

Base liner equivalency assessment for landfill sites

Gassner, F.W.

Golder Associates Pty Ltd, Melbourne, Australia

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ABSTRACT: The EPA in a number of states in Australia has a set of minimum requirements for landfill liners. The performance of a number of alternative liner systems have been modelled and assessed against the required performance of the minimum requirements liner systems, to propose alternative liner system at a number of landfill sites in Australia.

The equivalency has been assessed in terms of advective and diffusive flow through the liner and subgrade materials to demonstrate an equivalent or lower risk to the underlying groundwater. The assessments looked at sensitivity of material properties to demonstrate variations with respect to various parameters, which is presented in terms of different site conditions and selected construction materials.

1 INTRODUCTION

In Australia each state has its own EPA agency, with state specific requirements for landfills. One of the requirements is to design landfill liners with a minimum default liner configuration. The sites being presented in this paper are located in South Australia and Victoria, Australia. In summary the EPA minimum requirements for a landfill liner in these states is a gravel layer to control the depth of leachate to less than 300 mm, with a 1m thick compacted clay liner. For putrescible waste landfills the liner is required to be a composite liner including a geomembrane over the clay liner.

Due to lack of suitable materials at two sites, and due to construction considerations at the third site, alternative liner systems were investigated for three landfills. The first landfill site (No. 1) is in South Australia, with a lack of suitable clay liner materials. Site No. 2 is located south of Perth in Western Australia has a shortage of clay liner material and required an alternative liner system for better use of the existing shape of the site and construction considerations. Site No. 3 is located to the north of Melbourne in Victoria with an alternative liner system investigated to suit construction considerations.

2 SETTING OF SITES

Site 1: Site 1 is located in a quartzite pit, where the rock on the base is weathered and closely spaced joints and fissures. The available construction material comprises sandy and gravelly clay, generally in short supply. Depth to groundwater is 10's of meters, with fractured quartzite down to the groundwater. The accepted liner for the site comprised 0.6 m compacted clay with permeability 1×10^{-9} m/s and a 2.0 mm thick HDPE geomembrane liner.

Site 2: Site 2 is located in a shale quarry, with the groundwater elevation above the base of the cell. Clay for liner construction is imported to the site. The accepted liner for this site comprised 1m compacted clay with permeability 1×10^{-9} m/s. Side slopes at the site are up to 30 m high, with batters varying between 1.5H to 1V and 4H to 1V. An alternative side slope liner was required to suit construction considerations, and an alternative base liner was required to address the general shortage of low permeability clay.

Site 3: Site 3 is located in an active large basalt quarry, with the very hard rock slightly fractured basalt continuing below the base of the quarry. Groundwater level is near the base of quarry level, although

historically the groundwater was higher. High plasticity clay is available on site from overburden stripping of the quarry. The liner designed for this site has to be equivalent to 1 m clay liner of 1×10^{-9} m/s with a geomembrane liner. The alternative liner system is considered for 19 m high side slopes of 3H in 1V, to facilitate construction of the side liner in one lift.

The site owners requested that alternative liners be investigated to better suit the site requirements. The alternative liner systems are required to provide equivalent or better protection to the environment to be considered by the regulator. To assess the equivalency of the proposed liner system, GCLs are considered in composite with a geomembrane. The alternative system is assessed by modeling the advection and diffusion of the system, and compared to the modelled performance of the default or approved system.

3 MODELING

The modelling was carried out with the site conditions being identical for the accepted or default liner system and for the alternative system. The modelling was carried out using a program that was written by Dr Leo of Sydney University. The program is similar to the POLLUTE code prepared under the direction of Kerry Rowe.

The advection and diffusion through the liner system was modelled based on published data from various researchers for the coefficient of diffusion through a HDPE geomembrane. The modelling was carried out based on the migration of chloride, which is known to be a highly mobile ion, with similarities to ammonia, which is one of the contaminants commonly found in landfill leachate.

3.1 Site 1:

The following key parameters were used for the modelling at this site:

- 200 mm clay layer $k = 1 \times 10^{-8}$ m/s
- 10 mm thick GCL, $k = 1 \times 10^{-10}$ m/s
- 1.5 mm thick HDPE geomembrane, $D = 4 \times 10^{-13}$ m²/s
- Rock permeability = 2.5×10^{-7} m/s
- 300 mm depth of leachate, $\text{Cl}^- = 4200$ mg/L

Modelling period of 20 years and 100 years were adopted.

Based on a selected defect rate in the geomembrane liner and a lateral transmissivity related to the expected level of contact between the either the clay or GCL, a seepage rate through the liner system was included in the model.

The GCL was modelled with a higher permeability than the GCL that was used at the site to allow for the potential impact of elevated calcium in the natural

materials at the site, which can lead to an increase in permeability resulting from ion exchange in the bentonite of the GCL.

The seepage rate for the accepted liner was estimated at 1.5 L/ha/day, and the rate through the alternative liner system at 0.08 L/ha/day. These seepage rates are based on the published work by Rowe and Giroud.

The results were plotted compared to the clay liner system on log scale graphs (Figure 1) to present the concentration with depth below the top of liner after a period of 20 years and 100 years.

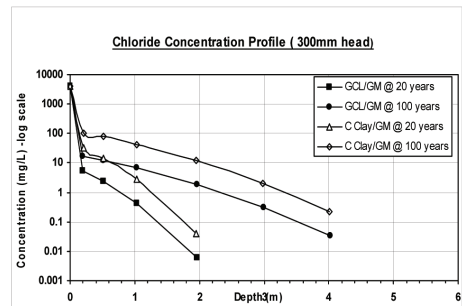


Figure 1. Site 1 – GCL and geomembrane, vs clay and geomembrane.

The effect of using a 2 mm HDPE geomembrane in place of a 1.5 mm geomembrane was also modelled. The difference was modelled for the GCL composite liner only. The results of the modelling indicate a marginal reduction in the concentration with depth for the 2 mm geomembrane compared to the 1.5 mm geomembrane. The reduction is about 20% at 100 years relative to the 2 mm geomembrane concentrations. This difference should be considered in terms of the reduction of the leachate concentration at depth with respect to the concentration above the liner, being 0.15% at 1m below for the 2 mm geomembrane.

3.2 Site 2

This site was modelled with a groundwater collection system below the liner system. Four liner systems were modelled to assess the likely performance of the different systems.

The following key parameters were used for the modelling of the four liner system options:

- 9 mm thick GCL, $k = 5 \times 10^{-11}$ m/s
- 1.5 mm thick HDPE geomembrane,
- 300 mm depth of leachate, $\text{Cl}^- = 9000$ mg/L

The four liner options comprised the following combinations:

Option 1: 600 mm clayey soil layer overlain by a geomembrane.

Option 2: 300 mm bedding layer overlain by GCL overlain by geomembrane.

Option 3: 1300 mm of clayey silt overlain by geomembrane.

Option 4: 600 mm of clayey silt overlain by geomembrane.

Based on the above combinations and assumed defect rates in the geomembrane and permeabilities for the underlying soils, the following advection rates were estimated, based on Giroud et al:

Table 1. Advection rates.

Option 1	2 L/ha/day
Option 2	0.9 L/ha/day
Option 3	24 L/ha/day
Option 4	70 L/ha/day

The advection rate through the accepted liner system of 1 m of compacted clay is estimated at 246 L/ha/day. Hence, based just on advection rates all of the alternative liner options result in a lower flow rate than the accepted liner. Figures 2A presents the concentration of chloride through the liner at 32 years and Figure 2B at 128 years after commissioning the liner system. Depths are measured from top of liner system.

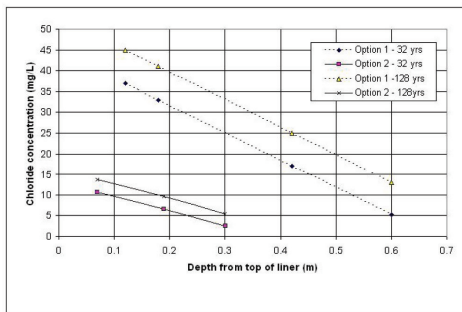


Figure 2A. Site 2 – Chloride concentrations in liner Options 1 and 2.

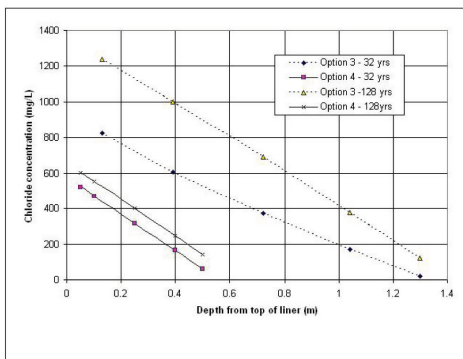


Figure 2B. Site 2 – Chloride concentrations in liner Options 3 and 4.

The above trends indicate that the composite liner Options 1 and 2 result in low migration of chloride, whereas Options 3 and 4 the rate of migration is approximately an order of magnitude higher. In comparison to the accepted liner of 1 m of compacted clay the chloride concentration at the base of the 1 m liner is estimated at 1000 mg/L and 2000 mg/L at 32 years and 128 years respectively. Clearly all four options exceed the performance of a 1m thick compacted clay liner.

3.3 Site 3

The design of the side slope liner system is intended to determine what distance is required between the alternative liner system and the groundwater so that the risk to the groundwater is similar to that below the default composite liner. The analysis was carried out based on the following parameters:

- 5 mm thick GCL with $k = 3 \times 10^{-11}$ m/s
- 1.5 mm thick HDPE geomembrane, $D = 4 \times 10^{-13}$ m²/s
- The fill used in the construction of the side liner subgrade comprised high plasticity clayey gravel to gravelly clay, with a permeability of 1×10^{-3} m/s.
- 1 m of compacted clay at toe of slope, $k = 1 \times 10^{-9}$ m/s.
- 30 mm depth of leachate, $Cl^- = 5000$ mg/L

Point of compliance for the liner system is a horizontal plane projected from the underside of the default composite liner which is 1 m below the underside of the leachate collection system. This results in an attenuation layer of at least 1 m below the alternative composite liner.

4 DISCUSSION

The analyses indicate the following trends:

- A distance of between 1 m to 2 m between top of a GCL and geomembrane composite liner system and the groundwater generally results in very low concentrations of inorganic contaminants reaching the groundwater over 100 years.

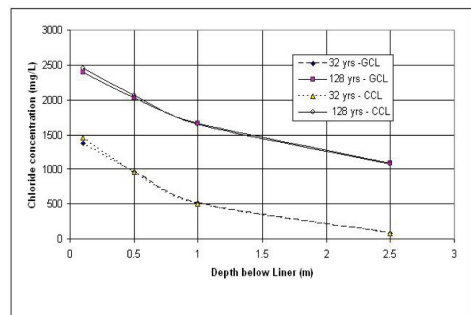


Figure 3. Concentration below liner for Site 3.

- The composition of the material below a composite liner has relatively minor impact on the rate of migration below of inorganic contaminants below the liner. The largest impact on the rate of migration is the composition and quality of the liner system.
- A composite liner system underlain by soil of moderate permeability results in a significant reduction in the rate and extent of migration of inorganic contaminants relative to a compacted low permeability clay liner.
- A GCL and geomembrane composite liner system generally requires an attenuation layer below the composite liner to be equivalent in performance to a thicker compacted clay and geomembrane composite liner system.
- A GCL and geomembrane composite liner system results in very low concentrations in the material below the liner, due to limitation of advection rates through the system to very low rates.
- An increase in geomembrane thickness has a minor impact on the overall performance of the liner system.

Migration rates of organic contaminants have not been included in this assessment. Where a facility is expected to include organic contaminants of concern, these should be assessed based on measured and material specific diffusion and advection rates for the contaminants.

5 CONCLUSIONS

Comparative analyses are used to demonstrate equivalence of alternative liner system to minimum requirements specified by regulators. The analysis shows that the comparative method to assess equivalence of liner systems is effective where the

regulator has set a minimum or default liner system. The method can also be used to determine the minimum attenuation distance between groundwater and a liner system, to achieve equivalent performance of the system at a particular site.

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