

Behaviour of draining geosynthetics for landfill capping systems

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ABSTRACT: Landfill cap systems are composed of layers of different materials, each with a specific function. One of these layers is mainly intended as a drain to prevent rainfall from reaching the waste, thus avoiding excess leachate production. Drainage geocomposite layers are commonly used to replace gravel layers for drainage. This paper describes two investigations made on tubular drainage geocomposites used as drainage layers in two landfill caps in Italy and France. The first test compared the drainage performance (water flow and drainage velocity) of both gravel and a tubular drainage geocomposite in a lined cap at a landfill in Italy. The performance of both methods was comparable. It was also comparable for caps with mild slopes. The second test involved a semi-permeable tubular drainage geocomposite used to allow some water to enter the waste to accelerate degradation and increase LFG production. The infiltration rate through this geocomposite was monitored on a semi-permeable cap in France. After one year, preliminary results show that the rate of infiltration is dependent on the flow capacity of the geocomposite, the angle of the slopes and the amount of rainfall.

Keywords: Drainage, Semi-permeable, Tubular geocomposite, Drainage geocomposite, Caps, Landfill

1 INTRODUCTION

One of the main purposes of a final landfill cap is to minimize the infiltration of precipitation into the waste. The cap is composed of several layers, each with a specific function (waterproofing, drainage, mechanical protection, filtration, etc.) and geosynthetics are widely used to perform one or more of these functions. Depending of the type of the waste and the location of the landfill, the cap may be either impermeable or semi-permeable (to allow some water to pass through the cap into the waste). In all cases, an efficient rainwater drainage layer above the impermeable (or semi permeable) layer is essential to control the water head, avoid excessive infiltration and increase the stability of the overall cap.

In this paper, the efficiency of a tubular drainage geocomposite is observed first, in terms of drainage capacity in a test pad in Italy where it was compared to a 0.50 m thick gravel layer and second in terms of impermeability when monitored in a semi-permeable cap in France that included a semi-permeable tubular drainage geocomposite (see Figure 1).

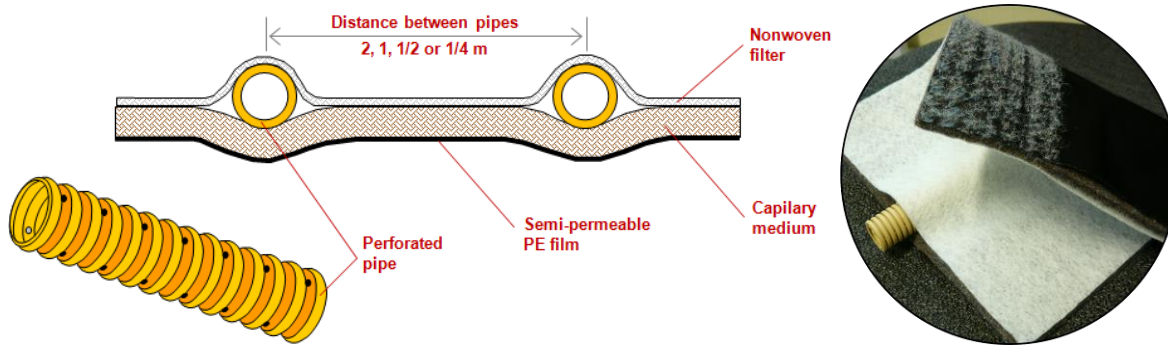


Figure 1. Semi-permeable Draitube drainage geocomposite.

2 BEHAVIOUR OF TUBULAR DRAINAGE GEOCOMPOSITE COMPARED TO A GRAVEL LAYER

Two test pads have been constructed at a landfill site in Italy to compare the behaviour of a tubular drainage geocomposite to a granular layer. The first pad reproduces common cap layers used in Italy while the second replaces the 0.5 m gravel drainage layer with a drainage geocomposite. The pads are identical and rainfall is simulated. At the toe of each slope, a flow meter measures the flow rate and the total volume of water collected. The distance between the perforated pipes of the tubular drainage geocomposite is 1 m.

2.1 Test pad construction

The test pads are 4 m wide and 10 m long, both having a slope angle of 5% (see figure 2). In order to get lateral confinement, a contour with small embankments has been made for each field. A geomembrane was installed at the base in order to provide isolation for vertical drainage towards the base.

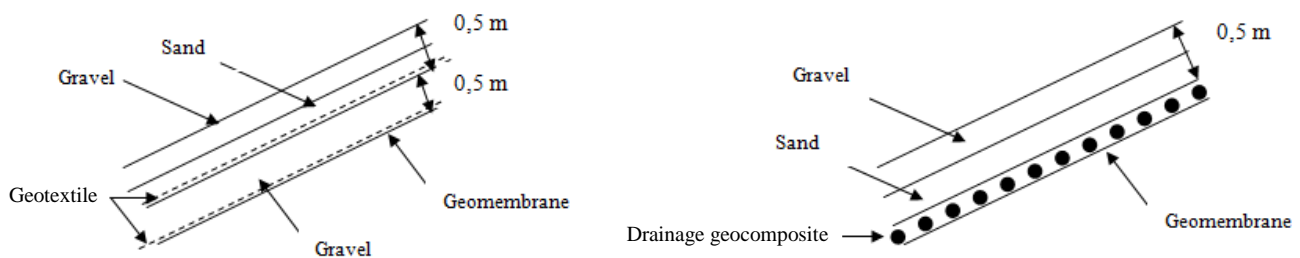


Figure 2. Illustration of the two test pads with gravel as drainage layer and with tubular drainage geocomposite.

The tubular drainage geocomposite was installed to replace the 0.50 m thick gravel layer and two separator geotextiles. The soil cover above the drainage layer is composed of 0.25 m of gravel and 0.25 m of sand, these layers do not take any part in the water evacuation, they let water infiltrates to the drainage layer. The first test was performed with low permeability topsoil but despite continuous irrigation for 6 days, no relevant drained flow was collected. Figures 3 to 7 show the construction phases of the test pads.



Figure 3. Pad graded with a 5% slope.



Figure 4. Geomembrane Installation.



Figure 5. Gravel drainage layer.



Figure 6. Tubular drainage geocomposite.



Figure 7. Sand and gravel cover layer.



Figure 8. Rainfall simulation.

Rainfall was simulated with a removable irrigation system mounted on the testing area and equipped with 6 nozzles for a uniform rain. The rain intensity is approximately 22 l/min, corresponding to an effective rainfall of 33 mm/h (see Figure 8).

At the toe of the test pads, collectors were installed to collect all the flowing water (see Figure 9).



Figure 9. Drained water collection.

2.2 Inputs

The gradation curve of the gravel used for the drainage layer is presented in figure 10. This is a coarse gravel with a uniformity coefficient < 2 .

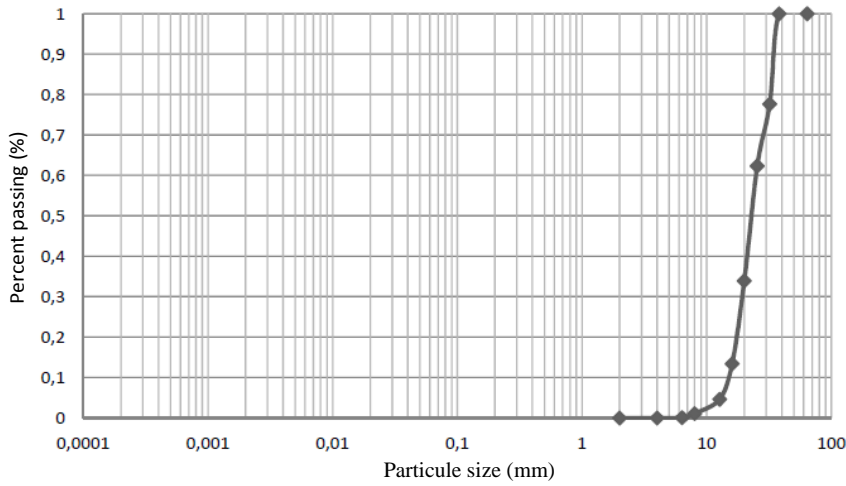


Figure 10. Gradation curve of the gravel drainage layer.

The irrigation system simulates a rainfall of 33 mm/h for 6 hours. Two series of tests were completed. The first, just after the construction of the test pads with dry gravel and sand, the second after a few weeks when the gravel and sand were partially saturated.

During the tests, no runoff was observed. All of the water infiltrated the cover. The time for the initial flow to reach the bottom of the drainage layer was measured, as well as the amount of flow drained over time.

Table 1 introduces the nomenclature that will be used to present the different results.

Table 1. Definition of the abbreviations used.

Drainage layer	Hydraulic conditions	
	Dry	Partially saturated
Gravel	G_d	G_{ps}
Tubular drainage geocomposite	TD_d	TD_{ps}

2.3 Results

The time for the water to reach the end of the drainage layer was measured under four different configurations. Results are presented in the Table 2.

Table 2. Time for the initial flow to reach the end of the drainage layer.

Test pad	Time (min)
G_d	77
TD_d	54
G_{ps}	45
TD_{ps}	30

For both dry and partially saturated conditions, the tubular drainage geocomposite had a faster response time than gravel. That can be explained by the fact that water has to go through the extra 0.50 m of gravel to reach the geomembrane for G_d and G_{ps} pads while it is directly evacuated with the tubular drainage geocomposite.

The initial flow collected at the bottom of the slope has been measured for all four configurations. Figure 11 presents this flow over time.

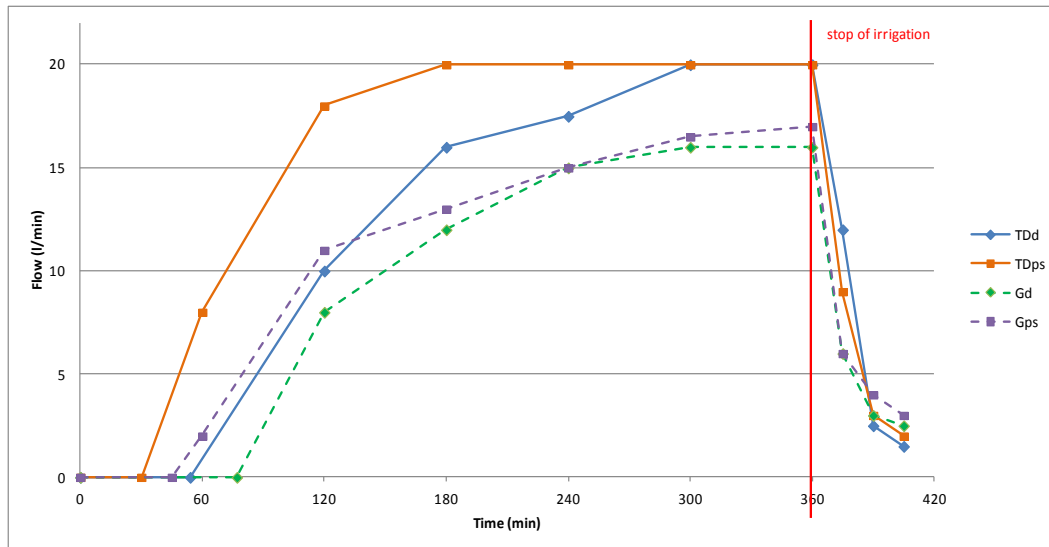


Figure 11. Flow drained over time for different tests.

As shown in figure 11, configurations with tubular drainage geocomposites always drained water faster than the gravel layer. That has also been observed in small scale tests, particularly for mild slopes (Del Greco et al., 2012). The mini-pipes of the geocomposite collect and drain the water in one given direction (the direction of the pipes) even if the slope is almost flat.

The total amount of drained water is also greater with tubular drainage geocomposites. All things being equal, the gravel layer retains between 20% and 25% more water than the tubular geocomposite. The water remaining in the gravel layer is in contact with the underlying layer and may increase the infiltration rate into the waste through any defects in the geomembrane or in the presence of a semi-permeable layer. This is especially true with differential settlements of the cap that change the geometric conditions.

3 BEHAVIOUR OF A SEMI-PERMEABLE TUBULAR DRAINAGE GEOCOMPOSITE IN A LANDFILL CAP

This test was conducted on a landfill cap in France. The purpose of the study was to evaluate the performance of a semi-permeable tubular drainage geocomposite, described in figure 1, for rainfall drainage and the long term permeability reduction of the cap.

The tubular drainage geocomposite is semi-permeable and allows some water pass into the waste to accelerate degradation. Previous laboratory studies show that this type of geocomposite reduces the rainwater infiltration rate to between 5% and 15% of the actual rainfall when used on a silty clay subgrade (Fourmont & al., 2005). Observations from other landfill sites indicate that the product will become impermeable over time due to soil clogging the needle-punch holes in the geofilm by the underlying soil layer if it contains fine particles (clayey soil, silty clay, etc.).

3.1 Description of the cap

Figures 12 and 13 depict the landfill cap. It is divided in two zones by the ridge line at the top. The semi-permeable tubular drainage geocomposite is unrolled on the subgrade and covered with 0.10 m of topsoil (see Figures 14 & 15).

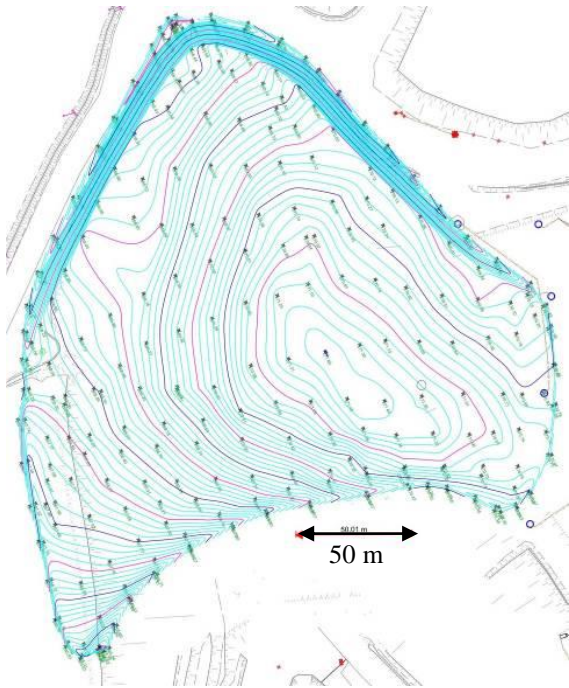


Figure 12. Landfill cap design.

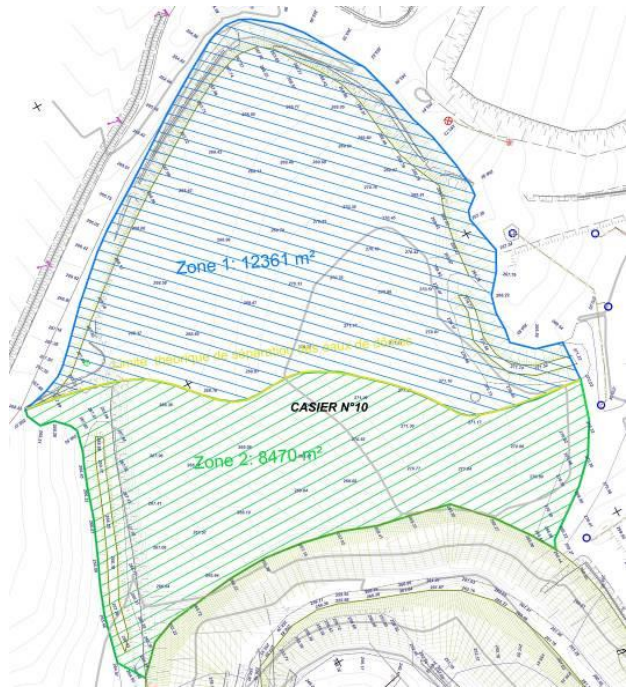


Figure 13. Landfill cap separation zone.

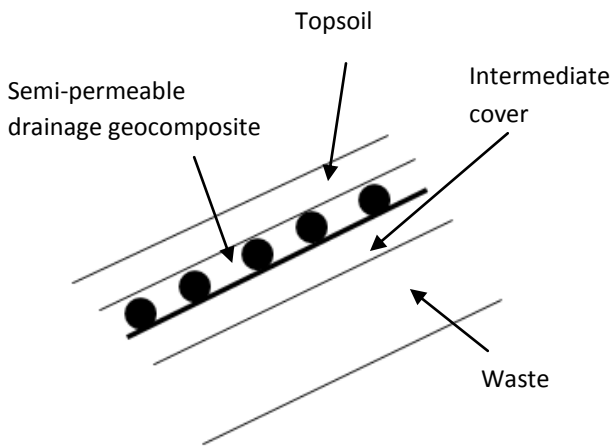


Figure 14. Landfill cap design.



Figure 15. Drainage Geocomposite Installation.

3.2 Measurement device

3.2.1 Collection system

In order to quantify the amount of water passing through the cover described above, the runoff from the topsoil was collected separately from the water drained by the geocomposite. At the toe of the slope, a double membrane system was installed in the peripheral ditches as shown in the figures 16 & 17.

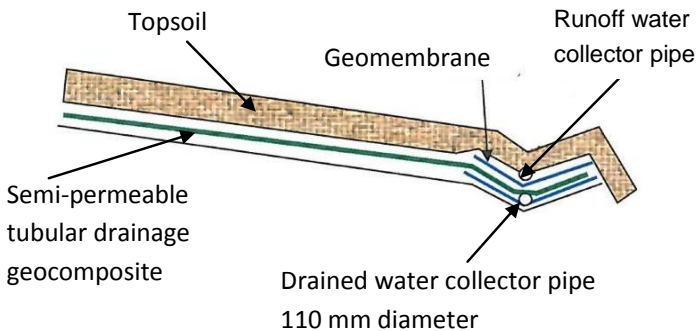


Figure 16. Cross-section of the water collection system.

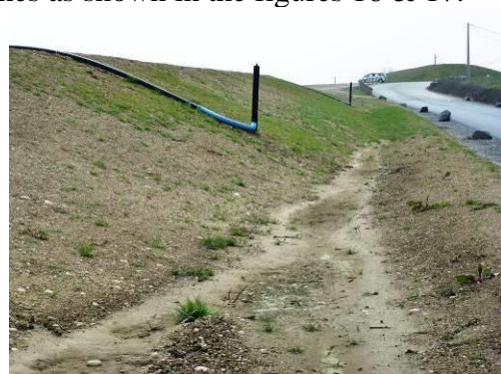


Figure 17. Ditch after backfilling.

3.2.2 Flow meters

Two measurement units have been installed on the two sections of the site (zones 1 & 2) with flow meters to measure the cumulative volume of water drained by the geocomposite for each zone (see figure 18).

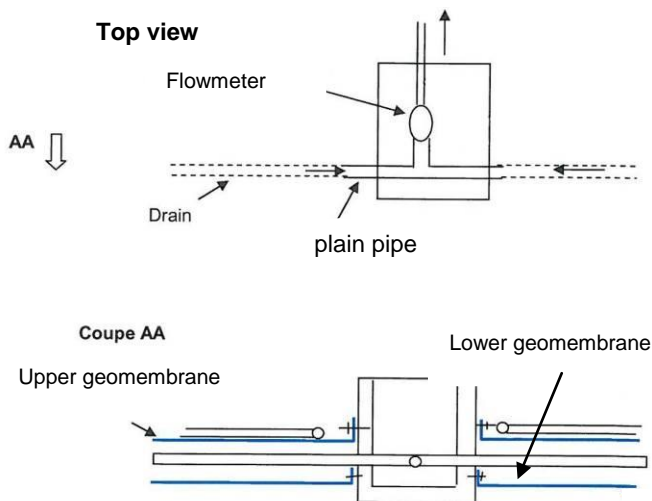


Figure 18. Cross section of the measurement units.

3.3 Results and analysis

3.3.1 Monitoring

The cumulative volume of water drained by the geocomposite in each zone is measured once a month by the flowmeters. Also measured are the rainfall data and the volume of leachate produced in the cells under zones 1 & 2.

Initially, the volume of rainwater actually reaching the geocomposite was estimated from rainfall data using a typical runoff and evapotranspiration coefficient of 0.5 (ADEME, 2001). This coefficient is much too dependent on the geographical location of the site and the local climate variations over the seasons (sunshine, temperature, wind, etc.). Therefore, a numerical model will be used to precisely assess runoff and evapotranspiration. The infiltration volume will be the difference between the actual rainwater and the drained water measured with the flowmeters. This will also be compared to the volume of leachate produced.

The monitoring will be done over several years to follow variations of the infiltration rate through the geocomposite. It is expected that this rate will decrease over time due to clogging by the subgrade soil of the holes in the semi-permeable geofilm.

3.3.2 Initial results

Figure 19 shows the cumulative volume of water drained by the semi-permeable tubular drainage geocomposite as well as the leachate production and the rainfall data during the first 10 months of monitoring. We observed a stagnation of the volume of water drained during the summer months, due to low rainfall and high evapotranspiration at this period. We also observed a peak in the production of leachate in June which follows the rainfall peak that occurred in May. These measures indicate that the infiltration through the geocomposite occurs as expected and seems to be dependant of the amount of water that reaches it.

Because measurements are not constant, a real correlation between the water drained by the geocomposite and leachate production cannot yet be demonstrated. After the first year of monitoring, equipment will be installed to allow automatic data collection, with daily measurements to allow better analysis. Despite the measurement difficulties, this experiment has provided some usable data, even if it must be continued in order to determine the behaviour of the geocomposite.

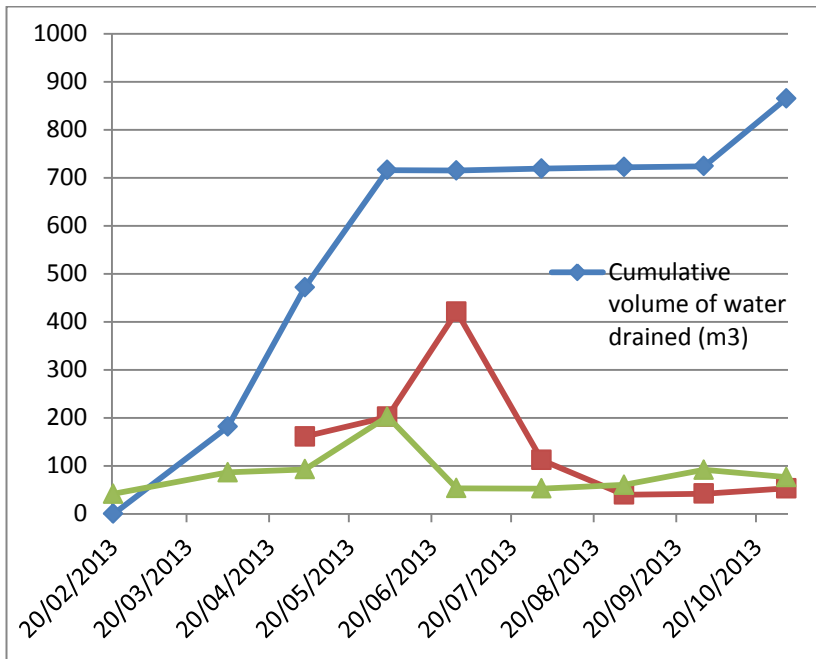


Figure 19. Water drained by the geocomposite, leachate production and rain data.

CONCLUSIONS

The use of a tubular drainage geocomposite in a landfill cap decreases the time that water is in contact with the underlying impermeable layer and reduces water retention in the drainage layer. These benefits should be taken into consideration, especially when the underlying impermeable layer is composed of soil. In that case, the semi-permeable tubular drainage geocomposite will limit the amount of water passing through the cap. The second field study, which is ongoing, will allow the amount of infiltrated water to be quantified. It is expected that this infiltration rate will decrease over time because the semi-permeable geocomposite becomes more and more impermeable. This type of cap will allow some water into the waste to accelerate biodegradation after the final cap is installed. In time, as the rate of biodegradation declines, the water infiltration rate will also decrease.

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