Applicability of Drain Tubes planar Geocomposites for Heap Leach Pads

S. Bourgés-Gastaud, HBAN unit, Irstea, Antony, France & Afitex, Chartres, France
E. Blond, SAGEOS, St-Hyacinthe, Qc, Canada
P. Saunier, Afitex-Texel, Boucherville, Qc, Canada

ABSTRACT

Heap leaching is a mineral processing technology whereby piles of crushed rock are leached with solutions to extract metals. Drainage geocomposites are used in civil engineering to lower piezometric surfaces. This paper presents drain tubes planar geocomposites (DTPG) performances in heap leach pads (HLP) to recover the pregnant solution. To evaluate this use, two studies were conducted. On the one hand, transmissivity tests were performed under high normal loads (up to 2MPa). On the other hand, long-term flow tests were conducted during 90 days. The tests involved acid circulation through DTPG overlined by crushed copper ore. Hydraulic properties were not significantly affected despite the filtration of suspended particles, load and acid condition. DTPG seem to be able to fulfil functions (drainage and puncture protection) in HLP. With the goal of providing design recommendations, a further step will be to install geocomposites in monitored HLP to confirm current laboratory results.

1. INTRODUCTION

Heap leach pads (HLPs) are among the world's largest man-made structure. Typically, the ore are staked at heights in the range of 40 to 70 meters, by successive 5 to 10 meters lifts (Breitenbach et al. 2005). Thiel and Smith (2004) even report heap leach pads 150 m and 230 m high in South America. Heap leaching is a mineral processing technology whereby large piles of crushed rock are leached with various chemical solutions that extract valuable minerals. This method is used for copper, gold, nickel and uranium. The mined ore is crushed and heaped on a lined impermeable pad and irrigated with a leaching solution for an extended period of time (weeks, months or years). As the solution gradually percolates through the ore heap, it dissolves the valuable mineral, producing what is known as a 'pregnant solution'. This solution is collected at the base of the heap leach pad where a drainage base of crushed rock and embedded perforated pipes is installed above the liner system and below the ore heap. The importance of this drainage base cannot be overemphasized. This layer has to:

- Protect the geomembrane liner against puncture,
- Allow efficient removal of the ore-bearing solution from beneath the heap, and
- Assess stability combining maintain of low hydraulic head and high friction angle of liner interfaces.

The critical components of heap leach pads are the liner system and the drainage system. To recover all the 'rich' pregnant solution, leaks are prohibited and drainage has to be fully efficient over the full design period. On the other hand, the global stability of the heap is tremendously affected by the efficiency and design of the drainage system. When HLP is properly designed, the pregnant solution is easily recovered: moreover economic and environmental costs are reduced.

Drain tubes planar geocomposites have been increasingly used in environmental applications such as leachate drainage systems of waste disposal areas. This paper presents the performance of drain tubes planar geocomposites (DTPG) in heap leach pads, where they are used to enhance recovery of the pregnant solution. An overview of the general aspect of HLPs design is first given in Section 2 of this paper. The role of the drainage layer is precisely described. Then results of two experimental programs are reported. These evaluations were conducted to assess the applicability of DTPG for this particular application:

- First, transmissivity tests were conducted in order to assess how the flow rate is affected on the long run by extreme normal loads. These evaluations are reported in Section 3.
- Then, long-term flow tests were conducted with a typical crushed ore from a copper mine with the aim of evaluate the filtration capabilities of two different filters. The testing program involved circulation of 20 g/l sulphuric acid through the ore and DTPG under a normal load of 100kPa during 90 days. This is reported in Section 4.

2. GENERAL ASPECTS OF HLPs DESIGN

2.1 Heap leach pads stability

The historic slope instability of geomembrane lined HLPs concerns the downhill side of the exterior slopes. These failures have shown that geomembrane liner induced slides along its interface (Breitenbach and Thiel, 2005). The elevation of saturated surface above the liner is usually of a few meters but can reach 30 meters in valley fill pads. This condition can compromise the stability of the heap leach facility particularly in active seismic zones (Castillo et al., 2005). In order to improve stability, drainage layers have to maintain the saturated zone as low as possible to decrease interstitial pressure.

In the literature, high friction angle between the geomembrane liner and the overliner is emphasized, but in the authors' opinion, friction angle is not the sole limiting factor. If the traditional stability modelling suggests a preferential failure plane along the liner, the solution is not to find higher friction angle but it is to change the design of the bedding fill. Actually inverse slope of the bottom of the downhill side or keys between bedding and ore stack can increase the stability sufficiently (Figure 1). This is why this paper does not treat interface strength.

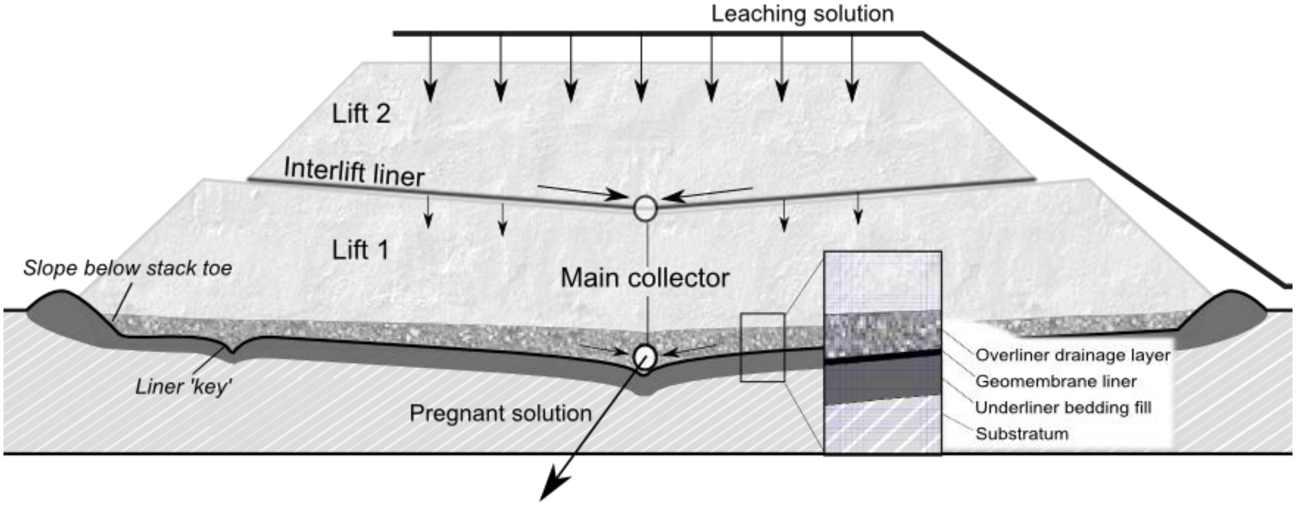

Figure 1 Schematic section of a heap leach pad. Interlift is an optional solution (see Section 4)
Pregnant solution is recovered by primary pipe collector and then flows to the main collector.
In italics, alternative bedding fills design to improve stability. Box shows three layers composite system.

2.2 Conception of a heap leach pads

In the introduction the need for HLPs stability and ease of pregnant solution recovery were emphasized. In this part, an overview of heap leach pads conception is reported. Combining height of ore, water pressure and harsh chemical condition (alkaline leachate for gold and silver or acidic for copper), liner and drainage system are submitted to new conditions as compared to what can be encountered in environmental protection works and especially in landfills (Lupo, 2010). The preferred pad base liner system is a single composite liner made of a soil and geomembrane liners with an overlying drain cover fill for gravity solution flow (Breitenbach, 1999; Fourie et al. 2010).

2.2.1 Liner design

The primary purpose of the composite liner is to prevent the loss of pregnant solution from the lined HLPs for both economic and environmental reasons. The composite liner system is composed of two layers. At the base, underliner bedding fill is typically fine-grained soils which provides a secondary containment barrier and also protect the overlying geomembrane liner from substratum rock puncture (Breitenbach, 2005). On this bedding fill, geomembranes are installed. Mechanical stresses induced by the confined materials could produce a deformation of the membrane and could ultimately puncture it. Typically heavy weight geotextiles reduce occurrence of local stresses and thus allow reducing potential puncture of the liner (Blond et al. 2003; Gaillard et al. 2011). In the mining industry despite of the very high loads and angular material, geotextiles are not widely used (Touze-Foltz et al. 2008). Thick geomembranes are often preferred (1.5mm– 2.5mm; Koerner, 1997). This choice may imply that leaks are common. The required level of geomembrane protection for a particular project depends on the consequences of failure and the cost of the repair

(Narejo, 1995). Following this advice, geotextiles use must be reconsidered, sometimes when leaks of high concentration metals solution are not acceptable, designers should not do without cushion geotextiles.

2.2.2 Drainage layer

The overliner drainage layer is usually coarse typically native clean crushed ore or granular materials (Breitenbach, 2005). In addition, to provide protection to the exposed geomembrane, this layer allows efficient removal of the ore-bearing solution from beneath the heap. For maintaining one or two orders of magnitude higher permeability in the drain fill compared to the overlying ore heap fills, this layer is generally supplemented with drain pipes at controlled intervals (2 to 10 m; Smith and Zhao, 2004) to transport the pregnant solution and maintain low hydraulic heads on the composite liner system. The pipe network often consists of a series of different sizes drain pipes arranged in a herringbone pattern (Figure 2).

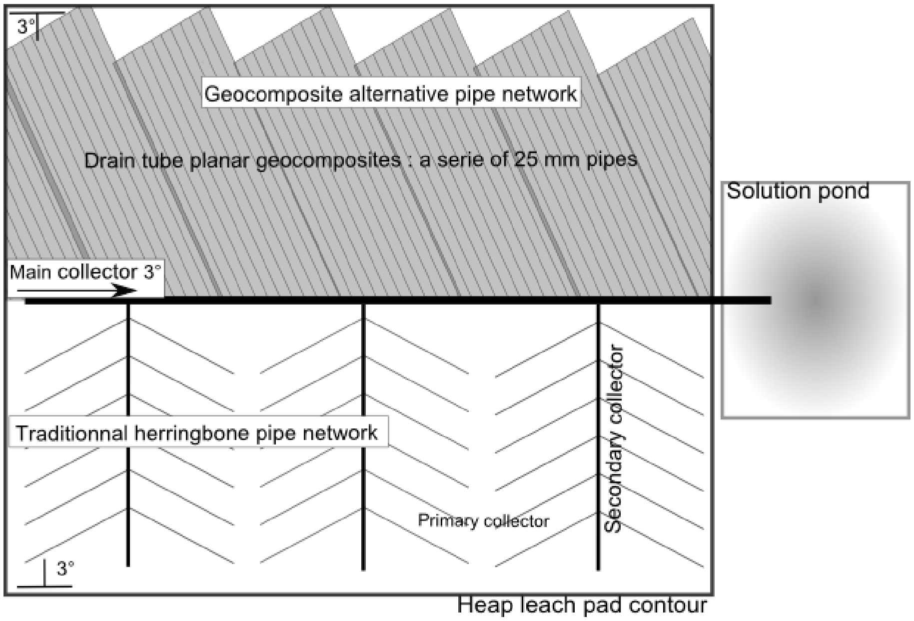

Figure 2 Traditional pipe network compare to the alternative using DTPG.
A part of the primary collector could be replaced by DTPG.

Heap leach pad and landfills present similarities. Indeed needs around the overliner drainage layer are similar: puncture protection and high drainage capacities. Because in European landfills, drain tubes planar geocomposites (DTPG) are increasingly used to collect leachate at the bottom of cells (Fourmont et al. 2004; Arab et al. 2009), authors propose an alternative solution using DTPG in place of the drainage layer in heap leach pads (Figure 2). The thick geotextile can advantageously protect geomembrane (Bellenfant, 2001). Hornsey et al. 2010) and drains allow free circulation of the pregnant solution. The aim of this study is to evaluate the potential for use of DTPG in heap leach pads.

2.3 Drain tubes planar geocomposites (DTPG)

The use of geomembranes in mining applications has been widely documented. However geocomposites compatibility studies with mined material are scarce and very limited information is available. A study of Smith and Zhao (2004) clearly shows that drainage geocomposites lead to improved service and cost reduction in heap leaching. Gulec et al. (2005) indicated no major changes in the hydraulic and mechanical properties of polypropylene geotextiles after immersion in acid mine drainage after 22 months. Similar results were brought by Grubb et al. (2001), Jeon (2006) and Fourie et al. (2010). DTPG are sometimes used in landfills for collecting leachate. Budka et al. (2007) proved that DTPG can advantageously replace a part of the granular layer (0.20 m of gravel).

The DPTG used in this study is developed by AFITEX-TEXEL and called DRAINTUBE™. It is composed by (Figure):

- a non-woven polyethylene geotextile acting as a filter,
- a series of corrugated polypropylene tubes spaced at regular intervals (1 to 4 by meter width). These perforated tubes provide most of the drainage capability of the product, and
- a non-woven thick polypropylene geotextile acting as the drainage medium and as a cushion to protect the underlying geomembrane.

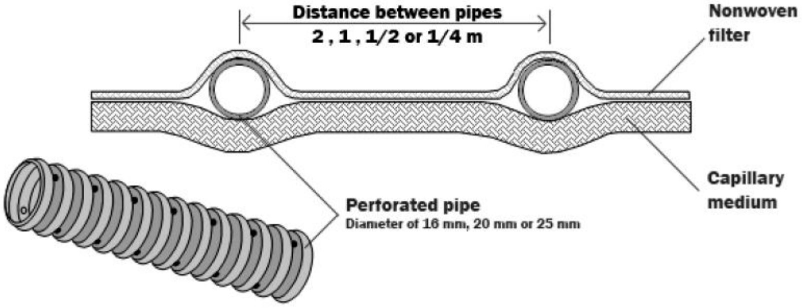

Figure 3 Drain tubes planar geocomposite

Filtration application in HLPs and more generally with mine residues may be among the most challenging filtration applications. First the high seepage forces and suspended particles that must be filtered can lead to a particular clogging. Second leachate is typically a high loaded solution and mineralization can lead to chemical clogging (Faure, 2004; Fourie et al. 2010; Legge et al. 2009). Although likely clogging problem would also occur with mineral drainage systems (such as gravels; Giroud, 1996). In order to check if DTPG are able to fulfil the function of drainage layer in heap leach pads, long-term hydraulic properties, soil retention and chemical resistance must to be evaluated. Results of experimental studies aiming at checking theses points are presented in the following sections.

3. LONG-TERM FLOW TEST WITH COPPER ORE

A long-term flow test was conducted in SAGEOS laboratories in Canada to observe the performance of DTPG when subjected to acid circulation at a concentration representative of those used in the mining industry during 3 months (Kappes, 2005). To run this test, Flow test cells (0.1m x 0.2m) were designed to simulate field conditions (Figure 4Figure). The filter used was a polyester filter with a filtration opening size of 120 µm (FOS, per CGSB 148.1 n°10). The DTPG was installed in the bottom of the cell, and covered by one kilogram of crushed copper ore with an average grade of 3% Cu from a Chilean copper mine (Lomas Bayas). The ore was covered by a geo-spacer to facilitate uniform infiltration of the solution. This latter component was then covered by a closed cell foam compressed by a rigid plate, in order to seal the system while applying a nominal confining stress of 100 kPa.

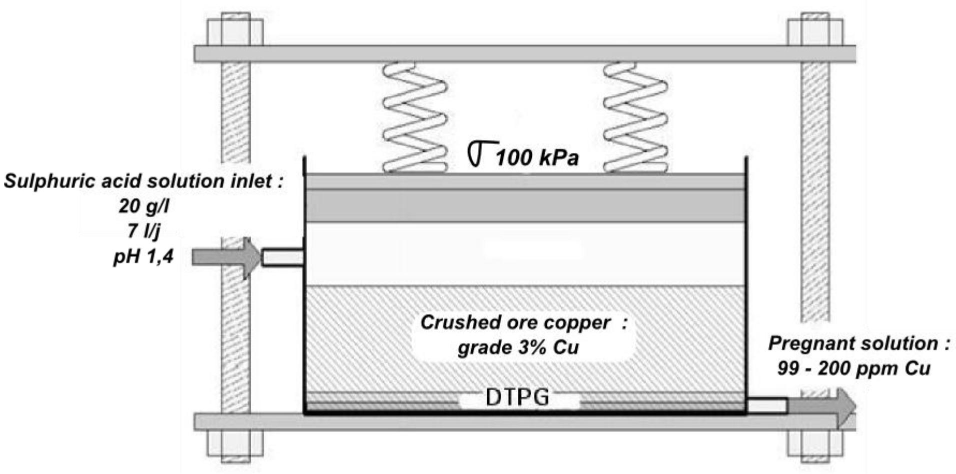

Figure 4 Cross section of an experimental leaching cell. During 90 days, acid leachate crosses the ore then DPTG.

An average daily flow of 15 L/h/m² of the 20 g/l sulphuric acid solution with a pH of 1.4 were circulated during 90 days through each cell. This flow rate represents 32 m³ per square meter of drainage system.

The solution was injected through the geo-spacer, in order to flow downward into the ore, the DTPG and eventually into the perforated tube before exiting the cell through the outlet. The solution was replaced 3 times the testing period in order to avoid excessive copper concentration and facilitate the control of the pH.

The representativity of the extraction process modelled at the laboratory scale was assessed by monitoring periodically the copper concentration of the sulphuric acid. The observations are reported on Table 1.

Table 1 Copper concentration in the leaching solution during experiment, (mean of 10 cells)

Days of leaching	Copper concentration (ppm)	Copper recovered (g)
20	267.5	2.40
40	120	1.08
60	122.5	1.10
80	111.5	1.00
90	99	0.89

Based on these observations, it is possible to state that the chemical reaction which is expected to take place in a heap leach pad was actually taking place at the laboratory scale. Given adjustment of the other test parameters such as the flow rate, it is possible to conclude that the behavior which was observed at a laboratory scale is likely to reflect the actual filtration behaviour of a DTPG exposed to a pregnant solution.

3.1 Results

3.1.1 Flow rate

The flow rate was monitored to determine the evolution of the hydraulic properties i.e. to evaluate a possible clogging. Results are expressed as an ‘equivalent flow rate under a hydrostatic head of 5 mm. This value does not have any significance by itself and cannot be related to the in-plane transmissivity of the geocomposite nor the permeability of the filter. However, it can be used as an indicator of the clogging of the system as it the flow going through the system will be reduced if any of the component loses its functionality:

- blinding or clogging of the filter;
- clogging or collapse of the drainage media.

¡Error! No se encuentra el origen de la referencia. shows a typical flow rate curve as it has been monitored over time for each of the cells that were tested.

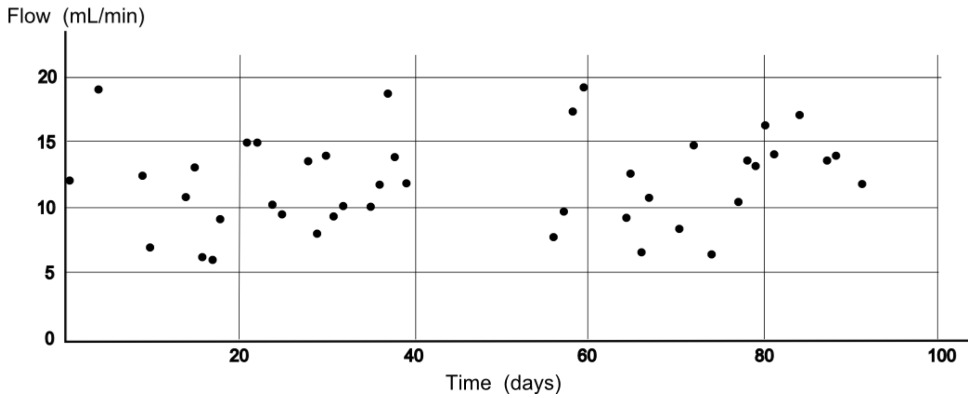

Figure 5 Typical flow rate under a hydraulic head of 5 mm.

From Figure 5, it is possible to observe that the flow rate remains relatively constant over time, which suggests that the DTPG drainage system has maintained its functionality over the duration of the test.

3.1.2 Observation of the exhumed geocomposite

After 3 months of continuous flow in the conditions described above, the cells were dismantled to permit visual inspection of the geocomposites. Once observed that the integrity of the drainage pipe and perforated pipe had been fully maintained, three observations were made during these inspections:

- Quantity of particles retained on the upper geotextile (filter), making sure to remove the particles that were on top of the geotextile but not the embedded ones;
- Quantity of particles retained on the lower geotextile as well as trapped between the two geotextiles;
- Quantity of particles retained into the pipe.

A quantity of 80 g/m² of particles in average was observed into the upper geotextile, while only 10g/m² were found on the lower geotextile. On the other hand, the perforated drainage pipe was found to be completely free of particles.

Following these measurements, permittivity tests were conducted on the filter. The tests were conducted with a hydraulic head of 10 mm to avoid excessive pressure that could have washed out the embedded particles. With these conditions, a reduction in permittivity in the range of 10% could be observed, which is consistent with the observation of a moderate quantity of particles embedded in the filter, and the fact that the geotextile was looking almost ‘clean’ on its inner side, compared to the outside, as can be seen on Figure 6.

Figure 6: external and internal view of the geocomposite after 3 months of percolation of sulphuric acid

3.2 Behavior under high compressive load

With an ore density between 1.5 and 1.8 the compressive load on the drainage layer can reach 2 MPa (Thiel and Smith, 2004; Castillo, 2005). For traditional planar geocomposites involving a planar drainage core (such as biplanar or triplanar geonet), it has been shown by several authors that the hydraulic properties of these geosynthetics are adversely affected by such high compression stresses. However, Saunier et al. (2010) have shown that the particular structure of drain tube planar geocomposites is favourable to the development of an arching effect around the pipe. As a consequence, the transmissivity is affected neither by the compression stress, nor by time, as no creep can develop into the pipe. Their results are reported on Figure.

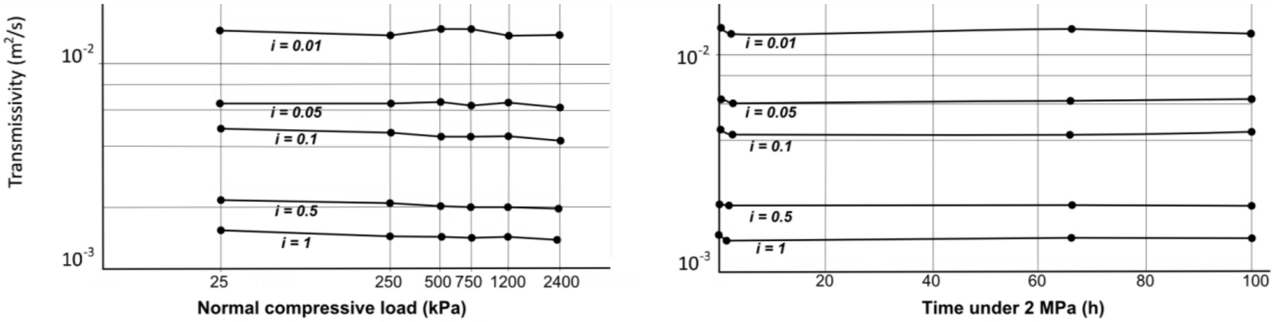

Figure 7 Transmissivity under differrent loads up to 2 Mpa and 100 h (i = hydraulic gradient) (after Saunier et al, 2010)

Based on these observations, it can be concluded that circulation of sulphuric acid through the ore / geocomposite system is not likely to create any clogging problem neither on the surface nor in the drainage media, with the particular DTPG tested involving a 25mm diameter perforated pipe and a geotextile having a 120µm filtration opening size. Despite the experiment was conducted under a normal load of 100kPa, the lack of sensitivity of the product to compression loads up to 2400 kPa suggests that these observations are likely to be applicable to the high normal loads which are typically experienced in heap leach pads.

4. THEORITICAL CONSIDERATION AND DISCUSSION

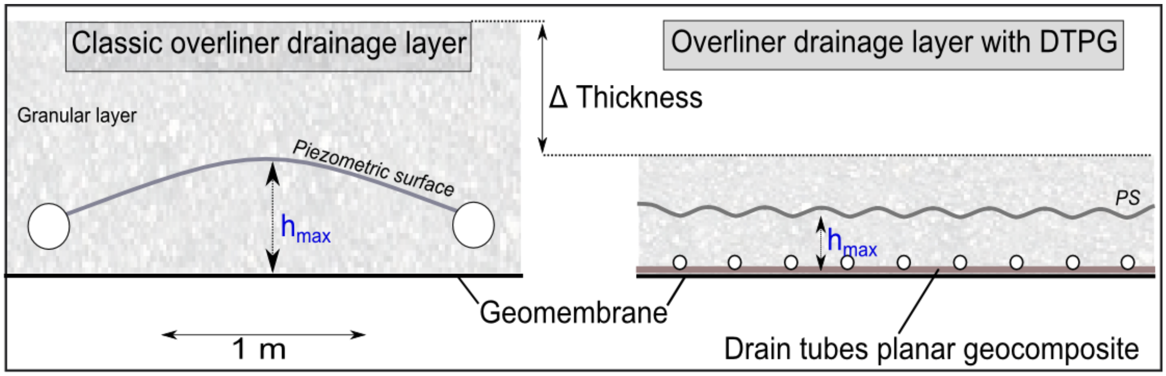

Figure 8 Comparison between a classic drainage layer with complete pipe network and alternative drainage layer with DTPG. Note thickness difference and change in hydraulic head.

In addition of the two keys elements highlighted before, DTPG resistance in relation to both clogging and high load effect, more theoretical reflexions are reported. To go ahead with new research fields, there are a lot of points to study, and some hypotheses are submitted below (Figure 8):

- With a same global transmissivity, when more pipes are closer and smaller, the global hydraulic head is lower. The saturated surface wavelength is shorter because space between pipes is small. Moreover, the space between the DTPG's tube and the geomembrane is virtually inexistent when larger pipes need more than one diameter under.
- The global thickness of the drainage layer is lower with DTPG. To develop arching effect to protect pipes, the thickness of overlying soil layer must be 3 times larger than the pipe diameter. Comparing DTPG tubes of 25 mm in the DTPG to the classic pipe (at least 100mm). So it is easy to understand that the layer is thicker.
- Thanks to the cushion protection offered by the needle-punched geotextile, the geomembrane liner does not suffer of puncture (Hornsey et al. 2010).
- DTPG tubes and big pipes traditionally used in HLP follow a very close behaviour

According to Smith and Zhao (2004), who proved that geocomposites was technically suitable to replace part of the granular drainage layer (geonet); and all these new elements, we strongly suppose that DTPG can be useful for drainage layer in HLPs. By replacing a part of the smallest pipes network, this solution can provides a very good puncture protection to the geomembrane and offers a rapid drainage recovery of the pregnant solutions. With DPLG, the low space between tubes (0.25 or 0.5m) could help to maintain uniform low hydraulic heads above the HLP liner. Moreover, numeric methods can help us to evaluate equivalency between classic pipe network and new overliner drainage layer.

Finally, another application is mentioned. When heap leach pads are very high, the impermeability of lower and older lifts can slow down the leachate. To recover the pregnant solution directly under the last lift, an interlift liner can be installed (Breitenbach, 2005) see Figure 1. The interlift liner may be designed to partially leak and releach the lower lifts, while most of the solution flow in the fresh ore lift is directly collected (Kappes, 2004). What is more, DTPG exists with a polymeric film (as a thin geomembrane) directly attached on the lower face of the product. In only one operation, a complete interlift layer could be installed. Combining very high transmissivity and low permittivity (cross plane) this kind of DTPG could collect 80 % of the solution.

5. CONCLUSION

The behavior of drain tube planar geocomposite (DTPG) as a pregnant solution collection layer in heap-leach pads was investigated considering existing and genuine laboratory work as well as from a theoretical prospective. No evidence of clogging could be detected after 90 days of circulation of a 20 g/l sulphuric acid through a copper ore and the DTPG. As a consequence, it was concluded that the pregnant solution is not likely to affect the performance of DTPG with respect to its filtration and drainage efficiency.

This preliminary study is considered to be very encouraging. In-situ tests shall be performed in a large scale project to confirm the excellent efficiency of the DTPG for the collection of pregnant solution.

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