containment application and a project-specific basis. The comprehensive nature of research and field performance assessment of these materials now facilitates better engineering of containment systems and lower risk of liability for landfill and mine-site operators. One such area of research showing GCL's are leading the way is in odour and greenhouse gas emission reduction - performance data is now available to prepare landfill owners to meet the new Kyoto-driven greenhouse gas emission restrictions and for Carbon Trading! This paper also highlights applications where GCL's are providing unique solutions and pushing the barriers (so to speak) of containment facility designs in a way that only GCL's currently can.

Keywords: Landfill barrier systems, GCL’s, odour control, gas emissions, leakage rates.

1. INTRODUCTION

Greater regulation of the disposal and municipal, industrial, and hazardous wastes have seen the need for better-engineered barrier systems. 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, which combines a low permeability bentonite clay, typically $k \sim 1$ to 5×10^{-11}, with geosynthetics for ease of placement and durability.

One of the primary advantages 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 won locally, and the mineralogy and characteristics of the clay used to line a containment cell is never the same from one site to the next – often the clay used in the construction of one cell at one 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, despite only a decade and a half of use in containment facilities.

The performance testing and monitoring of GCL’s have been extensive since introduction into waste management in the mid 1980’s. It is the intention to highlight how recent advances in performance knowledge have been used to prove barrier system conformance to regulatory standards, and construct barrier systems on challenging sites.

2. COMPOSITE BASE LINERS FOR CONTAINMENT CELLS

2.1 Theoretical Performance Assessment

Composite Liners are often required to meet the barrier performance requirements for facilities to accept industrial and hazardous material. In terms of potential leakage rates, composite liner systems comprising a GCL and GM (in direct/intimate contact) are considered essentially no-leak systems. 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 a low-permeability clay in direct contact with a geomembrane (GM), 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, such as sodium bentonite.

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

	Hydraulic Head (m)	
Liner Type	**~ 0.01**	**~ 0.3**
CCL, k ~ 1×10^{-8} m/s, 0.3 < thickness (D) < 0.9 m.	9000	15000
CCL, k ~ 1×10^{-9} m/s	900	1500
Geomembrane, k_{soil} ~ 1×10^{-2} m/s	600	3000
GCL, k ~ 1×10^{-11} m/s, thickness (D) = 6mm	25	450
Composite Liner, GM/CCL, k_{CCL} ~ 1×10^{-9} m/s	0.05	1
Composite Liner, GM/GCL, k_{GCL} ~ 1×10^{-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 (eg clay mineralogy or polymer chemistry) of the barrier system used. Rowe (1998) addresses the issue of equivalency and advective/diffusive transport through composite lining systems. Two composite barrier systems - one utilising a GM and a thick CCL, another a GM and thin GCL - 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.

2.2 Field Performance Assessment.

Daniel (1999) believes that GCL use will increase even further in the next 10 years because: (1) GCL's cost less than nearly all conventional CCL's, and (2) field performance data indicate that GCL's are outperforming CCL's. Table 2 shows data collected from a US-EPA sponsored study into liner system field performance.

Table 2. Summary of Preliminary Data on Leakage Rates through Primary Liner Systems during the Active Period of Waste Disposal (Daniel 1999)

Liner Type	**Number of Landfill Cells in the Data Base**	**Average Leakage Rate (lphd)**
Geomembrane	28	200
Geomembrane/CCL	11	90
Geomembrane/GCL	19	0.7

2.3.1.1.1 Case Study – Summerhill Landfill, Newcastle NSW.

The City of Newcastle produces over 200,000 tonnes of waste each year. Of this, about 50,000 tonnes comes from households. Newcastle City Council is responsible for the management of this waste safely, efficiently, and in a way that protects the environment now and for the future.

In March 1990 Newcastle City Council purchased the former Wallsend Colliery (known as Summer Hill). The mine had stopped operations leaving unsightly areas disturbed by open cut mine workings. A public inquiry into its development as a waste management facility resulted in the highest environmental safeguards achieved. The use of composite base (geosynthetic) liners composed of 2mm HDPE and non-woven needled punched GCL on top of 1 metre thick-compacted bridging layers was deemed to provide this safeguard. An added safeguard has been provided by the use of a flexible GCL capable of withstanding large biaxial strains (>30%) caused by settlements – from potential differential settlement resulting from underlying coal seams and the extra surcharge of the waste body.

Figure 1. GCL installation completed followed by HDPE.

Figure 2. Water tightness maintained after damage to HDPE in a composite liner.

Since the commissioning in 1995, numerous cells have been constructed using a composite base (geosynthetic) lining system. This system has the following benefits:

- GCL's provide an additional 0.9 m^3 per square metre of landfill plan area, replacing a thick CCL.
- The dual liner is in excess of a thousand times less permeable than the CCL alone (based on table 1).
- Desiccation and cracking of the compacted clay liner (CCL) after placement is avoided.
- The swelling and self-healing properties of the bentonite in the GCL seal any holes in the HDPE liner.

To-date up to 200,000 m^2 of GCL has been used at this landfill.

3. GCL'S FOR 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. GCL's 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 GCL's with various gases, further improving predictability of performance (Figures 3 & 4). The normal in-situ moisture content of a GCL in a capping barrier system will be in excess of 80% (by weight).

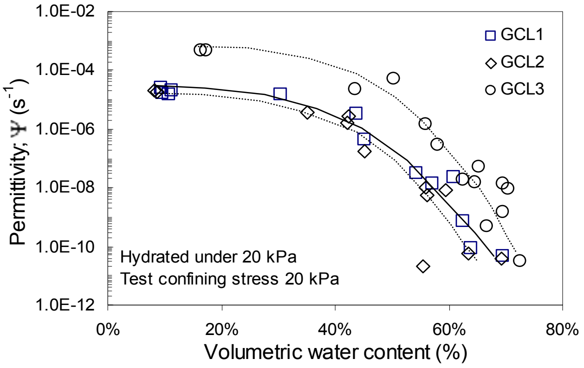

Figure 3: Variation of nitrogen gas permittivity with volumetric water content for confined hydration

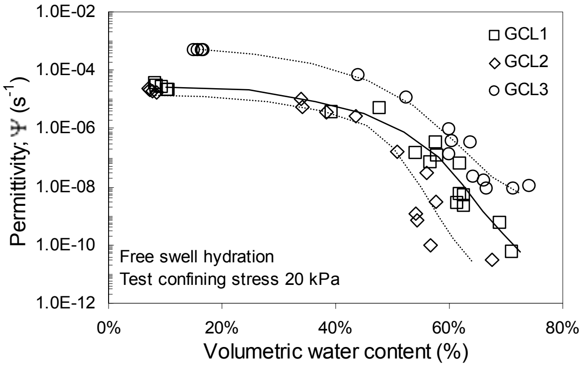

Figure 4: Variation of nitrogen gas permittivity with volumetric water content for free swell hydration

[Source: Vangpaisal & Bouazza (2001)]

3.1 Case Study-Rehabilitation of Kings Park (Port Stephens Council)

Kings Park is a former landfill (Raymond Terrace Landfill) decommissioned late in 1989, and adjoins the banks of the Williams River at Raymond Terrace, north of Newcastle, NSW.

Rehabilitation consisted of levelling the site, covering the area with approximately 300 mm of sandy material (as a final cover layer) and re-vegetating with a durable grass suitable for playing fields. Current environmental EPA laws now require these sites have relatively sophisticated base liners and capping systems.

Poor water quality readings in the adjoining Williams River indicated landfill leachate discharge. Other problems included reports of odours, and waste materials exposed at surface level. To resolve these problems a development application was approved to rehabilitate the site by incorporating a cap in line with current standards before reinstating the sporting facilities. The Councils' objective was to install a system that would minimize any further pollution of the groundwater and river and reduce landfill gas emissions.

Port Stephens Council investigated the various capping options, based on the following criteria.

- Relative impermeability of each system
- Ease of construction
- Thickness (impact on local flood storage capacity)
- Durability
- Ease of installation of services
- Cost

In the end, it was decided to use a GCL to cap the landfill.

Passive gas collection trenches were also constructed around the perimeter and across the landfill to control emissions. These trenches were located beneath the GCL to promote lateral movement of the gas into the collection trenches (refer to figure 6).

Figure 5: Placement of 300 mm cover layer over the GCL cap.

Figure 6: Passive collection trenches beneath the GCL cap.

Utilising this system, installation of the liner could be completed by Councils' day labour with minimal supervision and training. Installation rates in excess of 5,000 m^2 per day were achieved, enabling costs to be minimized, along with risk of exposure to poor weather.

Approximately 130,000 m^2 of GCL were supplied, along with 20,000 m^2 of non-woven, needle-punched geotextile for the passive gas collection trenches.

4. QUARRY (AND OTHER STEEP-SIDED) LANDFILLS.

Although many regulatory bodies discourage the siting of landfills in valleys and exhausted quarries due to environmental and technical reasons, these options are often considered due to political and economic motivations. Old quarry sites often have to be filled and restored, so if an owner can gather revenue at the same time, filling the quarry with municipal waste becomes an attractive option. Preparing quarries or valleys with engineered lining systems for waste disposal can be very challenging. Quarry wall surface preparation (1), side-slope inclinations (2), and extended UV/weather exposure (3), are all at the 'extreme' end of the scale. Most of these challenges however can be overcome with advanced engineering of the barrier system.

(1) Quarry/Cell Surfaces.

The potential damage to a synthetic liner by the rough, irregular surface of a quarry face can be reduced by using a thick, robust non-woven geotextile cushion. This will prevent excessive abrasion of the liner during filling and will minimise liner damage due to point loads when normal stress is applied. With highly irregular surfaces, some liner materials become unsuitable as the strain induced in the liner (after waste placement forces the liner to conform to the irregular surface) can exceed the materials safe long-term strain. For example, HDPE geomembranes should not be placed under more than around 3% strain in the long-term as stress cracking becomes an issue. Simple calculations using the typical geometry of the irregular surface of the cell wall can be used initially to eliminate lining materials with unsuitable mechanical properties. Selection of a suitably robust liner is critical. The thick non-woven geotextile also acts as drainage blanket under the impermeable membrane.

(2) Steep Side Slopes.

Old quarry side slopes can reach near vertical, so this poses problems relating to the stability and constructability of a lining system. It is very difficult to weld plastic sheets while abseiling vertically from the top of the quarry – although it has been done, but the added expense is significant. GCL's offer a system of sealing adjacent panels that simply relies on the bentonite's swelling/sealing capacity and confining stress, and by using a GCL made from high-elongation non-woven geotextiles, conformance to irregular surfaces ensures good contact with both the cell side-slopes and adjacent GCL panels. Anchor trenches need to be well designed to accommodate the self-weight of the liner and the down-drag forces imposed on the liner during waste filling and compacting operations. Using a GCL also allows the nailing or pinning of the liner to the quarried surface. Small, permanent penetrations will be effectively sealed by the bentonite in the GCL (Bouazza *et al*, 1996). This also eliminates some of the problems associated with abrasion due to wind and filling operations while the liner is exposed, and allows progressive lining of the cell as the waste is being placed.

(3) Extended UV and Weather Exposure.

Large cells will take some time to be filled, potentially in excess of 12 months. This creates problems associated with the exposure of the liner to UV and other elements. Wind uplift can cause significant damage to light geomembranes, especially if they are not made from a flexible type of polymer such as EPDM or polypropylene. GCL's have sufficient weight (approximately 5kg per square metre in a dry state) not to be significantly affected by wind uplift, however they need to be protected from UV and excessive hydration during the active (filling) life of the cell. Light woven, semi-permeable membranes have been used successfully on many projects above the GCL to shed excess water during rainfall events and to act as a sacrificial UV barrier, as described in the case history below.

4.1 Case Study – Kincumber Landfill (Gosford Council)

Kincumber Landfill is located on the Central Coast of NSW and takes domestic waste from the Gosford City Council region, having a population of 160,000. Until recently, most cells were constructed using a conventional CCL system – 900 mm of clay ($k \sim 1\times10^{-9}$ m/s) for the base and walls. Clay is imported from a mine in the Mangrove Mountains approximately 30 km away. This cell consisted of approximately 10,000 m^2 of base liner and 1300 m^2 of wall liner (Figures 7 and 8).

The wet season delayed the construction of the cell and with space running out the council sought alternatives. One such alternative was to use a GCL for the base and wall. It represented the fastest installation and cheapest alternative with a cost saving of approximately 20%. The base was constructed using a dual liner system comprising GCL and 300 mm CCL.

Leachate drains were lined longitudinally with a non-woven needle-punched GCL cut in half from 4.55 metre rolls to minimize overlaps. The GCL was selected based on flexibility and conformability, and overlapped the trench by 300 mm. The base GCL was then finished in the trench.

Figure 7: Steep wall lined with cushioning fabric, GCL and semi-permeable membrane.

Figure 8: Cushioning fabric installed followed by GCL.

Construction of the walls presented a more difficult problem to solve. The height of the wall ranged from 16 metres to 46 metres and a slope angle in excess of 70º cut in hard shale. After careful consideration, a proposal was made to the Council incorporating a cushioning fabric having a mass in excess of 500 g/m^2, a non-woven needle-punched GCL, and a sacrificial semi-permeable membrane. The semi-permeable membrane was placed to protect the GCL until covered. All three geosynthetic products were supported at the top of the slope by an anchor trench. Due to the height of the wall, special lengths of up to 48 metres of GCL were made. Council staff and day labour carried out supervision and construction of this project.

5. CONCLUSIONS.

With the maturing of landfill practices and regulations in Australia it is important that research and field performance monitoring on the various options being proposed is available for designers and regulators to make informed decisions. Geosynthetic Clay Liners (GCL's) are increasingly being employed in 'best practice' barrier designs both overseas and in Australia - and further increase in use is expected. The increased usage is partly due to the fact there is a wealth of information on the performance of GCL's in landfill applications, and it is encouraging to see local universities and research bodies getting involved with local manufacturers to further develop the collective knowledge.

REFERENCES

Bouazza, A. (1997). "Performance of Geosynthetic Clay Liners", *GeoEnvironment 97,* Bouazza, Kodikara & Parker (eds), Balkema, pp 307 - 313.

Daniel, D.E. (1999). "Future Trends in Liners and Covers", *Proceedings of the GRI-13 Conference on "Geosynthetics in the Future: Year 2000 and beyond,* P.A. USA, pp 263 - 273.

Eberle, M.A., Wright, M., Peter, P. (2000). "GCL/Minesite Leachate Hydraulic Performance Testing in the Laboratory using Simulated Site Conditions", *Proceedings of the Second European Geosynthetics Conference,* Bologna, Italy, pp 719 - 724.

Giroud, J.P., Badu-Tweneboah, K., & Soderman, K.L. (1994). "Evaluation of Landfill Liners", *Fifth International Conference on Geotextiles, Geomembranes and Related Products*, Vol 3, pp 981 - 986.

Rowe, R.K. (1998). "Geosynthetics and the Minimisation of Contaminant Migration through Barrier Systems Beneath Solid Waste." *Proceedings of the Sixth International Conference on Geosynthetics, Atlanta USA*, pp 27 - 02.

Vangpaisal, T., & Bouazza, A. (2001) "Gas permeability of three needle punched geosynthetic clay liners", 2nd ANZ Conference on Environmental Geotechnics, Newcastle, NSW, Australia.