Use of an electrically conductive drain-tube planar geocomposite (eGCP) for accelerating the dewatering of mine tailings

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ABSTRACT: The management of tailings is one of the major operational and environmental challenges faced by the mining industry. Indeed, the consolidation rate of high water-content materials such as tailings is generally limited by their high physical stability and low hydraulic conductivity. For example, oil sands tailings tend to reach equilibrium with as little as about 30 wt% solids within a few years. Afterwards, they will not consolidate any further. Their storage thus requires large dedicated areas for virtually infinite periods, or until innovative solutions are found to permit additional consolidation / dewatering.
Extended laboratory work conducted in the last 4 years has shown that the use of electrically conductive drain-tube planar geocomposites (eGCP) can accelerate the dewatering rate of oil sands tailings. eGCPs combine a nonwoven geotextile which provides filtration and drainage, perforated pipes regularly positioned within the geotextile, and a conductive component acting as an electrode. Water displacement to the product drainage pipes is driven by electro-osmosis potential. From there, water is evacuated by gravity through the pipes.
The efficiency of eGCP for dewatering mature fine tailings (MFT) was demonstrated with a laboratory device developed to simulate tailings dewatering in the field. An increase in solids content from 45 to 70% was obtained with the application of 10.6 kWh per dry ton of treated MFT, leading to an improvement in shear strength from ± 0 to a mean value of 25 kPa in a little more than 40 days. The study also investigated the effect of eGCP characteristics, conditions of the electrokinetic treatment, and tailings composition and temperature. The results demonstrate the large potential of eGCPs at accelerating the dewatering of mine tailings with a minimal impact on mining operations.

Keywords: Mine tailings, electrically conductive drainage geocomposite, electro-osmosis, consolidation, dewatering, mature fine tailings (MFT)

1 INTRODUCTION

The mining industry generates huge quantities of tailings. In 2000, the daily production of mine tailings was estimated to a few hundreds of thousands tons per day (Jakubick et al. 2003). Nowadays, some mines produce more than 200,000 tons of tailings per day. For instance, open-pit oil sands mining operations generate about 16 tons of tailings for each ton of synthetic crude oil produced (Allen 2008). These tailings are transported and deposited in a slurry form; They initially contain about 70-80 wt% water, 20-30 wt% sand, silt and clay, and 1-3 wt% residual bitumen (Allen 2008). These tailings are currently pumped in settling ponds where the sand separates rapidly from silt and clay fine particles, then forms perimeter beaches, leaving what is called fluid fine tailings (FFT) in the center of the pond (Jeeravipoolvarn 2010).

However, the high stability and low hydraulic conductivity of FFT limits their timely consolidation: FFT reach a maximum concentration of about 30 wt% solids after a few years. They are then called mature fine tailings (MFT), and experience almost no further consolidation (Mikula et al. 1996). These MFT must be stored in dedicated areas and monitored for extended periods. For instance, there are currently more than 180 km^2 occupied by tailings ponds in Northern Alberta, Canada (Fair 2014). In addition to this problem of land sequestration, issues associated with oil sands tailings and other stable water-containing tailings include the immobilization of water, which is not available for reuse in the extraction process (Junqueira et al. 2011); the very low bearing capacity of MFT, which represents a hazard for wildlife and workers and a constraint to reclamation (Mamer 2010); and the risk of contaminant migration to surface and ground water (Frank et al. 2014).

A series of solutions have been explored over the years to speed up the dewatering of 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 non-segregating slurry; and filtration (Davies et al. 2010). Approaches also include recombination techniques leading to the creation of 'consolidated tailings' (Simieritsch et al. 2009); the addition of superabsorbent polymers (Farkish & Fall 2013); thin lift fines drying (Caldwell et al. 2014); and CO_2 coagulation (Zhu et al. 2011). However, these solutions have had limited success with high stability, low hydraulic conductivity materials such as oil sands tailings (Fair 2014).

Extended laboratory work has been conducted in the last 4 years to explore the use of electrically conductive drain-tube planar geocomposites (eGCP) to accelerate the dewatering rate of oil sands tailings. Planar drainage geocomposites have been developed in the late 90's to increase the internal drainage of low permeability backfill soils in reinforced walls and slopes (Sarsby 2007). They combine the functions of drainage and reinforcement in a single product and include two or three layers of nonwoven geotextiles assembled by needle punching and parallel rows of corrugated perforated pipes regularly positioned between the geotextile layers (Fig. 1). The perforated pipes provide most of the drainage capability while the top nonwoven geotextile acts as a filter and the central or bottom one as a capillary medium. Planar drainage geocomposites can sustain high normal loads without significant changes in transmissivity and are not creep-sensitive when confined in soil (Saunier & Blond 2009).

eGCPs are produced by adding a conductive component acting as an electrode in a drain-tube planar geocomposite. Voltage applied between two eGCPs causes water and positively charged compounds to move towards the cathode by electro-osmosis while anions are directed towards the anode (Fig. 2). Once in the eGCP perforated pipes, gravity flow is used to drain the water away from the tailings.

This paper presents results demonstrating the efficiency of eGCP prototypes at dewatering and consolidating oil sands tailings. The measurements were performed using a laboratory device designed to simulate the entire path of water taking place in an oil sands tailings pond operation. The study also investigated the effect of the eGCP characteristics, conditions of the electrokinetic treatment, and tailings composition and temperature.

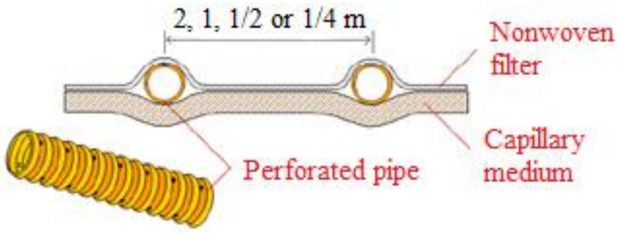

Figure 1. Drain-tube planar geocomposite.

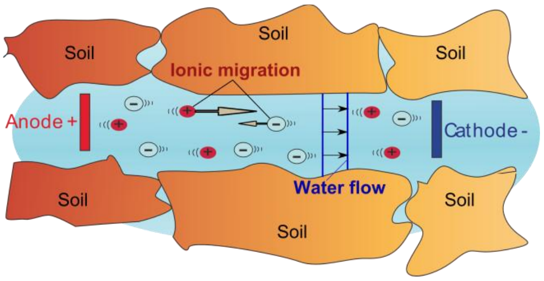

Figure 2. Principle of electrokinetic dewatering.

2 EXPERIMENTAL

2.1 *eGCP prototypes*

eGCP prototypes were prepared using two different models of a three-layer polyester geotextile made of two outer filters confining a heavier nonwoven designed to act as a capillary layer. The difference between the geotextiles lies in the characteristics of the outer filters, the capillary layer remaining the same. Table 1 gives the main characteristics of these two geotextiles.

Table 1. Characteristics of the geotextiles used in the eGCP prototypes.

	Geotextile A	Geotextile B
Thickness (ASTM D5199)	3.7 mm	3.9 mm
Mass per unit area (ASTM D5261)	420 g/m^2	400 g/m^2
Filtration opening size (filter layers, ONGC 148.1-10)	200 µm	120 µm

The eGCP prototypes also included a 20-mm outer diameter polypropylene drainage pipe positioned inside a gusset between the central nonwoven and a filter layer (Fig. 3). Finally, two materials were used for the electrode: a cylindrical tin-plated copper braid (diameter 25 mm, linear resistance 1.43 10^{-3} Ω/m) positioned around or along the perforated pipe in the gusset (Figure 3) and nine 24k carbon fiber tows (equivalent linear resistance 2.16 Ω/m) wrapped around the drainage pipe (Figure 4).

Figure 3. eGCP prototype with Geotextile A and tin-plated copper braid electrode.

Figure 4. Carbon fiber tows wrapped around the drainage pipe.

2.2 *Oil sands tailings*

Experiments were conducted with two samples of MFT (MFTR #1 and MFTR #2) obtained from Canadian oil sands producers. Their solids contents (ASTM D4959) and Methylene Blue Index (MBI) (Kaminsky 2014) values are provided in Table 2. The MBI values stand at both ends of the typical range for MFT. Non-segregating tailings (NST) with a sand-to-fine ratio of 4.5 and a solids content of 66 wt% were also prepared using MFTR #2 and mine sand.

In addition, the study used a formulation of synthetic MFT (MFTS). These synthetic MFT were developed to allow controlling the tailings composition in dewatering experiments (Dolez, Chappel, & Blond 2015). The synthetic MFT formulation includes 2.25 wt% bitumen, 0.4 wt% bentonite, 40.4 wt% kaolinite, 57 wt% water, and 0.015 wt% sodium chloride. The solids content and MBI values of the synthetic MFT formulation are also provided in Table 2.

Table 2. Characteristics of the tailings used in the study.

Label	Description	Solids content (%)	MBI (g/m^2)
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	43	58 ± 6

2.3 *Laboratory dewatering device*

A 20-L laboratory scale dewatering device has been developed to simulate the entire path of water taking place in real FFT disposal, i.e. under self-weight consolidation, electro-osmosis, and drainage (Bourgès-Gastaud et al. 2015). Two eGCPs are positioned horizontally on each side of the tailings (Fig. 5). Normal stresses are applied to the tailings by a pneumatic actuator and a metal loading plate to simulate consolidation under the weight of the overlying fill. The filtrate is continuously discharged through the pipes of the top and bottom eGCPs.

Fig. 6 illustrates the test sequence followed to simulate a typical dewatering scenario. During the first phase, consolidation takes place under self-weight exerted by the amount of tailings in the test cell; only the lower eGCP is installed and the filtrate is drained through its drainage pipe by gravity. The second phase of the dewatering process involves applying incremental normal stresses of 5, 10, and 20 kPa to simulate the effect of the MFT overlying layers as the pond is progressively filled. A normal stress of 20 kPa corresponds to a 1.5-m thick layer of MFT with a density of 1,400 kg/m^3. Water is expelled from the MFT through both eGCPs, i.e. at top and bottom of the cell, because of the normal pressure applied. In the last phase, the normal stress is maintained at 20 kPa and a voltage of 12 V is applied between the electrically conductive components of the eGCPs, with the cathode being positioned at the bottom of the cell. Each phase is terminated when the filtrate expulsion has reached 60% of its asymptotic value. The amount of filtrate extracted from the upper and lower eGCPs and the height of MFT are recorded as a function of time. At the end of the experiment, the cell is opened and two cores are sampled in the MFT to determine the solids content vertical distribution. In addition, shear strength measurements are performed at three different depths and five different horizontal locations using a Geonor vane shear tester with a 25.4 x 50.8 mm vane.

Some tests were conducted using a modified procedure to study the impact of a particular aspect of the process on the dewatering efficiency of the eGCP: the presence of an electro-osmosis phase (section 3.1); the relative position of the anode and cathode (section 3.3); the timing of the electro-osmosis phase vs. the consolidation under normal stress (section 3.3); and the voltage (section 3.3).

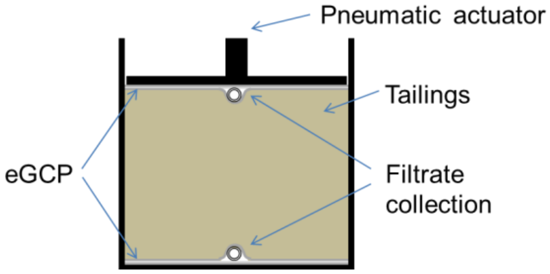

Figure 5. Laboratory scale dewatering device.

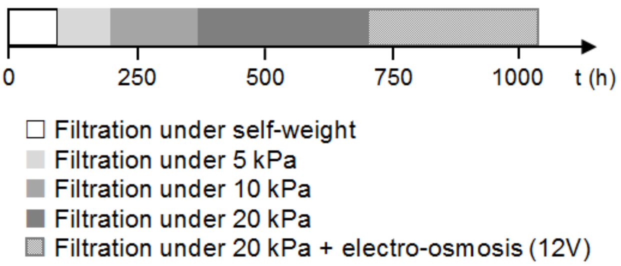

Figure 6. Dewatering test sequence.

3 RESULTS AND DISCUSSION

3.1 *Dewatering efficiency of eGCP with oil sands tailings*

An experiment involving MFTR#1, Geotextile A, and a tin-plated copper braid electrode positioned around the eGCP drainage pipes was conducted following the standard test sequence illustrated in Fig. 6. The mass of filtrate collected from the lower and upper eGCPs respectively as a function of time is shown in Fig. 7. The transition between the different phases is clearly observed: when the normal stress is increased or a voltage applied, the filtrate collection rate suddenly increases, then eventually reaches a plateau. Filtrates collected from both lower and upper eGCPs did not exhibit any turbidity detectable with a naked eye, except immediately after initiation of the flow at the very beginning of the test.

The experiment lasted 43 days. It led to an increase in solids content from 45 to 70%, with a reduction of 51% of the total volume of MFT. Simultaneously, the shear strength increased from nearly 0 kPa (i.e. below the detection level of the shear vane tester) to a mean value of 25 kPa. The energy consumed during the experiment was 130 Wh, corresponding to 10.6 kWh per dry ton of treated MFT.

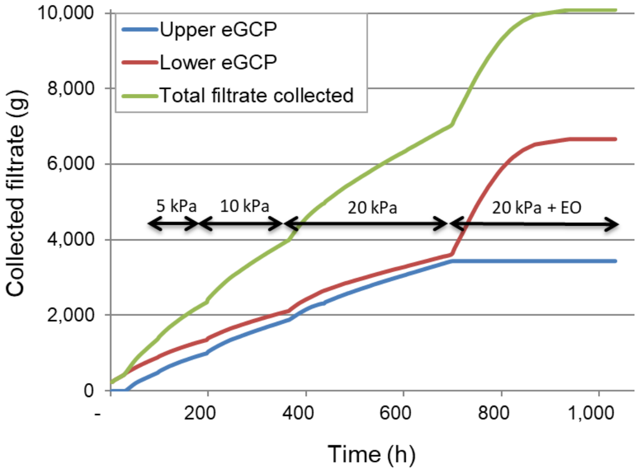

Figure 7. Filtrate collected as a function of time with MFTR #1, Geotextile A, and tin/copper electrode.

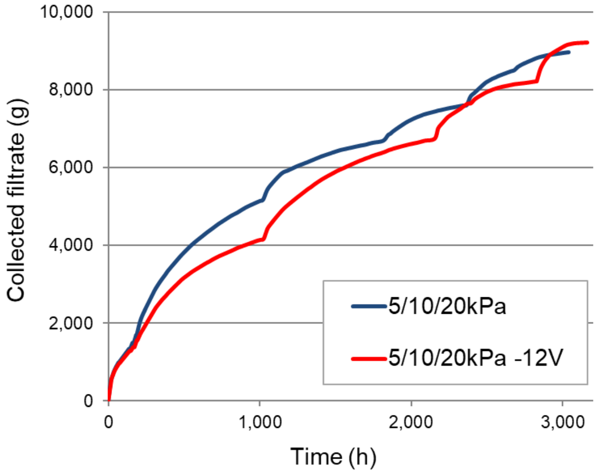

Figure 8. Filtrate collected as a function of time with MFTR #2, Geotextile B, and tin/copper electrode.

In order to quantify the impact of electro-osmosis on dewatering efficiency, two experiments were conducted in the same conditions: MFTR #2, Geotextile B, and tin-plated copper braid electrode along the eGCP drainage pipes. One of the experiment was carried out according to the typical timeline illustrated in Fig. 6 (labelled as 5/10/20kPa-12V in Fig. 8). In the second experiment (labelled as 5/10/20kPa in Fig. 8), the electro-osmosis treatment was omitted.

The amount of filtrate collected during both experiments was comparable. On the other hand, significant differences in the final shear strength and solids content were observed. An average of 2.75 kPa was measured for the experiment without electro-osmosis, i.e. below the 5 kPa requirement of Alberta Energy Resources Conservation Board (ERCB) Directive 074 for fine tailings within the year of deposition (ERCB, 2009). On the other hand, a value of 14.7 kPa was measured for the experiment with electro-osmosis, i.e. above the ERCB 10 kPa requirement within five years of active deposition. There is also a difference in the final solids content, with an average of 55.2% without electro-osmosis and 62.2% with electro-osmosis. These results demonstrate the advantage of electro-osmosis in obtaining trafficable tailings within a short period.

3.2 *Effect of the eGCP characteristics*

Experiments were conducted to compare the performance of eGCPs made with two different geotextiles (Table 1). The geotextiles have relatively similar thicknesses and masses, but the filtration opening sizes of the filter layers are different. The experiments were conducted according to the typical timeline illustrated in Fig. 6, using MFTR #2 and a tin-plated copper braid electrode positioned along the eGCP drainage pipes.

The total filtrates collected as a function of time were similar (Fig. 9). Small differences observed between the two experiments may be attributed to slight variations in the normal stress program due to dried tailings on the internal walls of the dewatering cell increasing the friction with the metal loading plate. Final solids contents were also similar with 60.9% for Geotextile A and 62.2% for Geotextile B. The absence of significant effect of the type of geotextile on the dewatering efficiency of eGCP was confirmed using a small scale dewatering device used to investigate the electro-osmosis phase of the treatment. No variation between different geotextiles was recorded either using a filtration cell specially developed for measuring the filtration compatibility of soil geotextile systems for very low hydraulic conductivity materials such as oil sands tailings (Dolez & Blond 2017).

Experiments were also carried out using two different types of electrode materials: tin-plated copper braid electrode positioned around the eGCP drainage pipes and carbon fiber electrode wrapped around the eGCP drainage pipes. Both experiments were run according to the typical timeline illustrated in Fig. 6 using MFTR #1 and Geotextile A. Similar volumes of filtrate were extracted, about 10,000 g (Fig. 10), resulting in similar solids content (70%) and shear strength (25 kPa) of the consolidated MFT.

The experiment with the tin-plated copper braid electrode lasted a little longer than the one with the carbon fiber electrode. However, it seems to have been left running unnecessarily for some time after the final plateau was reached. The energy consumed was 154 Wh when using the carbon fiber electrode, compared to 130 Wh when using the copper electrode. However, if the experiment with the copper electrode had been stopped at the same stage the one with the carbon fiber electrode was, the difference in consumed energy would have been even larger. This can be attributed to the higher linear resistance of the carbon fiber electrode.

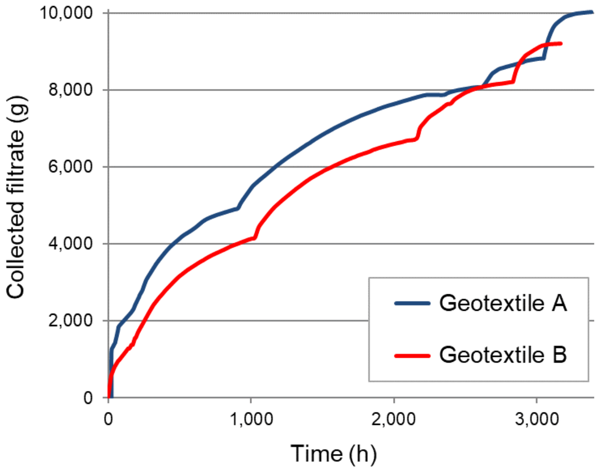

Figure 9. Filtrate collected as a function of time with MFTR #2 and tin/copper electrode.

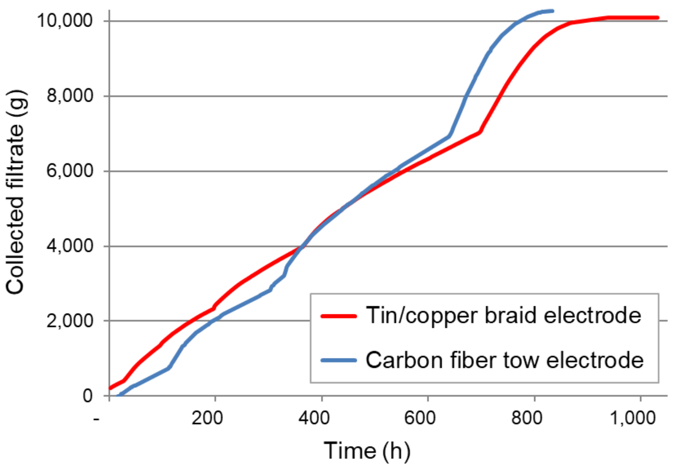

Figure 10. Filtrate collected as a function of time with MFTR #1 and Geotextile A.

3.3 *Effect of the electrokinetic treatment conditions*

The first condition studied was the effect of the relative position of the anode and the cathode. The other parameters were kept the same: experiments were conducted according to the typical timeline illustrated in Fig. 6 using MFTS, Geotextile A, and a tin-plated copper braid electrode positioned along the eGCP drainage pipes. The duration and amount of collected filtrate for the electro-osmosis step were quite different for the two experiments: 197 h and 2.25 L with the cathode located at the bottom on the cell, and 146 h and 1.47 L with the cathode located at the top. Final MFT solids content and shear strength were also different, with respectively 66% and a mean value of 25.5 kPa with the cathode at the bottom, and 62% and 11.9 kPa with the cathode at the top. The corresponding values of energy consumed are respectively 80 and 45 Wh. However, when the energy consumed is divided by the amount of filtrate collected during the electro-osmosis phase, similar values are obtained with 35.6 Wh/L with the cathode at the bottom, and 30.5 Wh/L with the cathode at the top. This observation suggests that the position of the electrode influences the amount of water that can be extracted by electro-osmosis with eGCPs but not the energy it takes to extract that water.

Another series of tests studied the timing of the electrokinetic treatment. For that purpose, electro-osmosis was started during the application of the 5 kPa normal stress and left running until the end of the experiment. The corresponding volume of filtrate collected as a function of time is shown in Fig. 11 and compared to the condition corresponding to the typical timeline illustrated in Fig. 6, i.e. with the electro-osmosis applied at the end of the 20 kPa phase. All other conditions of the two experiments remained the same: MFTR #1, Geotextile A, and a tin-plated copper braid electrode around the eGCP drainage pipes. The experiment involving the early application of electro-osmosis was slightly longer (1,128 h vs. 1,032 h for the typical timeline) but less filtrate was extracted (8,294 g vs. 10,087 g). The energy consumed was relatively similar: 140 Wh for the experiment with the early application of electro-osmosis vs. 130 Wh for the typical timeline. However, the final shear strength with the early electro-osmosis was much lower at 6 kPa vs. 25 kPa for the typical timeline. These results show that the electro-osmosis energy is most efficiently spent at extracting tightly bound water that mechanical dewatering cannot extract.

The effect of voltage on the dewatering efficiency was studied using MFTS, Geotextile A, and a tin-plated copper braid electrode positioned along the eGCP drainage pipes. Three different values of voltage were used for the electro-osmosis phase: 6, 9, and 12 V. Fig. 12 shows the variation in the filtrate collected during the electro-osmosis phase and total filtrate collected as a function of applied voltage. Both the total filtrate collected and filtrate collected during the electro-osmosis phase increase with increasing voltage. The larger effect observed with the total filtrate amount is attributed to the variability in the initial self-weight and normal stress consolidation phases of the dewatering treatment. The values of solids content, final shear strength of the MFT, and energy consumed are also displayed in Fig. 12; an increase at higher voltage is obtained as well.

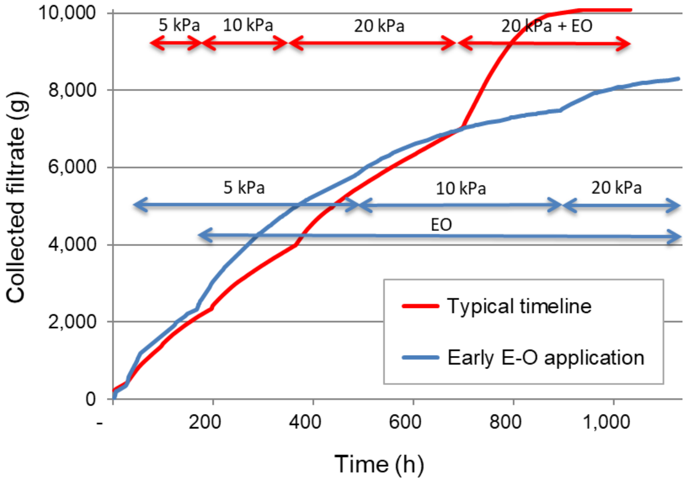

Figure 11. Filtrate collected as a function of time with MFTR #1, Geotextile A, and tin/copper electrode.

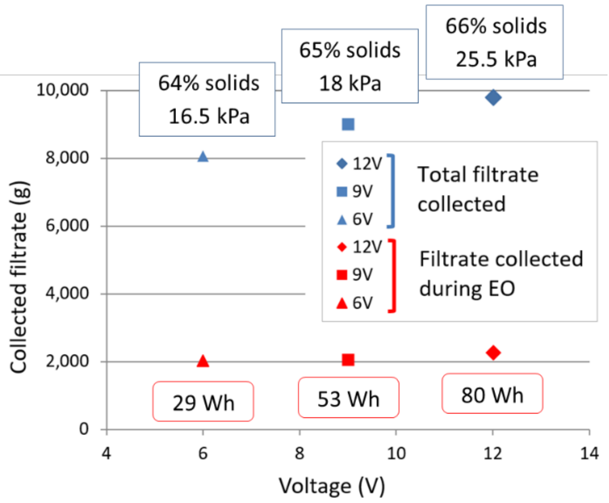

Figure 12. Filtrate collected as a function of voltage with MFTS, Geotextile A, and tin/copper electrode.

3.4 *Effect of site-related conditions*

A series of experiments were conducted to investigate the effect of the tailings composition on the dewatering efficiency with eGCP. Four types of oil sands tailings were used for this study: MFTR #1 and MFTR #2, both obtained from Canadian oil sands producers; NST prepared using MFTR #2 and mine sand; and MFTS, a synthetic MFT formulation. Their characteristics are given in Table 2. The other parameters of the experiments were kept the same: Geotextile A, a tin-plated copper braid electrode positioned along the eGCP drainage pipes, and the dewatering timeline illustrated in Fig. 6.

The total volumes of collected filtrate are shown in Fig. 13. The dewatering time is twice as high for MFTR #1 compared to the synthetic formulation (MFTS), and increases another three times for MFTR #2. The experiment with the NST tailings lasted 15% less than with MFT #2, which was used to prepare the NST. Except for one of the three MFTS experiments, the total volumes of filtrate collected over the entire dewatering process were similar for all three types of MFT samples. It was almost 20% higher for the NST. Volume reductions of about 50% for the MFT and 58% for the NST were recorded between the beginning and the end of the experiments.

Solids contents measured at the end of the dewatering treatment were 70% for MFTR #1, 61% for MFTR #2, around 66-67% for MFTS, and 82% for the NST. The average final shear strength values generally ranged around 25 kPa for all three types of MFT, and 20 kPa for the NST. In terms of energy consumption, experiments with the MFTR samples used two to three times as much energy (130 Wh for MFTR #1 and 218 Wh for MFTR # 2) than those with MFTS (75-80 Wh). With 87 Wh, the energy consumed for the NST treatment was much lower than for MFTR # 2. This indicates that eGCPs can greatly improve the dewatering of a wide range of oil sands tailings. However, their response to the treatment may vary, both in terms of treatment time, energy consumed, and final state of the tailings.

Due to space constraints, the effect of temperature was evaluated using a smaller dewatering cell. Only 4.5L in volume, its aim is limited to the investigation of the electro-osmosis phase of the eGCP treatment. More details about this device can be found in (Dolez, Blond, & Saunier 2015). Tests were performed at three temperatures (0-3, 10, and 23°C) by keeping the dewatering cell in a temperature-controlled chamber during the experiments. MFTS, Geotextile A, and tin-plated copper braid electrode were used. A 12 V voltage was applied between the two electrodes. The amount of filtrate collected was found to be significantly affected by temperature (Fig. 14), with a reduction of as much as 45% between 23°C and 0-3°C. However, the reduction between 23°C and 10°C was found to be more limited (11%). This reduced performance was also observed in the final solids content (67% at 23°C, 57.5% at 10°C, and 48% at 0-3°C) and shear strength (23 kPa at 23°C, 3.5 kPa at 10°C, and 0 kPa at 0-3°C). On the other hand, the dewatering rate remained relatively constant with temperature, at least initially.

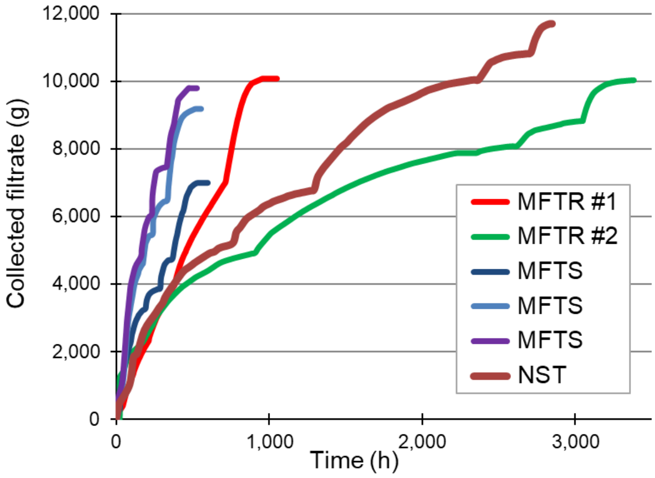

Figure 13. Filtrate collected as a function of time with Geotextile A, and tin/copper electrode.

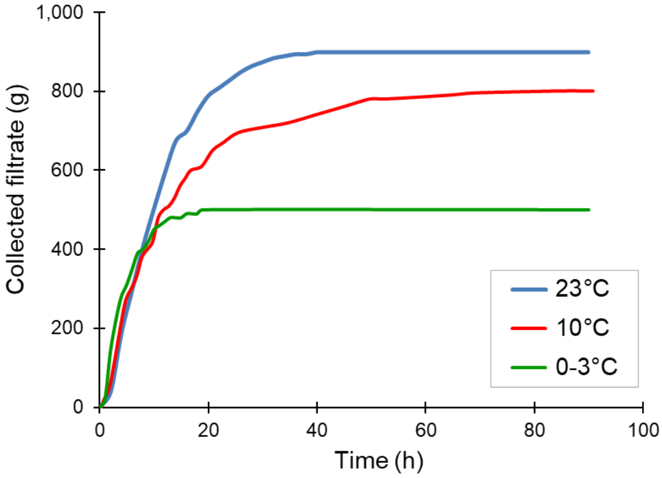

Figure 14. Filtrate collected as a function of time at different temperatures (small scale dewatering cell).

4 CONCLUSION

This study has investigated the performance of eGCP for dewatering oil sands tailings. The effect of eGCP characteristics, electro-osmosis treatment parameters, and site-related conditions were considered. Better results were obtained with a tin-copper braid electrode compared to a carbon fiber electrode, with the cathode located in the bottom of the tailing to be dewatered, and when electro-osmosis voltage was applied only after free water had been extracted through consolidation under the weight of the overlaying layers of MFT. The dewatering efficiency decreased when the voltage was reduced. Temperature was also found to affect the dewatering efficiency, but with a relatively limited effect except close to freezing conditions. Various types of tailings were successfully dewatered using the eGCP, even though differences in treatment time, energy consumed, and final state of the tailings were observed. The use of eGCP thus appears as a very promising solution, as it combines a cost effective method to remove free water sequestrated in the tailings with an on-request additional electro-osmosis treatment able to extract tightly-bound water and bring the tailings to a trafficable state in a short period.

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REFERENCES

Allen, E.W. 2008. Process water treatment in Canada’s oil sands industry: I. Target pollutants and treatment objectives. *Journal of Environmental Engineering and Science*, Vol. 7, pp. 123-138.

Bourgès-Gastaud, S., Stoltz, G., Dolez, P., Blond, E., Touze-Foltz, N. 2014. Laboratory device to characterize electrokinetic geocomposites for fluid fine tailings dewatering. *Canadian Geotechnical Journal*, Vol. 52(4), pp. 505-514.

Caldwell, J., Revington, A., McPhail, G., & Charlebois, L. 2014. Optimised seasonal deposition for successful management of treated mature fine tailings. *Proc. 17th International Seminar on Paste and Thickened Tailings - Paste2014*, Vancouver, BC, Canada, pp. 371-381.

Davies, M.P., Lupo, J., Martin, T., McRoberts, E., Musse, M., & Ritchie, D. 2010. Dewatered Tailings Practice – Trends and Observations. *Proc. 14th annual Tailings and Mine Waste Conference*, Vail, Colorado, USA, pp. 133-142.

Dolez, P.I. & Blond E. 2017. Evaluation of geotextile performance for the filtration of fine-grained tailings. *Proc. Geotechnical Frontiers 2017*, Orlando, FL, USA, pp. 269-277.

Dolez, P. I., Blond, E., & Saunier P. 2015. Effect of Electrical Conditions on Efficiency of Electrically Conductive Drain-Tube Planar Geocomposites (eGCP) for Tailings Dewatering. *Proc. Tailings 2015*, Santiago, Chili, 10p.

Dolez, P.I., Chappel, M., & Blond, E. 2015. Development of a synthetic formulation of oil sands mature fine tailings. *2015 COSIA Oil Sands Clay Workshop and Conference*, Edmonton, AB, Canada.

ERCB. 2009. *Directive 074: Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes*. Energy Resources Conservation Board of Alberta.

Fair, A. 2014. Oil sands tailings: An historical perspective. *Proc. Fourth International Oil Sands Tailings Conference 2014*, Lake Louise, AB, Canada, pp. 3-7.

Farkish, A. & Fall, M. 2013. Rapid dewatering of oil sand mature fine tailings using super absorbent polymer (SAP). *Minerals Engineering*, Vol. 50–51, pp. 38-47.

Frank, R.A., Roy, J.W., Bickerton, G., Rowland, S.J., Headley, J.V., Scarlett A.G., West C.E., Peru K.M., Parrott J.L., Conly, F.M., & Hewitt, L.M. 2014. Profiling oil sands mixtures from industrial developments and natural groundwaters for source identification. *Environmental Science & Technology*, Vol. 48 (5), pp. 2660–2670.

Jakubick, A., McKenna, G., & Robertson, A M. 2003. Stabilisation of Tailings Deposits: International experience. *Proc. International Experience. Mining and the Environment III*, Sudbury, ON, Canada, 25-28 May, pp. 1-9.

Jeeravipoolvarn, S. 2010. *Geotechnical Behavior of In-Line Thickened Oil Sands Tailings*. Ph.D. Dissertation: University of Alberta, Edmonton, Canada.

Junqueira, F.F., Sanin, M.V., Sedgwick, A., & Blum, J. 2011. Assessment of water removal from oil sands tailings by evaporation and under-drainage, and the impact on tailings consolidation. *Proc. Tailings and Mine Waste 2011*, Vancouver, BC, Canada, *6 - 9 November 2011*: 11p.

Kaminsky, H. 2014. Demystifying the methylene blue index. *Proc. Fourth International Oil Sands Tailings Conference 2014*, Lake Louise, AB, Canada, pp. 221-229.

Mamer, M. 2010. Oil sands tailings technology: understanding the impact to reclamation. *Proc. British Columbia Mine Reclamation Symposium*, Courtenay, BC, Canada, 5p.

Mikula, R.J., Kasperski, K.L., Burns, R.D., & MacKinnon, M.D. 1996. Nature and fate of oil sands fine tailings. *Advances in Chemistry*, Vol. 251, pp. 667-723.

Sarsby, R.W. 2007. *Geosynthetics in civil engineering*. Woodhead Publishing – CRC Press, Boca Raton, FL, USA.

Saunier, P., Blond, E. 2009. Behavior of ‘Draintube’ drainage geocomposites under high compression load. *Proc. Geosynthetics 2009*, Salt Lake City, UT, USA.

Simieritsch, T., Obad, J., & Dyer, S. 2009. *Tailings Plan Review - An Assessment of Oil Sands Company Submissions for Compliance with ERCB Directive 074: Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes*. Pembina Foundation and Water Matters, Calgary, AB, Canada.

Zhu, R., Liu, Q. Xu, Z., Masliyah, J.H., & Khan A. 2011. Role of dissolving carbon dioxide in densification of oil sands tailings. *Energy Fuels*, Vol. 25, pp. 2049–2057.