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ON-SITE NON-WOVEN GEOTEXTILE FILTRATION METHOD FOR REMEDIATION OF LAKE WATER

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Abstract: The aging of lakes can be described as the natural process of sediments and nutrient accumulation that leads to the lake trophic levels changes. Due to human interaction, this natural succession process is being accelerated within the lakes increasing eutrophication in many aquatic systems. Some lake restoration and remediation treatment methods are used to slow down the aging process such as sediment dredging, chemical addition, and water aeration. These remediation approaches can adversely affect the lake biota through disturbing water column and sediment. To tackle this issue, the on-site non-woven geotextile filtration method for improving lake water quality as a possible remediation technique is proposed. This present study has focused on improving the water quality of Lake Johanne, a shallow mesotrophic lake located in the Sainte-Anne-des-Lacs municipality in Quebec, by setting up an on-site floating geotextile filtration system. In this study, the lake water was filtered through a set of selected non-woven geotextiles of different pore sizes in both batch and continuous mode at different retention times. Filtered water quality was monitored during the tests by analyzing water samples for total phosphorus, chemical oxygen demand (COD), total suspended solids (TSS), and particle size analysis. The geotextile filters were effective for removing nutrients and suspended particles and resulted in about 74% and 47 % and an average of 35% and 40% total suspended solids and total phosphorus removals in the contained water for the batch and continuously test, respectively. This has shown that non-woven geotextile filters can be used as a filter media for improving surface water quality as a possible method for lake water remediation

1 INTRODUCTION

Lakes, like any living system, age naturally, and thus this succession/evolution normally occurs over hundreds or thousands of years, however, human interaction within the land is accelerating this process transforming low nutrient lakes to high nutrient lakes faster than before. Sometimes, called cultural eutrophication this acceleration is the primary problem facing most surface waters today caused by nutrient enrichment and resulting in excessive plant/algae/cyanobacteria growth (Zhao et al. 2020). The driving forces of this process are the increasing input of organic matter from point and non-point sources within lakes (e.g., sewage discharge and fertilizer/detergent use) (Le Moal et al. 2019), sediment input (e.g., watershed runoff), increased precipitation caused by climate change (Sinha et al. 2019), nutrient lake sediment release (Veetil et al. 2018), and organic matter degradation on lakes (Zhang et al. 2019).

The issues triggered by those mechanisms could lead to lake volume reduction and high algae/cyanobacteria productivity that in some cases can produce toxins, lake anoxia and other associated problems. As stressors are not to be reduced in those systems in the possible future, the number of affected lakes will increase over the years if no action are made (Le Moal et al. 2019). In this way, bringing to Quebec regional perspective, watercourses represent 22% of its territory, with approximately 3.6 million lakes of various sizes. Those lakes are highly important for Quebec source water protection, and consequently, the lakes' aging issues need to be addressed.

For classification criterion waters with low productivity are termed oligotrophic, waters with high productivity eutrophic, and the mid value is characterized as mesotrophic. In Quebec guidelines, the main parameters used for this classification include total phosphorus, chlorophyll-a, and water transparency in the specific range measured in the pelagic zone with the observation of aquatic plant abundance in the littoral zone. (MDEEP, 2012). It is worth mentioning, that phosphorus is often the limiting nutrient in freshwater ecosystems related to trophic level changes (Knoll et al. 2016). Additionally, the form that the phosphorus is found within lake water is of crucial importance. While nutrients from catchments are partly in the particulate form that settles in the water column and are not directly used by phytoplankton until released from particles, internal loads in lakes are predominantly in the dissolved form directly available for algal growth (Bormans et al. 2016). Therefore, it is necessary to propose removal means for both forms of phosphorus introduced into lakes.

In order to tackle this issue, internal and external nutrient loads, several invasive remediation approaches are used such as sediment dredging (Jing et al. 2019), lanthanum-modified bentonite addition (Spears et al. 2015), cement addition (Liu et al. 2020), and water column aeration. These remediation approaches can adversely affect the lake biota in the water column, as well as, reduce the lake volume, in the case of additives, and thus are not ideal remedial options. Consequently, non-invasive remediation techniques need to be proposed. The use of geotextiles as a filter media for removing the SS and other pollutants including nutrients and heavy metals from stormwater and surface water (Alam et al. 2018; Mulligan et al. 2009; Inoue et al. 2009) have been reported in the literature, indicating its potential.

Concordia University’s research environmental engineering team has been performing on-site filtration experiments on Lake Johanne and monitoring its water quality, over the past few years. The on-site experiments intend to improve the surface water quality using non-woven geotextiles as a filter media. Thus the objectives of this present study are to monitor the lake water quality and evaluate the effectiveness of nonwoven geotextile on-site filtration use in removing nutrients and suspended solids, as a possible method for lake water remediation

2 MATERIALS AND METHODS

2.1 Study area

The present study focused on improving the Lake Johanne water quality (45°50′23″N; 74°08′19″W), a shallow mesotrophic lake located in the Sainte-Anne des-Lacs municipality in Quebec. The lake is located in the *Massé* watershed (previously called *du Lac Olier* watershed) mainly occupied with wild trees and a few residents, is one of the 5 watersheds located in the municipality area contributing *to Rivière du Nord* (Coutore et al. 2013). Considered the watershed head lake, represented in Figure 1, Lake Johanne is a shallow lake with maximum and average depths of 3.5 and 1.7 m, respectively and approximate surface area and water volume of 44,910 m^2 and 74,900 m^3 (ABVLacs Org. 2018).

Internal phosphorus loading on the lake is linked to a wetland located at the head of the lake, possible septic tank discharges from the nearby neighborhood, and phosphorus sediment release. Sediment phosphorus concentration in some parts of the lake varied between 1186-1451 mg/kg (Veetil et. al. 2018). Additionally, external contributors of nutrients in the water are the runoff from a nearby road (i.e. Station 9), the runoff from the forested area and plant growth, death and in some decomposition of organic matter in the water.

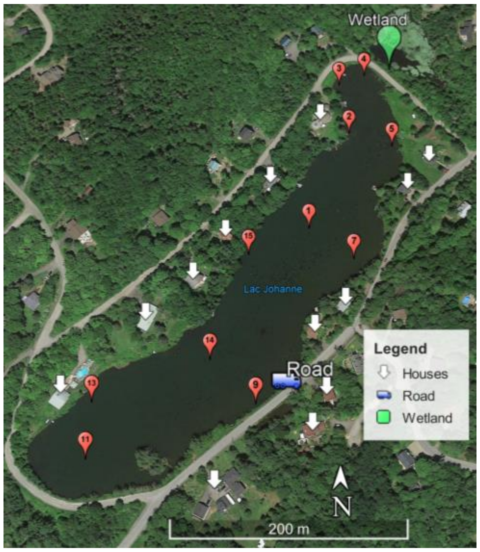

Figure 1: Lake Johanne with sampling stations

2.2 On-site geotextile filtration setup

On-site geotextile filtration experiments were performed using a 543 L plastic tank (35.6 cm height and width of 97.8 cm) placed on the ground near to station 2. This place was chosen due to the proximity to electrical energy outlets (for use in pumps) and being clean leveled area near to lakeshore.

The filtration unit consists of a cylindrical filtration column, made of plexiglass, of 20 cm internal diameter and 25 cm in height, and a square-shaped base, as a filter holder, with a circular hole at the center in the exact filtration column diameter (20 cm) showed in Figure 2 (a). The filtration column was placed on the base to hold water and support a maximum hydraulic head of 18 cm above the geotextile filter. Screws were used to fix and attach the filtration column to the square base. A water level controller, which can turn on and off the pump automatically, was used at a height of 18 cm in the filtration column to avoid water overflow.

In the filtration tests, the tank was first filled with about 300 L of lake water using a submersible pump. After this, the filtration unit, with selected geotextile filter combination, was placed on a polystyrene foam piece to float the entire unit on the tank water as presented in Figure 2 (b). A circular hole with a 20 cm diameter was made in the foam center to let filtered water pass through and return into the tank. In this study, two different types of filtration tests were performed: (i) 3 batch experiments, and (ii) 4 continuous filtration experiments with the retention times of 4, 3, 2 and 1 day.

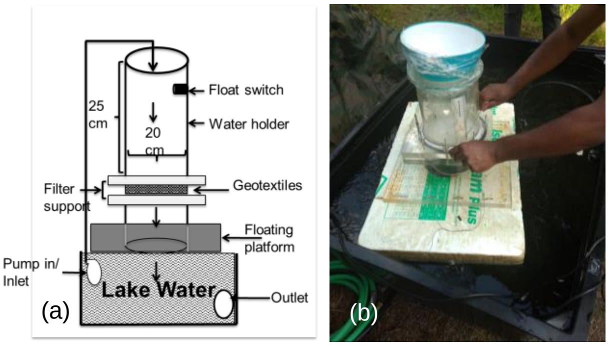

Figure 2: (a) Schematic of filtration set up and (b) On-site filtration unit;

The only difference between the batch experiments and continuous experiments is the batch experiment only treated 300L for an average of 7.3 days. On another hand, the continuous experiment had input from the lake and output to the lake, returning treated water to it, with a specific retention time for each experiment. For the continuous tests, the input was done with a calibrated medium flow rate peristaltic pump fed by lake water and the outlet was by overflow.

Additionally, in both experiments, four pumps with a very low flow rate were used in the tank continuously, in order to avoid any short-circuiting in filtering the entire tank water. Also, a tarpaulin was used for covering the whole filtration set-up to protect it from rain and other external influences. The system was checked every 2-3 days for geotextile clogging, pumping status, outlet and inlet clogging, and external influences.

2.3 Filter media

Five non-woven custom made geotextiles filters (TE-GTX300, TE-GTT100, TE-GTT120, TE-GTT200, and TE-GTN350B) were developed and received from Titan Environmental Containment Ltd., MB to use as a filtration media in this on-site lake water remediation project, related to suspended particles and nutrient removal of this mesotrophic lake. In Table 1, the physical characteristics of the geotextiles (based on the datasheets obtained from Titan Environmental Containment Ltd.) are defined with details.

Table 1: Non-woven geotextiles characteristics used in this study

Filters	Material	Apparent Opening Size (AOS) (µm)	Flow rate (L/m^2/min)	Permittivity (sec^{-1})	Mass per unit area (g/m^2)
TE-GTX300	[a]PET	110 µm	3,900	1.62	300
TE-GTT100	[b]PP	100 µm	75	-	150
TE-GTT120	PP	90 µm	70	-	120
TE-GTT200	PP	70 µm	50	-	200
TE-GTN350B	PP	65 µm	2,700	0.56	350

[a]PET: Polyester; [b]PP: Polypropylene

In relationship to the material used, the TE- GTX 300 geotextile filter is white and made of a continuous filament fiber polyester (PET) with 110 µm AOS. The TE-GTT100, TE-GTT120, and TE-GTT200 with AOS sizes of 100 µm, 90 µm, and 70 µm, respectively are also white, made in 100% virgin staple, UV resistance, and thermally bonded polypropylene (PP) fibers. The filter-GTN 350B (AOS: 65 µm) is black and is also made of 100% virgin staple, UV resistance, and thermally bonded PP fibers.

Filters were cut to a 22 cm diameter and arranged in descending order of their AOS. Figure 3 shows three non-woven geotextiles before the filtration process. The filter selection and combination were based on the previous on-site studies during 2017-2018. The same filter combinations were used for both batch and continuous experiments. Also, the set of filter layers were entirely changed at the end of the experiment or when clogged, whichever occurred first.

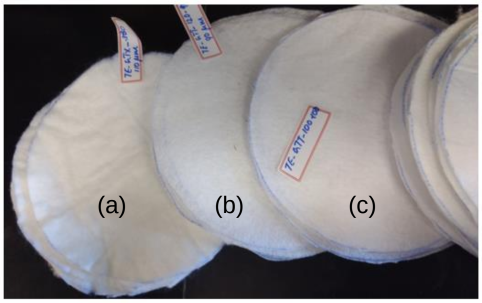

Figure 3: Non-woven geotextiles before the filtration process (a) TE-GTX300-110 µm (b) TE-GTT120-90 µm (c) TE-GTT100-100 µm

2.4 Water Quality Analysis

In order to access water quality throughout the entire lake, water samplings were performed at selected stations (St. 1, St. 4, St. 7, St. 9, and St. 11) over the 2019 summer. Water samples were collected in cleaned 1L high-density polyethylene (HDPE) amber bottles and 50 ml sterilized polypropylene test tubes. Both of them were stored at 4°C in the dark prior to any physico-chemical analysis and all analyses were performed within 48h. During the filtration on-situ tests, water samples were collected from both the tank and inlet to see the changes in the water quality due to the filtration.

The water samples were analyzed for the following parameters: particle size distribution (PSA), total suspended solids (TSS), TP, total nitrogen (TN), nitrate (NO_3^-), and Chemical Oxygen Demand (COD). Test kits from Hach chemicals were used for analyzing TP (Method 10209 - SM 4500-PE - Ascorbic Acid Method), TN (TNT 826, Method 10208, persulfate digestion), NO_3^- (TNT 835, Method 10206, dimethyl phenol method) and COD (TNT 820, Method 10221, reactor digestion method). Particle size analysis (PSA) was performed with a laser diffraction particle analyzer (LA-960 Horiba laser particle size analyzer).

3 RESULTS AND DISCUSSION

3.1 Lake water quality

The lake sampling results, shown in Table 2, indicate that under MDDEP trophic status classification, Lake Johanne, is a mesotrophic lake in the middle range (13-20 µg/L) possible going towards the high range (i.e., mesoeutrophic classification) in a near future. It is known that two more parameters (chlorophyll-a and transparency) are used in the comprehensive classification, but it is worth noting that the lake has an average depth of 1.7 m and there are no significant microscopic algae in suspension. Additionally, by the MELCC (2018) it is recommending on the Quebec *Réseau de surveillance volontaire des lacs* (RSVL) results from this lake the adoption of measures to limit nutrient inputs for avoiding further degradation of this lake and further loss of uses.

Table 2: Lake Johanne water quality during July-Sep, 2019

Parameters	2019[a]
TP (µg/L)	14.3±0.7
COD (mg/L)	23.6±0.2
NO_3^- (mg/L)	0.13±0.02
TN (mg/L)	0.86±0.03
TSS (mg/L)	4.3±0.7

[a] Average of 7 samplings of 5 lake stations

The COD concentration showed that the lake water is slightly elevated when compared with the Chapman and Kimstach (1996) average of 20 mg/L for unpolluted surface waters. When related to suspended matter concentrations, the lake water concentration should be a concern, because this is one of the external loadings inputs in the contribution to the reduction of lake volume and nutrient increasing. Even though the MDDEP (2012) guidelines give a slightly high value 13 mg/L to separate the class of water with a satisfactory quality of the dubious quality class in the IQBP (*l'indice de qualité bactériologique et physicochimique*), this parameter needs to be addressed.

Nitrate and TN concentrations are under Quebec guidelines (i.e., MDDEP, 2012) for protecting aquatic life, which are 2.9 mg/L and 1.0 mg/L, respectively. Also, PSA results showed that 90% of the particle's size (d90) was under the range of 67 to 84 µm and 50 % of the particles have (d50) diameters under the 9 to 14 µm range over the 7 samplings of 2019. Additionally, it was observed in the PSA analysis, large particle sizes were found at the St.4, near the wetland. This could be one of the internal sediment/nutrient inputs of the lake.

3.2 Filtration

Experiments ran for 92 days from July 23 to October 22 of 2019 (i.e., divided into 3 batch experiments and 4 continuous experiments) shortly after the start of summer until the mid-fall season. Also, as was explained before, the experiment system took place near the lakeshore and was checked every 2-3 days for sampling, geotextile clogging, pumping status, outlet, and inlet clogging (for the continuous experiment) and any other external influences.

For the whole experiment, 11 sets of filters were used from the cut 22 cm diameter layers arranged in descending order, totaling 0,418 m^2 for each AOS in the experiment. Figure 4 presents one set of used geotextile filters after 1 week of lake water filtration throughout the experiments. As can be seen, there was cake layer formation on the top of the geotextile. This layer was formed by particle accumulation and is explained that not only the straining filtration mechanism has occurred on this process but also depth filtration due to the initial ripening.

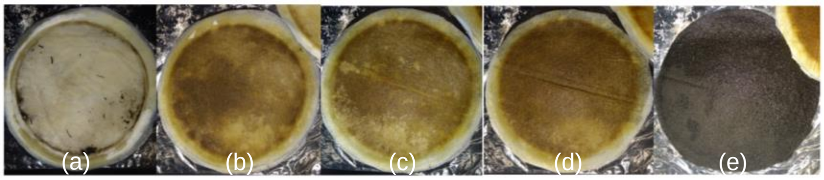

Figure 4: Non-woven geotextile after filtration process for AOS order: (a) 110 µm (b) 100 µm (c) 90 µm (d) 70 µm and (e) 65 µm

3.2.1 Batch Experiments

Three batch experiments were performed with an average of 7.3 days of filtering 300L of water. In the experiments carried out, a significant reduction in the parameters of TSS and D90 (i.e., diameter where ninety percent of the distribution has a smaller particle size) was observed, occurring immediately after the first day of filtration as seen in Figure 5 (a) and (b). This is, because after this period of filtration there was particle accumulation in the top layer of the filters, reducing its AOS, which thus ensures both a reduction of suspended particles in the tank and reduction of particle size to values significantly smaller sizes than the start of the process. In this way, the efficiency of this on-site non-woven geotextile filtration method was proven for reducing these parameters. For TSS, an average removal 74% removal was obtained as well as a D90 presented an average reduction of 89%, thus maintaining the D90 it in the tank water below 8 µm.

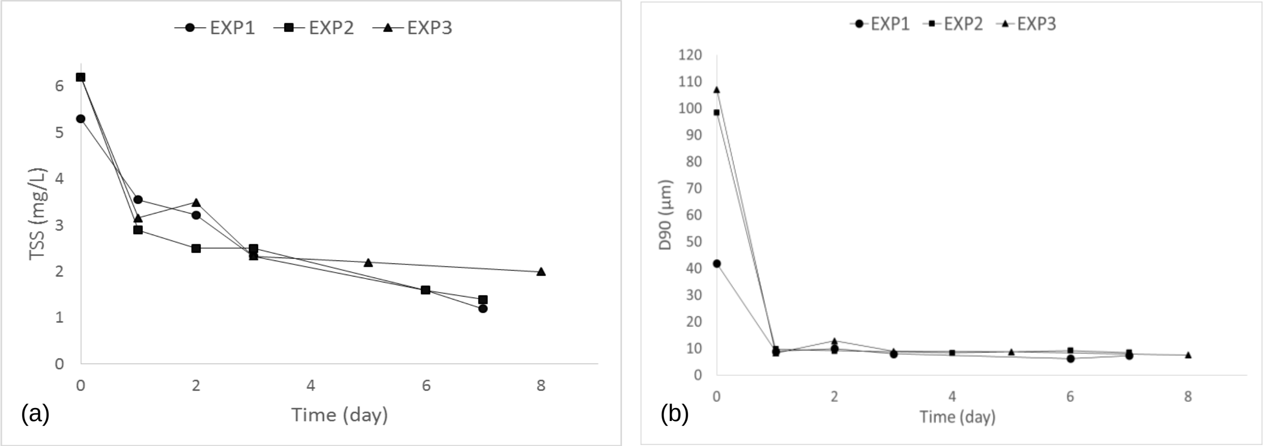

Figure 5: (a) TSS concentration (mg/L) and (b) D90 diameter (µm) in the tank water

The same reduction behavior was observed for the parameters of TP and COD, shown in Figure 6 (a) and (b). The filtration method can thus be used to remove particles containing phosphorus and particulate COD. If those particles are removed from the water column this will prevent possible settling and future release of nutrients and COD that can be directly uptaken by the phytoplankton. The reduction of total phosphorus led to a reduction in its values of oligotrophic trophic level lakes. Total removal in the system was approximately an average removal of 47% in the experiments. For COD, the values were reduced more significantly at the end of the experiment, when the cake layer was formed. Total removal in the system was approximately an average removal of 27% in the experiments. By the end of two experiments, the limit value for unpolluted surface waters was reached.

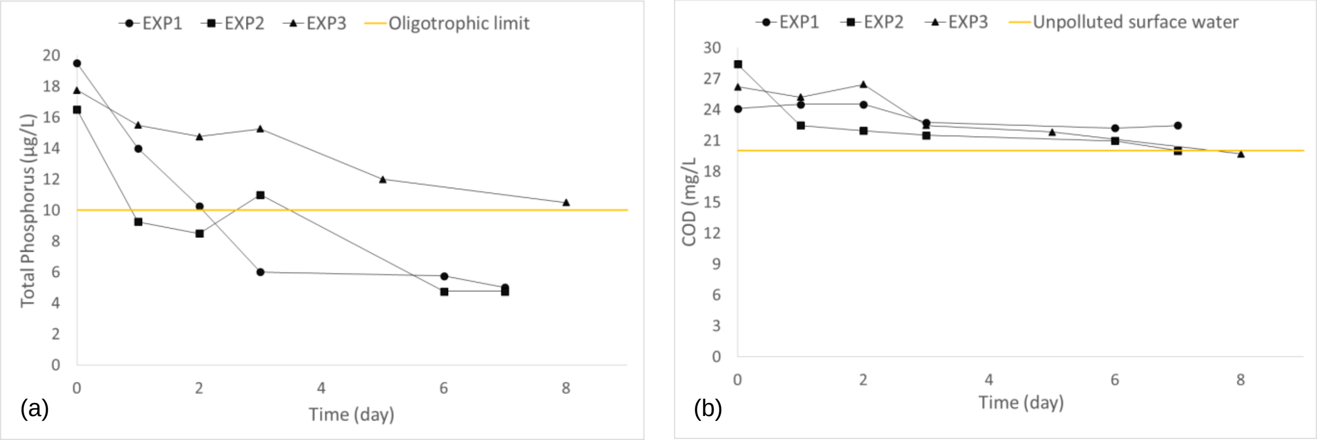

Figure 6: (a) TP concentrations (µg/L) and (b) COD concentrations (mg/L) in the tank water

It was noted during the experiments that there was no significant change for the concentrations of TN and nitrate. The average value was kept below the values present in the raw water and within the Quebec regulated values. For TN, the value was kept at a medium value of 0.89 ± 0.14 mg/L and for nitrate, its average value of 0.18 ± 0.02 mg/L was not affected by the experiment.

3.2.2 Continuous Experiments

Four continuous experiments were performed with an average of 12 days (except for the retention time of 1 day) with input from the lake and output returning treated water to the lake In the tests carried out, a significant reduction in the parameters of TSS was observed, as can be seen in Figure 7 (a) and (b). This can be explained by cake layer formation on the top of the filter, the same process occurred in the batch experiment. This enabled the water returned to the lake presented values to be below 2.0 mg/L after one day of filtration in the retention times of 4 and 3 days. The retention time of 2 days and 1 day required 8 days of filtration and 13 to present values below 2.0 mg/L, respectively to output water at the same level. The average removal was 74%, 37%, 38%, and 30% for the 4, 3, 2, and 1 day retention times, respectively.

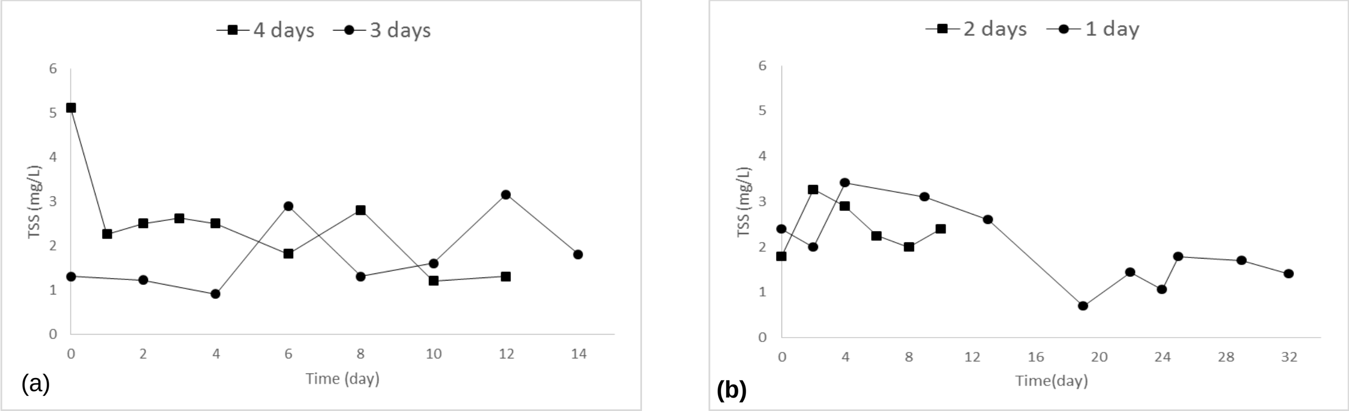

Figure 7: (a) TSS concentration for 4 and 3 days retention time (mg/L) and (b) TSS concentration for 2 and 1 day retention time (mg/L) in the tank water

In the PSA results, it was observed, after the second day of filtration a reduction in the particle size, as can be observed in Figure 8. This is explained with the same theory used in batch experiments. The reduced AOS tank particles feed in the inlet was maintained below the size of 8.5 µm from the second day of the experiment until the end with retention times of 4 and 2 days (average reduction of 90% and 67%,). The retention time of 3 days, an average reduction of 48%, presented a slight increase in particle size followed by its removal in the same size as the previous experiment. The retention time of 1 day presented an average particle size of 8.50 ± 0.16 µm for the whole experiment. As this test was the last experiment done this year, (from September 19, 2019, to October 22, 2019) at the start of the fall season, the water temperature started to decrease. This has caused the settling of larger-sized particles and thus only colloidal particles remain suspended.

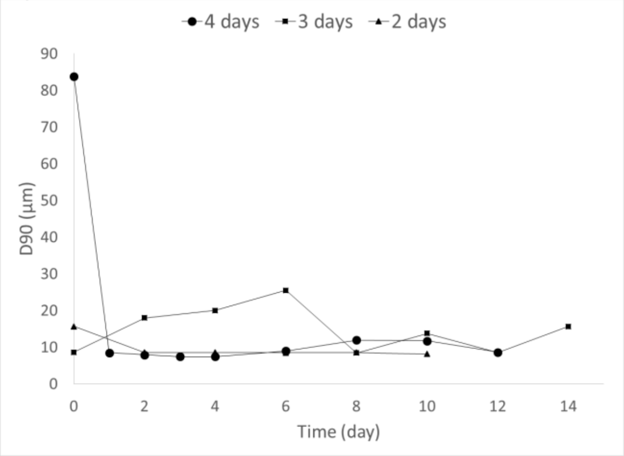

Figure 8: D90 (µm) in the tank water for specific retention time

The concentration of TP was kept below the inlet value for all experiments presented with exception of the 4 day retention time. Due to technical reasons, there was no inlet sampling for this experiment, as Figure 9 (a) and (b) presents. For this retention time, the tank water value remained below 10 µg/L after 3 days of the experiment. Due to the recirculation in the system, it was possible to return to the lake after filtration, oligotrophic water, when related to the total phosphorus parameter in the entire 3 day retention time. The 2 days and 1 day retention time presented different behaviors with a slight increase at the start of the test followed by removal of the inputted TP in the system. After 4 days and 13 days, respectively both of them were discharging filtered water with a TP concentration of oligotrophic lakes, differing for the inlet. The average removal was 40%, 42%, 35%, and 42 %, for retention times in the descending order.

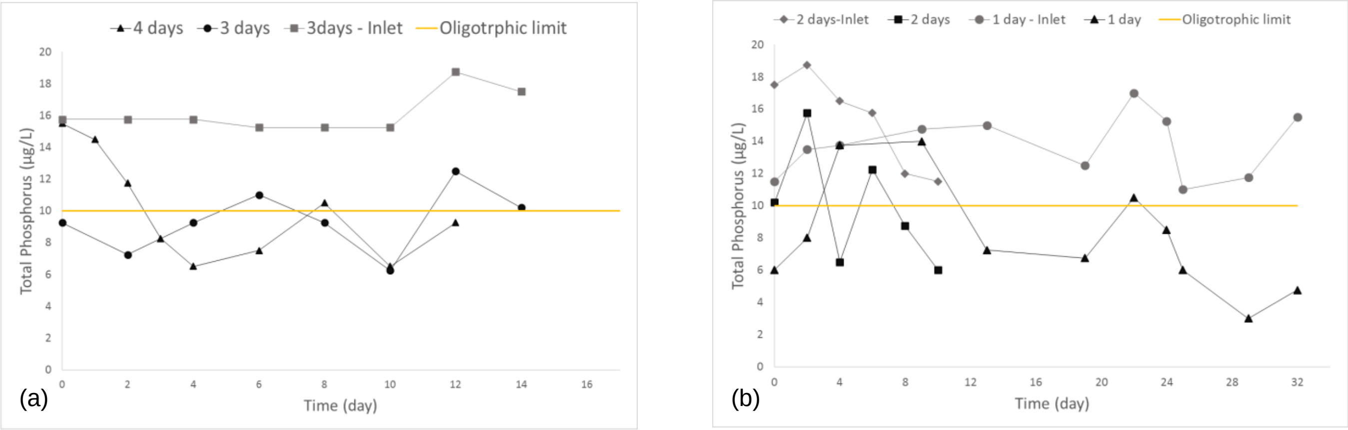

Figure 9: (a) TP concentrations for 4 and 3 day retention times (µg/L) and (b) TP concentrations for 2 and 1 day retention times (µg/L) in the tank water

The COD parameter presented a slight reduction in the continuous experiment with an average removal of 11.6% in the 4 retention times done. Figure 10 (a) and (b) shows the removal of COD in the experiments. This could be explained due to the nature of this COD, that presented in the dissolved form and the particle removal did not affect significantly this value. When compared with the batch experiment this is explained because the retention time used in those experiments was below the average time used in the batch trials and the uptake of some part of dissolved COD did not occur as the water kept being renewed.

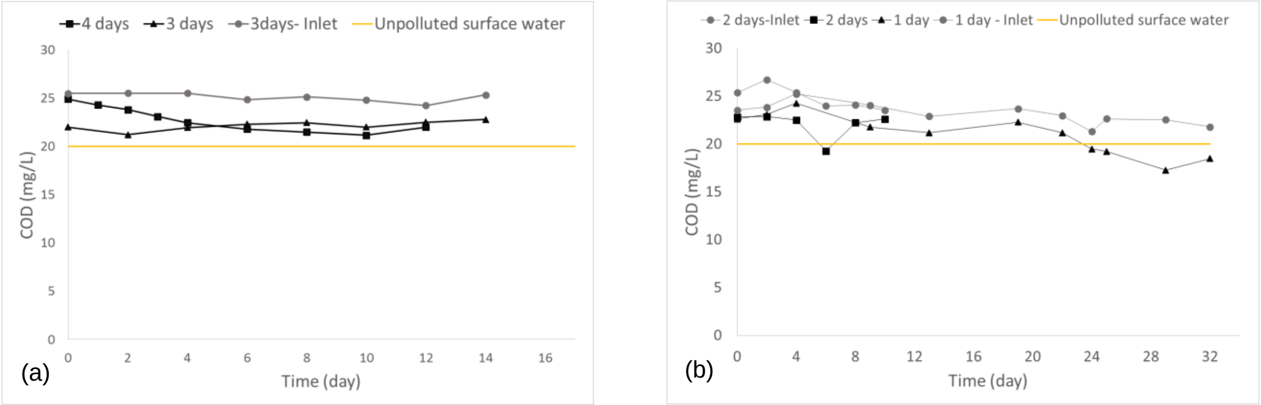

Figure 10: a) COD concentrations for 4 and 3 day retention times (mg/L) and (b) COD concentrations for 2 and 1 day retention times (mg/L) in the tank water

As for the batch experiments, there was no significant change for the concentrations of TN and Nitrate in the 4 continuous tests. The average value was kept below the values present in the raw water and within the Quebec regulated values. For TN, the value was kept with a medium value of 0.95 ± 0.21 mg/L and for nitrate, its average value was 0.17 ± 0.05 mg/L and was not affected by the experiment.

4 CONCLUSIONS

The on-site experiments have shown that non-woven geotextile filters can be used as a filter media for improving surface water quality is a possible method for lake water remediation. The geotextile filters allowed reduction of the TP, TSS and significantly reduced particle sizes. The TP concentration in both continuous and batch experiments set Lake Johanne water to the limit of oligotrophic lakes by MDDEP. As the particulate form phosphorus remains suspended in the water column, removing these particles, helped Lake Johanne improve water quality. It is worth mentioning that this method is environmental-friendly since it does not adversely affect the lake biota disturbing water column and/or sediment. Also, it is a simple and feasible method to operate onsite. For future work, attention will be made on the clogged geotextile filter reuse and dissolved COD removal in the lake water. Possible in situ filtration tests will be performed in the next phase of this project.

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REFERENCES

ABVLACS (Agence des Bassin Versants de Sainte-Anne-des-Lacs) 2018. Retrieved from http://abvlacs.org/lac-johanne/.

Alam, M.Z., Faisal Anwar, A.H.M., Heitz, A. 2018. Stormwater solids removal characteristics of a catch basin insert using geotextile. *Science of the Total Environment*, **618**: 1054-1063.

Bormans, M., Maršálek, B., and Jančula, D. 2016 "Controlling internal phosphorus loading in lakes by physical methods to reduce cyanobacterial blooms: a review." *Aquatic Ecology*, **50**(3): 407-422.

Couture, H.M., Gourlin, B., Gutjjahr, B., Mercier, C. Strategie de protection et de mise en valeur des milieux hummides sur le territoire de la Municipalite de Sainte-Anne-des-Lacs. Université de Sherbrooke (2013). Retrieved from: https://www.sadl.qc.ca/wp-content/uploads/2016/01/Rapport-final-Strategie_milieu-humides2.pdf

Inoue, T., Fuke, M., Mulligan, C.N., Uehara, K. 2009. In-situ Removal of Contaminated Suspended Solids from a Pond by Filtration. *Ecological Engineering*, **35**:1249-1254.

Jing, L., Bai, S., Li, Y., Peng, Y., Chenxi, W., Liu, J., Liu, G., Xie, Z. and Yu, G. 2019. "Dredging project caused short-term positive effects on lake ecosystem health: A five-year follow-up study at the integrated lake ecosystem level." *Science of the total environment,* **686:** 753-763.

Knoll, L. B., Morgan, A., Vanni, M. J., Leach, T. H., Williamson, T. J. and Brentrup, J. A. 2016. Quantifying pelagic phosphorus regeneration using three methods in lakes of varying productivity. *Inland Waters*, ***6***(4): 509-522.

Le Moal, M., Gascuel-Odoux, C., Ménesguen, A., Souchon, Y., Étrillard, C., Levain, A., Moatar, F., Pannard, A., Souchu, P., Lefebvre, A. and Pinay, G., 2019. Eutrophication: A new wine in an old bottle?. *Science of the total environment*, **651**: 1-11.

Liu, B., Liu, L. and Li, W. 2020. Effective removal of phosphorus from eutrophic water by using cement. *Environmental Research*, **183**: 109218.

MDDEP- Ministère du Développement durable, de l'Environnement et des Parcs, 2012. Portrait de la qualité des eaux de surface au Québec 1999 – 2008, Québec, Direction du suivi de l'état de l'environnement. Retrieved from: http://www.environnement.gouv.qc.ca/eau/portrait/eaux-surface1999-2008/intro.pdf

MELCC - Ministère de l'Environnement et de la Lutte contre les changements climatiques, 2018. Réseau de surveillance volontaire des lacs - Lac Johanne (0497A)- Suivi de la qualité de l'eau. Retrieved from http://www.environnement.gouv.qc.ca/eau/rsvl/relais/fiches bilans/2018/PDF/Johanne,%20Lac_0497A_2018_SA_SU.pdf.

Mulligan, C.N., Davarpanath, N., Fukue, M., Inoue, T. 2009. Filtration of Contaminated Suspended Solids for the Treatment of Surface Water. *Chemosphere*, **74**: 779-786.

Sinha, E., Michalak, A.M. and Balaji, V., 2017. Eutrophication will increase during the 21st century as a result of precipitation changes. *Science*, **357**(6349):405-408.

Spears, B.M., Mackay, E.B., Yasseri, S., Gunn, I.D., Waters, K.E., Andrews, C., Cole, S., De Ville, M., Kelly, A., Meis, S. and Moore, A.L., 2015. A meta-analysis of water quality and aquatic macrophyte responses in 18 lakes treated with lanthanum modified bentonite (Phoslock®). *Water Research*, **30**:111-121.

Veetil, D.P., Mulligan, C.N. and Bhat, S., 2018. Phosphorus Speciation of Sediments of a Mesoeutrophic Lake in Quebec, Canada. In *The International Congress on Environmental Geotechnics* Springer, Singapore, **1**:780-787.

Zhang, S., Wang, W., Zhang, K., Xu, P. and Lu, Y., 2018. Phosphorus release from cyanobacterial blooms during their decline period in eutrophic Dianchi Lake, China. *Environmental Science and Pollution Research*, **25**(14):13579-13588.

Zhao, J., Gao, Q., Liu, Q. and Fu, G., 2020. Lake eutrophication recovery trajectories: Some recent findings and challenges ahead. *Ecological Indicators*, **110**:105878.