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A circular economy approach for geotextile reuse following lake water filtration

Pereira, Antonio C.[1], *Palakkeel Veetil,* Dileep [2], *Mulligan,* Catherine N. [3*], *and Bhat,* Sam[4]

[1] Concordia University, Canada
[2] Concordia University, Canada
[3] Concordia University, Canada
[4] Titan Environmental Containment Ltd., Canada

Abstract. Eutrophication in lake systems is intensifying. To reduce this possible scenario, a method for suspended solids and associated nutrient removal by a novel on-site remediation has been investigated, using nonwoven geotextiles as filter media. These procedures generate clogged geotextile layers with captured suspended solids on them. To become more sustainable, circular economy principles were employed, more precisely reuse. Thus, this investigation aims to assess the potential reuse strategies by washing clogged layers and determining their possible reuse. The washing method was pressurized water (i.e., using a gardening pump sprayer). Preliminary results have shown the efficiency of the washing method in removing visible geotextile (non-woven) clogging, with permeate flow rates reaching values close to the initial process values. The geotextile apparent opening size increased by an order of 20%. Also, no geotextile fibre disruption was observed by scanning electron microscope (SEM) imagery, indicating its possible reuse. The dilute liquid waste preliminary findings showed high concentrations of some metals such as manganese, (112.72 µg/L) and zinc (88.12 µg/L) in addition to phosphorus (120.18 µg/L) which requires additional studies. The washed geotextile leaching test did not indicate any contaminants in the permeate which would enable geotextile layer reuse for lake water filtration.

1 Introduction

Anthropogenic actions have been the trigger of countless environmental impacts that the biosphere is experiencing nowadays. There is a long list of possible issues instigated by human and economic development comprising not only over-consumption of natural resources and all possible water, air, and soil pollution related to it but also the excessive waste generation and its improper management and final disposal.

As the global economy is reaching a point of no turn, if its development is kept at a 3.0% annual rate, in the next 30 years, energy and resource consumption will be comparable to the previous 10,000 years [1]. With this understanding, humans will not be able to ensure an improved environment for future generations using the present practices. Consequently, how

* Corresponding author: mulligan@civil.concordia.ca

will the sustainable perspective of meeting the needs of the present generations without compromising the ability of future ones be achieved?

Under the present economic linear model, businesses and industries pursue a framework that is based on the notion that raw materials are gathered and then converted to products which are used until they are finally discarded as waste. Conversely, an alternative economic model based on sustainability principles, the circular economy, maximizes the use of extracted resources for minimum waste generation and disposal [2] retaining all possible wastes in a closed loop.

This circular economy strategy is well sustained by the Sustainable Development Goal (SDG) 12 - Responsible Consumption and Production from the United Nations agenda. For this agenda, multiple alternative pathways are to be applied to generated wastes altering the way goods and resources are produced and consumed. Potential routes are based on the 4R'sD premise, which are waste reduction (i.e., generation avoidance), reuse, recycling, recovery, and finally ultimate disposal. The 4R's-D application should always follow the order presented meaning that waste generation reduction/prevention should be taken into consideration before reuse and so on.

As proper waste management is key for the progress of any project/investigation, these concepts are being reflected in a novel remediation method for removing suspended solids and their associated particulate nutrients [3-4] from Quebec lake waters using geotextiles as filter layers. In this investigation, the waste produced, which needs to be managed are polyethylene terephthalate (PET) and polypropylene (PP) non-woven clogged geotextile layers (i.e., with retained suspended solids). Since this research is expected to further expand, the focus of this study will be on the management routes for the generated waste in this investigation. Thus, the objective of this initial investigation is to explore the potential reuse approaches for the clogged geotextiles after lake water filtration. It is intended to achieve a viable assessment with a detailed characterization of the material and whether any alternative route should be investigated further.

2 Materials and Methods

2.1 Clogged Geotextile Layers

Clogged filter layers used in this investigation were obtained from an on-site water filtration deployment in a mesotrophic lake (i.e., a continuous experiment using a tank of 300 L with a retention time of 0.5 day). The layers were composed of 22cm square nonwoven geotextile layers which were used approximately for a 7-day filter experiment. The clogged geotextile layers were of different apparent opening size (AOS) sizes with captured suspended solids.

Precisely, the non-woven geotextile filtration combination used was composed of five membranes of different AOS. They were from the first to the last layers: 110 µm, 100 µm, 90 µm, 70 µm, and 65 µm, respectively. After washing, only the 110 µm and 65 µm layers were further characterized hydraulically. Fig 1 presents the full set of non-woven geotextiles before washing with the hydraulic characteristics of the top and bottom layers given in Table 1.

Fig. 1. Non-woven geotextiles before the washing process according to the AOS order: (a) 110 µm (b) 100 µm (c) 90 µm (d) 70 µm and 65 µm.

Table 1. Non-woven characteristics were used in the investigation.

Filters	Material	Apparent Opening Size (AOS) (μm)	Flow rate (L/min/m)	Permittivity (sec^{-1})	Mass per unit area (g/m^2)
TE- GTX300	[a]PET	110	3900	1.62	350
TE-GTN350B	[b]PP	65	2700	0.56	350

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

2.2 Geotextile Cleaning Procedure

The washing procedure in this investigation was executed using pressured tap water with a gardening pump sprayer. No cleaning agents were employed for facilitating fouling removal on the geotextile layers since they could contaminate the generated liquid waste further.

The tank was filled with 2L of tap water and mechanically pressured using a hand pump sprayer of 4L, as shown in Fig. 2. After reaching the required pressure (45psi), each geotextile set was then cleaned on both sides in a line pattern using approximately 250-350 mL for each layer. The generated leachate was retained on a plastic tray and the washed layers were placed on a table to dry at room temperature for 24 hours before further analysis.

Fig.2. Washing method used for the non-woven geotextile.

2.3 Geotextile Assessment after Washing

Once dried, the washed geotextiles were segregated by AOS size, placed in hermetically sealed plastic bags, and sent for hydraulic investigation. Hydraulic geotextile assessments were managed out at the Geotextile Testing Lab SGI Testing Services, LLC in compliance with ASTM procedures: ASTM D 4751 - Method for determining geotextiles, ASTM D 4491 - Method for determining permittivity and flow rate.

Additionally, images of unused, clogged, and washed filter layer surfaces (i.e., top and bottom layers only) were taken with a scanning electron microscope (SEM) (Hitachi S-3400 N). The method used was the variable pressure mode after geotextile surface coating with a layer of gold using a sputter (QuorumQ150 RES).

2.4 Leachate Analysis

In the liquid waste generated, heavy metal and phosphorus concentrations, as well as chemical oxygen demand (COD) and nitrate concentrations, were assessed. Hach Chemicals test kits were employed for nitrate (TNT 835, technique 10206, dimethyl phenol technique) and COD (TNT 820, Method 10221, reactor digestion method) determination. For phosphorus and heavy metal content, partial acid-peroxide digestion (HNO_3-H_2O_2) of liquid samples by USEPA 3050B [5] was employed followed by determination using elemental analysis on inductively coupled plasma mass spectrometry (ICP-MS) with a quadruple mass analyser.

2.5 Geotextile Washing with Ultrapure Water

To determine if the washed geotextile could be properly used for the same application (i.e., lake water filtration) a continuous experiment with ultra-pure water was performed. By using 35 L of ultra-pure water, the membrane set was placed on a filtration unit [4] and was continuously washed for 2h to determine phosphorus and organic leaching from the washed geotextile. Samples were taken every 10 min.

3 Results and Discussion

3.1 Proposed Washing Method

For cake removal, the proposed methodology of an unconventional cleaning procedure with pressurized water was successful with no additional chemical or energy. The approach proved effective in eliminating visible fouling from non-woven geotextiles. Fig. 3 depicts one filter combination prior to use, after filtration, and after washing. This treatment lowered the potential environmental footprint, which should reduce the cost regarding geotextile acquisition in this project, while also delivering an inexpensive approach for geotextile cleaning and reuse.

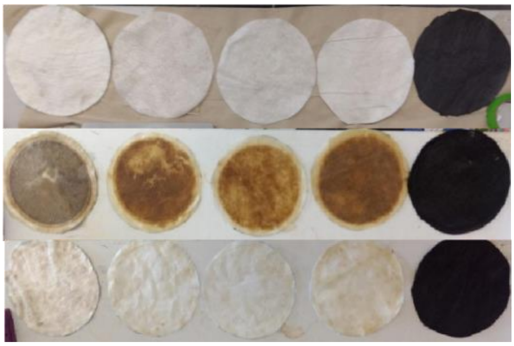

Fig. 3. Prior to use, used, and washed geotextile layers (top-bottom) in the following AOS order from left to right (110 µm, 100 µm, 90 µm, 70 µm, and 65 µm).

3.2 Geotextile Hydraulic Assessment

A hydraulic assessment of the cleaned geotextile was undertaken to determine if the treatment alone was sufficient for eliminating the existing foulants on the geotextile layers. The cleaning procedure would be only effective when the permeate flow rate approaches the starting value [6]. Table 2 shows the results of the analysis of the non-woven geotextiles. In summary, all geotextiles attained values near the pristine ones, indicating their possible reuse.

Table 2. Characteristics of non-woven geotextiles before use and after washing.

	Prior to use	After washing

	AOS	Flow rate	Permittivity	AOS	Flow rate	Permittivity
	(mm)	(l/min/m^2)	(1/s)	(mm)	(l/min/m^2)	(1/s)
TEGTX300	0.11	3900	1.62	0.141 ± 0.01	4208.25 ± 247.36	1.38 ± 0.08
TEGTN350 B	0.065	2700	0.56	0.078 ± 0.01	1387.25 ± 300.48	0.455 ± 0.10

The nonwoven GTX300 showed an increased AOS of 28%, possible due to force of the water flow during washing. The flow rate across the membrane rose by 8% as a result, which was within the confidence range. Permittivity, on the other hand, decreased by 15%, which may be attributed to the fact that this material had previously been utilized and was completely blocked. Lastly, TE-GTN350B exhibited a similar pattern, with a 20% rise in geotextile pore size followed by a 51% decrease in geotextile flow rate, leading to a 19% loss in permittivity.

3.3 SEM Superficial Images of Geotextiles

The physical state of the used geotextiles was another evaluation of the cleaning approach for determining the potential reuse of washed geotextile layers. In addition, a visual examination of the material structure was performed to assess whether the water jet procedure would alter the filtration media. These findings are illustrated using SEM images of nonwoven materials.

Washed, non-woven geotextiles showed excellent removal, as shown in Fig. 4. The pressured jet did not rupture the fibres, which were roughly 20 microns in size, and their structure remained consistent after the procedure. The first layer (TE GTX300) of the employed combination demonstrated good filtration performance considering the fabric propensity to hold large, suspended solids loads on the surface, as shown in Fig.4 (b). In contrast, the TE-GTN350B layer did not clog on the surface and showed only a small amount of debris within the layer (Fig 4. (h)), which was eliminated with the washing. The cleanup procedure also removed particles that had become lodged within the geotextile material and its underside.

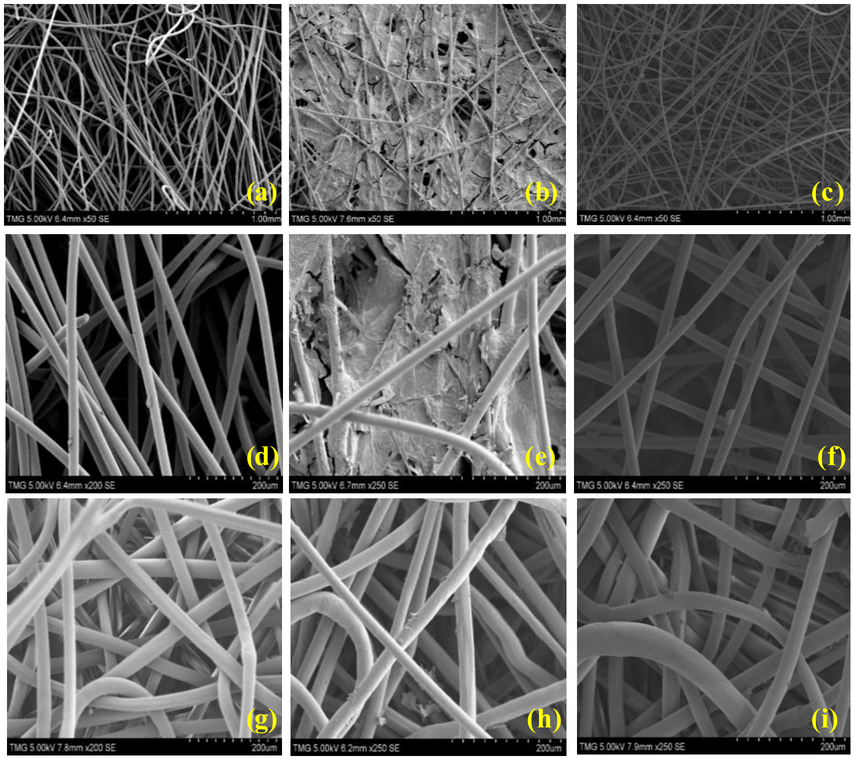

Fig.4. Unused, used and washed non-woven geotextiles: (a) Unused TE GTX300, (b) Used TE GTX300, (c) Washed TE GTX300, (d) Unused TE GTX300, (e) Used TE GTX300, (f) Washed TE GTX300, (g) Unused TE-GTN350B, (h) Used TE-GTN350B, (i) Washed TE-GTN350B

3.4 Liquid Waste Assessment

The liquid waste produced during washing was around 2L for each non-woven geotextile set. This effluent included a high quantity of several heavy metals and phosphorus. As there are no specific regulations in Quebec for this waste, they were compared to the Chapter Q-2, Rule 19 of the Environment Quality Act [7] with quality requirements for water or leachate discharged into the environment. In addition, for reuse purposes, the Water Quality Guidelines for the Protection of Agriculture Concentrations on the Environment [8] were utilized as a standard.

High quantities of phosphorus, zinc, manganese, and copper were found in the liquid waste, as shown in Table 3. Despite being high, the readings for these individual heavy metals were below the standards for Agriculture Protection, which may be used to categorize its reuse for irrigation. It is worth noting that if reuse is recommended, the following factors should be considered, including the levels of COD and nitrate present in the effluent.

Table 3. Liquid Waste Characterization

Contaminants	**Non-woven leachate diluted**	***Règlement sur l'enfouissement et l'incinération de matières résiduelles***	**Water Quality Guidelines for the Protection of Agriculture**
Manganese (μg/L)	0.33	50.00	200.00
Cobalt (μg/L)	0.10	-	50.00

Nickel (µg/L)	0.34	20.00	200
Copper (µg/L)	20.57	-	Variable[a]
Zinc (µg/L)	29.15	500	Variable[b]
Arsenic (µg/L)	0.13	-	100
Selenium (µg/L)	0.95	-	Variable[c]
Cadmium (µg/L)	0.00	5.00	5.10
Lead (µg/L)	0.04	10	200
Phosphorus (µg/L)	73.38	-	-
Nitrate (mg/L)	4.47	10	-
COD (mg/L)	844	-	-

[a] 200 µg/L for cereals = 1000 µg/L for tolerant crops; [b] 1000 µg/L when soil pH < 6.5 and 5000 µg/L when soil pH > 6.5; [c] 20 µg/L for continuous use on all soils = 50 µg/L for intermittent use on all soils

3.5 Possible Waste Routes and Challenges

Geotextiles can be reused by washing them with pressured water, as shown in this study. When geotextiles were washed with ultrapure water during a 2h continuous experiment no leaching of organic matter or nutrients occurred. The washing did not strongly affect its physical integrity, permeability, or flow rate, suggesting that these layers might be effectively reused. Also, for this effluent generated (i.e., liquid waste) only if a COD removal mechanism is in place then proper reuse might be applied.

4 Conclusions

Waste management routes for the non-woven geotextiles were presented as part of a circular economy for decreasing waste and resource utilization. The cleaning process with pressured water jet did not disrupt the fibres on the non-woven geotextile, as demonstrated by a visible physical structural autopsy given. It was demonstrated that the recovered geotextiles have hydraulic properties comparable to that of the unusable membranes. When used on-site, this extends the product's life and delays disposal. In terms of liquid waste, viable reuse might occur if new strategies for lowering metal and organic matter concentrations are investigated. Also, washed geotextiles when washed with ultrapure water did not show any further organic or nutrient contamination in this water, which enable reuse. In further work, it should be determined how often the geotextile may be reused without losing its original properties. Additional waste management pathways should be investigated and implemented to avoid final disposal.

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