CONSIDERATION OF UNCERTAINTY REGARDING THE SERVICE LIVES OF ENGINEERED SYSTEMS IN ASSESSING POTENTIAL CONTAMINANT IMPACT

R. K. Rowe and M.J. Fraser
Geotechnical Research Centre, Department of Civil Engineering
University of Western Ontario, London, Ontario, Canada

ABSTRACT

The modelling of contaminant transport through barrier systems will be discussed in the context of uncertainty regarding the service life of various components of the engineered barrier systems. A technique for performing a stochastic analysis that takes consideration of finite but uncertain service lives of different components of the system is discussed and will be illustrated by a number of examples. The barrier systems to be considered will include conventional clay liner systems that include multiple leachate collection systems, systems involving composite (geomembrane and clay) liners, and systems involving geosynthetic clay liners.

INTRODUCTION

An assessment of the potential contaminant impact of a landfill on groundwater is of critical importance in the design and approval process for landfills (Rowe et al. 1994). This impact can be assessed by examining the peak concentrations of contaminants migrating from a landfill into an underlying aquifer. These peak concentrations will depend on the interaction between the hydrogeology and the engineered systems of the landfill.

In designing an effective barrier system for a landfill the service life of the engineered systems must be considered. For systems such as geomembranes and leachate collection systems this service life may be finite. Although the service lives of the engineered systems may not be known accurately, the effectiveness of the barrier systems may be assessed for a range of service lives. In addition, stochastic analysis may be used to study the effect of uncertainty in the service lives of the engineered systems.

The effectiveness of a barrier design in minimizing the migration of contaminants can be assessed by examining the impact of the landfill on an underlying aquifer. To quantify this impact the migration of chloride and dichloromethane will be studied. Initial source concentrations of 1500 mg/L for chloride and 1500 μg/L for dichloromethane are assumed. The mass of chloride is assumed to represent 0.2% of the total mass of the waste, which has a density of 600 kg/m^3 and thickness of 31.25 m. And the mass of dichloromethane is assumed to be in direct proportion to the initial source concentration (i.e., 0.0002% of total mass). Biological decay with a half life of 75 years is assumed to occur for the dichloromethane in the landfill and the underlying soil.

In the analysis below six different barrier designs are assessed according to their impact on the hypothetical hydrogeology described below. Only one hydrogeologic system is examined due to space limitations. The impact of a given landfill will depend on the interaction between the engineered barrier system and the hydrogeology (Rowe, 1992). Therefore, the numerical results presented below should not be generalized beyond the level discussed in this paper. To assess the impact of the barrier designs the effect of the mass of contaminant was modeled as described by Rowe (1991a, 1991b).

All the analyses contained in this paper were performed using a finite layer contaminant transport model (Rowe and Booker, 1985, 1987) as implemented in computer program POLLUTEv6 (Rowe, Booker and Fraser, 1994).

HYDROGEOLOGY

A hypothetical landfill, 1500 m long in the direction of groundwater flow, situated in a deposit of a relatively permeable glacial till will be used in this study. The glacial till extends 10 m below the top of the primary leachate collection system, and overlies a 1 m thick sand aquifer. A hydraulic conductivity of 1 x 10^{-5} cm/s and a porosity of 0.25 are assumed for the glacial till. It is also assumed that the glacial till will have an effective diffusion coefficient of 0.015 m^2/a for chloride and dichloromethane, and a product of soil density, ρ, and dichloromethane partitioning coefficient, K_d, given by $\rho K_d=0.5$.

The underlying aquifer is assumed to have a porosity of 0.3 and a hydrostatic head 6 m above the top of the aquifer. At the up-hydraulic gradient edge of the landfill the horizontal flow in the aquifer is assumed to be 20 m/a. This flow will be increased at the down-hydraulic gradient edge by any downward Darcy flux originating from the landfill.

In this analysis the infiltration through the cover of the landfill is assumed to be 0.15 m/a, which is based on experience in Southern Ontario.

BARRIER DESIGNS

To evaluate the effect of the service life of the engineered barrier systems on contaminant impact, six barrier designs will be considered. These designs will have barriers composed of clay, geomembranes and clay, and geosynthetic clay liners and clay for single liner and double liner systems. The leachate collection systems in these designs consist of a granular layer 0.3 m thick, unless stated otherwise, with a porosity of 0.3.

The first barrier design incorporates a primary leachate collection system and a 1 m thick compacted clay liner (Figure 1). In this and subsequent designs the compacted clay is assumed to have a hydraulic conductivity of 2×10^{-8} cm/s, a porosity of 0.35, and an effective diffusion coefficient of 0.019 m^2/a. And the sorption of dichloromethane in the clay is controlled by $\rho K_d=2$. The remaining deposit consists of 9 m of glacial till.

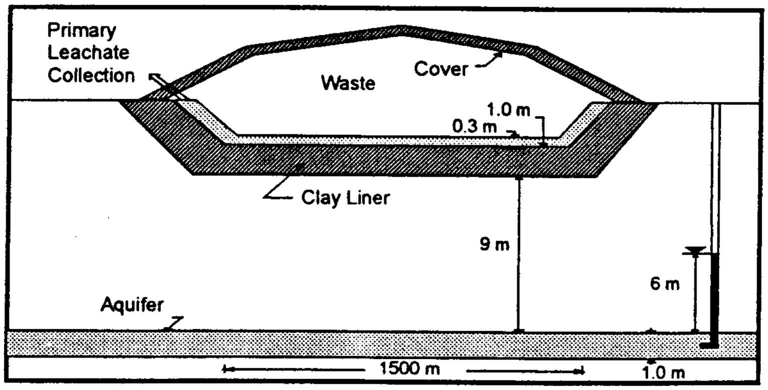

Figure 1. Design 1: Single Liner - Compacted Clay

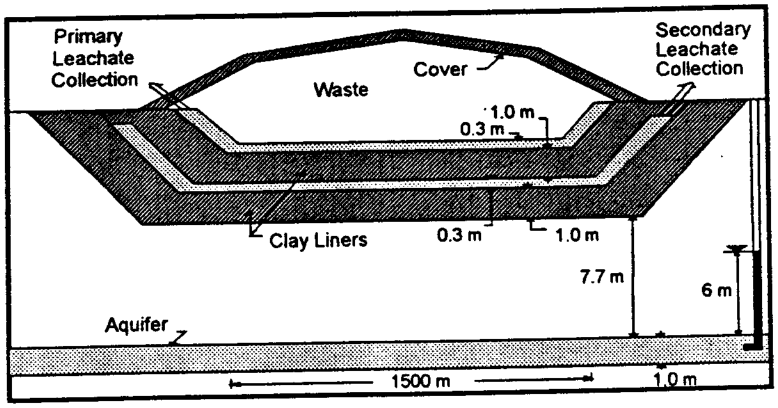

Figure 2. Design 2: Double Liner - Compacted Clay.

In the second barrier design, primary and secondary leachate collection systems are utilized (Figure 2). The primary and secondary liners are both composed of a 1 m thick compacted clay. In this design the glacial till extends 7.7 m below the base of the secondary liner.

The third design is similar to the first, except an 80 mil (2 mm) geomembrane has been added on top of the clay (Figure 3). In this and other designs incorporating a geomembrane, it is assumed that the geomembrane has an effective hydraulic conductivity of 10^{-12} cm/s and an effective diffusion coefficient of 3×10^{-5} m^2/a. The effective hydraulic conductivity of the geomembrane was backfigured based on consideration of the likely leakage through a "well constructed" composite liner with some holes, using information from Giroud and Bonaparte (1989). In this design the till below the base of the clay liner is 9 m thick.

In the fourth design a double liner is incorporated similar to the second design, however in this design both the primary and secondary liners consist of an 80 mil (2 mm) geomembrane over 1 m of compacted clay (Figure 4). To maintain the base of the landfill at the same relative elevation as the previous designs the glacial till in this design is 7.7 m thick.

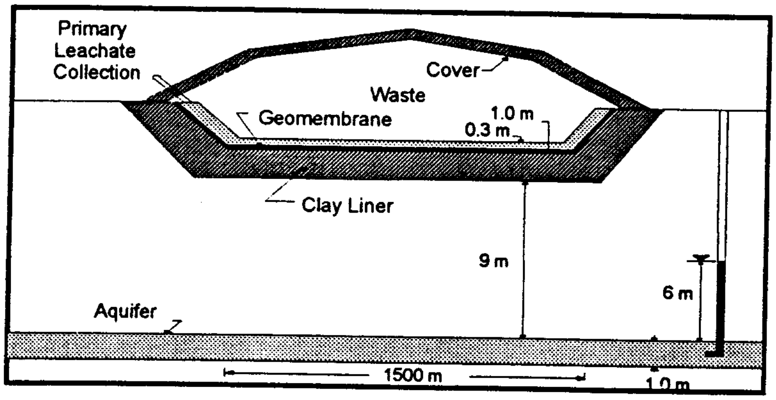

Figure 3. Design 3: Single Liner - Geomembrane and Compacted Clay.

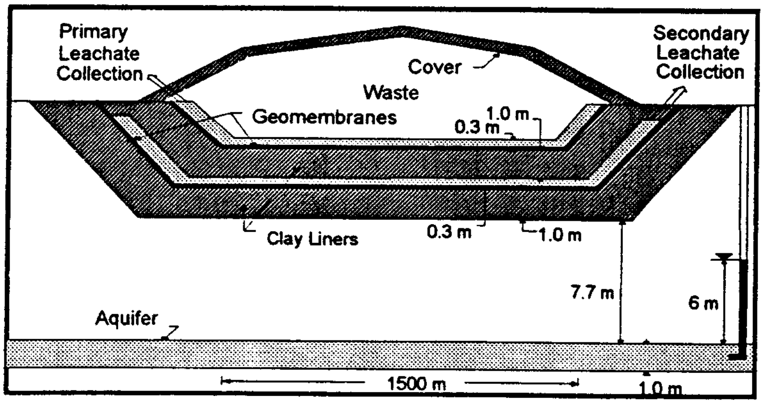

Figure 4. Design 4: Double Liner - Geomembrane and Compacted Clay.

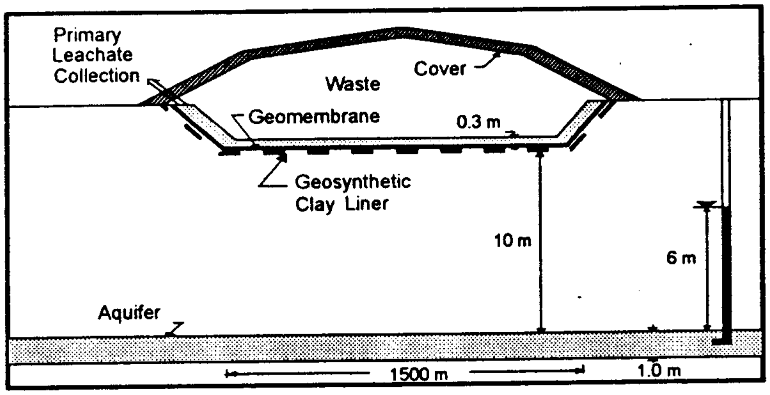

Figure 5. Design 5: Single Liner - Geomembrane and Geosynthetic Clay Liner.

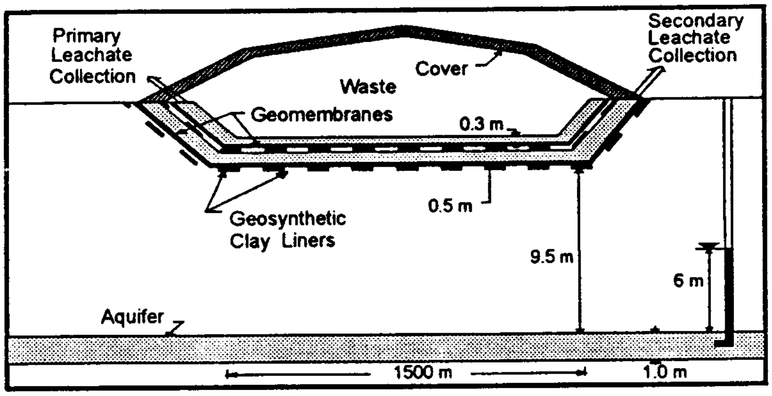

Figure 6. Design 6: Double Liner - Geomembrane and Geosynthetic Clay Liner.

For the fifth barrier design (Figure 5) a primary leachate collection system and a primary composite liner are utilized. The composite liner consists of an 80 mil (2 mm) geomembrane over a geosynthetic clay liner (GCL). In this and the sixth design the GCL is assumed to have a hydraulic conductivity of 4×10^{-10} cm/s, a porosity of 0.75, an effective diffusion coefficient of 0.0047 m^2/a, and a sorption of dichloromethane given by $\rho K_d=2$. The thickness of the glacial till in this design is 10 m.

The sixth design utilizes primary and secondary leachate collection systems and primary and secondary composite liners (Figure 6). In this design the composite liners consist of an 80 mil (2 mm) geomembrane over a GCL, as described above. The secondary leachate collection system is assumed to be 0.7 m thick to allow for a granular sand and geosynthetic cushioning layer above and below the coarse stone collection layer.

SERVICE LIVES

Engineered components of a landfill barrier system can be expected to have finite service lives. The leachate collection systems will eventually clog due to chemical and biological activity. And the geomembranes will age due to chain scission caused by chemical attack and other processes, which results in an increase in their effective hydraulic conductivity.

Initially after closure of the landfill when the primary leachate collection system is still functioning the leachate mound can be assumed to be 0.3 m. After the primary leachate collection system fails and becomes clogged the leachate mound will start to build at rate controlled by the infiltration and the downward Darcy velocity through the primary liner. For the barriers considered, the downward Darcy velocity is small compared to the infiltration and thus the rate of increase in the leachate mound is controlled by the infiltration rate, assuming that the primary liner has not yet failed. If it is assumed that the waste is at field capacity prior to failure of the primary leachate collection system, then the rate of increase in the leachate mound can be calculated using the difference in water storage capacity of the waste between field capacity and saturation, and the infiltration rate through the cover.

In this analysis the waste is assumed to have a field capacity for water of 300 mm/m and at saturation is 550 mm/m, which gives a rate of increase in the leachate mound equal to 0.60 m/a. The leachate mound is assumed to build to its full height of 30 m above the primary liner, where the maximum height of the mound is controlled by the thickness of the waste. Unless otherwise specified the service life of the primary leachate collection system is assumed to be 50 years after closure.

In the designs incorporating geomembranes, the primary geomembrane will be subjected to chemical attack very early in the life of the landfill due to the presence of even a relatively small leachate mound. The service life of the primary geomembrane is assumed to be independent of the service life of the primary leachate collection system, since the degree of chemical attack is anticipated to be controlled by the concentration of contaminants in the leachate and not the height of the leachate mound. For the assessment of the barrier designs in this paper the service life of the primary geomembrane is assumed to be 125 years after closure, unless stated otherwise.

If present the secondary leachate collection system and secondary geomembrane will also have finite service lives. It is anticipated that for barriers incorporating a primary geomembrane, the service life of the secondary leachate collection system and geomembrane will be primarily controlled by the service life of the primary geomembrane rather than the service life of the primary leachate collection system. In the analysis below the service life of the secondary geomembrane is assumed to be 175 years after landfill closure and the service life of the secondary leachate collection system is assumed to be 200 years after closure, unless stated otherwise. Space does not permit the examination of this assumption that the secondary leachate collection system fails after the secondary geomembrane which will be discussed in another paper.

The geosynthetic clay liner is considered an engineered system, but unlike the geomembranes and leachate collection systems it is not assumed to have a finite service life. This assumption may be reasonable on the grounds that the geosynthetic clay liner may experience similar aging characteristics as a compacted clay liner, which is assumed to have an infinite service life.

PRIMARY LEACHATE COLLECTION SERVICE LIFE

When the source of contamination is finite as in a landfill, the concentration in an underlying aquifer will initially increase as contaminant is transported from the landfill to the aquifer. The contaminant mass entering the aquifer will then be transported along the aquifer away from the landfill. Eventually sufficient mass of contaminant in the landfill will have been removed either by leachate collection or downward migration, such that the mass subsequently transported to the aquifer will decline. Thus there will be an initial increase in concentration in the aquifer followed by a decline in concentration creating a peak concentration in the aquifer.

Figures 7 and 8 show the calculated variation in concentration with time for chloride and dichloromethane respectively. Results are shown for the six barrier designs, assuming a primary collection system service life of 50 years. All of the barrier designs generate a peak concentration in the aquifer. The magnitude and time of the peak differs for each barrier design, and is an indication of the relative performance of each design. It is evident that the double liner designs have lower peaks occurring at later times than the single liner designs.

The time of the peak concentration for the single liner designs occurs shortly after the primary leachate collection system has failed at 50 years, and if there is a geomembrane present the peak occurs after this is assumed to have failed at 125 years. In the double liner designs the peak does not occur until after the secondary leachate collection system has failed at 200 years.

All of the barrier designs show a very sharp rise in the chloride concentration in the aquifer, except for the double liner with clay design. This sharp increase shows that there is relatively little contaminant flux into the aquifer until the leachate collection systems and geomembranes have failed. The double clay liner design shows a more gradual increase in chloride concentration in the aquifer, indicating that there is significant contaminant transport into the aquifer after the primary leachate collection system has failed (at 50 years) and prior to the failure of the secondary leachate collection system (at 200 years).

The concentration of dichloromethane in the aquifer shows a more gradual increase for the six barrier designs (see Fig. 8). This more gradual increase in concentration results from the attenuation provided by the sorption of dichloromethane in the clay and glacial till.

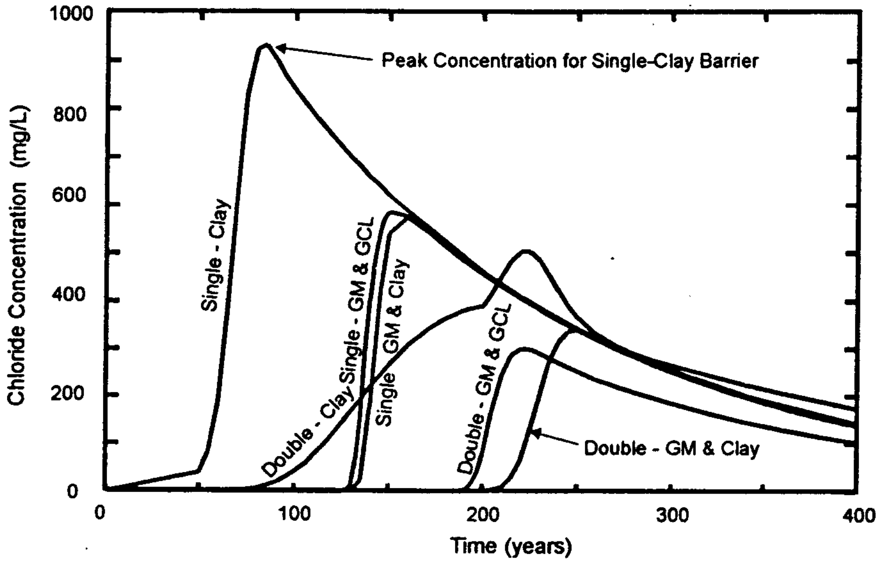

Figure 7. Chloride Concentration in Aquifer

To evaluate the effect of the service life of the primary leachate collection system for the barrier designs a range of service lives were examined. Figures 9 and 10 show the calculated peak contaminant impact in the underlying aquifer for chloride and dichloromethane. In these calculations the service lives of the leachate collection systems and geomembranes are finite as described above, and the primary leachate collection system has a service life between 25 and 75 years after closure.

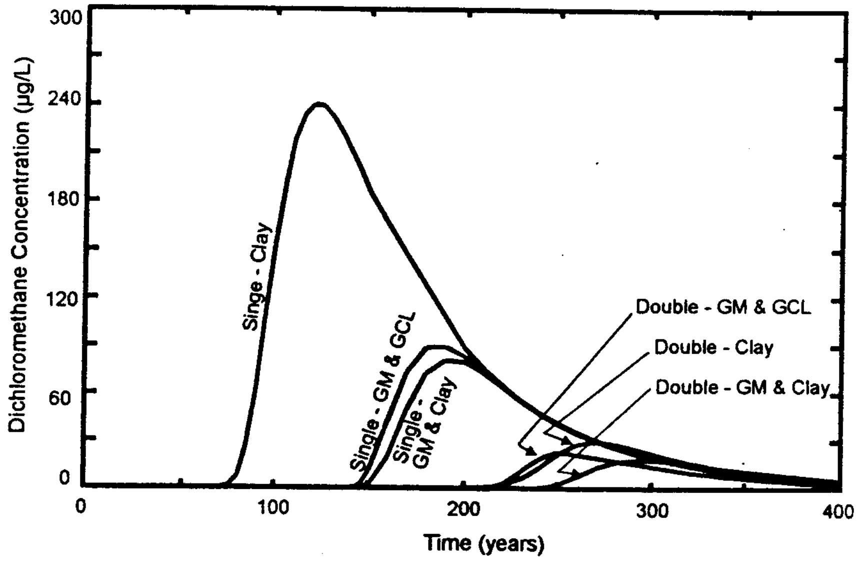

Figure 8. Dichloromethane Concentration in Aquifer

As would be expected the peak concentration decreases with increasing primary leachate collection system service life, with the decrease being most noticeable for the single liner with clay design. Although the double liner designs show a slight decrease in peak concentration with service life, relative to the single liner designs they are largely unaffected by the service life of the primary leachate collection system. For both the chloride and dichloromethane the double liners designs perform better than the single liner designs, and the designs incorporating a geomembrane provide a better barrier than those with compacted clay only.

The double liner with geomembranes and GCLs gives a lower peak impact than the double liner with geomembranes and clay for chloride. This results from the primary geosynthetic clay liner allowing a larger flow of contaminant through the primary liner, than the primary compacted clay after the failure of the geomembrane in the primary liner. During the 75 years between the failure of the primary geomembrane and secondary leachate collection system, there is more contaminant collected by the secondary leachate collection system resulting in a lower peak chloride concentration in the aquifer.

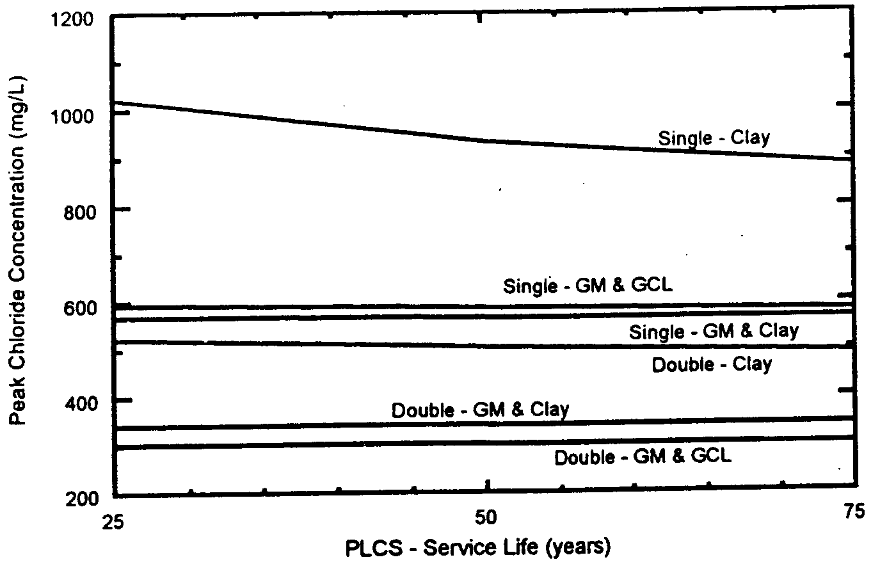

Figure 9. Primary Leachate Collection System Service Life - Chloride.

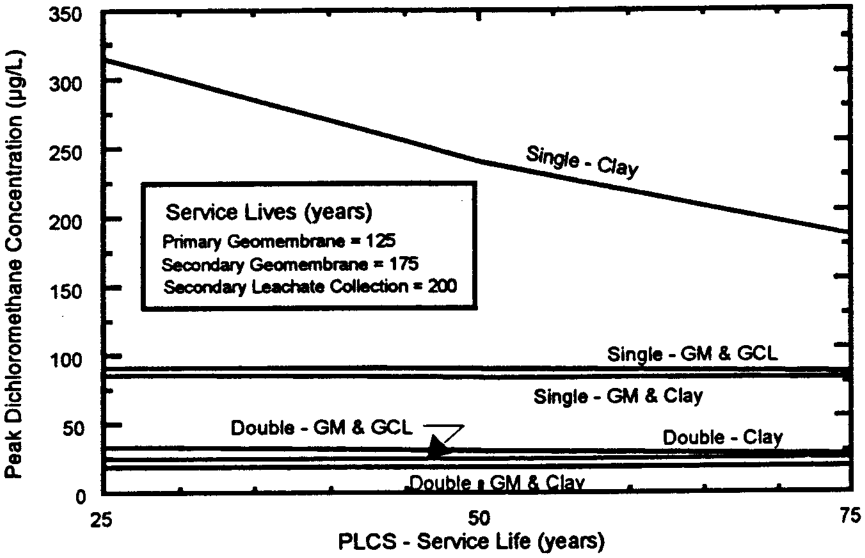

Figure 10. Primary Leachate Collection System Service Life - Dichloromethane.

In the case of dichloromethane the geomembrane with compacted clay single and double barriers give a lower peak concentration in the aquifer than the geomembrane with geosynthetic clay liner single and double barriers. This is due to the greater retardation in the compacted clay liner relative to the geosynthetic clay liner and the consequent additional time that this permits for first order (eg. biological) decay of dichloromethane.

The Province of Ontario, Canada, Ministry of Environment and Energy's 'Reasonable Use' Policy (MOEE, 1993) limits the increase in the concentration of contaminants in the aquifer to a maximum of 125 mg/L for chloride and 12 μg/L for dichloromethane, assuming a negligible background concentration. According to this policy none of the barrier designs would be acceptable for the service lives considered.

Table 1. Infinite Primary Leachate Collection Life

Barrier Design	**Chloride** (mg/L)	**Dichloromethane** (μg/L)
Single - Clay	662	30.0
Double - Clay	231	0.3
Single - GM & Clay	329	6.0
Double - GM & Clay	110	0.1
Single - GM & GCL	512	54.0
Double - GM & GCL	102	0.1

If the primary leachate collection system were assumed to never fail then it would be logical to also assume that the secondary leachate collection system should also never fail. Based on these assumptions, the calculated peak contaminant concentrations in the aquifer for the six barrier designs are shown in Table 1. The service lives of the geomembranes, if present, were assumed to be 125 years for the primary geomembrane and 175 years for the secondary geomembrane. From this table it is evident that the double liner with geomembranes and clay and geomembranes with geosynthetic clay liners may be acceptable for chloride. For dichloromethane, all the barrier designs may be acceptable except the single clay liner and the single composite geomembrane and geosynthetic clay liner.

PRIMARY GEOMEMBRANE SERVICE LIFE

A range of service lives for the primary geomembrane were examined to illustrate the effect of the primary geomembrane service life on the peak concentration of the contaminant in the aquifer. Of the six barrier designs only the last four incorporate geomembranes; thus for the first two designs that incorporate compacted clay liners only, the peak concentration is independent of the geomembrane service life.

In the designs with double liners and geomembranes (i.e., designs 4 and 6) there will be a significant increase in contaminant contact with the secondary leachate collection system and secondary geomembrane after the primary geomembrane fails. This increased contact might be expected to accelerate the degradation of these systems. After the failure of the primary geomembrane these systems are assumed to fail after 50 years for the secondary geomembrane and 75 years for the secondary leachate collection system.

Figures 11 and 12 show the calculated peak impacts in the aquifer for chloride and dichloromethane assuming service lives of the primary geomembrane of between 100 and 200 years. The peak impact on the aquifer decreases with increasing service life of the primary geomembrane, with the largest decrease occurring for the single composite barrier designs. This decrease in peak impact results from the source concentration decreasing with time as contaminant is being removed from the landfill by leachate collection and transport through the primary liner.

As anticipated the barriers with double composite liners significantly reduced the impact on the aquifer for all the geomembrane service lives examined. The double composite barrier with geomembranes and geosynthetic clay liners performs better than the barrier with geomembranes and compacted clay for chloride for the conditions examined here.

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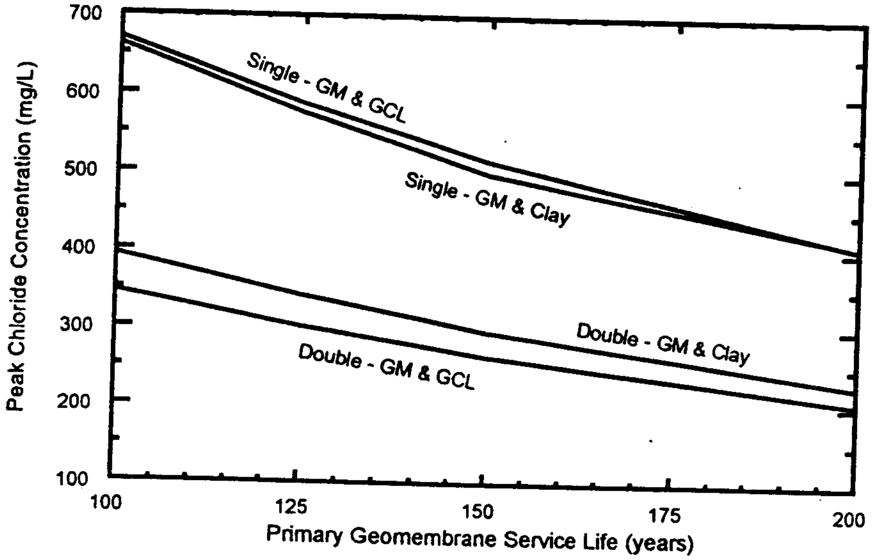

Figure 11. Primary Geomembrane Service Life - Chloride.

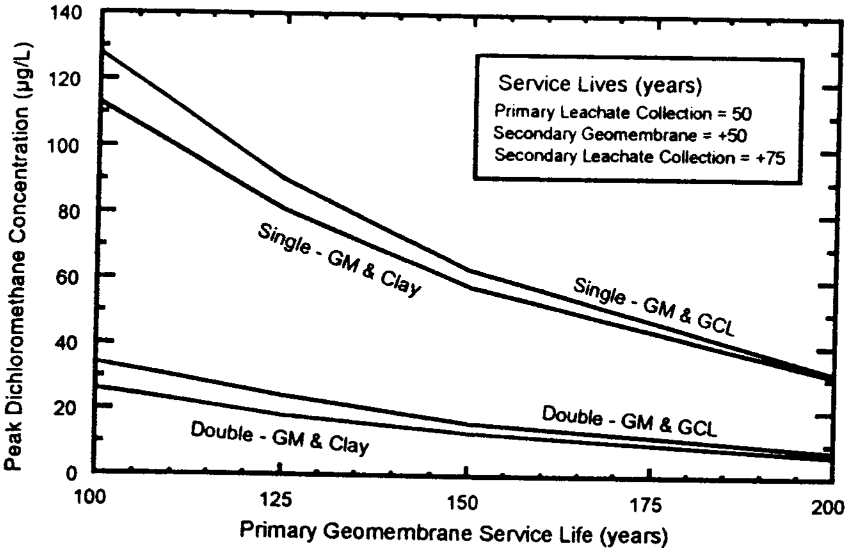

Figure 12. Primary Geomembrane Service Life - Dichloromethane.

When examined with respect to the MOEE's 'Reasonable Use' Policy, none of the barrier designs are able to keep the peak contaminant impact on the aquifer within acceptable limits for chloride. In the case of dichloromethane, the double composite liner involving geomembranes and compacted clay and the double composite liner involving geomembranes and geosynthetic clay liners are able to reduce the impact to within acceptable limits for primary geomembrane service lives greater than 200 years.

Table 2. **Infinite Primary Geomembrane Service Life.**

Barrier Design	**Chloride** (mg/L)	**Dichloromethane** (μg/L)
Single - GM & Clay	110	0.06
Double - GM & Clay	10	0.0003
Single - GM & GCL	108	0.07
Double - GM & GCL	11	0.0005

If the geomembranes are assumed to have an infinite service life, then there would be little exposure of the secondary leachate collection system to contaminant and the service life of the secondary leachate collection system could also be assumed to be infinite. In Table 2 the peak chloride and dichloromethane concentrations in the aquifer are given for the four barrier designs assuming that the primary geomembrane, secondary geomembrane, and secondary leachate collection system have infinite service lives. The primary leachate collection system was assumed to have a service life of 50 years for all the barrier designs. It is evident from Table 2 that for infinite geomembrane service lives all the barrier designs would fall within acceptable limits for contaminant impact on the aquifer. Whereas, when service lives of less than 200 years are assumed none of the designs were within acceptable limits. This clearly illustrates the significant role of the geomembrane and the importance of assessing the effects of reasonable uncertainty concerning the service life of these materials.

SECONDARY LEACHATE COLLECTION SERVICE LIFE

Upon failure of the primary leachate collection system and primary geomembrane, if present, the secondary leachate collection system will be exposed to increased amounts of contaminants. The secondary leachate collection system may clog due to this increased contaminant load. To assess the effects of this finite service life the peak contaminant impacts on the aquifer are examined for chloride and dichloromethane over a range of secondary leachate collection system service lives for the barrier designs with double liners. (Figures 13 and 14).

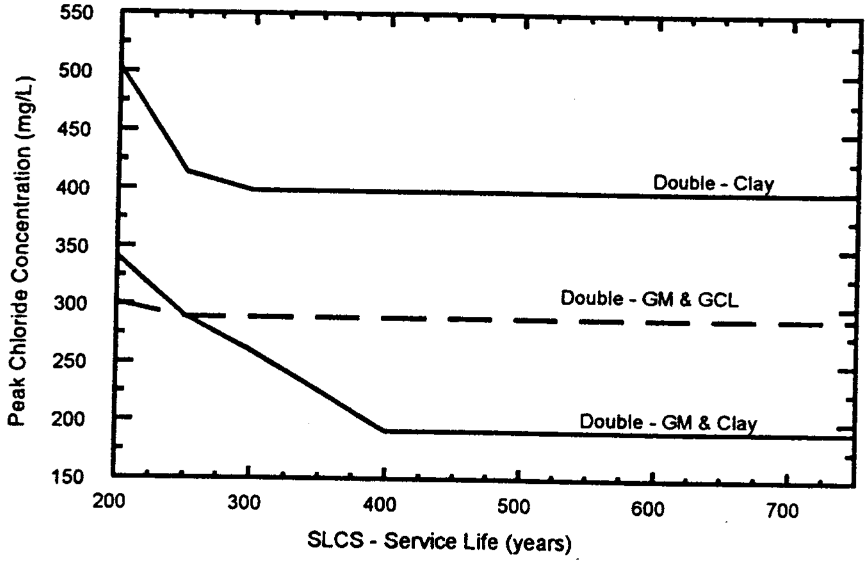

Figure 13. Secondary Leachate Collection System - Chloride.

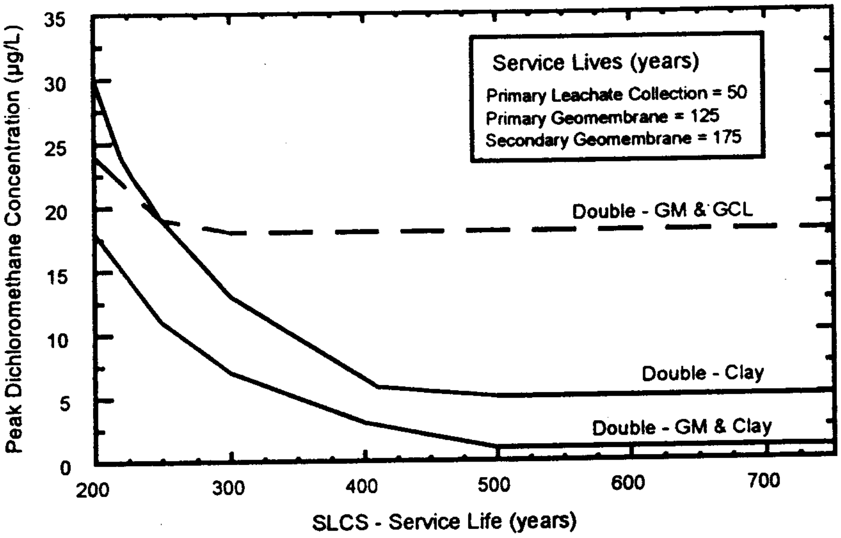

Figure 14. Secondary Leachate Collection System - Dichloromethane.

For chloride all of the barrier designs with double liners show a decrease in peak concentration initially and then reach a limiting peak concentration as the secondary leachate collection system service life increases. This is due to there being a significant contaminant flux through the secondary liner prior to the failure of the secondary leachate collection system for the three designs. The contaminant flux will result in a peak concentration occurring in the aquifer, which for long service lives will occur prior to failure of the secondary leachate collection system. For these long service lives, when the secondary leachate collection system eventually does fail the resulting second peak concentration in the aquifer will be lower in magnitude than the previous peak. For shorter service lives of the secondary leachate collection system there will be an increased peak concentration in the aquifer because additional higher strength contaminant can now escape.

For dichloromethane the peak concentrations for the three barrier designs decrease with increasing service life, and do not reach the limiting peak concentration in the aquifer until longer service lives. This is because of the

Table 3. Infinite Secondary Leachate Collection Service Life

Barrier Design	Chloride (mg/L)	Dichloromethane (μg/L)
Double - Clay	398	5
Double - GM & Clay	191	1
Double - GM & GCL	289	18

STOCHASTIC ANALYSIS

Service lives of engineered components are uncertain and difficult to predict with any degree of accuracy. The rate of clogging of leachate collection systems depends on a number of factors; such as, residency time of leachate, surficial area of collection stone, leachate chemistry, and the type and layout of the piping system. In geomembranes the failure rate due to chain scission will depend on the type of geomembrane, construction methodology, and chemical composition of the leachate (which will likely change with time).

Although it may be difficult to assign a service life to a leachate collection system or geomembrane, it is possible to assign a range of service lives and a most likely value (i.e., minimum, maximum, and mode). Using the minimum, maximum, and mode a triangular distribution can be used for the service life. These distributions for the service life can then be used in Monte Carlo simulation to determine an expected cumulative probability distribution for the peak contaminant concentration in the aquifer. This cumulative distribution can then be used to make predictions regarding the probability of the peak concentration in the aquifer exceeding a given value.

The cumulative probability distribution is calculated using Monte Carlo simulation by performing a series of repetitive calculations of possible values of the peak concentration in the aquifer. Each peak concentration is computed using values for the service lives of the engineered components selected from their respective distributions. The specific values for the service lives for each computation of peak concentration are selected such that over a series of repetitive calculations the values selected will be in the same distribution as that specified (i.e., the triangular distribution).

For each of the six barrier designs Monte Carlo simulations were performed to obtain the cumulative probability distributions of peak chloride and dichloromethane concentrations in the aquifer. In these simulations triangular distributions were assumed for the primary and secondary leachate collection systems (Figure 15). The primary leachate collection system was defined by a triangular distribution with a minimum of 25, a mode of 50, and a maximum of 75 years. When present, the primary geomembrane was assumed to have a service life 75 years longer than the primary leachate collection system, and the secondary geomembrane was assumed to have a service life 50 years longer than the primary geomembrane. The secondary leachate collection system was assumed to have a service life defined by the triangular distribution of 150, 200, and 700 years for the minimum, mode, and maximum respectively. Where the service life of the secondary leachate collection system is equal to the time span selected from its distribution plus the previously selected primary leachate collection system service life (i.e., the distribution for the secondary leachate collection system represents the difference in time between the failure of the primary and secondary leachate collection systems).

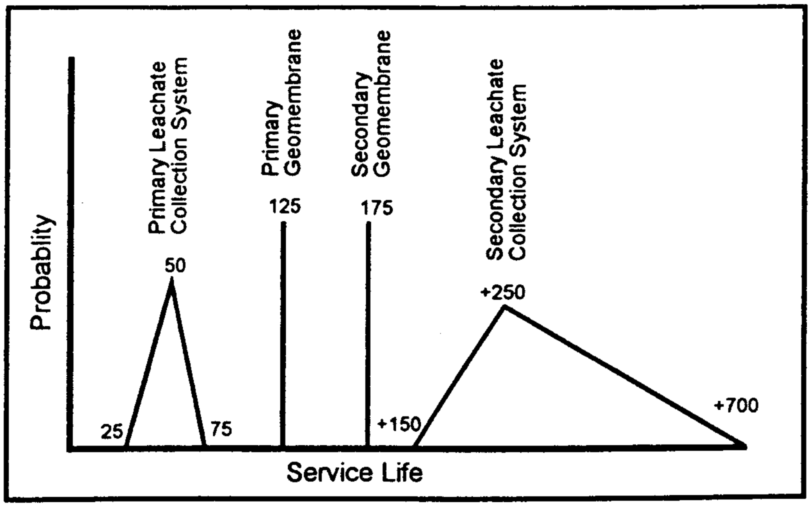

Figure 15. Service Life Distributions.

Using these distributions for service lives of the primary and secondary leachate collection systems, the peak concentration in the aquifer for each barrier was calculated for 5000 simulations (Figures 16 and 17). The cumulative probability curves give the probability that the concentration will be less than a particular value and all have a minimum concentration below which there is negligble probability of occurrence. In general, there is wider range of possible concentrations for barriers with single barriers than double barriers. This indicates that the single barrier systems are more sensitive to the service life of the leachate collection systems than the double barrier systems. When the MOEE 'Reasonable Use' policy is considered for chloride and dichloromethane, it is apparent that all of the single barrier systems would have a 100% probability of exceeding the maximum acceptable chloride and dichloromethane concentrations in the aquifer.

In Figures 18 and 19 only the double barrier system cumulative distributions are shown for chloride and dichloromethane. These cumulative distributions are the same as in Figures 16 and 17 and are for the case where the primary and secondary leachate collection systems have distributions for their service lives, and the service lives of the geomembranes are held fixed.

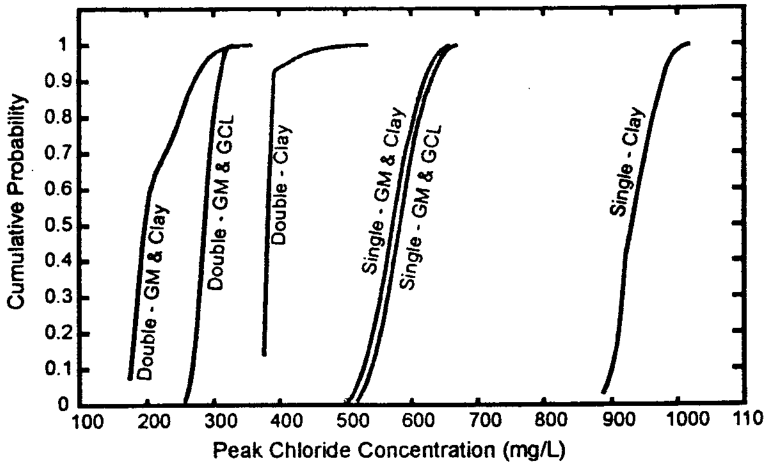

Figure 16. Peak Chloride Cumulative Probability

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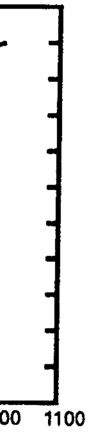

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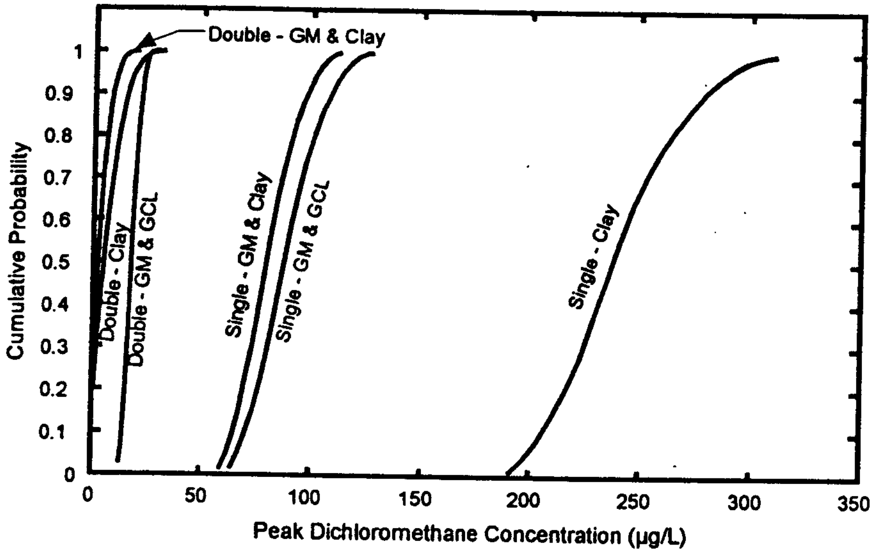

Figure 17. Peak Dichloromethane Cumulative Probability

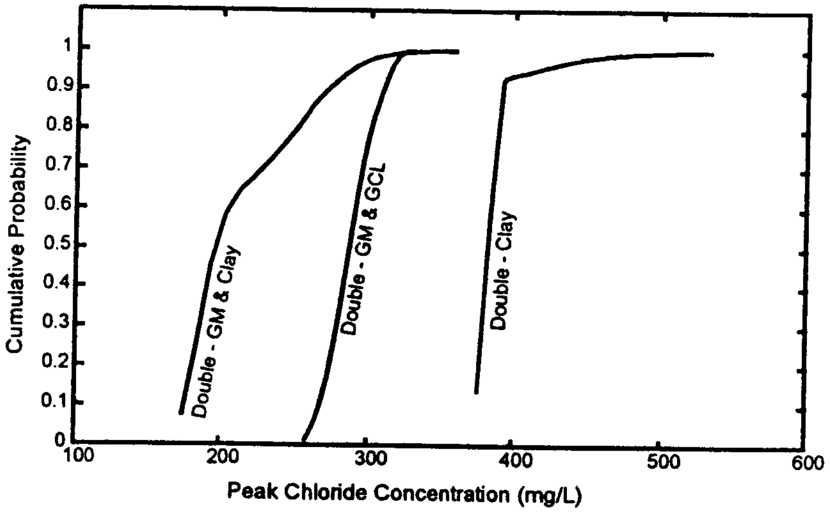

Figure 18. Double Barrier Peak Chloride Cumulative Probability

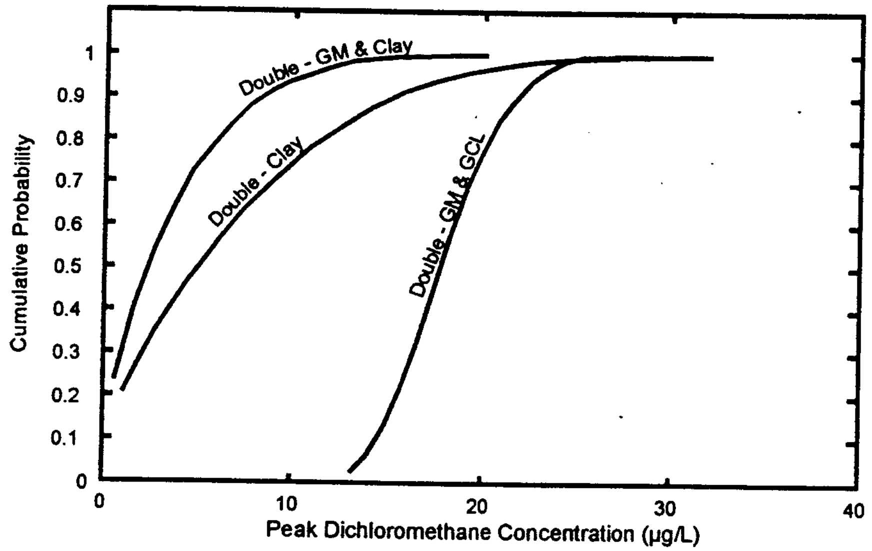

Figure 19. Double Barrier Dichloromethane Peak Cumulative Probability

The chloride cumulative probability of the clay only double barrier shows a very high probability of being 398 mg/L, indicated by the steepness of the curve. This high probability is a result of the peak chloride concentration in the aquifer being reached at times prior to the failure of the secondary leachate collection system, for longer secondary leachate collection system service lives. Thus causing the peak chloride concentration to be independent of the service life of the secondary leachate collection system. At relatively short secondary leachate collection system service lives (below 250 years) the peak concentration in the aquifer can be fairly large, causing the cumulative distribution to level of at higher concentrations. These results correlate well with those obtained when examining the effect of secondary leachate collection system service lives in the previous section (Figure 13). None of the barriers would have acceptable chloride concentrations in the aquifer under the MOEE 'Reasonable Use' policy for drinking water (125 mg/L). However, when compared to the MOEE 'Drinking Water Objective' of 250 mg/L, the double barrier with geomembranes and clay would have a 99.9% probability of having acceptable chloride concentrations in the aquifer.

The peak dichloromethane cumulative distributions show a much higher sensitivity to service life than the chloride distributions. This is due to the peak concentrations in the aquifer occurring much later for dichloromethane than chloride, resulting in a much larger sensitivity to the service life of the secondary leachate collection system. As mentioned previously the peak concentrations occur later for dichloromethane because of its biological decay and adsorption. For dichloromethane both the barriers with clay show a greater degree of sensitivity than the barrier with geomembranes and geosynthetic clay liners. When examined with respect to the MOEE 'Reasonable Use' policy the double barrier with clay has an 80% probability of the peak dichloromethane concentration in the aquifer being below 12 μg/L, and the double barrier with geomembranes and clay has a 98% probability of the peak dichloromethane concentration in the aquifer being below 12 μg/L.

SUMMARY

In assessing the impact of a landfill on the groundwater the contaminating lifespan of the landfill must be considered. The contaminating lifespan of a landfill is defined as the period of time during which the landfill produces contaminants which may have an unacceptable impact if discharged to the environment (MOEE, 1993b; Rowe, 1991a, 1991b). To prevent the levels of contaminants released from a landfill from being unacceptable, the combined engineered systems must have long enough service lives to maintain an adequate barrier during the contaminating lifespan of the landfill.

The service life of the primary leachate collection system has been shown to effect the peak concentrations of contaminants reaching the landfill. At longer service lives of the primary leachate collection system the peak impact on the aquifer is smaller, particularly for barrier design incorporating a single liner of compacted clay only. Peak concentrations in the aquifer are also sensitive to the service life of the primary geomembrane, with longer service lives corresponding to smaller concentrations. This sensitivity is true for both single liner and double liner designs. Service lives of the secondary leachate collection system also affect the peak concentration in the aquifer, however at long service lives this peak may occur prior to failure of the secondary leachate collection system.

Composite barriers which incorporate geomembranes and compacted clay perform better than barriers incorporating geomembranes and geosynthetic clay liners in most situations. Particularly for long service lives of the secondary leachate collection system and where the contaminant species experiences first order (eg. biological) decay. This results from the compacted clay providing a reasonable barrier to contaminant migration even after the geomembrane fails.

Uncertainty in the service lives of the engineered systems can be assessed using Monte Carlo simulation. The results of the simulation can indicate the degree of sensitivity of the contaminant impacts on the service lives of the systems. In the cases examined, the barriers with single liners showed a greater sensitivity to service life of the engineered systems than the barriers with double liners. Monte Carlo simulation can be used to provide a probability of the peak contaminant impact on an aquifer being below a specific value, which can be used in assessing the acceptability of a landfill design.

The service life of an engineered component can be a major factor in assessing the impact of a landfill on the underlying hydrogeology. If the service life is neglected (i.e., assumed to be infinite) in the analysis of contaminant impact, the contaminant concentrations obtained may be non-conservative and misleading. When this service life is considered the relative merits of different barrier designs may change.

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