A PERFORMANCE COMPARISON OF LINERS FOR WASTEWATER LAGOONS

The rehabilitation and expansion of municipal wastewater treatment and storage lagoons usually involves the installation of a low-permeability bottom liner. State regulations on liner performance often specify that a compacted clay liner shall be 12” thick and have a maximum coefficient of hydraulic conductivity (permeability) of 1 x 10^{-7} cm/sec. However, the most meaningful performance parameter for liners is not permeability but leakage. Minimizing the leakage should be the primary design and performance objective for any liner system. State regulation is equivalent to a leakage rate of 500 gallons per acre per day for a 6-foot head. This discussion evaluates three types of liners using leakage as the primary performance criterion.

CALCULATING LEAKAGE

The amount of leakage through soil liners is related to permeability by Darcy's Law and is expressed as a function of:

- Certain intrinsic properties of the soil which allow it to conduct flow, as collectively expressed by its permeability (k)
- The driving force that pushes the liquid through the soil, as expressed by the hydraulic gradient (i)
- The area (A) over which leakage occurs

In other words, Q = k i A, where:

Q = total soil liner leakage
k = permeability of soil liner
i = hydraulic gradient = (head +liner thickness) / liner thickness
A = area of flow.

Using this equation, the predicted leakage through any compacted clay liner can easily be calculated. Calculating the leakage through a geomembrane, however, requires a more complex analysis. It first is important to recognize that geomembrane liners do leak. Although large portions of a geomembrane are essentially impermeable, small holes are present (especially at seams), even in the most rigorously controlled installation. Leakage through these holes can be modeled as flow through an orifice, resulting in localized zones of "infinite" permeability, which can dramatically decrease geomembrane performance.

Giroud (1997) has developed a widely accepted series of equations, based both on theory and field data, which are used to quantify geomembrane leakage through holes. They found that for a 5 mm diameter circular hole in a geomembrane overlying 10^{-4} cm/s soil with a 10 foot (3 m) head would have a leakage rate of 230 gal/day.

Field experience has shown that typical geomembrane holes occur at a frequency of from 1 to 30 per acre, depending on the level of construction quality assurance (CQA) during installation. For this comparison, we will assume very good CQA such that there are only 5 holes per acre of geomembrane. We can now evaluate the performance of various types of liners using the above equations.

LINER EVALUATION EXAMPLE

Assume that a liner is to be installed in a 1-acre lagoon. The average wastewater depth will be 10 feet. If the design goal is to minimize overall leakage, which of the three available lining options (compacted clay, geomembrane overlying soil, or Bentomat® CL/Bentomat CLT/Claymax® 600CL) is superior?

SOLUTION

Appendix A provides details of the calculations and assumptions used to obtain the following leakage rates:

TYPE OF LINER	DESIGN PARAMETERS	LEAKAGE (gal/day)
Compacted Clay	1 ft thick at $k = 10^{-7}$ cm/s	1015
Geomembrane	five 5mm dia. holes; 10^{-4} cm/s soil	1150
Bentomat CL/ Claymax 600CL	0.7 cm thick at $k = 5 \times 10^{-10}$ cm/s	205

Note that these results assume the compacted clay liner was perfectly installed, with absolutely no areas of increased leakage due to the presence of preferential flow paths. This is an unrealistic assumption, because it is well known that clay liners inherently can have tremendous variations in permeability due to stress or desiccation cracking, poor compaction, poor inter-lift bonding, inadequate moisture control, and uneven clay quality. Similarly, it was assumed that the CQA program for the lagoon geomembrane installation was comparable to the rigorous CQA programs implemented for landfill liner installations. Geomembrane CQA for a lagoon installation is seldom this stringent, and the number of undetected holes is likely to be higher than these calculations assumed.

The leakage calculations for Bentomat and Claymax, assumed only nominal performance characteristics and thus represent the actual expected leakage. Comparing this typical 200 gpd leakage rate to the best case compacted clay and geomembrane liner performance scenarios, it is clear that Bentomat CL, Bentomat CLT and Claymax 600CL are the best liners for this wastewater lagoon.

CONCLUSIONS

The high-swelling sodium bentonite provides Bentomat and Claymax not only with an extremely low permeability but also with an exceptionally uniform permeability. Such uniformity is seldom, if ever, achieved with compacted clay liners. The swelling ability of the bentonite also means that small holes, so dramatically damaging the to geomembrane performance, simply cannot be present in Bentomat CL, Bentomat CLT and Claymax 600CL.

In addition to these significant performance advantages, Bentomat CL, Bentomat CLT and Claymax 600CL are far more easily and rapidly installed than either compacted clay liners or geomembranes. The overall cost of Bentomat CL, Bentomat CLT and Claymax 600CL is in many cases much less than the other liners, especially when CQA requirements are considered. Under almost any feasible containment scenario, it is clear that Bentomat CL, Bentomat CLT and Claymax 600CL are the best liners for a wastewater lagoon.

For additional information, contact your local CETCO representative or call CETCO at (800) 527-9948.

REFERENCES

Giroud, J.P., "Rate of Liquid Migration Through Defects in a Geomembrane Placed on a Semi-Permeable Medium," Geosynthetics International, IFAI, St. Paul, MN, 1997, Vol.4, Nos.3-4.

Giroud, J.P., “Geosynthetic Lining Systems for Landfills” (Seminar Literature), Presented at Geosynthetics ’91 Conference, Feb. 1991, Atlanta, Georgia.

APPENDIX A

LINER LEAKAGE CALCULATIONS

Leakage Through Clay Liner

Clay liner is 1 foot thick with a uniform permeability of 1×10^{-7} cm/sec. Then,

Q = k i A, where

Q = total liner leakage in gal/day
k = 1×10^{-7} cm/sec
i = (hydraulic head + liner thickness)/liner thickness = (10 + 1)/1 = 11
A = 1 acre
9.225×10^{8} = conversion factor from cm/sec to gal/acre-day

Q = $(1 \times 10^{-7})(11)(1)(9.225 \times 10^{8})$ = **1,015 gal/acre/day**

Leakage Through BentomatCL/Bentomat CLT/Claymax 600CL

The hydrated thickness of the GCL is typically 0.7 cm (0.023 ft), with a permeability of 5×10^{-10} cm/sec under these conditions. Then,

Q = k i A, where

Q = total liner leakage in gal/day
k = 5×10^{-10} cm/sec
i = (hydraulic head + liner thickness)/liner thickness = (10 + 0.023)/0.023 = 440
A = 1 acre
9.225×10^{8} = conversion factor from cm/sec to gal/acre-day

Q = $(5 \times 10^{-10})(440)(1)(9.225 \times 10^{8})$ = **205 gal/acre/day**

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APPENDIX A (continued) LINER LEAKAGE CALCULATIONS

Leakage Through Geomembrane

Applying the method of Giroud (1997), it is assumed that the geomembrane holes are approximately circular in shape and are an average of 5 mm in diameter. It is also assumed that the layer of subsoil upon which the geomembrane is placed has an average permeability of 1 x 10^{-4} cm/sec (1 x 10^{-6} m/s) and is relatively thick. It is lastly assumed that there is "good" contact between the geomembrane and the underlying soil. Then, Figure 5 from Giroud yields a liquid migration rate of 10^{-5} m^3/s.

number of geomembrane holes = 5 per acre
2.283 x 10^7 = conversion factor from m^3/sec to gal/day

Q = (1 x 10^{-5} m^3/s)(5) (2.3 x 10^7) = **1,150 gal/acre/day**

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