



**FIGURE 1** Installing a geotextile filter at a tailing pond.  
*Photograph courtesy Afitec-Textel*



# Filtration of oil sands tailing slurries

By Eric Blond, Pascal Saunier and Patricia I. Dolez

**M**ining and some energy operations generate large quantities of water-containing tailings. These tailings are made of crushed-rock particles that are deposited in a slurry form. This is the case for coal, tar sand, lead, zinc, gold, silver, copper, molybdenum, nickel, taconite (iron), phosphate, bauxite (aluminum oxide), uranium, trona (soda ash) and potash, for example.

There are a few solutions available for dewatering mining and energy tailings. The most common strategies involve the use of a hydrocyclone or a spigot to separate coarse from fine particles, which are then managed independently; the addition of a thickener to produce a dewatered, ideally nonsegregating slurry; and filtration. Other techniques involve the recombination of various gradations, leading to consolidated tailings, and the addition of super-absorbent polymers, thin lift fines drying and CO<sub>2</sub> coagulation.

Beside these active, energy-consuming techniques, a very common solution is to rely on a combination of sedimentation and sometimes filtration by a geotextile filter, i.e., in tailing ponds (**Figure 1**).

The use of large-scale geotextile tubes for the dewatering of tailings fines and mine-water sludge goes back to the early 2000s. Belt filters are commonly used in the energy and mining industries to increase the solids content of tailings. Several attempts were also made to use electrokinetic potential for the dewatering of tailings with geotextile filters wrapped around an electrically conductive geonet-cathode or with prefabricated vertical wick drains. More recently, a specific product was developed, with a cathode inserted in a multilinear drainage geocomposite. Laboratory evaluations showed 25% more water extracted from a synthetic tailing, thanks to the activation of the electrokinetic dewatering process, after stabilization of gravity-based dewatering.

A multilinear drainage geocomposite consists of a series of small-diameter perforated pipes, confined between two nonwoven geotextiles. They were introduced in the 1990s in Europe and in the early 2000s in North America. They are supplied in a variety of configurations: The two layers of geotextiles can be adapted to a specific project's needs, just as the distance between pipes can be adapted to the hydraulic requirements.

One of the main advantages of this type of structure is its ability to connect the pipes together and attach the structure to a main drainage collector or, for the drainage of gases, to a vacuum system. Although not part of this study, efforts are being made to assess the field performance of such products for accelerated dewatering and gas draining thanks to the application of a negative pressure on the outlet of the drainage system.

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**FIGURE 2** Multilinear drainage geocomposite used in a slurry dewatering facility. Photograph courtesy Afitec-Textel

Even without the addition of an electrokinetic dewatering function, multilinear drainage geocomposites have been used in a variety of slurry- and sludge-dewatering projects, with less demanding types of tailings than the ones considered in this article (**Figure 2**). Oil sand tailings have proven to be among the most difficult to dewater, given the very fine particles, presence of oil residues and thickness of deposits.

### Challenges faced with the filtration of tailing slurries

Disregarding the details of the dewatering technique used, filtration of fine-grained tailings generated by the oil sands and other mining/energy industries raises soil-filtration issues. First, the filter must retain enough coarse particles to facilitate development of a self-filtering structure on the upstream face of the geotextile. Coarser particles of the tailing, retained on the geotextile, then become the filter that will eventually retain the finer

particles. Second, the filter must let the water pass through without generating a head loss that would affect the flow rate or endanger the structural stability of the project.

Performance of the geotextile as a filter may be affected in different ways. A too-high density of very fine particles accumulated on the upstream side of the geotextile may create a virtually impervious layer, blinding the geotextile. Fine particles may also accumulate within the pores of the geotextile, reducing significantly its permeability or clogging it. Clogging may also develop because of the accumulation of mineral or organic material on the fibers of the geotextile. Finally, if the openings of the geotextile are too large, the inability of the geotextile to avoid excessive migration of fines through its plane is called piping.

The filtration mechanism prevailing with slurries presents additional challenges, as there is little to no contact between particles at the beginning of the filtration process. To permit retention on the geotextile, the process will involve the formation of a filter cake on the upstream surface of the geotextile. Development of this filter cake will be initiated by the retention of coarser particles of the slurry passing through the geotextile. These coarser particles will then offer support to finer particles, which can then be retained as well. This mechanism continues until all the particles of the slurry are retained on the structure created on the upstream face of the geotextile, including particles far smaller than the smallest openings of the geotextile.

However, as the percentage of particles retained on the geotextile increases, the thickness of the filter cake increases, and its density tends to increase as well. The thicker the filter cake, the lower the hydraulic gradient ( $i$ ), for a similar water head ( $\Delta h$ ), as  $i = \Delta h/t$ , where “ $t$ ” is the thickness. In addition, densification of

the filter cake also leads to a reduction in permeability—as for any soil. Both phenomena tend to reduce the flow of liquid passing through the geotextile. In summary, the thicker the filter cake, the smaller the dewatering efficiency of the geotextile-filter-cake system.

For this article, the filtration behavior of needlepunched and heat-bonded non-woven geotextiles in contact with various types of oil sands tailings is investigated. The test equipment was designed specifically for the evaluation of this type of slurry, since the hydraulic conductivity of fine-grained tailings such as oil sands tailings is too low to permit the use of the ASTM D5101 standard.

## Laboratory investigation: Materials and methods

### Geotextiles

Three geotextiles were used in the study. Filter 1 and Filter 2 are needlepunched polyester nonwovens, and Filter 3 is a heat-bonded polypropylene nonwoven. Selected properties are provided in **Table 1**.

### Tailings

Experiments were conducted with two samples of matured fined tailings (MFT), identified as MFTR #1 and MFTR #2, and obtained from Canadian oil sands producers. Their solids contents (ASTM D4959) and methylene blue index (MBI) values are provided in **Table 2**. The MBI values stand at both ends of the typical range for MFT. Nonsegregating tailings (NST) with a sand-to-fine ratio of 4.5 and a solids content of 66% by weight (wt%) were also prepared using MFTR #2 and mine sand.

In addition, the study used synthetic MFT with various compositions. This synthetic MFT formulation was developed by Dolez et al. (2015) to allow controlling the tailings composition in dewatering experiments. It includes 2.25

	Filter 1	Filter 2	Filter 3
Thickness (ASTM D5199)	0.80 mm	2.14 mm	0.35 mm
Mass per unit area (ASTM D5261)	110 g/m <sup>2</sup>	298 g/m <sup>2</sup>	107 g/m <sup>2</sup>
Filtration opening size (CGSB 148.1 n°10)	75–120 μm	51 μm	84 μm
Permittivity (ASTM D4491)	1.8 s <sup>-1</sup>	0.55 s <sup>-1</sup>	0.41 s <sup>-1</sup>

**TABLE 1** Selected properties of the geotextile filters

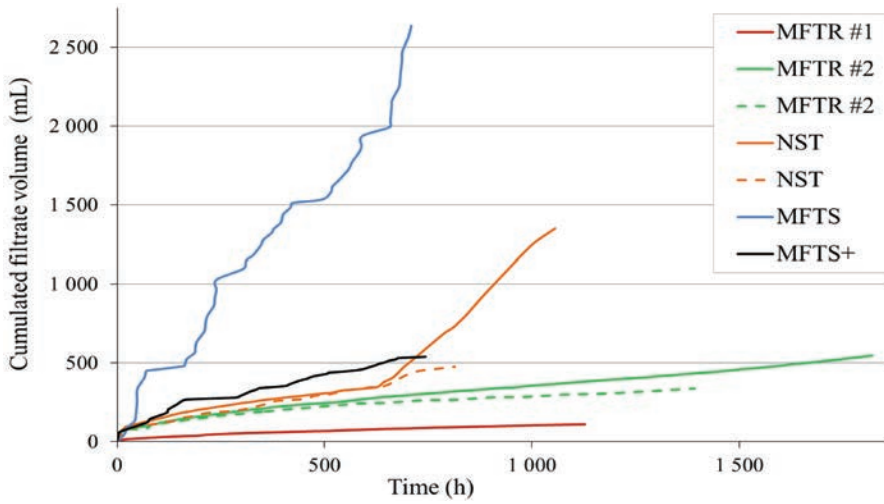
Label	Description	Solids content (%)	MBI (g/m <sup>2</sup> )
MFTR #1	MFT sample provided by Canadian oil sands producer	43.3 ± 1.7	59 ± 4
MFTR #2	MFT sample provided by Canadian oil sands producer	29.7 ± 0.3	127 ± 8
NST	NST sample prepared by mixing MFTR #2 with sand	65.8	
MFTS	Synthetic MFT with 0% illite	43	58 ± 6
MFTS+	Synthetic MFT with 21% illite	43	88 ± 3

**TABLE 2** Characteristics of the tailings used in the study

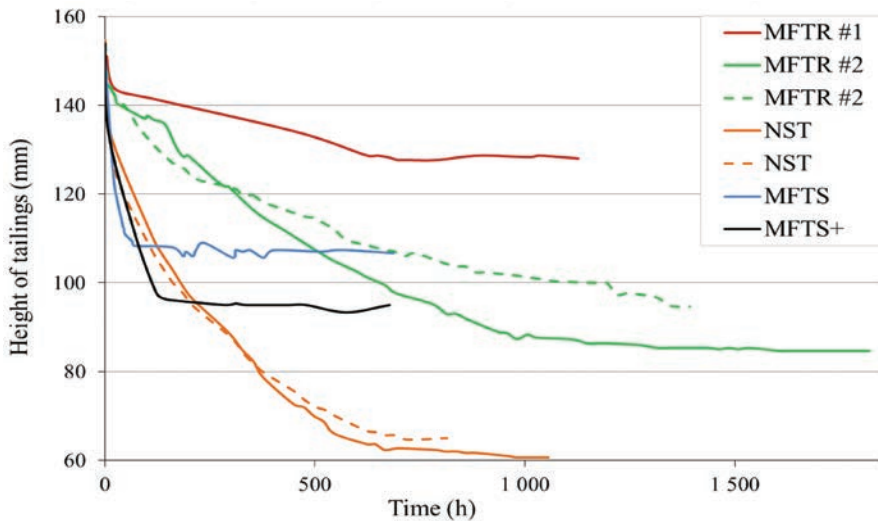
wt% bitumen, 0.4 wt% bentonite, 40.4 wt% kaolinite/illite, 57 wt% water and 0.015 wt% sodium chloride. Two different formulations were used in this study: 100% kaolinite (labeled MFTS), and 21% illite, 73% kaolinite and 6% feldspar/calcite (labeled MFTS+). The solids contents and MBI values of the synthetic MFT formulations are provided in **Table 2**.

### Filtration cell

The design of the filtration cell developed for this study is similar to the one of Yeo et al. (2010). It involves a 3-inch (7.6-cm) internal diameter cylindrical cell. The 12-inch (30.5-cm) high main chamber holds a volume of tailings and water over a geotextile specimen supported by a wire mesh. The lower chamber is filled with water. The water used in the cell is recovered from oil sands tailings dewatering experiments to ensure it has



**FIGURE 3** Cumulative filtrate as a function of time for various types of tailings tested with geotextile Filter 3



**FIGURE 4** Height of tailings as a function of time for various types of tailings tested with geotextile Filter 3

the relevant chemistry. The lower chamber is connected to a graduated cylinder, used to record the volume of water filtered through the tailings/geotextile system. Water evaporation from the graduated cylinder is prevented by adding a small quantity of mineral oil, floating on top of the water. A total pressure of 2.9 psi (20 kPa) is applied on the upper chamber, which is separated from the main chamber by a rubber membrane. The 2.9 psi pressure was selected to simulate conditions near the surface in a tailings pond, i.e., equivalent to the stress applied by a 4.9-foot (1.5-m) thick layer of oil sands tailings with a density of 87.4 pounds/cubic foot (1,400 kg/m<sup>3</sup>). Water can be added at regular intervals in the main chamber through an inlet to maintain the rubber membrane in a low deformation state.

## Results

### Comparison of the results obtained with different types of oil sands tailings

Figure 3 shows the variation of the cumulative filtrate volume as a function of time for the geotextile Filter 3 tested with the two samples of real MFT (MFTR #1 and MFTR # 2), the NST and the two compositions of synthetic MFT (MFTS and MFTS+). In the case of MFTR #2 and NST, two replicates were conducted and showed a good reproducibility. In all instances, the collected filtrate was clear except at the very beginning of the tests. The tests were continued until no more consolidation could be observed, that is, no change of thickness of the tailings, except for a few instances discussed in the following paragraphs.

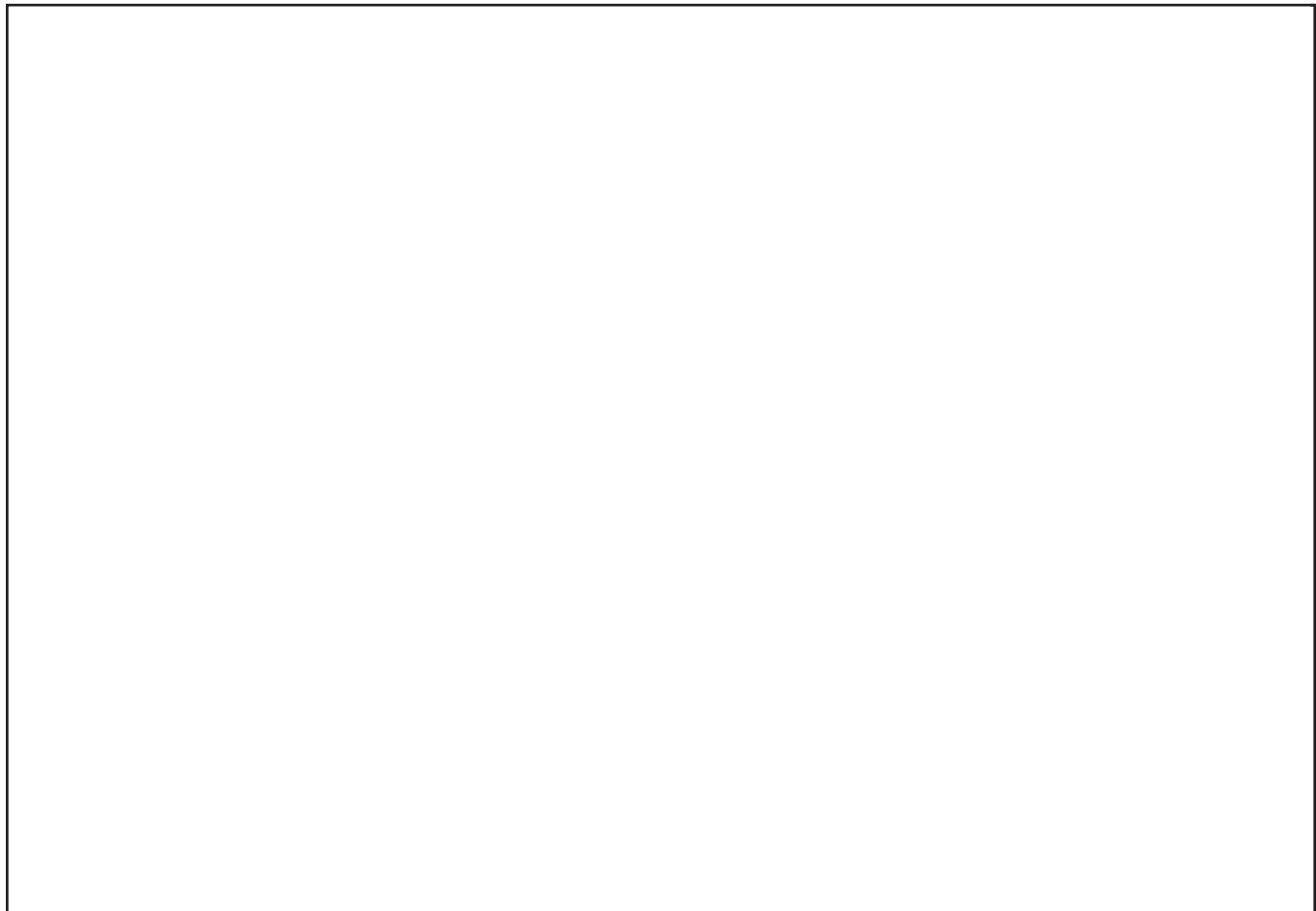
The flow rate was found to be significantly larger with MFTS (0% illite) compared to all the other tailings samples. In fact, the measured flow was at the limit, or above the capability of the apparatus and its operating strategy, as shown in

the steps observable in **Figure 3**. The addition of 21% illite to the synthetic MFT formulation (MFTS+) produced a strong reduction in the filtrate flow rate compared to 100% kaolinite formulation and approached the responses of the real MFT samples.

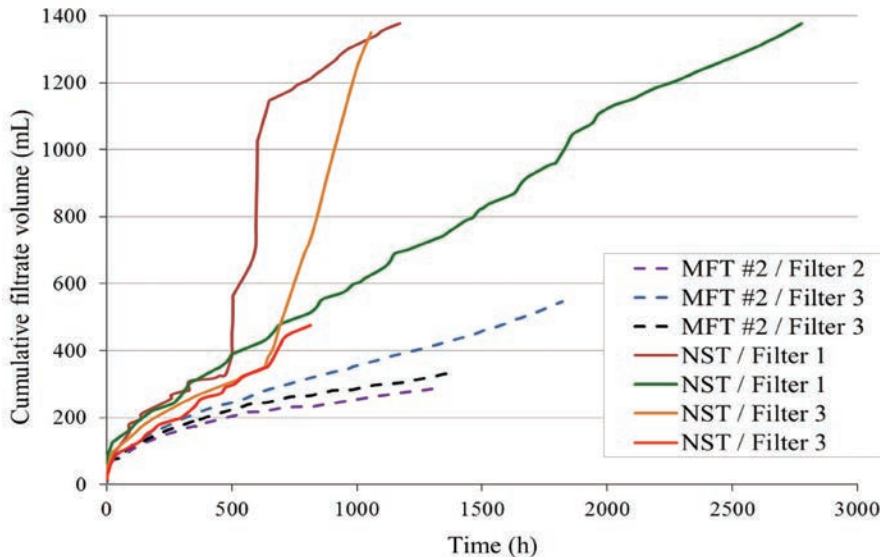
A geotextile/MFT system permittivity of  $1.8 \times 10^{-9} \text{ s}^{-1}$  was measured for MFTR #1 and  $4.9 \times 10^{-9} \text{ s}^{-1}$  for MFTR #2, which is about eight orders of magnitude lower than the water permittivity of the geotextile. This measurement reflects the permeability of the filter cake of densified MFT, which has developed in the vicinity of the geotextile due to the filtration process. This consolidated layer of MFT was observed while dismantling the

cell, when the tests were over. Although the consolidated slurry was exhibiting a low permeability, no sign of clogging or blinding was observed over the 1,127 to 1,820 hours (47 to 76 days) duration of the tests.

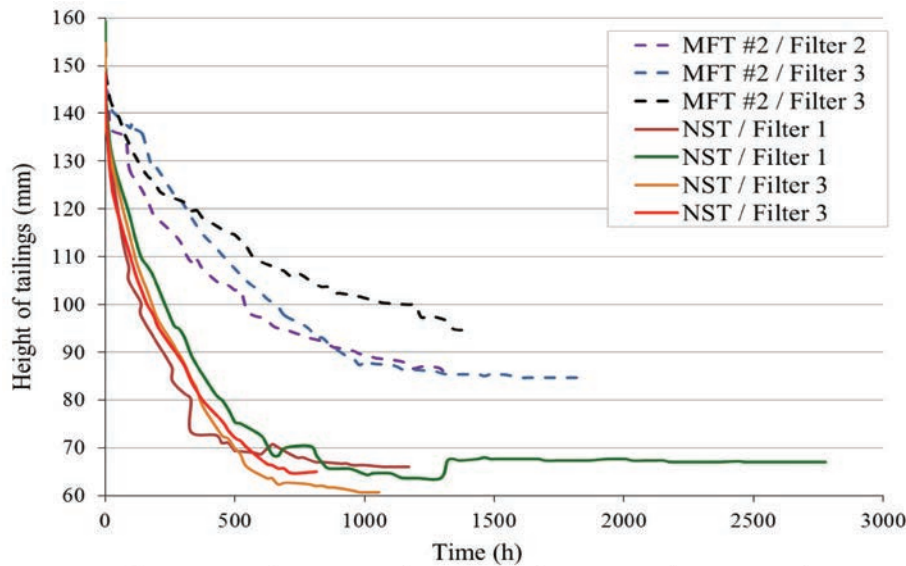
For tests performed using NST, the flow rate was typically between 0.27 and 0.37 ounce/day (8–11 mL/day), which corresponds to a geotextile/NST permittivity of  $8.4\text{--}11.5 \times 10^{-9} \text{ s}^{-1}$ . In some instances with NST, sudden increases of flow rate were observed, with variable magnitude and duration. For example, one experiment experienced an abrupt change in the filtrate flow rate from 0.27 to 2.03 ounces/day (8–60 mL/day) on day 26, and remained at 2.03 ounces/







**FIGURE 5** Cumulative filtrate as a function of time for MFT #2 and NST tested with geotextiles Filter 1, Filter 2 and Filter 3



**FIGURE 6** Height of tailings as a function of time for MFT #2 and NST tested with geotextiles Filter 1, Filter 2 and Filter 3

day (60 mL/day) for 18 days in a row. The experiment was terminated at that time. A similar increase of flow rate took place in another experiment, conducted with NST, but led to a different outcome. In that case, a sudden increase of flow appeared on day 27, lasted 76 hours, after which the flow rate returned to its initial value of 0.37 ounce/day (11 mL/day) and remained stable for 94 hours, until the test was terminated. These rapid changes of flow rate were caused by the appearance of cracks in the filter cake. In one case, the crack eventually healed and the system returned to its previous flow rate, while it did not heal in the other case.

Solid content of the NST filter cake was measured at the end of the test when dismantling the test cell. A gradient of solids content was recorded across the layer of NST, with values of 30%–45% at the top of the NST column and of 60%–70% just above a highly densified layer located immediately on top of the geotextile, which had reached a solid content as high as 80%.

The overall consolidation of the tailings samples is shown in **Figure 4** on page 16 for geotextile Filter 3. MFTR #1 settled by 15% while MFTR #2 maximum consolidation reached as much as 43%. This difference is partially related to the initial solids content of MFTR #1, which was much higher than the one of MFTR #2 (**Table 2** on page 15). Ultimately, the maximum consolidation level of the synthetic MFT formulation was similar to the one of MFTR #2. Additionally, the settling rates were much higher with synthetic MFT (MFTS and MFTS+), which reached their maximum consolidation level after 122–144 hours (5–6 days), while it took as many as 700 to 1,600 hours (29–67 days) for the real MFT (MFTR #1 and MFTR #2). In the case of NST, maximum consolidation was observed after 720 to 980 hours (30–41 days), with a final volume reduction of 55–60%.

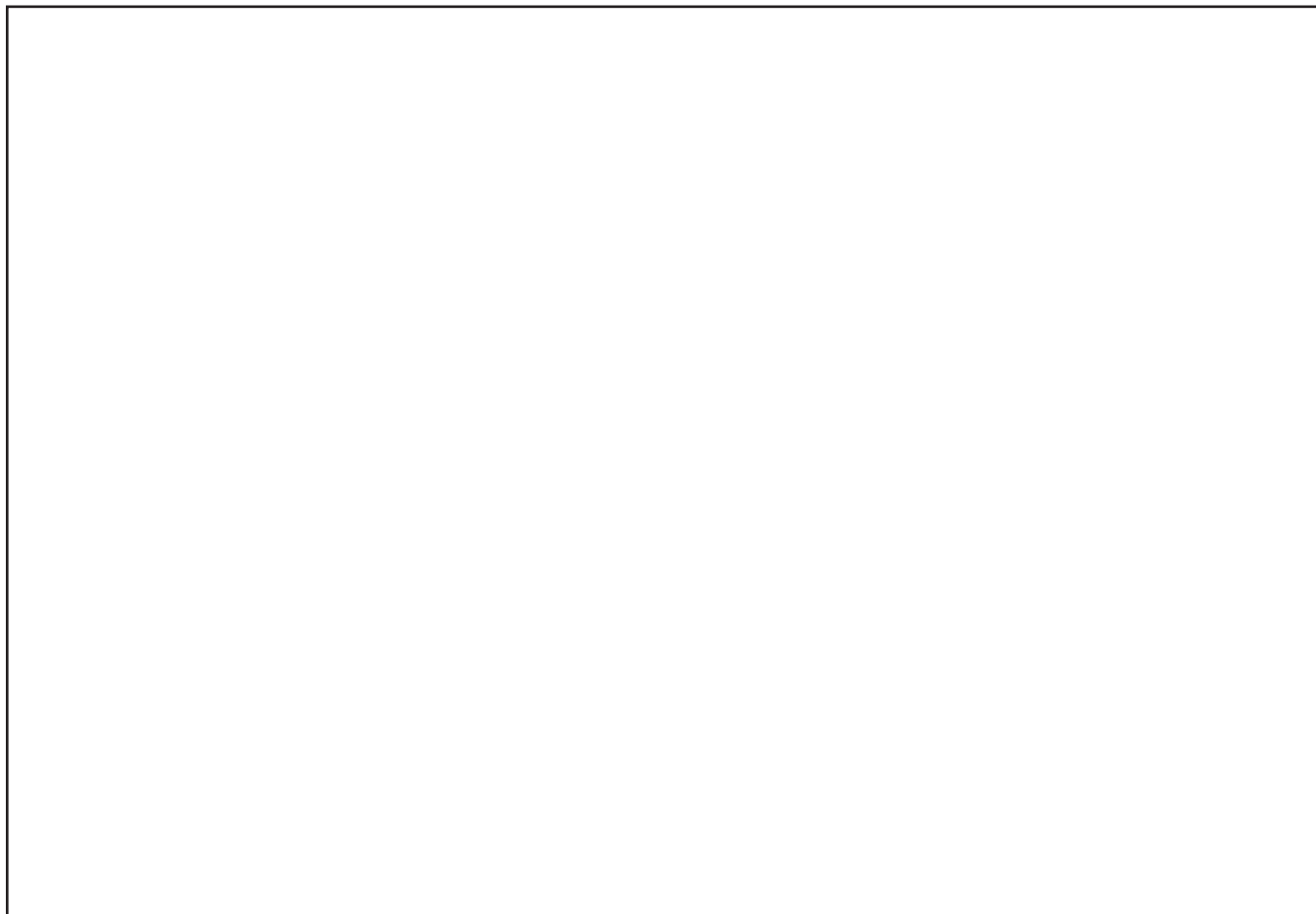
### Comparison of the behavior of different types of geotextile filters

Figure 5 shows the cumulated filtrate volume as a function of time for geotextile Filter 1, Filter 2 and Filter 3 in contact with MFT #2 and NST. For both synthetic and real tailings, the geotextile does not seem to have an impact on the volume of water passing through the filter, despite their filtration properties and their structure being significantly different (Table 1 on page 15). Differences between the NST cumulative filtrate curves after 500 hours (21 days) are attributed to cracks that have developed (and eventually sealed) in the filter cake. No effect of the geotextile on the total consolidation of the tailings was observed either (Figure 6).

However, the tests conducted using Filter 1 and MFT #2 showed evidences

of piping, with large clumps of soil passing through the geotextile at the beginning of the experiment, suggesting the inability of the filter to favor creation of a self-filtering structure. The test had to be interrupted shortly after its initiation, as the bottom of the test cell was full of tailings that had passed through the filter. However, other filtration tests conducted with the same tailing/geotextile combination but in a larger test cell and different hydraulic conditions did not show such poor behavior, as reported by Dolez et al. (2016). This observation suggests that not only the filtration properties but also the hydraulic conditions prevailing around the filter interface may affect the filtration behavior, i.e., the hydraulic gradient and total pressure.

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For the particular experiments reported here, the permittivity of the geotextile/tailings systems was several orders of magnitude lower than the permittivity of the geotextile.

## Conclusion

This article has investigated the performance of needlepunched and heat-bonded nonwovens for the filtration of oil sands MFT and NST using a test setup specially designed for slurries exhibiting very low hydraulic conductivities. For the particular experiments reported here, the permittivity of the geotextile/tailings systems was several orders of magnitude lower than the permittivity of the geotextile.

Very low flow rates were reported for all systems, suggesting that the water flow is controlled by the tailings, which has consolidated in the immediate vicinity of the geotextile filter, reaching a solid content as high as 80% with a small thickness.

For some slurry/geotextile systems, sudden increases of flow rates were observed, with variable magnitude and duration depending on the tested configuration. This behavior was associated with the formation of cracks in the filter cake, and subsequent healing after some time, suggesting that a fragile self-filtering structure had developed on the interface under the particular hydraulic conditions prevailing for this test.

Evidences of piping were observed for geotextile Filter 1, under the particular test conditions retained in this study. However, this observation is in contradiction with the observations made using another test configuration (not presented here), where good performance was observed using the same slurry/geotextile system but different hydraulic conditions. This observation suggests that beyond the filtration properties, hydraulic conditions prevailing at the interface (i.e., hydraulic head) will affect the filtration performance. Laboratory evaluation of the slurry/geotextile system using the anticipated field conditions should thus be considered a mandatory step to ensure adequate performance of the dewatering process.

## Acknowledgments

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