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EXPERIMENTAL EVALUATION OF THE BIOLOGICAL CLOGGING OF DRAINAGE GEOCOMPOSITE AT THE BOTOM OF LANDFILL

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ABSTRACT

This paper presents a study of the biological clogging potential of drainage geocomposites installed in the bottom of landfills, as a replacement to 0.20 cm of granular material. Ìn a first section of the document, the drainage capacity actually needed is analyzed with respect to the biological clogging potential. The general principles governing experimental evaluation of biological clogging are presented in a second step. The apparatus used to conduct the evaluation is then presented, along with the results obtained after several months of monitoring. The results presented involved circulation of a fresh leachate, pumped in a class 2, non-hazardous landfill into 9 cells, and monitoring of the flow through the system, either geocomposites or granular drainage layer.

1. INTRODUCTION

Drainage geocomposites are more and more used by Waste Storage Centers operators who use them in replacement of granular material and more often for capping.

View sites replace a part of the granular layer at the bottom with a drainage geocomposite due to risks of variability of long term hydraulic performance.

Partial replacement of the granular layer at the bottom by a geocomposite permits to save granular material which is more and more difficult to find and involve significants costs. Moreover, this solution increases the storage capacity of the cell and reduces the truck traffic.

Design of the geocomposite must be specific to this type of application since it will be subjected to high stress and an aggressive environment due to leachate.

For this type of application, a safety factor of 10 on the drainage capacity of the geocomposite is generaly considered to take into account the biological clogging of the filter. However, there is curently no specific study for determining the long term properties of the drainage layer and this value of 10 was set following a principle of circumspection.

This study aims at determining a bacterial clogging factor for a geocomposite with mini-pipes specifically developped for use at the bottom of landfill. The long term integrity of the geocomposite was validated by video inspection in real situation (Fourmont et al., 2008).

2. BACKGROUND OF THE STUDY

French legislation for Waste Storage Centers recommends a 0.50 m thick gravel layer with a conductivity superior to 10^{-4} m/s to drain leachate at the bottom of landfill. Height of leachate in the bottom must not exced 0.30 m. The last 0.20 m of gravel above the maximum permissible height of leachate is a security layer witch are more considered as a mechanical protective layer against puncture of very large objects Insofar as this aspect is related to operating methods of the site and not to the design of the sealing device, it will not be considered here.

The replacement of these 0.20 m of gravel with a drainage geocomposite specifically designed for this application and having superior properties will increase the storage capacity of the cell, reduce the truck traffic on site without override the leachate collection principles defined in the legislation.

To proof that the real hydraulic capacity of the drainage layer (0.30 m of gravel + geocomposite) will always be superior to the needs of the application, we have to validate that the drainage layer will be able to evacuate the flow of leachate with a hydraulic head less than 0.30 m. In order to do this, it is essential to:

- Know the needs, that is to say the functional life cycle of the drainage layer,
- Know the behaviour of the drainage layer with constraints that reduce its drainage capacity over time, essentially creep and biological clogging.

3. STUDY OF NEEDS

Leachate production varies during operation of the cell. Two major phases are to be considered, the first one during filling of the cell (this phase lasts between 1 and 5 years) and a second one when the capping is done. In the first phase, the leachate production is the largest because the cell is open and infiltration of rain water is then consistant.

Several parameters influes the amount of leachate production:

- Thickness of waste: the greater the thickness, the greater the waste act as buffer and reduce the amount of leachate produced (Bellenfant, 2009),
- Operating of the cell.

The LCA model (SITA, CREED, EIA, 1998) gives an idea of leacahte production function of the age of the cell and the type of capping:

- Waste from 0 to 1.5 years: 20 % of rainfall water,
- Waste from 1.5 to 5 years: 6.6 % of rainfall water,
- Waste from 5 to 10 years: 6.5 % of rainfall water,
- Waste 10 years old or more: 0.2 % of rainfall water (for capping with geomembrane).

Drainage layer at the bottom of landfill is mainly used during the two first years of operation of the cell. Moreover, after putting into place the capping, the leachate production decreases by a factor of 4 to 5. So we can consider that the transmissivity of the drainage layer (gravel + drainage geocomposite) may be decreased by a factor of 5 after 1.5 years without compromising the overall performance of the cell.

In this study, we propose to reduce the gravel layer thickness of 40%, from 0.50 m to 0.30 m, and to replace it by a drainage geocomposite. Given the above explanation, the drainage geocomposite must keep its hydraulic performances up to the cell closure. After this date, the reduction of performance of the geocomposite won't afect the global performance of the cell due to the reduction of the leachate production.

4. CONSTRAINTS WHICH CAN REDUCE THE LIFE OF DRAINAGE SYSTEMS

The constraints that can reduce the life of drainage systems are:

- Creep in compression,
- Clogging: biological, mineral, etc.

All polymeric materials under compression are likely to creep. To design drainage geocomposites which the drainage layer is a geonet, it is often considered:

- Factor of safety of 2 or more on the mechanical properties of the geonet, and more precisely, the compressive strength
- In-plane flow capacity required with standard ISO 12958 but under a stress a least 2 times greater than the operating stress. This factor of safety of 2 (or more) permits with a simple test to take into acount the creep of the drainage layer. It permits also to apply separately the other factors of safety for the other constraints like biological clogging.

For drainage geocomposites with small diameter mini-pipes into the drainage layer, the soil above the product is directly in contact with the soil under for more than 90% of the area. Vertical loads are directly transmissed one side to the other of the mini-pipe. The arch effect limits the stress on the mini-pipes. Saunier et al. studies (2010) show that this type of geocomposite is not sensible to creep under compression. This result comes from laboratory tests under load up to 2500 kPa. For leachate drainage at the bottom of landfill, we can then consider that the biological clogging is the only factor that may decrease the drainage capacity of the geocomposite.

The number of studies on the biological clogging is few and most of time did a qualitative approach. The factor of safety to consider biological clogging is usually taken at 10. However, a better understdanting of needs and behaviour of drainage systems will allow to precise this factor.

An experimental study has been carried out with a landfill owner and a laboratory to determine the impact of biological clogging on the drainage capacity of geosynthetics drainage systems. This study is presented below.

5. STUDY OF BIOLOGICAL CLOGGING

Characteristics of leachate change over time, like bilogical activity (Biological Oxygen Demand BOD, BOD_5 …) and chimical activity (COD …). Moreover, the temperature at the bottom of the cell may reach high values, function of the height of waste and their compsition and also the operating mode of the cell.

Drainage geocomposites are generaly chemicaly inert, no degration due to interaction between leachate and geocomposite are expected but rather a growing of biomass that may clog the drainage net. The biomass is constitued by bacteria feeding on the leachate and can therefore be described as living organism. The growing of these organisms is function of temperature, leachate, oxygen supply, etc.

Therefore, to be relevant to the site conditions, the essential points are:

- place the experimental device on a waste storage center to have fresh leachate going into the experimental cells,
- have a leachate temperature as close as possible form the temperature at the bottom of the cell. Indeed, the types of bacteria growing at 30°C or more are different from those at 15-20°C. Then a study made with a temperature of leacahte of 20°C could not be relevant if the temperature at the bottom of the cell is superior,
- operating conditions are relevant to reality, especially the oxygen supply (aerobic / anaerobic conditions).

The study has been carried out on a non-hazardous waste storage center for which leachate are known to have an importante activity.

Tested geocomposites are Draintube FT wich result from needle punching of the foolowing elements:
- a non-woven, needle-punched polypropylene drainage layer,
- polypropylene mini-pipes, perforated at regular intervals on two alternate axes at 90°,
- a non-woven needle-punched polypropylene filter layer.

Figure 1 shows the tested geocomposites.

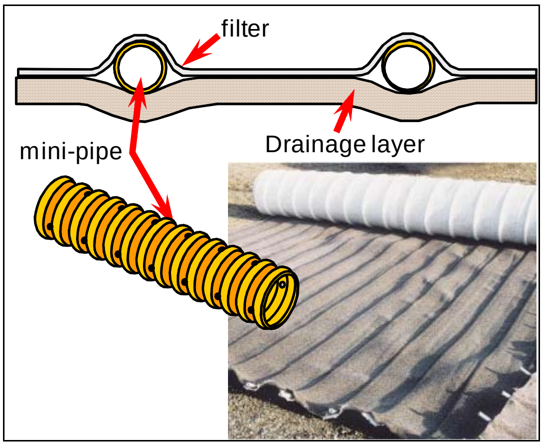

Figure 1. Structure of geocomposites

6. EXPERIMENTAL DEVICE

6.1. General principle

The experimental device must allow to circulate leachate into test cells in wich differents solutions of drainage are installed (geosynthetics and gravel) and to observe their behaviour. The experimental device is placed near a leachate pumping well (to have fresh leachate) and into a bungalow heated between 25 and 30°C to maximaize the activity of leachate (figure 2). Over the time, mesures of flow trought the systems are made.

Figure 2. Bungalow near the well

6.2. Test cells

The test device has been developped to force the leachate passing through the filter of the geocomposite then into the mini-pipe as shown on the figure 3. This system permits to assess the behaviour of the global system:

- passing through the pores geotextile,
- enter into the mini-pipe through the perforations,
- circulation into the mini-pipe.

The test device is composed of 9 square cells 0.25 m width. The total length of the test device is 3 m and its width is 1 m.

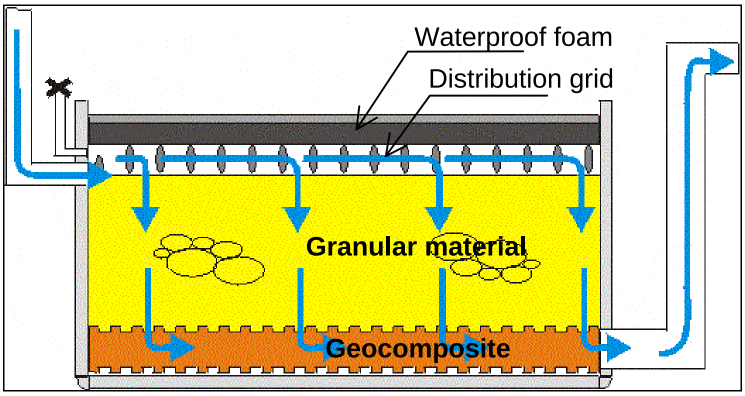

Figure 3. Test cell

The cells maintain the system in anaerobic conditions. This choice has been done because in real conditions, oxygen entry is negligeable.

Moreover, a vertical stress of 100 kPa has been applied on the system to reproduce mechanical conditions at the bottom of landfill. This stress is not enougth to damage the geocomposite. In our study, it will be assumed that only the biological clogging will be responsible of a decrease of the drainage capacity of the system. The stress effect has been studied in previous testing related in litterature (Fourmont et al. 2008). The stress is applied thanks to calibrated springs as shown on the figure 4.

Figure 4. Application of the normal stress

6.3. Leachate admission

The quantity of leachate injected into the cells is controlled all over the duration of the test. The leachate admission is described on the figure 5; it consists of a pump activated at regular intervals to fulfill up to overflow intermediate reservoirs named dosing reservoirs. These dosing reservoirs are directly linked to the test cells thanks to valves. After having filed the dosing reservoirs and stopped the pump, the valves are opened. A controlled volume of leachate is then injected into the cells by gravity. This system permits to control the volume injected into the cells and also to alternate static periods and flow periods in order to maximize the biomass developement.

The inlet flow has been fixed at 10 times 1 liter at regular intervals on a period of 24 hours that meens 1 liter every 144 minutes. This inlet flow is superior to the need of biomass for its development but the volume of leachate injected into the cells will determine the volume of suspended material which may stay on the filter.

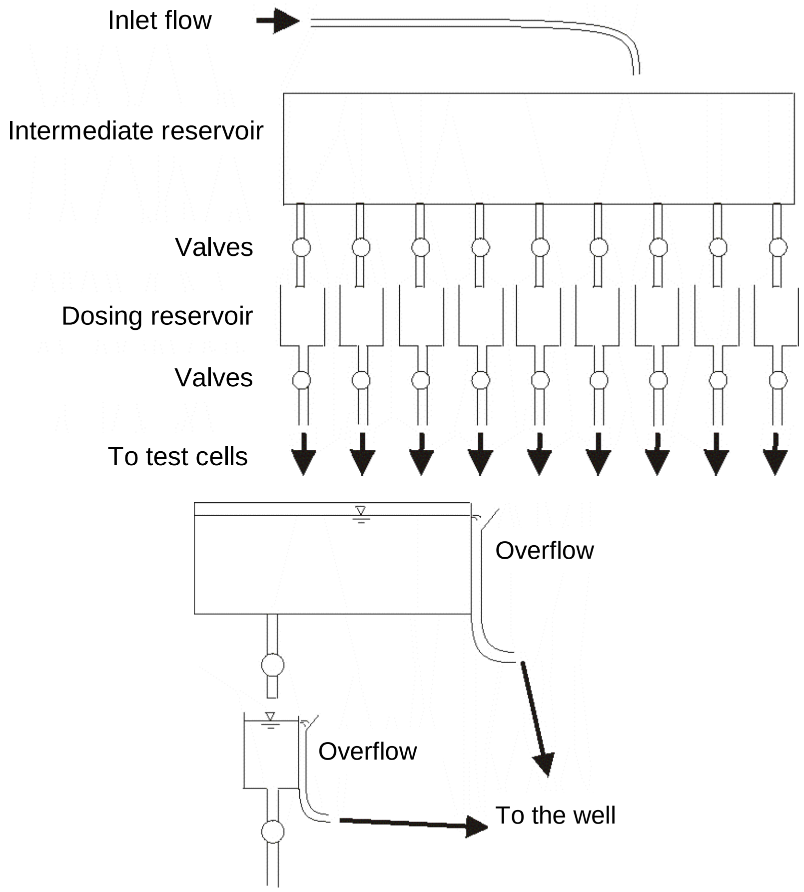

Figure 5. Leachate admission

6.4. System performances

During the experimentation, the flow through the cells is measured by a speed of discharge of the cell. This measurement permits to define a ratio between the speed of discharge and the head loss through the system. The measure is based on a falling head transmissivimeter test. This measure shows the global performance of the system, since a bacteriological glogging of any part of the system will induce a decrease of the speed of discharge. At the end of the experimentation, a vusual inspection will be done at the disassembly of the system.

Figure 6 shows the experimental device to measure the speed of discharge. The opened tube upstream the cell is full to the H0 level. We measure the time for the liquid to fall to the level H1. More the system is clooged, the more time increases.

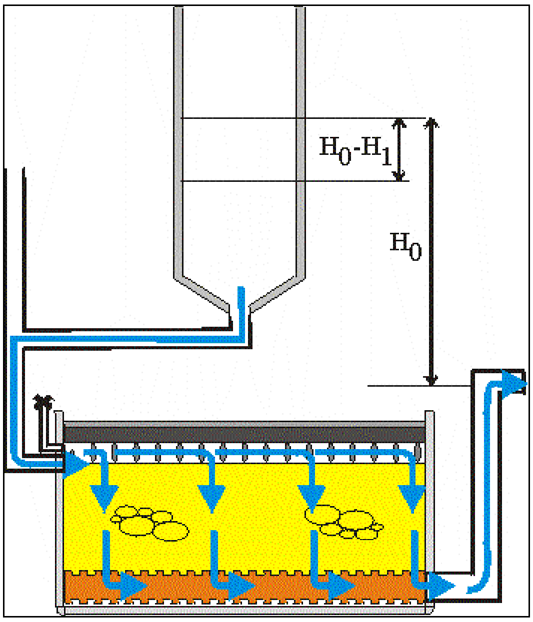

Figure 6. Measure of the speed of discharge

6.5. Additional observations

The overall experiment will finish when one of the two conditions below is achieved:

- Speed of discharge extremly low,
- End of the experimental time fixed by advance.

The disassembly of the cells will permits to:

- Observe the biomass on the filter, and into the mini-pipes to determine the critical part of the system in case of the speed of discharge is extremly low,
- Weigh the biomass,
- If needed, identification of the bacteria by microbiological analysis,
- Other relevant observations.

7. TESTING

Three configurations of drainage systems have been tested. Each configuration has been reproduced three times. Two of these three configurations have drainage geocomposites with anti clogging filter geotextiles 160 g/m² and 240 g/m². Properties of these geotextiles are shown on the table 1. The third configuration contains only crushed drainage gravel 20/40 mm, for comparison (figure 7).

Table 1. Properties of tested geocomposites

	Norme	**‘A’ type**	**‘B’ type**
Cell number		1, 4, 7	3, 6, 9
Mass per unit area of the filter (g/m²)	NF EN 9864	160	240
Mass per unit area of the drainage layer (g/m²)	NF EN 9864	800	800
In-plane flow capacity (m²/s)	NF EN ISO 12958	$5,7\times10^{-4}$ under 400 kPa and i=0,1	$5,7\times10^{-4}$ under 400 kPa and i=0,1

Figure 7. Drainage gravel used on the third configuration (size of the cell: 250 mm x 250 mm)

Each configuration has been reproduced three times to permits to see and eliminate anormal measures. Anormal measures would be clogging of the leachate admission pipe for example.

Figures 8 (a) and (b) show an overview of the equipment.

(a) (b)

Figure 8. Overview of the equipement

8. RESULTS

After 18 months of leachate ciraculation into the cells, figure 9 shows the clogging index on the last 8 months. This value is calculated by normalizing the speed of discharge at the time 't' in relation to the speed of discharge measured immediately after installation of each system:

$$\text{Clogging index} = \frac{\text{Initial speed of discharge}}{\text{Speed of discharge at the time 't'}}$$

If one of the component of the system cloogs, the speed of discharge will decrease and the clogging index will increase. This approach permits to compare material with different properties and to follow the evolution of the systems by the time.

Figure 10 shows the leachate temperature onthe same period.

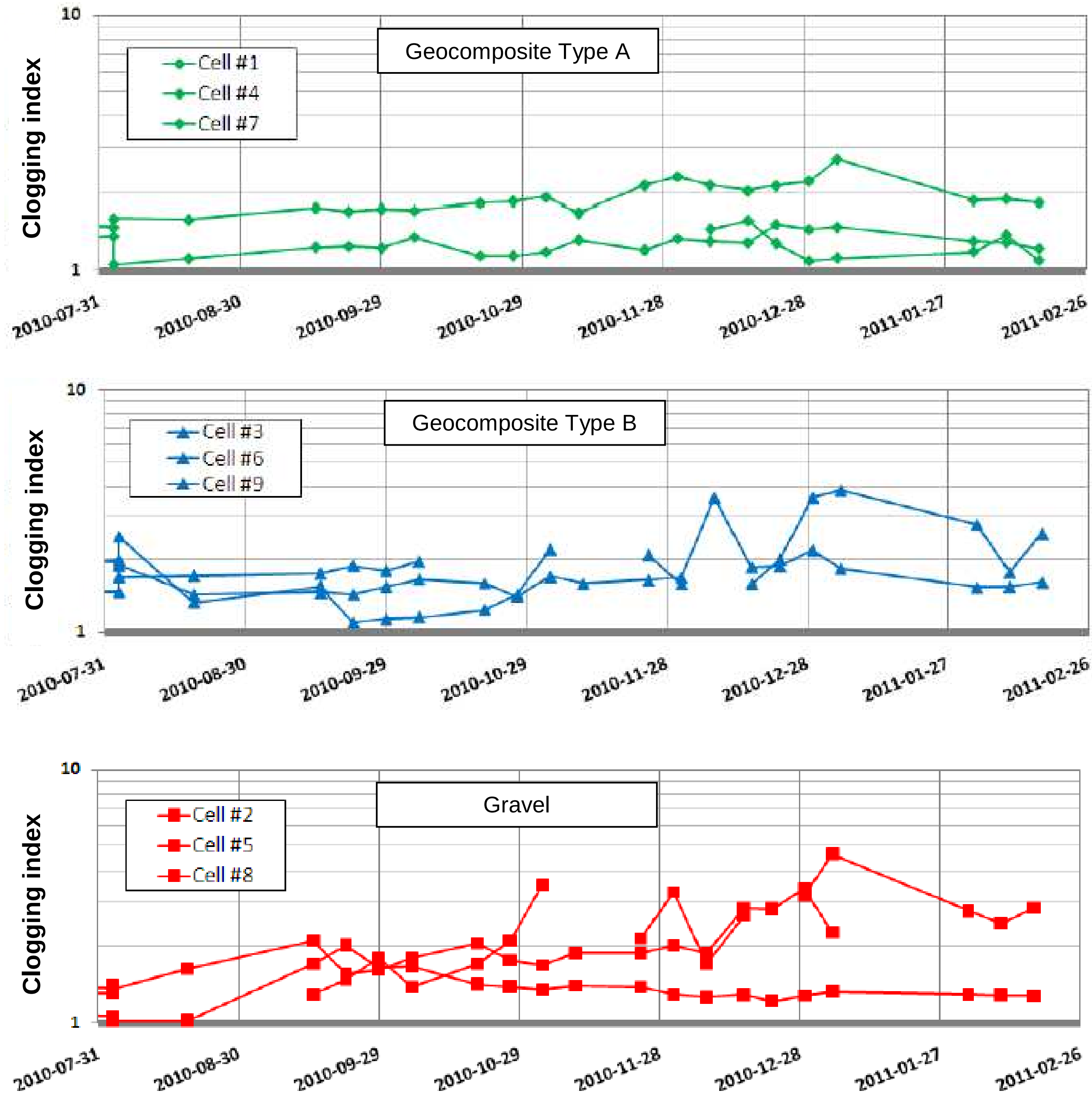

Figure 9. Clogging Index for the 3 configurations of cells

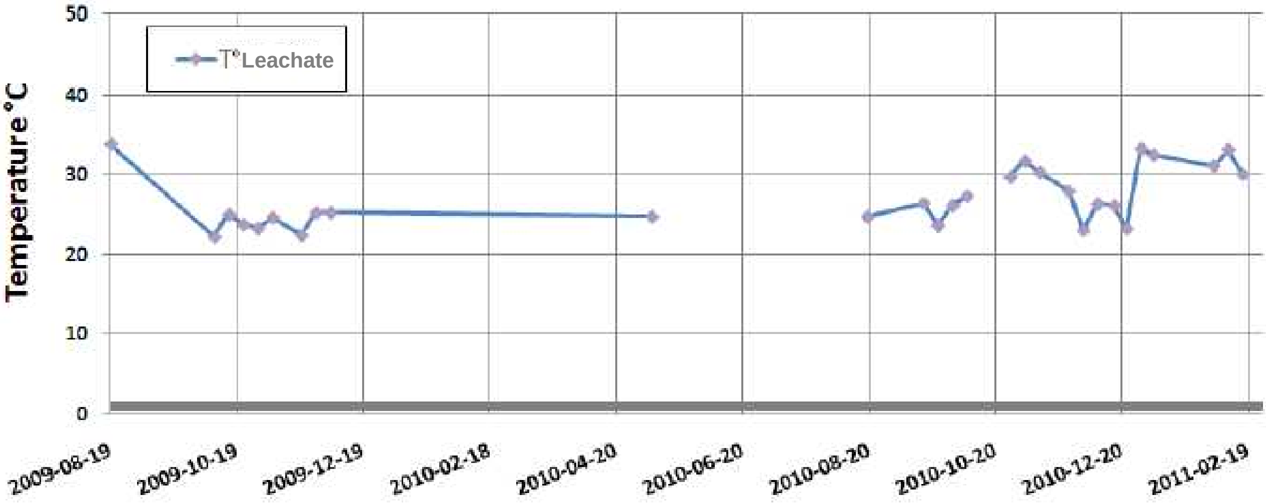

Figure 10. Leachate temperature

After more than 18 months of testing, the speed of discharge for each system didn't change significantly.

9. CONCLUSIONS

After this study, the mains results and conclusions are:

- Needs of clogging resistance of drainage systems must be defined function of the operating life of the cells of the waste storage center (before capping). Indeed, after capping of the cell, the quantity of leachate to drain drops significantly. In this context, even if the drainage geocomposite performance is totaly lost, the 0.30 m of gravel on the geocomposite will bring enough drainage capacity.
- A lot of factors may influence the biological clogging activity, as described in this study. We may mention the temperature and the age of leachate. To be releavant, the choice has been done in this project to be in anaerobic conditions and to use a fresh leachate at a temperature superior to 25°C.
- After 18 months of exposure to leachate circulation, the behaviour of the three tested systems does not show any significant biological clogging. In this context, we can conclued that the tested geocomposites have a similar behaviour compared to the 20 mm thick gravel layer tested.

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