

Determining the Long-Term Transmissivity of Selected Drainage Geocomposites to Landfill Leachate

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Abstract

In the design and construction of landfill leachate collection and detection systems, it is important to maintain adequate drainage in order to minimize the hydraulic head on both primary and secondary liner systems. This is reflected in minimizing the leakage through the liner system. The situation is heightened when wet (also called bioreactor) landfilling is practiced in order to have rapid degradation of the organics as opposed to traditional dry landfilling. Concern has been expressed over such aggressive liquid management practices in bioreactor landfilling in regard to the long term clogging of geocomposites in either the leachate collection or leak detection systems of double lined municipal solid waste (MSW) landfills. In order to evaluate different geocomposite drainage systems we tested several per the GRI-GC1 Standard, "Test Method for Soil-Filter Core Combined Flow Test". These experiments were conducted for three years in a field laboratory at a major MSW landfill in the U.S.A. The investigation was conducted until system permeability reached equilibrium. It was found that the tubular geocomposite performed well over time. Good performance was predicated on proper geotextile filter selection with this particular leachate and set of environmental conditions. Conclusions and recommendations as to various possible drainage geocomposites and their behavior are presented.

INTRODUCTION

Stemming from U.S. EPA landfill regulations beginning in the 1980's, that is, Resource Conservation and Recovery Act (RCRA) Subtitle C for hazardous solid waste and RCRA Subtitle D for municipal solid waste, a leachate collection and removal system (LCRS) is necessary so as to collect the downward flowing leachate and remove it for proper off-site disposal. This LCRS is to be designed such that no more than 300 mm of liquid head is acting on the underlying liner system. Of course, the objective is to limit leakage out of, and away from, the landfill. Even further, default regulations call for a hydraulic conductivity of the collection soil to be a minimum of 0.01 cm/sec. This is comparable to medium sized sand, e.g., a SW classification, although permeability testing is required to verify the precise value.

While many types of geocomposite drainage systems (geonets, geospacers, etc.) have been used as technically equivalent to such soil, or to augment a lower permeability soil, the numeric value of permeability has remained constant. Even further, this same value has been required in fifty-two countries worldwide; Koerner and Koerner (2007).

A fundamental change in liquid management practices occurred during the subsequent 15-years which culminated in a U.S. EPA landfill bioreactor conference in 1995 and a book on the same topic by Reinhart and Townsend (1998). The practice of bioreactor (or wet) landfilling purposely injects leachate into the landfill and possibly adds additional liquids so as to reach field capacity moisture content of the organics in the waste mass. There are several categories of wet landfilling in this regard:

- leachate recirculation,
- anaerobic bioreactor,
- hybrid bioreactor, and
- aerobic bioreactor.

To greatly varying degrees one can anticipate high sediment and/or microorganism laden leachate when practicing bioreactor, or wet, landfilling. Such leachates have been shown in the field Bass (1984) and the laboratory G. Koerner (1993) to be problematic insofar as excessive clogging (sands and geotextiles) is concerned. In this regard, G. Koerner (1993) has found that when leachate has greater than 2500 mg/l of suspended solids and/or 2500 mg/l BODm clogging becomes problematic.

FIELD EXPERIMENTS AND FIELD EXHUMING

With the cooperation of a local (MSW) landfill owner, a shed was constructed adjacent to leachate storage tanks as shown in Figure 1. The individual flow boxes per GRI-GC-1 are in the shed. They are as follows:

- 150 sand/woven geotextile filter with drain tube;
- 150 sand/nonwoven geotextile filter with drain tube;
- 150 sand/needle punched nonwoven geotextile filter with biaxial geonet; and
- 150 sand/heat bonded nonwoven geotextile filter with biaxial geonet.

The field setup is shown in Figures 1 through 3.

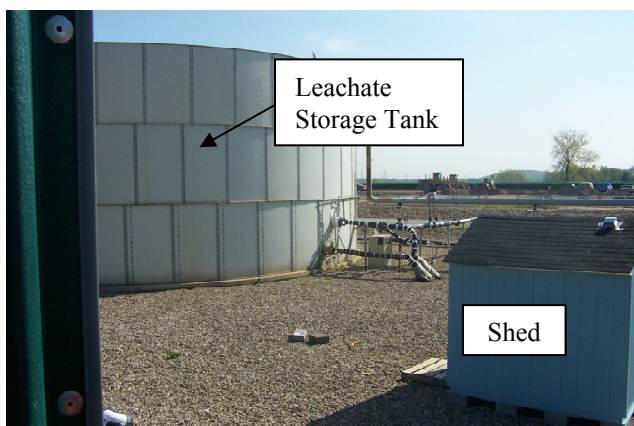


Figure 1. Field shed containing test columns.



Figure 2. Overview of field lab.

Each flow box is permeated with leachate taken from the site's leachate storage tank on a weekly basis. These are constant head tests permeated with 300 mm of leachate head. The flow columns are housed in heated drums of leachate so as to maintain anaerobic conditions. The project has been ongoing for three years.



Figure 3. GRI-GC1 flow boxes.

MATERIALS USED FOR TESTING

Four geotextiles were used in this study with significantly different properties. One is a nonwoven heat bonded geotextile over a biaxial geonet. It is made of polypropylene, continuous filament and is the tightest (smallest pore size opening) of any of the filters used in the study. The second geotextile is a needle punched nonwoven fabric made of polypropylene with staple fibers over a biaxial geonet drain. The third geotextile was a woven monofilament made of polypropylene with tubes embedded within it. The fourth is a needle punched nonwoven with tubes embedded in it. The materials are shown in Figure 4 along with the various test property results of the geotextiles in Table 1. The corrugated pipe is 25 mm in diameter and the biaxial geonet is 6.4 mm thick. Both have a transmissivity of $1.5 \times 10^{-3} \text{ m}^2/\text{sec}$ at a gradient of 0.1 and a normal pressure of 100 kPa.



(a) Tubular system.



(b) Biaxial geonet.

Figure 4. Photographs of selected materials used in the experiments.

Table 1. Test results of geotextile properties used in this study.

Property	Test Method	Units	Nonwoven Heat Bonded Over Geonet	Nonwoven Needle Punched Over Geonet	Woven Geotextile with Tube	Nonwoven Needle Punched with Tube
Abbreviation	---	---	NWHB w GN	NWNP w GN	WM w Tube	NWNP w Tube
Mass per Unit Area	ASTM D5261	g/m ²	141	240	208	245
Thickness	ASTM D5199	mm	0.47	1.0	0.69	1.2
Apparent Opening Size	ASTM D4751	mm	0.20	0.31	0.43	0.36
Permittivity	ASTM D4491	sec ⁻¹	0.31	0.70	1.5	0.90
CRB Puncture Strength	ASTM D6241	kN	1.82	1.61	3.35	1.71

The sand soil used over the drainage geocomposites for this study was a well graded concrete sand classified by the United Soil Classification System (USCS) as “SW”. It had very few fines and 100% was retained on the #4 sieve. A combined (sieve/hydrometer) grain size analysis for the soil is shown graphically in Figure 5 and in tabular form in Table 2.

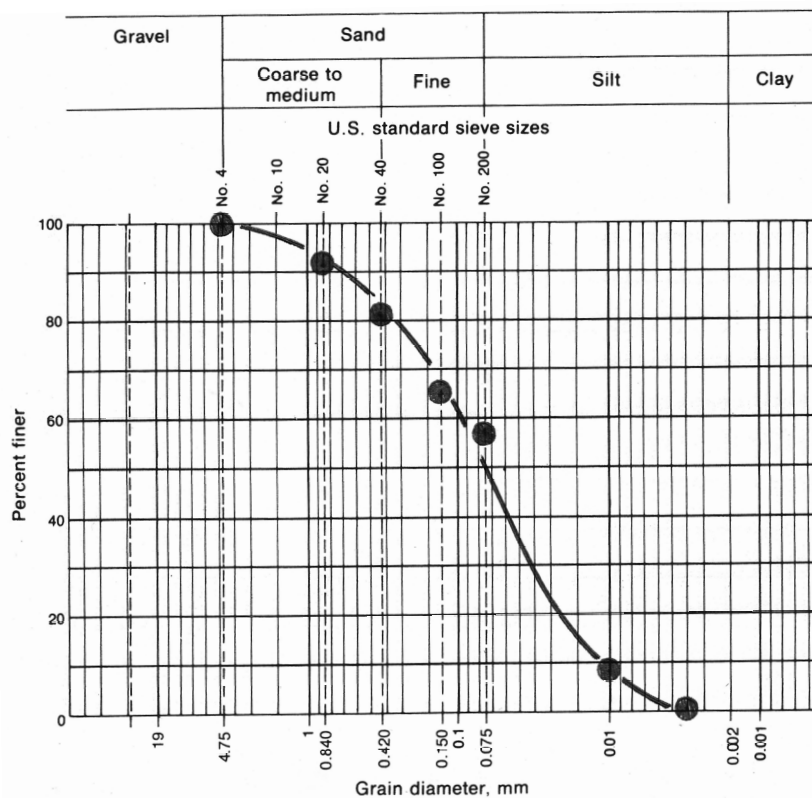


Figure 5. Combined grain size analysis of sand used in the experiment.

Table 2. Test results of soil properties used in this study.

Property	Test Method	Units	Soil Properties
USCS Classification	NA	NA	SW
Coefficient of Uniformity (CU)	ASTM D421 & D422	NA	6
Coefficient of Concavity (CC)	ASTM D421 & D422	NA	2
Percent passing #200 sieve	ASTM D422	percent	4
Permeability	ASTM D2434	cm/sec	0.0013
Plasticity Index	ASTM D4318	NA	3

TEST PROCEDURE

The test procedure used in this study is GRI-GC1 Test Method for “Soil-Filter Core Combined Flow Test.” Figure 6 shows the test setup while Figures 7 and 8 shows schematics of the key components of the apparatus and the flow box, respectively. The experiments were run for three years with a MSW leachate from a Subtitle D landfill.



Figure 6. Photo of a single flow box unit.

The leachate had an average BOD₅ of 10,000 mg/l and a total solids content of 5,000 mg/l. The governing equation for this equipment is simple flow rate as expressed in equation 1.

$$q = Q/t \quad (1)$$

where q = flow rate (liter/min), Q = total flow (liter) and t = elapsed time (min). It should be noted that the resulting combined flow rates (geotextile filter and drainage material) are being expressed in the usual units of cc/sec. Each flow box is permeated with leachate on a weekly basis. Each box is permeated under falling head conditions.

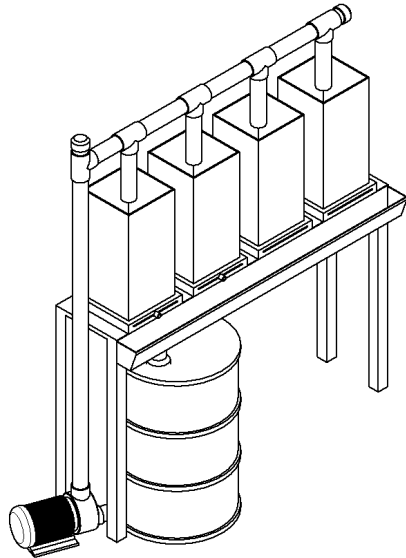


Figure 7. Schematic of all four units.

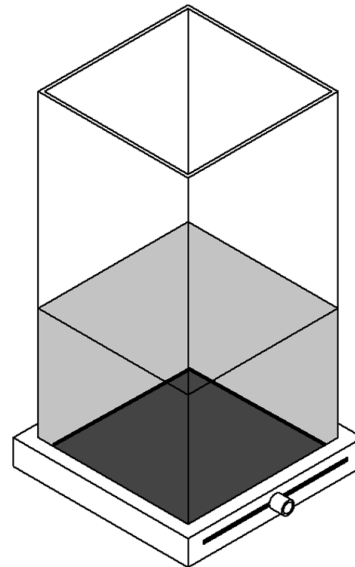


Figure 8. Detail of flow box.

TEST RESULTS

The results for the four experiments are presented in Figure 9. It should be noted that all four flow boxes were exposed to the same conditions over the course of the study. The temperature within the shed ranged from 10 to 55°C. The leachate was replenished with “fresh leachate” from the landfill on a monthly basis. The condition of the flow boxes is believed to be a mix of both aerobic and anaerobic conditions. This particular MSW leachate is very reactive with an average Chemical Oxygen Demand (COD) of 25,000 mg/l, Total Solids (TS) of 10,000 mg/l and a pH of 7.5.

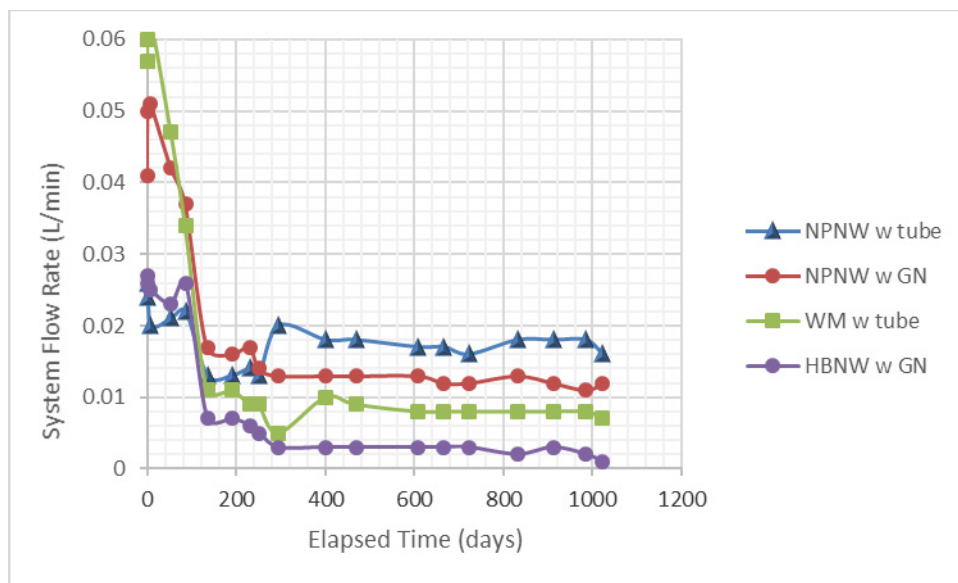


Figure 9. Combined long-term flow curves for the four different geotextiles with two different drainage components.

DISCUSSION

Observing Figure 9 of the previous section it is important to note that the needle punched nonwoven geotextile performed the best when placed over the tubular drainage composite. It is well designed with respect to the concrete sand's gradation to avoid piping and is open enough to resist long term clogging. This is demonstrated by its ability to remain free flowing with leachate as a permeant for over three years of testing. This can be contrasted with the poorest performance being that of the heat bonded geotextile over the biaxial geonet. It should be noted that the two geotextiles over tubes gave similar results to the needle punch nonwoven geotextile over the geonet, which is thought to be the norm for this application. regardless of the drainage media contained therein.

SUMMARY

This experimental study evaluated flow rates through four different drainage media while permeated with leachate over three years. All four systems remain flowing over this time frame but to different extents. It appears that drainage tubing as well as geonet can be used in LCRS for various long-term drainage systems.

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