Statement on the long-term flow rate of tubular drainage geocomposites to landfill leachate

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ABSTRACT

Cost-effective, efficient, and effective leachate collection systems are critical to the operation, maintenance, and regulatory compliance of a well-run landfill. In the design and construction of such systems, it is important to maintain adequate drainage so that the hydraulic head on both primary and secondary liner systems is limited, and the risk for leachate leakage through the liner system is reduced. The situation is heightened when wet (also called bioreactor) landfilling is practiced, where rapid degradation of the organics is promoted as opposed to traditional dry landfilling where the landfill degradation processes are not purposefully enhanced. Concern has been expressed over such aggressive liquid management practices in bioreactor landfilling regarding the long-term clogging of geocomposites in either the leachate collection or leak detection systems of double lined municipal solid waste (MSW) landfills. Geonet drainage geocomposites are commonly used in leachate collection systems and tubular drainage geocomposites (a form of multi-liner drainage geocomposites) offer the advantage, among others, of a better creep resistance under high loads.

This paper presents an update to, and makes final, the comparative drainage geocomposite study presented Steinhauser et al. (2015). It was found that the tubular drainage geocomposites performed well over time. Conclusions and recommendations as to various possible drainage geocomposites and their behavior are presented.

INTRODUCTION

Proper management of leachate within a lined landfill is essential. Solid waste regulations limit the head of leachate that is allowed above a landfill liner system, and the failure to efficiently remove leachate could lead to stability concerns. The current state of the practice is to use a granular material that exhibits a high hydraulic conductivity (e.g., sand, gravel, or fine aggregate), a geosynthetic drainage material that exhibits a high transmissivity, or a combination of both. The selection of the leachate drainage layer materials is based on many considerations including the landfill configuration, climate, and available materials. Often, a combination soil/geosynthetic layer is used, in which the soil layer also serves as the protective layer between the waste and the underlying geomembrane liner. In addition to the hydraulic considerations, landfill designers must also consider protecting the geomembrane liner from puncture of the overlying drainage/protective cover soil under the anticipated load during construction and throughout the life of the landfill.

Because of the regulatory requirement to limit the head of leachate on the geomembrane liner, geosynthetic drainage geocomposites are commonly used. These materials can provide both the desired hydraulic characteristics as well as puncture protection. To date geonet drainage geocomposites (i.e., a geocomposite comprised of a geonet core sandwiched between two nonwoven geotextiles heated bonded to the core) have been used in North America. However, in Europe and Africa more than 10 million square meters of tubular drainage composites (e.g., a perforated, small diameter tube spaced between two nonwoven geotextiles needle-punched together) have been installed since 1992 for gas or liquid drainage in building, roadwork, environmental and mining applications (Figures 1 and 2).

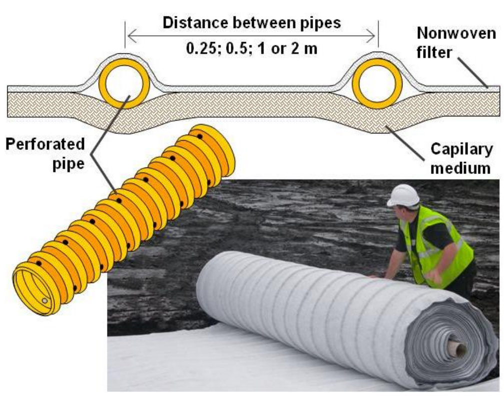

Figure 1 Roll of tubular drainage geocomposite

Figure 2 Leachate drainage at the bottom of landfill

An important characteristic of tubular drainage geocomposites is that they maintain their transmissivity (the volumetric flow rate per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen; see ASTM D4716) under significant normal stresses (Saunier, et. al., 2010) in large part because they do not experience geotextile intrusion into the primary high-flow component. Therefore, for most of the applications, the applied combined reduction factors (intrusion of the geotextile into the drainage core RF_{IN}, creep of the drainage core RF_{CR}, chemical clogging of the drainage core RF_{CC} and biological clogging of the drainage core RF_{BC}) for tubular drainage geocomposite are almost half of those applied to standard geonet geocomposites (Maier, et. al., 2013). Figure 3 present a schematic of a transmissivity testing device. Figure 4 provides transmissivity test results for a tubular drainage geocomposite with four equally spaced, 25-mm diameter pipes per meter width of product.

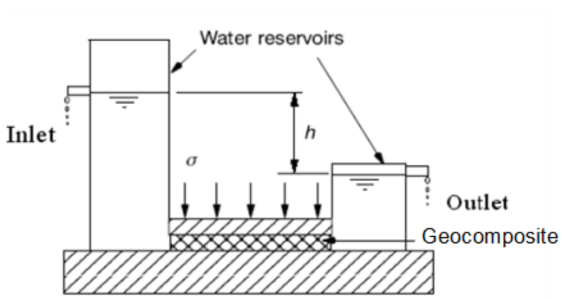

Figure 3 Transmissivity test device

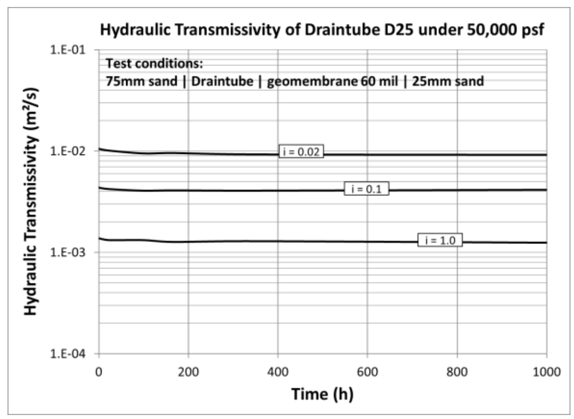

Figure 4 Transmissivity test results for a tubular drainage geocomposite with four, 25-mm diameter pipes per meter width.

The rationale for considering tubular drainage composites in leachate collection layers is based on an evaluation of laboratory testing of different types geocomposite drainage materials, and is presented below.

LABORATORY TESTING

Background

The design of drainage geocomposites for leachate collection layers for lined landfills considers several factors including the capacity of the geocomposite to transmit the liquid and the ability of the geotextile component of the geocomposite to protect the underlying geomembrane from puncture from the overlying granular material. These two functions are related because the mass of the nonwoven geotextile has a direct effect on the hydraulic characteristics of the geocomposite. According to GRI Standard GC8 (Geosynthetic Institute, 2013), the design standard for the liquid conveyance performance of the drainage geocomposite is based on a 100-hour transmissivity test performed in accordance with ASTM D4716.

For design purposes, the results of ASTM D4716 are modified (i.e., reduced) to account for anticipated flow reductions. Recommended reduction factors are presented in GRI Standard GC8 and Part III of GSI White Paper #4 (Geosynthetic Institute, 2007). Because the aforementioned reduction factors do not address the geotextile component (other than its intrusion into the geonet core), reduction of the geotextile component as outlined in Part II of GSI White Paper #4 should also be applied.

Designers must be aware that the hydraulic testing of the drainage geocomposite should be performed using the nonwoven geotextile components selected to protect the underlying geomembrane from puncture due to the overlying granular soil. The procedure to select the required mass of the geotextile component of a drainage geocomposite should follow the steps defined in GSI White Paper #14 (Geosynthetic Institute, 2008), which is based on an extensive testing program. In this procedure, the mass of the geotextile (the presence of the drainage core is not considered) may be calculated from the anticipated loads applied to the geomembrane (reduced by a factor of safety) (i.e., allowable pressure) in consideration of the protrusion height of the granular soil (i.e., portion of the granular soil likely to exert a puncturing effect on the geotextile). In additional, there are several modification and reduction factors that should be applied. The modification factors address the shape, density, and arching characteristics associated with the granular soil. The reduction factors address long-term chemical/biological clogging and long-term creep. GSI White Paper #14 provides recommended modification and reduction factors and specifically indicates conditions (i.e., geotextile mass-protrusion height combinations) that are not recommended.

Hydraulic Testing of Tubular Drainage Geocomposites

It is acknowledged that tubular drainage geocomposites have not yet been used in landfill leachate collection systems in the US; however, these materials are used in leachate collection layers in African and European landfills. (Tubular drainage geocomposites have been used in the US for landfill gas collection and as the drainage layer in final cover systems.) Because of concerns relative to biological and chemical clogging for tubular drainage geocomposites, a testing program to assess the performance of tubular drainage geocomposites under anaerobic conditions (to simulate the atmosphere of a liner system) was developed for two non-hazardous landfills – one in France and the other in Morocco (Blond, 2013 and Riot, 2013, respectfully). For both sites, a tubular drainage geocomposite that included an anti-bacterial nonwoven geotextile (composed of special fibers including silver ions in their formulation as a biocide agent) as the upper layer was evaluated with site-specific leachate.

The apparatus used to test the tubular drainage geocomposite is shown in Figure 5 and an illustration of the apparatus is presented as Figure 6.

To evaluate the clogging potential of both the nonwoven geotextile and perforated pipes of the geocomposite, the following testing conditions were established:

- Constant normal load of 100 kPa on the geocomposite;
- Anaerobic conditions (cells always saturated with leachate);
- Fresh leachate directly pumped from a sump in the cell;
- Temperature maintained above 22°C (72°F);
- Same amount of leachate injected into each cell (about 5.5 m^3 in 18 month, equivalent to a flow of 2 10^{-6} $m^3/s/m^2$ to evacuate); and
- Each configuration was replicated 3 times.

Figure 5 View of the test apparatus

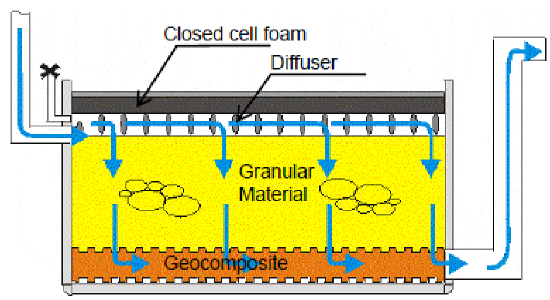

Figure 6 Cross section of a test cell

For comparison, test cells filled with crushed gravel (20 to 40-mm [0.8 to 1.6-inch] diameter) were also included in the test program.

During the 18-month testing program the equivalent hydraulic conductivity of the material (velocity of the water into the cell under an average head of 0.15 m [6 inches]) in each test cell was measured over the time. Figure 7 shows the relative changes in the flow rate of the tubular drainage geocomposite and the gravel layer.

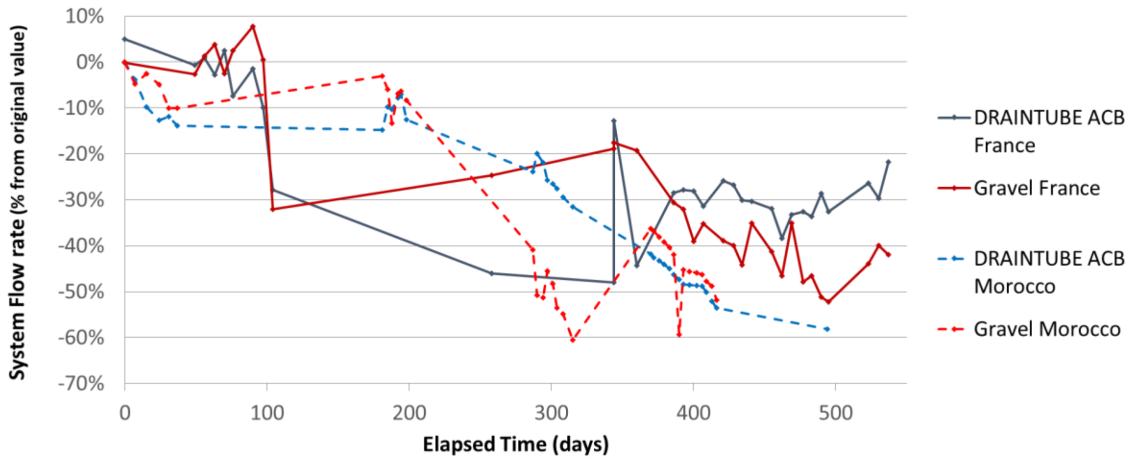

Figure 7 Relative changes in the flow rate for both tubular drainage composite and crushed gravel, results from France and Morocco testing programs

As indicated in Figure 7, neither the geotextile filter nor the tube of the tubular drainage geocomposite appeared to clog during the 18-month test program. For both testing programs, the tubular drainage geocomposite exhibited the same or a better long term hydraulic behavior than the gravel layer. The residual long term flow capacity of the tubular drainage geocomposite is between 70% and 80% for the experiment in France (compared with 50% to 60% for the gravel) and between 40% and 50% for both tubular drainage geocomposite and gravel for the experiment in Morocco. The difference in results between France and Morocco testing programs is attributed to the different nature and organic content in the leachates.

Geosynthetic Research Institute (USA)

With the cooperation of a local (MSW) landfill owner in Pennsylvania, a long-term, comprehensive study to observe changes (if any) in system flow of various drainage geocomposites was performed (Fourmont and Koerner, 2017). The study used a similar testing apparatus to that used in France and Morocco, where the geocomposite is placed at the bottom of the cell under a 150-mm (6-inch) thick layer of sand. For this study, an enclosure (see Figure 8) was constructed adjacent to the landfill leachate storage tanks to protect the flow boxes.

Figure 8 Field shed containing test columns

The flow boxes were constructed in accordance with GRI Test Method GC1 (i.e., Soil-Filter Core Combined Flow Test) (Geosynthetic Institute, 1996). Figures 9 and 10 illustrate the flow box design and setup.

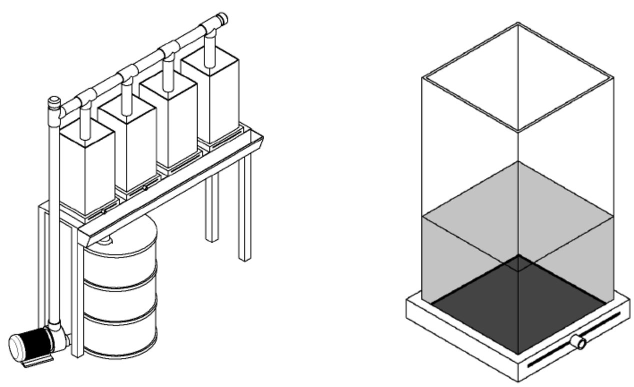

Figure 9 Apparatus and box design

Figure 10 Constructed flow boxes

Each flow box was permeated weekly with leachate taken from the nearby leachate storage tank (Figure 10).

Geocomposites used for testing

Several geocomposites comprised of different geotextile types with significantly different properties were studied. Among them, was a needle punched nonwoven geotextile made of polypropylene with staple fibers over a 6.4-mm (250-mil) thick biaxial geonet. Another was a tubular drainage geocomposite composed of a needle punched nonwoven geotextile with 25 mm (1-inch) diameter mini-tubes tubes embedded in it. The materials are depicted Figure 11, and their test properties for the geotextiles components are provided in Table 1.

(a) Tubular system. (b) Biaxial geonet.

Figure 11 Photographs of selected materials used in the experiments

Table 1 Test results of geotextile properties

Property	Test Method	Units	Nonwoven Needle Punched over Geonet	Nonwoven Needle Punched with Tube
Abbreviation	---	---	NWNP w GN	NWNP w Tube
Mass per Unit Area	ASTM D5261	g/m^2	240	245
Thickness	ASTM D5199	mm	1.0	1.2
Apparent Opening Size	ASTM D4751	mm	0.31	0.36
Permittivity	ASTM D4491	sec^{-1}	0.70	0.90
CRB Puncture Strength	ASTM D6241	kN	1.61	1.71

The sand soil used over the drainage geocomposites for this study was a well graded concrete sand, classified as "SW" according to the United Soil Classification System (USCS) with 100% passing the US #4 sieve and very few fines (i.e., passing the US #200 sieve).

Test protocol

The test protocol followed the GRI GC1 Test Method. The tests were run for three years with leachate obtained from a MSW Subtitle D landfill that was replenished with "fresh leachate" monthly. The leachate had a Chemical Oxygen Demand (COD) of 25,000 mg/l, Total Solids (TS) between 5,000 and 10,000 mg/l, a pH of 7.5, and a Biological Oxygen Demand (BOD5) of 10,000 mg/l. The temperature within the shed ranged from 10 to 55°C (50 to 131°F).

To simulate in-landfill conditions, on a weekly basis, leachate was applied to each flow box so that may permeate the drainage geocomposites under falling head conditions. The falling head within the flow boxes is believed to create a mix of both aerobic and anaerobic conditions. The flow rate through the system was obtained by measuring the time for one liter of leachate to drain (see Figure 12).

Figure 12 Drainage from a flow box

Test results

Test results for the geonet and tubular drainage geocomposites are presented in Figure 13. It should be noted that all boxes were exposed to the same conditions over the course of the study.

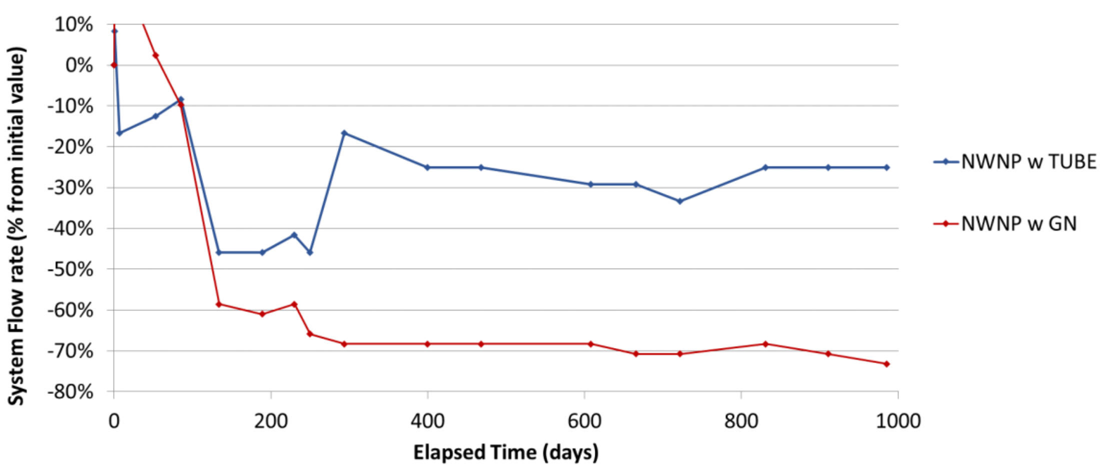

Figure 13 Combined long-term flow curves for the two different geocomposite configurations

After three years of experimentation, the residual long term flow capacity of the tubular drainage geocomposite is about 75% whereas the one for the geonet composite is about 30%.

DESIGN CONSIDERATIONS FOR LEACHATE COLLECTION LAYERS

It appears that tubular drainage geocomposites are acceptable for use in leachate collection systems. Considering that the results of the hydraulic testing on tubular drainage geocomposites do not indicate significant reductions over time when anti-biological geotextile components are used, it is possible to reduce the reduction factor for chemical clogging RF_{CC} and biological clogging RF_{BC} values as they apply to the geotextile. Also, by using tubular drainage geocomposites it is possible to reduce the reduction factors associated to the drainage core (i.e., reduction factor for intrusion of the geotextile in the drainage core RF_{IN}, and reduction factor for creep RF_{CR}). Both reduction factors can be taken equal to 1 (Saunier et al., 2010). From the hydraulic testing performed in France, Morocco and USA, considering both the geotextile and tube components, an overall reduction factor (RF_{IN} x RF_{CR} x RF_{CC} x RF_{BC}) between 1.4 and 2.5 is possible for tubular drainage geocomposites as leachate collection layer. In comparison, using recommendations from GSI White Paper 4 and tests carried out in USA, the overall reduction factor (RF_{IN} x RF_{CR} x RF_{CC} x RF_{BC}) appropriate for use with a geonet geocomposite is 7 and above.

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