Proceedings of Geosynthetics Mining Solutions, 2014
September 8–11, 2014, Vancouver, Canada
Published by InfoMine,, ISBN: 978-0-9917905-5-5

Laboratory Evaluation of the Performance of Tubular Drainage Geocomposites for Ore Filtration and Acid leachate Collection

Eric Blond, SAGEOS, St-Hyacinthe, Canada
Pascal Saunier, Afitex-Texel, Boucherville, Canada

Abstract

Heap leaching is a mineral processing technology in which 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 the performances of drain tubes planar geocomposites (DTPG) in heap leach pads (HLP) to recover the pregnant solution. To evaluate this, two studies were conducted. In one study, transmissivity tests were performed under high normal loads (up to 2 MPa). In the other study, long-term flow tests were conducted over ninety 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.

Introduction

Heap leach pads (HLPs) are among the world's largest man-made structures. Typically, the ore is staked at heights in the range of 40 to 70 m, in successive 5 to 10 m 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 extraction. 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.

- Assist stability by combining maintenance of low hydraulic head and a 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 must be eliminated 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 a 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 HLP, where they are used to enhance recovery of the pregnant solution. The role of the drainage layer is precisely described and the results of the 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 in the long run by extreme normal loads.
- Then, long-term flow tests were conducted with typical crushed ore from a copper mine with the aim of evaluating the filtration capabilities of two different filters. The testing program involved circulation of 20 g/L sulfuric acid through the ore and DTPG under a normal load of 100 kPa over 90 days.

Description of 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 by Smith and Zhao (2004) clearly shows that drainage geocomposites lead to improved service and cost reduction in heap leaching. Gulec et al. (2005) indicated there were no major changes in the hydraulic and mechanical properties of polypropylene geotextiles after immersion in acid mine drainage for 22 months. Similar results were reported 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 of (Figure 1):

- a nonwoven polyethylene geotextile acting as a filter,
- a series of corrugated polypropylene tubes spaced at regular intervals (1 to 4 m width). These perforated tubes provide most of the drainage capability of the product; and

- a nonwoven thick polypropylene geotextile acting as the drainage medium and as a cushion to protect the underlying geomembrane.

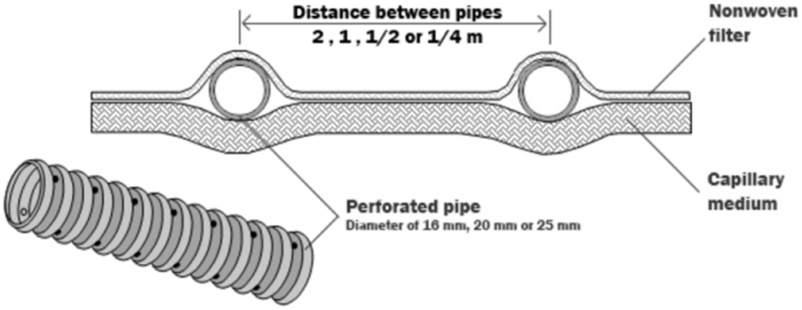

Figure 1: Drain Tubes Planar Geocomposite

Filtration applications 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 clogging. Second, leachate is typically a highly loaded solution and mineralization can lead to chemical clogging (Faure, 2004; Fourie et al., 2010; Legge et al., 2009). Although it is likely that a clogging problem would also occur with mineral drainage systems (such as gravels, see Giroud, 1996). In order to check if DTPG are able to fulfil the function of a drainage layer in HLPs, long-term hydraulic properties, soil retention, and chemical resistance must be evaluated. Results of experimental studies aiming at checking theses points are presented in the following sections.

Long-term Flow Test with Copper Ore

A long-term flow test was conducted in the 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 over three months (Kappes, 2005). To run this test, Flow test cells (0.1 m × 0.2 m) were designed to simulate field conditions (Figure 2). 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 percent 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.

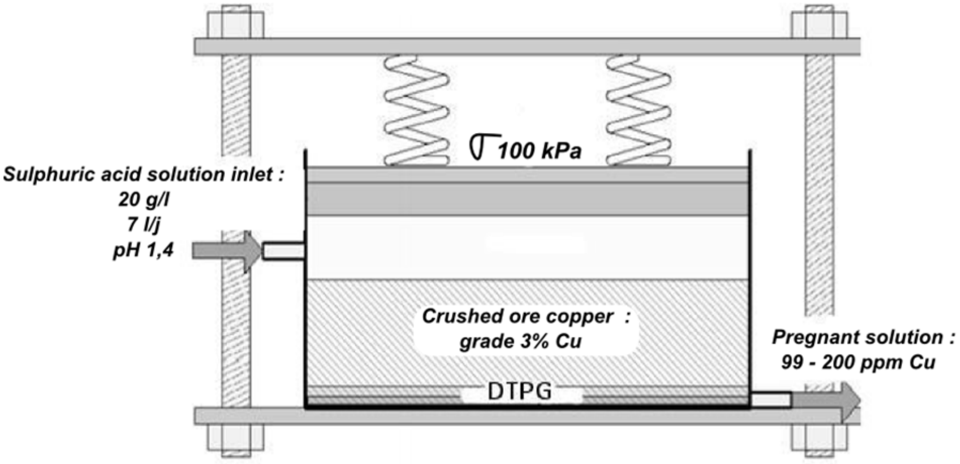

Figure 2: Cross section of an experimental leaching cell.
Over 90 days, acid leachate crosses the ore, then the DPTG

An average daily flow of 15 L/h/m² of the 20 g/L sulfuric acid solution with a pH of 1.4 was circulated over 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 during 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 periodically monitoring the copper concentration of the sulfuric acid. The observations are reported in Table 1.

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

Table 1: Copper Concentration in the Leaching Solution during Experiment (Mean of 10 Cells)

Results

Flow Rate

The flow rate was monitored to determine the evolution of the hydraulic properties, that is, to evaluate 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 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.

Figure 3 shows a typical flow rate curve as monitored over time for each of the cells that were tested.

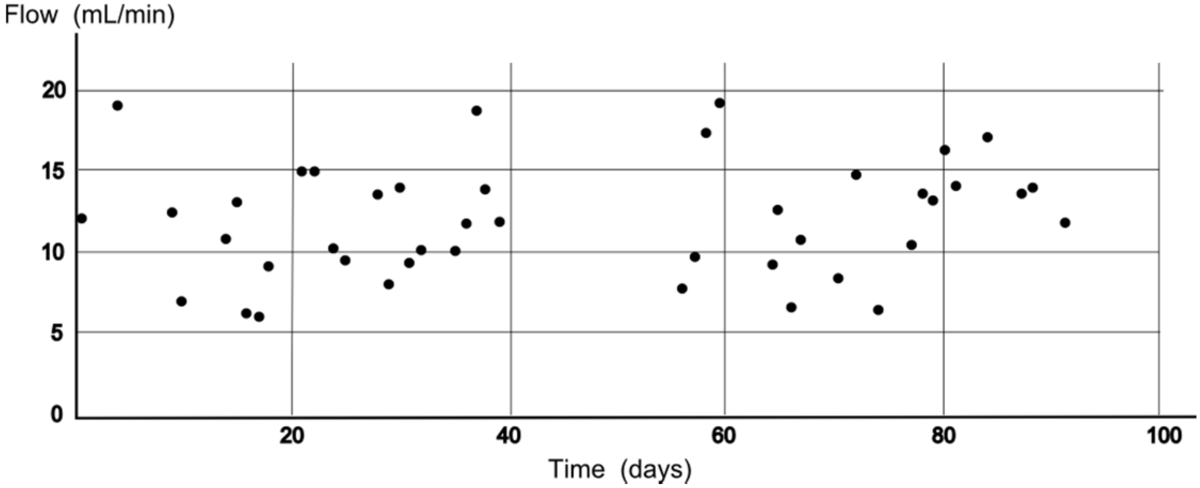

Figure 3: Typical Flow Rate under a Hydraulic Head of 5 mm

From Figure 3, 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.

Observation of the Exhumed Geocomposite

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

- the 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;
- the quantity of particles retained on the lower geotextile as well as trapped between the two geotextiles; and
- the quantity of particles retained in the pipe.

Figure 4: External and Internal View of the Geocomposite after Three Months of Percolation of Sulfuric Acid

A quantity of 80 g/m² of particles on average was observed in 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. Under these conditions, a reduction in permittivity in the range of 10 percent 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 looked almost “clean” on its inner side, compared to the outside, as can be seen on Figure 4.

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 favorable to the development of an arching effect around the pipe. As a consequence, the transmissivity is not affected by the compression stress, nor by time, as no creep can develop in the pipe. Their results are reported in Figure 5.

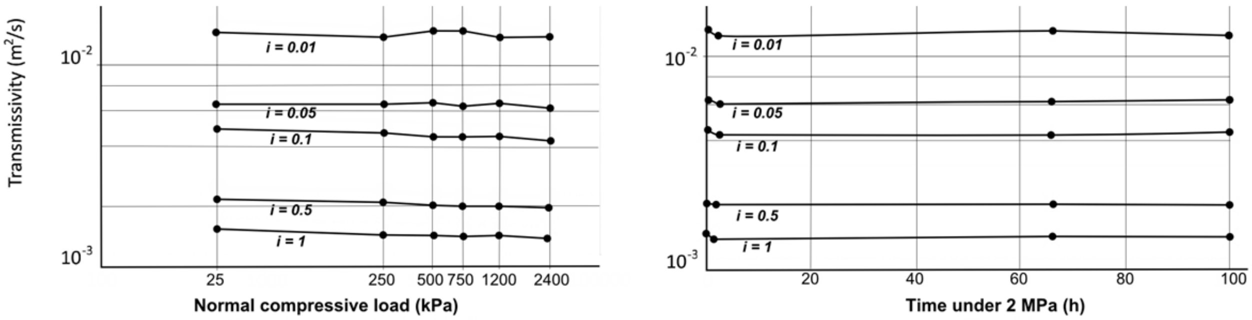

Figure 5: Transmissivity under Different Loads up to 2 Mpa and 100 h (i = Hydraulic Gradient) (after Saunier et al, 2010)

Based on these observations, it can be concluded that circulation of sulfuric acid through the ore/geocomposite system is not likely to create any clogging problem on the surface nor in the drainage media, with the particular DTPG tested involving a 25 mm diameter perforated pipe and a geotextile having a 120µm filtration opening size. Although the experiment was conducted under a normal load of 100 kPa, the lack of sensitivity of the product to compression loads up to 2,400 kPa suggests that these observations are likely to be applicable to the high normal loads which are typically experienced in heap leach pads.

Conclusion

The behavior of drain tube planar geocomposite (DTPG) as a pregnant solution collection layer in HLPs was investigated based on previous and current 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 sulfuric 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.

References

Arab, R., Cherifi, F. and Loudjani, F. 2009. “Landfill Drainage with Geocomposites,” Colloque International Sols Non Saturés et Environnement, Tlemcen, Algeria.

ASTM D 3895. “Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry,” American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

Blond, E., Bouthot, M., Vermeersch, O.G.m and Mlynarek, J. 2003. “Selection of Protective Cushions for Geomembrane Puncture Protection,” 56th Annual Canadian Geotechnical Conference, Winnipeg, Manitoba, Canada.

Breitenbach, A.J. 1999. “The Good, the Bad and the Ugly Lessons Learned in the Design and Construction of Heap Leach Pads,” SME Annual Meeting Presentation, SME, Denver, Colorado, USA, SME 99-186: 1-15

Breitenbach, A. J. 2005. *Heap Leach Pad Design and Construction Practices in the 21st Century.*

Breitenbach, A. J. and Thiel, R. 2005. *A Tale of Two Conditions: Heap Leach Pad Versus Landfill Liner Strength.*

Budka, A., Bloquet, C., Benneton, J-P., Croissant, D., Girard, H. and Khay, M. 2007. “Efficiency of Different Geotextiles for the Protection of the Geomembrane at Landfills,” Proceedings of Waste Management, Sardinia, Italy.

Castillo, J., Hallman, D., Byrne, P. and Parra, D. 2005. “Dynamic Analysis of Heap Leach Pad under High Phreatic Levels,” Proceedings of 27th Mining convention, Arequipa, Peru.

Faure, Y.H., Baudoin, A., Pierson, P. and Plé, O. 2006. “A Contribution for Predicting Geotextile Clogging during Filtration of Suspended Solids,” Geotextiles and Geomembranes, 24: 11-20.

Fourmont, S., Bloquet, C. and Haddani, Y. 2004. “Partial Replacement of the Granular Layer at the Bottom of a Landfill: Short and Long-Term Monitoring of Drainage Geosynthetics,” Proceeding of EuroGeo4, Edinburgh, United Kingdom 242

Gaillard, G., Croissant, D. and Touze-Foltz, N. 2011. “Evaluation of HDPE Geomembranes Protection against Puncturing,” Rencontres Géosynthétiques 2011, Tours, France.

Giroud, J.P. 1996. “Granular Filters and Geotextile Filters,” Geofilters'96, Montréal, Québec, Canada, 1: 565-680.

GRI Standard GC8. 2001. *Standard Guide for Determination of the Allowable Flow Rate of a Drainage Geocomposite*, Geosynthetic Institute, USA.

Grubb, D. G, Diesing, W.E., Cheng, S.C. J. and Sabanas, R. M. 2001. “Compatibility of the Durability of Geotextiles in an Alkaline Mine Tailing Environment,” Geosynthetics International 8: 49-79.

Gulec, S., Benson, C., and Edil, T. 2005. “Effect of Acid Mine Drainage (AMD) on the Mechanical and Hydraulic Properties of Three Geosynthetics,” *Journal of Geotechnical and Geoenvironmental Engineering* 131: 937-950.

Hornsey, P.W., Scheirs, J., Gates, W.P., and Bouazza A. 2010. “The Impact of Mining Solutions/Liquors on Geosynthetics,” *Geotextiles and Geomembranes* 28: 191-199.

Jeon, Han Yong. 2006. “Chemical Resistance and Transmissivity of Nonwoven Geotextiles in Waste Leachate Solutions,” *Polymer Testing* 25: 176-180.

Kappes, D.W. 2005. “Heap Leaching of Gold and Silver Ores,” *Developments in Mineral Processing* 15: 456-478.

Koerner, R.M. 1997. *Designing with Geosynthetics*, 4th Ed. Prentice Hall, USA.

Legge, K.R., Baxter, P., Meyer, P.J., Sander, M.G., and Viljoen, D.T.V. 2009. “Keynote Lecture: Geosynthetics for Africa,” Proceedings 1st African Regional Geosynthetics Conference, Cape Town, South Africa, (CD-ROM), pp. 1-40.

Lupo, J.F. 2005. “Liner System Design for Heap Leach Pads,” *Geotextiles and Geomembranes* 28: 163-173.

Lupo, J.F. and Morisson, K.F. 2007. “Geosynthetic Design and Construction Approaches in the Mining Industry,” *Geotextiles and Geomembranes* 25: 96-108.

Narejo, D.B. 1995. “Three Levels of Geomembrane Puncture Protection,” Geosynthetics International, 2: 765-769.

Saunier, P., Ragen, W., and Blond, E. 2009. “Assessment of the Resistance of DTPG to High Compressive Loads,” Proceedings of 9th International Conference on Geosynthetics, 2010, Brazil, 3: 1131.

Fourie, A.B., Bouazza, A., Lupo, J., and Abrao, P. 2009. “Improving the Performance of Mining Infrastructure through the Judicious Use of Geosynthetics,” Proceedings of 9th International Conference on Geosynthetics, 2010, Brazil, 1: 193-219

Saunier et al. 2010. *Papier IGS Guaruja*.

Smith, M.E. and Zhao, A. 2004. “Drainage Net for Improved Service and Cost Reduction in Heap Leaching,” Proceedings Meeting of the Geosynthetics Research Institute, Las Vegas, Nevada, USA.

Thiel, R. and Smith, M.E. 2004. “State of the Practice Review of Heap Leach Pad Design Issues,” *Geotextiles and Geomembranes* 22: 555-568.

Touze-Foltz, N., Lupo, J., and Barroso, M. 2008. “Geoenvironmental Applications of Geosynthetics,” Keynote Lecture, Proceedings Eurogeo 4, Edinburgh, Scotland.