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Project Summary

Leachate Clogging Assessment of Geotextile and Soil Landfill Filters

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This project focused on the performance, design, testing, and recommendations for filters used for leachate collection drainage systems at the base of landfills, waste piles, and other solid waste facilities. The emphasis of the project was on geotextiles because of their manufactured uniformity, ease of placement, and savings in landfill volume; natural sand soil filters were also evaluated. Field exhuming of four sites indicated that problems existed at three of them. These three sites employed "socked pipe," where a geotextile was wrapped around perforated pipe. The testing and subsequent design showed that socked pipe designs should not be used in landfills nor should permitting agencies allow them this application. At the fourth site where the geotextile was moved away from the pipe, in a trench-wrap configuration performance was acceptable. Even further, the laboratory testing portion of the study indicated that an open geotextile over the entire base of the landfill (the footprint) is the proper design strategy and, thus, is recommended for general use. The introduction of a term called the "drainage correction factor" (DCF), in the standard design equation was recommended. This DCF was used to assess the various design options, and the results corroborated findings at the exhumed field sites. Other related investigations included the "no-filter" design strategy (which can be used only with extreme caution and when accompanied by long-term testing) and the use of biocides (which is not recommended).

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The proper collection, transmission, and removal of leachate from the base of solid waste landfills is at the heart of a proper liquids management strategy. Although many design issues are involved, excessive system clogging is an often-raised concern. Since most leachate collection and removal systems consist of a filter, a drainage material, and a perforated pipe system, focusing on the material with the smallest void spaces, i.e., the filter, is logical.

Historically, leachate collection and removal system filters have been granular soils, primarily sands. These have recently been replaced in large measure by geotextiles because of the quality control of manufactured geotextiles, their ease of placement, and the subsequent savings in landfill volume. This project focused primarily on geotextile filters insofar as the potential for excessive clogging by leachate was concerned. Sand filters were also evaluated for comparative purposes. The project consisted of a number of separate tasks brought together in a recommended design methodology for determining a factor-of-safety value for a specific candidate filter and a set of site specific conditions.

Task 1 - Exhuming of Field Sites

The first task was arguably the most difficult and also the most rewarding of the entire project. Field sites-of-opportunity were solicited for the purpose of exhuming their respective leachate collection and removal systems. Obviously, the overlying solid waste had to be removed before the collection system could be investigated. Although only four sites were obtained, they were very significant. Table 1 gives some of the physical details and observations of the sites, and Table 2 gives the leachate characteristics at the time of exhuming. Note that the leachate removal system at Sites 1, 3, and 4 were not functioning because their filters were excessively clogged. Site 2 was still functioning; however, flow rates were less than the designer/operator had anticipated. Comments and conclusions about these exhumed sites include:

- All sites had relatively harsh leachates high in total solids (TS) and/or biochemical oxygen demand (BOD_5).
- The exhumed sites that were excessively clogged had geotextiles wrapped directly around perforated drainage pipes (socked pipes).
- Obviously, this practice of socked pipe should not be used for leachate collection systems.
- In the still-functioning site, a geotextile was wrapped around gravel that in turn, contained a perforated drainage pipe.
- These observations led to the suggested optimum design: using a filter over the landfills's footprint and as far away from the leachate removal pipe network as possible.
- This suggested design had to be corroborated by laboratory tests, analytic modeling, and appropriate design modeling. The remainder of the project focused on those specific tasks.

Task 2 - Laboratory Investigations

To determine the long-term allowable permeability (k_{allow}) of a particular filter (geotextile or sand), an new test method was proposed, carried through the necessary committees, and eventually adopted by the American Society of Testing and Materials. Its designation is ASTM D1987, and it is specifically intended to determine the leachate permeability of geotextile and soil landfill filters. In the course of this project, 144 permeameters (Figure 1) were constructed and used for periods of 120 to 300 days. The experimental variations consisted of:

- 12 filters (10 geotextile and 2 sands)
- 4 permeants (water and 3 leachates)
- 3 flow rates (all significantly greater than typical field flow rates)

The use of flow rates greater than field flow rates constituted accelerated testing with respect to the amount of leachate passing through the filters. A typical response curve for a single flow rate is shown in Figure 2. When the equilibrium value was determined, it was used with the same type of filter at different flow rates to establish a trend. Results of accelerated tests at all three flow rates were plotted and can be back-extrapolated to field anticipated flow rates. These trends for the 12 evaluated filters are given in Figure 3. These curves represent a set of master curves of commercially available filter materials for which k_{allow} can be taken at a particular site specific value of field anticipated flow rate.

Table 1. *Overview of Exhumed Leachate Collection Systems*

Site No	*Waste Type*	*Age Exhuming*	*Liquid Management Scheme*	*Performance Exhuming*	*Critical Element in Drainage System*
1.	*Domestic and light industrial*	*10*	*Leachate recycling*	*Excessively clogged*	*Geotextile filter*
2.	*Domestic and light industrial*	*6*	*Leachate recycling*	*Marginally clogged*	*Drain location*
3.	*Industrial solids and sludge*	*0.5*	*Leachate withdrawal*	*Excessively clogged*	*Geotextile filter*
4.	*Domestic and rural*	*6*	*Leachate recycling*	*Excessively clogged*	*Geotextile filter*

Task 3 - Analytic Modeling

To counterpoint the allowable permeability of a given filter (as just described) to a required permeability, a suitable analytic model is needed. This model must be site specific for hydrology, waste type, geometry, material properties, etc. For this purpose, the EPA-sponsored model entitled Hydrologic Evaluation of Landfill Performance (HELP) is regularly used in the United States and its use is becoming common throughout the world. The HELP model is a liquids balance model that tracks the moisture in the waste and augments it with the site-specific rainfall and snowmelt. This total amount is then partitioned via a number of subroutines into runoff, interception, transpiration, evaporation, and infiltration. The infiltration is then tracked through the various layers until it meets the leachate collection and removal system at the base of the landfill.

The value of required permeability (k_{reqd}) was obtained by sequentially varying a series of trial permeabilities from 1.0 to 1 x 10^{-8} cm/sec while tracking the peak daily discharge output of the model. A site specific value for k_{reqd} was then defined as the point at which the peak daily discharge was negatively influenced by changes in the trial permeability of the filter. In effect, when the permeability of the trial filter began to significantly decrease the amount of leachate discharged, the value of k_{reqd} was reached. Version 3 of the HELP model was used to develop the k_{reqd} values of Table 3, which were based on the characteristics of the four sites.

Task 4 Design Method and Substantiation

Having values of "k_{allow}" for a particular filter and the HELP-generated "k_{reqd}" value for a particular landfill site allows for the formulation of a factor-of-safety (FS) against excessive filter clogging. A direct comparison was not possible, however, because of observations made at the field exhumed sites. For a filter with only a small drainage area directly beneath it, as in the case of socked pipe, the classical FS equation had to be modified. This was done by using a "drainage correction factor (DCS) in the denominator of the conventional FS equation. The DCF is defined as the ratio of the landfill area divided by the available drainage flow area immediately downstream of the filter. (In the case

Table 2. Summary of the Leachate Characteristics of the Exhumed Field Sites

Site No.	Landfill Type	pH	COD (mg/l)	TS (mg/l)	BOD_5 (mg/l)
1.	Municipal	10	31,000	28,000	27,000
2.	Municipal	6	10,000	3,000	7,500
3.	Municipal	0.5	3,000	12,000	1,000
4.	Municipal	6	24,000	9,000	11,000

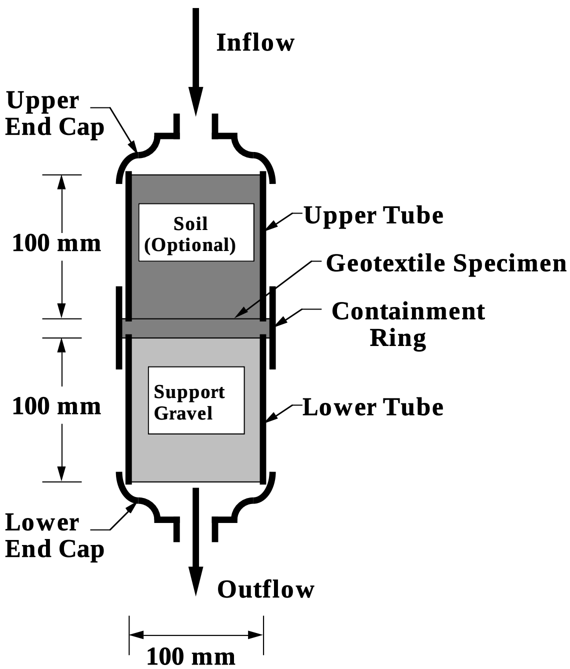

Figure 1. *ASTM D1987 type permeameters.*

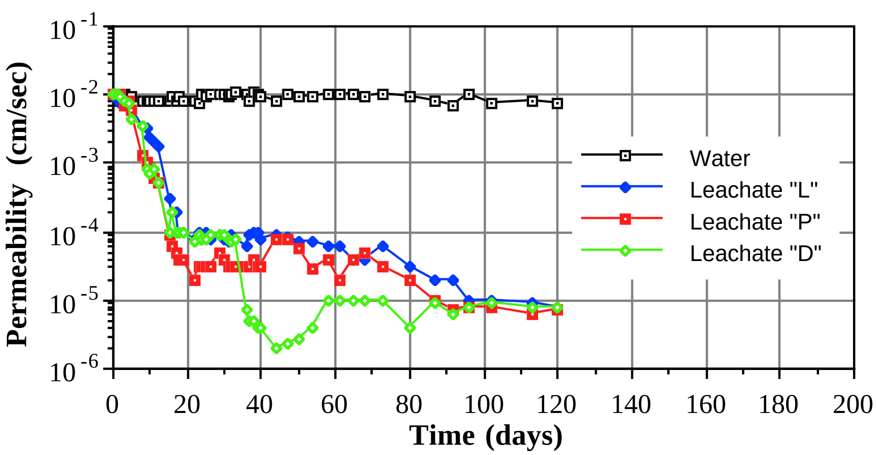

Figure 2. *Typical permeability test results for a particular geotextile filter.*

of socked pipe, its value is very large). The resulting formulation was as follows:

$$FS = \frac{k_{allow}}{k_{reqd} \times DCF}$$

where:

FS	=	*factor-of-safety (against excessive filter clogging)*
k_{allow}	=	*allowable filter permeability*
k_{reqd}	=	*required filter permeability*
DCF	=	*drainage correction factor*

With the use of k_{allow} value for the geotextile exhumed at each of the four field sites, the k_{reqd} value for each of the field sites from the HELP model, and the calculated site specific DCF, we obtained the data of Table 4. Here it can be seen that the three sites with excessively clogged geotextiles could easily have been predicted as failures based on their extremely low FS values.

Possible Less Expensive Alternative

Because the suggested laboratory work and design modeling are both time consuming and expensive, we explored conditions in which a "default" geotextile could be used as the filter. We concluded that if the leachate was relatively mild, i.e., TS < 2500 mg/L and BOD_5 < 2500 mg/L, geotextiles with the properties shown in Table 6 could be used with a reasonable degree of confidence. The proviso, however, is that the geotextile must cover the full footprint of the landfill or cell under consideration. In the context of this study, this type of design is defined as an aerial filter with a drainage correction factor of one, i.e., DCF = 1.0.

Additional aspects of the study investigated the use of biocides (which were not particularly encouraging) and the "no filter" design scenario (which places emphasis on potential clogging of the downstream drainage stone). Both of these design strategies can be evaluated by the laboratory test methods and design formulation developed in this study.

If the leachate has higher values than 2500 mg/L for TS and for BOD_5, the procedure and details given for Tasks 1 through 4 should be followed. The laboratory test data and the requisite design may permit less conservative filters than those described in Table 6. Properly designed they are acceptable.

The values of strength listed in the above table are required Class 2 and Class 1 values per the proposed AASHTO M288 specification for transportation facilities in the high and very high survivability ratings, respectively [15].

Conclusions

This project, which focused on the filters of landfill leachate collection and removal systems, resulted in a design methodology to predict the anticipated FS against excessive filter clogging. It evaluated laboratory and analytic models, along with making observations from field-exhumed sites. The use of the design model nicely substantiated the field findings. Use of the modified FS equation is recommended for design of leachate collection filters to assess the possibility of excessive clogging at the base of solid waste landfills, waste piles, and other solid waste facilities.

The full report was submitted in fulfillment of CR-819371 by Drexel University under the sponsorship of the U.S. Environmental Protection Agency.

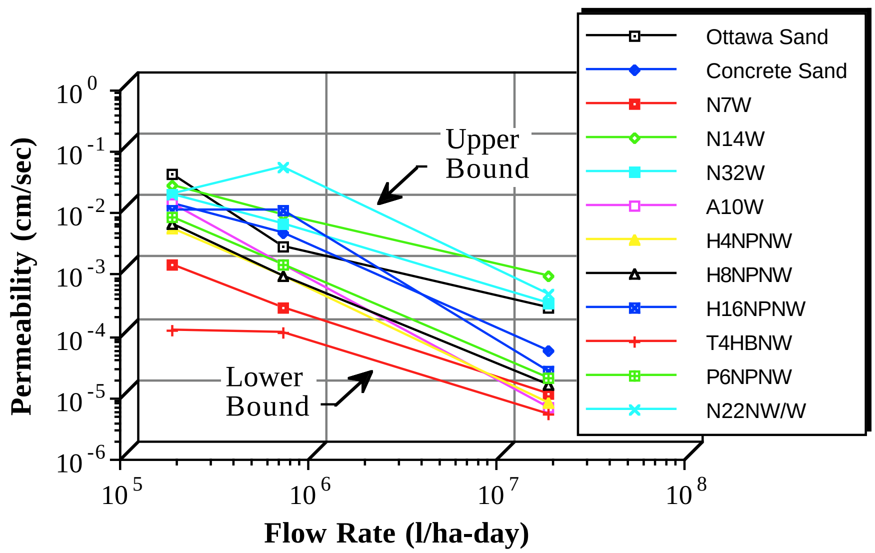

Figure 3. *Master curve of 12 filters for "k_{allow}" determination at a Site specific flow rate.*

Table 3. *Input Data of Exhumed Sites for Use in HELP Model to Obtain Required Filter Permeability*

Site No.	*Cell Area (ha)*	*Base Slope (acre)*	*Pipe Spacing (0%)*	*$K_{drainage\ Stone}$ (m)*	*k_{reqd} (ft)*	*(cm/sec)*	*(cm/sec)*
1.	*2.8*	*7*	*1.5*	*61*	*200*	*0.01*	*1×10^{-5}*
2.	*2.8*	*7*	*1.5*	*61*	*200*	*0.3*	*1×10^{-5}*
3.	*2.9*	*2.9*	*2.0*	*61*	*200*	*0.3*	*5×10^{-5}*
4.	*5.6*	*13.8*	*1.5*	*31*	*100*	*0.3*	*1×10^{-5}*

Table 4. *Corroboration of the Modified Factor-of-Safety Equation as Applied to Four Exhumed Field Sites*

Site	*Observed Performance*	*kallow (cm/s)*	*kreqd (cm/s)*	*Value of DCF*	*Calculated FS Value*	*Predicted Performance*
1.	*Terrible*	*6×10^{-4}*	*1×10^{-5}*	*24,000*	*0.0003*	*Failure*
2.	*Good*	*1×10^{-2}*	*1×10^{-5}*	*140*	*7.1*	*Acceptable*
3.	*Terrible*	*9×10^{-3}*	*1×10^{-5}*	*990*	*0.18*	*Failure*
4.	*Poor*	*9×10^{-3}*	*1×10^{-5}*	*1,700*	*0.53*	*Failure*

The variable term that greatly decreased the FS values was the DCF (Table 4). As seen in Table 5, for a number of design scenarios, the value of DCF can be enormous.

*Table 5. Selected Values of Drainage Correction Factors for Use in Calculating the Factor-of-Safety of a Leachate Collection Filter**

Drain Configuration	Drain Spacing		Drain Size		Hole Size		Number of Holes		Drain Correction Factor
	(m)	(ft)	(mm)	(in.)	(mm)	(in.)	(per m)	(per ft)	
Areal coverage	n/a+	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1
Geotextile	15	50	450x300	18x12	n/a	n/a	n/a	n/a	10
wrapped around	30	100	450x300	18x12	n/a	n/a	n/a	n/a	20
gravel (i.e., socked	45	150	450x300	18x12	n/a	n/a	n/a	n/a	30
trench wrap)	60	200	450x300	18x12	n/a	n/a	n/a	n/a	40
Geotextile around	15	50	150	6.0	n/a	n/a	n/a	n/a	60
corrugated pipe (i.e.,	30	100	150	6.0	n/a	n/a	n/a	n/a	130
socked	45	150	150	6.0	n/a	n/a	n/a	n/a	190
piped)	60	200	150	6.0	n/a	n/a	n/a	n/a	260
Geotextile around	15	50	150	6.0	12	0.5	1.8	6	7,500
smooth wass	30	100	150	6.0	12	0.5	1.8	6	12,000
pipe (i.e., socked	45	150	150	6.0	12	0.5	1.8	6	18,000
pipe)	60	200	150	6.0	12	0.5	1.8	6	24,000

+n/a = Not applicable.
**All calculations are based on a 0.4 (1 acre) cell.*

Table 6. Recommended Geotextile Filters for Use with Relatively Mild Landfill Leachates (Those Having TSS and BOD_5 Values < 2500 mg/L)

Type of Geotextile	Sand Protection Layer Over Filter		Select Waste Placed Directly on Filter	
Woven Monofilament Mass per unit area, g/sq. M (oz/sq yd)	170	(5.0	200	(6.0)
Percent open area, %	10	----	10	0000
Grab tensile strength, N (lb)*	1100	(250)	1400	(300)
Trapezoidal tear strength, N (lb)	400	(90)	490	(110)
Puncture strength, N (lb)	400	(90)	490	(110)
Burst strength, kPa (lb/sq in.)	1800	(400)	2200	(500)
Nonwoven Needle Punched Mass per unit area, g/sq. M (oz/sq yd)	270	(8.0)	400	(12.0)
Apparent opening size, mm (sieve size)	0.212	(#70)	0.212	(#70)
Grab tensile strength, N (lb)	1100	(250)	1400	(310)
Trapezoidal tear strength,N (lb)	400	(90)	490	(110)
Puncture strength, N (lb)	400	(90)	490	(110)
Burst strength, kPa (lb/sq in.)	1800	(400)	2200	(500)

**N=Newton*

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Robert E. Landreth *is the EPA Project Officer (see below).*
The complete report, entitled "Leachate Clogging Assessment of Geotextile and Soil Landfill Filters," (Order No. PB95-265542; Cost: $27.00, subject to change) will be available only from:
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