

Nonwoven from Cigarette Butt Applied in Pre-treatment of Surface Water

Nãotecido Oriundo de Bituca de Cigarro Aplicado no Pré-tratamento de Água Superficial

Ana Silvia de Lima Vielmo¹ , Ailton Borges Rodrigues¹ ,
Eduardo Volkart da Rosa² , Dayane Gonzaga Domingos¹ ,
Juliana Barden Schalleberger¹  & Maria Eliza Nagel-Hassemer¹ 

¹Universidade Federal de Santa Catarina, Departamento de Engenharia Sanitária e Ambiental, Florianópolis, SC, Brasil

²Universidade Federal de Santa Catarina, Departamento de Engenharia Têxtil, Blumenau, SC, Brasil

E-mails: ana.vielmo@ifc.edu.br; ailton-4@hotmail.com; eduardo.volkart@hotmail.com; day_domingos_@hotmail.com;

juli-sch@hotmail.com; maria.eliza@ufsc.br

Corresponding author: Ana Silvia de Lima Vielmo; ana.vielmo@ifc.edu.br

Abstract

This study aimed to evaluate a nonwoven (NW) production and performance from cellulose acetate fiber from cigarette butts and applied to a filtration system for surface water pre-treatment. The system had a surface area of 528 cm², cellulose acetate from cigarette butt as filter media, was used and was fed with surface water from a pond. In order to evaluate the treatment performance of the filtration system were evaluated in the raw water (RW) and the filtered water (FW) the classical parameter of water quality as turbidity, total suspended solids (TSS), apparent color, true color, and total organic carbon (TOC) and heavy metals (iron, copper, and cadmium). Moreover, the presence of nicotine was investigated in the FW. The results showed a mean removal efficiency in order to 62.01%, 54.42%, 50.36 %, 6.73%, and 5.20% for turbidity, TSS, apparent color, true color, and TOC, respectively. The removal of metals varied in the order of 72.26%, 9.61%, and 2.12% for cadmium, iron, and copper, respectively. The presence of nicotine in RW and FW was not identified. In this way, besides reducing the negative environmental impacts caused by cigarette butts present in the environment, the developed technology showed potential for removing pollutants present in surface waters.

Keywords: Cigarette butt; Filtration; Cellulose acetate

Resumo

O objetivo desse estudo foi avaliar a produção e desempenho de um nãotecido (NW) desenvolvido a partir da fibra de acetato de celulose oriunda da bituca de cigarro e aplicado a um sistema de filtração no pré-tratamento de água superficial. O filtro possuía as seguintes características: uma área superficial de 528 cm², construído a partir de acetato de celulose oriundo de bituca de cigarro e foi alimentado com água superficial de uma lagoa. Para avaliar o desempenho de tratamento do sistema de filtração foram avaliados na água bruta (AB) e na água filtrada (AF) os parâmetros clássicos de qualidade de água como turbidez, sólidos suspensos totais (TSS), cor aparente, cor verdadeira e carbono orgânico total (COT) e metais pesados (Zn, Fe, Cu, Cd, Mn e Pb). Além disso, também foi avaliado a presença de nicotina e metais pesados na AF. Os resultados demonstraram remoção na ordem de 62.01%, 54,42%, 50,36%, 6,73% e 5,20% para turbidez, TSS, cor aparente, cor verdadeira e COT, respectivamente. A remoção de metais variou na ordem de 72,26%, 9,61% e 2,12% para Fe, Cd e Cu, respectivamente. Não se identificou a presença de nicotina na AB e na AF. A tecnologia desenvolvida mostrou potencial para remoção de poluentes presentes em águas superficiais, além de reduzir os impactos ambientais negativos causados pelas bitucas de cigarro presentes no ambiente.

Palavras-chave: Bituca de cigarro; Filtração; Acetato de celulose

1 Introduction

Worldwide, cigarette butts are one of the most common solid residues found in public areas, corresponding to values in the range of 25% to 50% of the amount of waste collected in these areas (Dobaradaran et al. 2017; Heaton et al. 2011). This type of residue is composed of a cellulose acetate material, which is used to filter toxic substances present in cigarette smoke (Novotny et al. 2015; Wang et al. 2020). In this sense, this residue has limited potential for biodegradation, due to the high acetate concentration, which makes it inert to the microbial degradation process, requiring a long time for the degradation (Puls, Wilson & Hölter. 2011). Moreover, during the cigarette manufacturing process, plasticizers are added, and the fibers receive high compaction, thus making the disintegration process difficult. In this sense, studies showed that the degradation rate of a cigarette butt is low, resulting in a reduction of only 37.8% of initial mass, after two years of decomposition (Bonanomi et al. 2015).

In addition to the low degradation capacity of cigarette butts, they have negative environmental impacts, when disposed of inappropriately. Recent studies have shown that cigarette butt residue (CBR) is lethal to 50% of the organisms present in surface water bodies, in addition to contaminating approximately 1000 L of water, as the leaching of these compounds can last up to 10 years (Liu et al. 2020b).

Currently, different strategies have been developed in order to make the CBR environmentally suitable, seeking to recover cellulosic material from cigarette butts (d'Henri Teixeira et al. 2017; Benavente et al. 2019). Nowadays, CBR is part of different products in the production chain from different sectors such as civil construction (Abdul, Kadir & Mohajerani 2015), metallurgical (Zhao et al. 2010) agriculture (Murugan et al. 2018), energy storage (Xiong et al. 2019) and pulp and paper industry (d'Henri Teixeira et al. 2017).

One of the technological alternatives is the manufacture of a nonwoven using cellulose acetate fiber from the butts cigarette and applying it in the surface water pre-filtration process. This is occurring because the cellulose acetate fiber is widely used as filtering agents, largely used for the production of membranes, given its high mechanical strength, biodegradability, high filtration capacity, and porosity, ease of processing and film formation, high flow, absent toxicity, and biocompatibility, in addition to being a low-cost material (Edgar et al. 2001). As early as 1953, studies showed that cellulose acetate-based membranes were used as a highly efficient material for saline retention

in reverse osmosis processes (Matsuura 2001). Moreover, the development of nonwovens is relevant trend, due to the wide field of application, especially in the control of air pollution and water treatment, as they are versatile and flexible structures to be designed in different ways (Hutten 2007). Several studies have shown that the application of nonwoven fabric has potential for the water filtration process (Inoue et al. 2009; Mulligan et al. 2009; Tian et al. 2011).

Due to its high filtration capacity, cellulose acetate is the material used to produce the cigarette filter (Santarini & Bianchin 2017), in addition to being used for the removal of particles during smoking (Cheng et al. 2010). It should be noted that this fiber has interesting adsorption properties, given studies aimed at the adsorption of antibiotics in water samples (Chen Wang & Huang 2012) organic pollutants removal from aqueous solutions (Lima et al. 2018), removal of polycyclic aromatic hydrocarbons from water (Liang, Han & Yan 2006). In this sense, this study aimed to evaluate the treatment performance of a cellulose acetate fiber filtration system applied for pre-treatment of surface water.

2 Materials and Methods

2.1 Cellulose Acetate Fiber Preparation

The first step in the process of making the filtration system was pre-cleaning the CBR, manually removing the external paper, burnt ends, and ash and tobacco residues. Subsequently, a process of cleaning the CBR was carried out in three stages. In steps 1 and 2 a cooking process was carried out, lasting 30 min each. In these two steps, a proportion of 500 g of CBR pre-sanitized, 160 g of sodium bicarbonate, and 100 mL of hydrogen peroxide (6%) were added to 5 L of water and left at a boiling temperature in a steel container stainless. Subsequently in step 3, the material was washed with water and placed in rest in 200 mL of sodium hypochlorite (2.5%) for 12 hours. After the resting time, the material was washed again with water, centrifuged (1000 RPM), and dried at room temperature for approximately 48 hours. This hygiene process was carried out following the Salem (2010) recommendations.

With dry cellulosic material (CM) the carding process was performed manually to obtain the NW. The carding process was used to separate the fibers, remove the knots and group them, forming a kind of blanket, leaving the material ready for consolidation. After this process, the carded blankets were moistened with an aqueous solution of acrylic resin (styrene acrylic copolymer 5-chloro-2-methyl-

2H-isothiazol-3-one;2-methyl-2H-isothiazol-3-one) under different solids concentration (10%, 20% and 30%). Acrylic resin was used for its wide application in the production of nonwoven, due to film-forming capacity, water vapor permeability and environmental stability (Chiantore & Lazzari 1996). In addition, acrylic resin provides thermal and chemical resistance to nonwovens, improving their performance (Hubbe & Koukoulas 2016; Manfredi & Rodri 2006; Patnaik et al. 2019). These concentrations were achieved by diluting the resin in water and evaluated with a portable analog refractometer (SBC10). The material moistened with the resin was spread on a metallic surface and taken to oven drying at 70 °C for 3 h.

2.2 Characterization of Cellulosic Material, Resin and Nonwoven

The chemical composition of CM, resin, the nonwoven containing a composition of 10 % solids (NW 10), nonwoven containing a composition of 20% solids (NW 20), and nonwoven containing a composition of 30% solids (NW 30) were investigated. For this, a fourier-transform infrared spectrometer (FTIR) (Cary 600 Series, USA), in the 640-4000 cm⁻¹ wavelength range, at a spectral range of 4 cm⁻¹ was used. The morphology of different samples (NW10, NW 20, and NW30) were identified by scanning electron microscopy (JEOL JSM-6390LV, EUA). In addition, the weight of nonwoven samples was evaluated following the recommendations of NBR 139 (ABNT. 2008) and NBR 12984 (ABNT. 2009).

Moreover, to evaluate the amount of liquid that can be retained by the nonwoven, an absorption test was conducted (Equation 1). NW10, NW20, and NW30 samples were soaked with two different solutions in isolation, one being tap water supplied by the water supply company and the other water from a surface water body. The test was performed in triplicate and followed the recommendations of Kakonke et al (2020).

$$\text{Absorption capacity} \left(\frac{\text{g of liquid absorbed}}{\text{g of NW}} \right) = \frac{W_2 - W_1}{W_1} \quad (1)$$

Where: W1: Dry nonwoven weight (g); W2: Nonwoven weight after the absorption process (g).

2.3 Cellulose Acetate Fiber Filtration System

The system was feed with surface water from Peri Pond, located in the city of Florianópolis, southern Brazil. In general, the raw water was pumped to the filter and later the filtration was stored in the filtered water tank. The process

was characterized as rapid filtration with ascending flow. The average flow was 3.123 L min⁻¹, the average pump pressure was 48.4 psi and the hydraulic loading rate was 2340.11 mm d⁻¹.

The system consisted of a raw water tank, a pump (¼ CV), a pipe that connected the elements, a support structure containing the filter element of the system, and the filtered water tank (Figure 1). To make the filtering element, a commercial filter tube was used, measuring 24 cm in height, 3 cm in diameter, and three blankets of NW 10 sample. After the carding process, three carded CM blankets were added to an aluminum container, resulting in a single blanket of approximately 65 g of material. The material was moistened with resin containing 10% solids. The blanket was wrapped in a commercial filter tube and taken to a drying and sterilization oven, where it remained in the drying process at 70 °C for 12 h. After drying, the filter material had a diameter of 7 cm, a height of 24 cm, a surface area of 528 cm², and a total volume of 692 cm³.

2.4 Cellulose Acetate Fiber Filtration System Monitoring

During the study period (June to October, 2020) collections of surface water (raw water) from Peri Pond were carried out twice a week. The physical-chemical parameters evaluated in the raw water (RW) and filtered water (FW) were absorbance, turbidity, pH, total organic carbon (TOC), apparent and true color, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS). All analyses followed American Public Health Association (2005)'s recommendations, except for TOC that a Shimadzu analyzer model TOC-L was used. All analyses were conducted in triplicate.

To assess the presence of nicotine in the FW, nicotine quantification was performed following an adaptation of the methodology of Al-Tamrah (1999). The readings were performed on the Spectrophotometer (HACH DR/5000) in a quartz cuvette, 1 cm optical path, 251 nm wavelength. Moreover, the quantification of different metals (iron, copper, and cadmium) was evaluated in the RW and FW samples, following recommendations from EPA 3050 e 3051 (Güven; Akinci. 2011). The samples were read on the flame atomic absorption spectrometer (SpectRAA 50-B).

2.5 Ecotoxicological Testing of Filtered Water

In order to evaluate the presence of some acute toxic effect in the FW such as the release of metals and nicotine, an acute toxicological test was performed with *D. magna*.

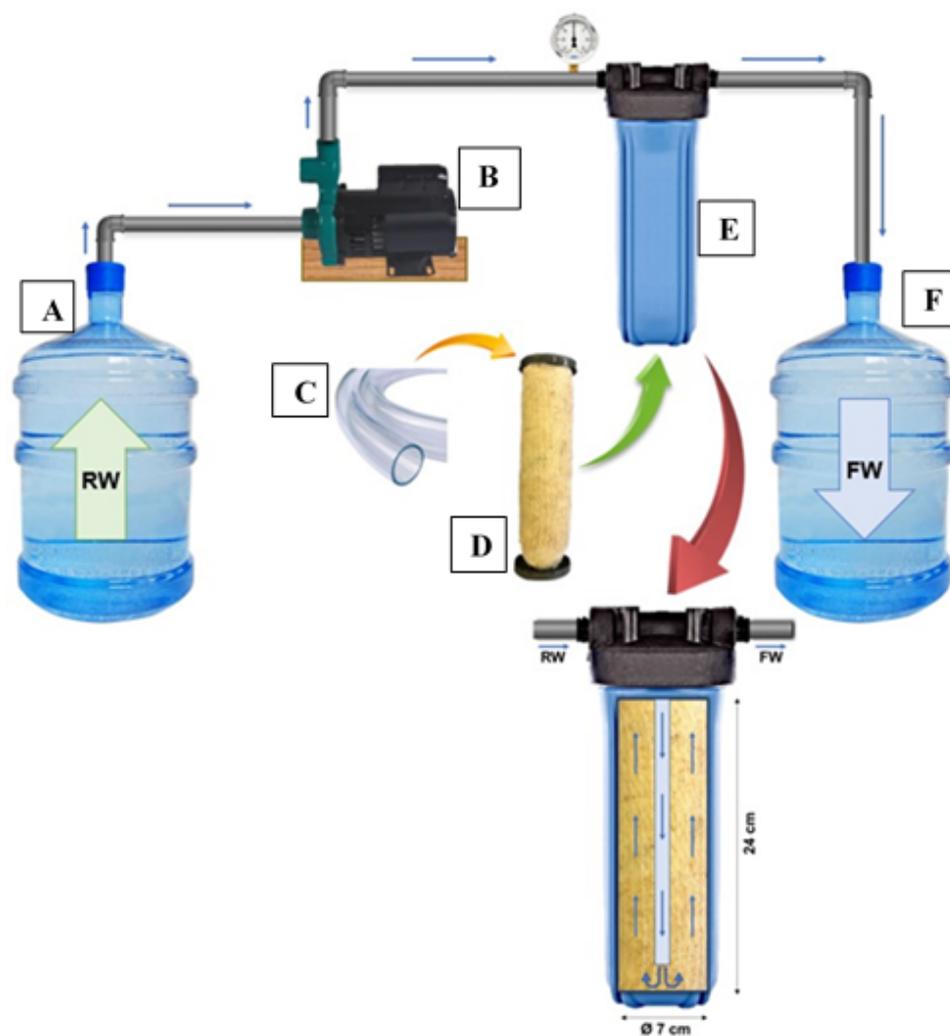


Figure 1 Scheme representing the Cellulose acetate fiber filtration system. A. Raw water tank; B. Pump; C. connecting pipe; D. Filter media; E. support structure of the filter material; F. filtered water tank.

The organisms, exclusively female, were preserved in 2 L beakers containing the M4 medium, with the density of an adult organism per 50 mL of medium. The culture was stored at a temperature of $20 \pm 2 \text{ }^\circ\text{C}$ and a photoperiod of 16 h. The filtered water samples were then suspended and homogenized in an ultrasonic device with probe and microtip (Q500 Sonicator 500 W, Q Sonica, USA), applying 250 W for 5 min. The acute toxicity test with *D. magna* followed the recommendations of ISO 6341/2012 and NBR 12713 (ABNT, 2016).

Newborn organisms (2-26h) were exposed to the FW sample and after 48 hours their immobility was measured. The evaluated data were analyzed statistically by the Trimmed Spearman-Kärber and the result was determined as LC 50, 48h, by EPA 821-R-02-012 (United States Environmental Protection Agency 2002). The tests were performed in triplicate.

3 Results and Discussions

3.1 Sanitization of Cigarette Butt Residues

Posteriorly the three cooking steps of CBR a dark liquor was released which originated during the cooking process, obtaining as a final product a clarified material (Figure 2 A, B and C). After drying this material, the CM sanitized was obtained (Figure 2 D). Cellulose acetate, the main input of RB, when placed in an alkaline medium undergoes hydrolysis reaction resulting in the formation of cellulose (d’Heni Teixeira et al. 2017). The methodology employed resulted in obtaining 50% of cellulose about the initial mass of CBR used. This fact happened because this reaction removed the lignin, dissolved other toxic contaminants present, in the butt cigarette (d’Heni Teixeira et al. 2017; Mehta et al. 2006).



Figure 2 Steps in the process of cooking cigarette butts: A. First stage of cooking; B. Second stage of cooking; C. Rest in sodium hypochlorite solution; D. Dry cellulosic material.

Subsequently, the fiber layers containing about 22 grams were wet bonded using a styrene copolymer acrylic resin (with initial solids concentration of 40%) using three solids concentrations (10, 20 and 30%). The surface of sample NW10 (Figure 3A) demonstrated greater flexibility, greater uniformity of the fiber layer, in addition to a smoother surface compared to other samples (Figure 3B and 3C). This fact may be associated with the concentration of solids, that is, the resin used was more diluted. In the case of the NW20 sample, a more rigid layer was identified, in addition to spots with lack of fibers (Figure 3B). In relation to NW30 samples, an irregular surface was identified, in addition to stiffness, showing ruptures in the fabrication of the filter element (Figure 3C).

3.2 Characterization of Cellulosic Material, Resin and Nonwoven

3.2.1. Functional Groups Present in The Samples of Cellulosic, Resin and Nonwoven Material

In order to evaluate the functional groups, present in the samples, FTIR analyses were performed for the resin CM and NW10, NW20, and NW30 samples (Figure 4 and Table 1). In general, a peak of 3360 cm^{-1} was observed for all samples, which is associated with the stretching vibrations of the O-H bonds, attributed to a hydrogen bond. The 2940 cm^{-1} peak is characteristic of the stretching vibrations of the aliphatic C-H bonds. The carbonyl group appeared at 1730 cm^{-1} , characterized by the stretching vibration of

the C=O bond, strongly suggesting the preservation of cellulose acetate.

More evident spectral changes are observed in the region from 1000 to 1500 cm^{-1} , with the CM having cellulose acetate in its composition, and this one presents an FTIR spectrum with bands characteristic of CO stretches of primary alcohol and ester in 1038 and 1226 cm^{-1} , respectively (Figure 4A). In addition, the band at 1371 cm^{-1} configures the alcohol group O-H stretch in the structure. Regarding the resin, there was the appearance of the CO stretching, characteristic of styrene, expressed in 1455 cm^{-1} , the weakening of the peak 1371 cm^{-1} belonging to the angular deformation of the CH groups, and the decrease in the peak 1226 cm^{-1} to the acetylated group (Figure 4B). The peak of 1169 cm^{-1} appears, it is identified as stretching vibration in C-O-C, characterizing the ether group and the peak related to the O-H bond disappears, explicit in 1038 cm^{-1} present in cellulosic structures.

When producing nonwovens using increasing proportions of solids content in the resin (10%, 20% and 30%), a gradual reduction in the peaks of 1038 and 1226 cm^{-1} and an increase in the peak of 1165 cm^{-1} were identified (Figure 4C). In addition, there is a reduction in the peak of alcohol O-H stretch by 1371 cm^{-1} and an increase in the O-H stretch of carboxylic acid by 1455 cm^{-1} . In this sense, it is identified that as the solids concentration of the resin increased, the absorption bands became weaker as well as the stretching vibrations of the O-H bonds. Therefore, the lower the presence of hydroxyls, the greater the stiffness of the non aluminum woven fabric and the lower the material's absorption capacity.



Figure 3 Images of nonwoven after consolidation of fibers with resin. A. NW10; B. NW20; C. NW30.

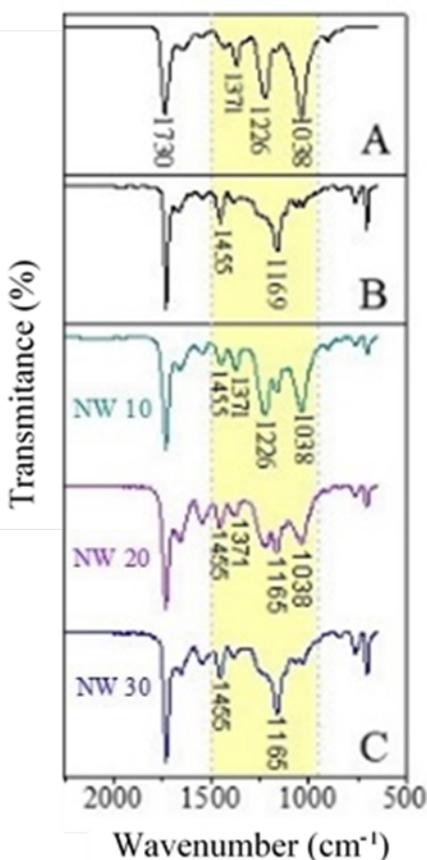


Figure 4 FTIR spectrum. A. Cellulosic material; B. Resin; C. NW10, NW20, and NW30.

3.2.2. Morphological Characteristics of the Nonwoven

Fiber misalignment was identified and the formation of nonwovens was proven (Figure 5). Nonwovens are characterized by having a flat, flexible, porous structure, consisting of disordered fibers (Dixit, Ishtiaque & Roy 2020). Fiber orientation in a carded mat is influenced by carding machine parameters (Dixit et al. 2020). However, in the present study, the carding process was performed manually, directly influencing the fiber arrangement. This influence

can be observed in the morphological characteristics of the samples, where the NW10 sample presented a uniform fiber layer, resin coating of fibers and fiber bonding in addition to a smooth surface (Figure 5A and 5B). Meanwhile, the sample from NW20 (Figure 5C and 5D), demonstrated a layer with disconnection points between the fibers, in addition to these not being encapsulated, resulting in an inhomogeneous layer caused by the non-continuity of the coating with the resin (Hemamalini et al. 2020). The sample from NW30 also showed an irregular surface, also with spots of gaps between the fibers, however it presented a greater connection between the fibers compared to NW20 (Figs. 5E and 5F). Therefore, NW10 denoted the best NW formation corroborating the images obtained after the consolidation of the fibers (Figure 3).

3.2.3. Grammage Analysis

The weight of a nonwoven is considered to be one of the important properties in the evaluation of its performance (Senthil & Punitha 2017). The weights obtained from samples NW10, NW20 and NW30 were 115g/m², 112g/m², 132g/m², respectively. Thus, the result identified showed that the concentration of resin solids showed a behavior directly proportional to the increase in weight since the weight of the NW30 grew considerably in relation to NW10 and NW20. In this way, all NW produced in this study are characterized as heavy, according to the classification of the Brazilian Association of Nonwoven and Technical Fabrics Industries (ABNT. 2019). The weight expressed in g/m² refers to the relationship between mass and area of the nonwoven, which is a factor directly linked to the number of fibers and the density of the material (Mendes 2006). Therefore, considering the same mass of fibers used for the NW production, the grammage was influenced by solids concentration present in the resin. This behavior may be related to the fact that the smaller the amount of solids in the resin, the lower the grammage, the greater is the uniformity and cohesion of the fibers, in addition to the NW 10 having greater absorption capacity.

Table 1 Wave number, types of vibrations and peak intensity obtained from the FTIR spectrum.

Sampling	Wave number (cm ⁻¹)	Types of vibrations	Intensity (%)
CM, Resin, NW10, NW20 and NW30	3360	v(O-H)	CM: 1.45; Resin: 27.08; NW10: 1.90 NW20: 2.29; NW30: 1.59;
	2940	v(C-Hs)	CM: 6.62; Resin: 7.31; NW10: 7.25 NW20: 8.40; NW30: 4.03
	1730	v(C=O)	CM: 9.92; Resin: 11.40; NW10: 10.03 NW20: 8.16; NW30: 9.30
Resin, NW10, NW20 and NW30	1455	v(C-O)	Resin: 4.89; NW10: 3.13; NW20: 3.10; NW30: 3.64
CM, NW10 and NW20	1371	δ(C-H)	CM: 4.87; NW10: 3.41; NW20: 2.66
CM, NW10	1226	v(C-O)	CM: 9.84; NW10: 12.07
Resin	1169	v(C-O-C)	Resin: 23.35
NW20 and NW30	1165	v(C-O-C)	NW20: 4.68; NW30: 20.27
CM, NW10 and NW20	1038	δ(O-H)	CM: 20.05; NW10: 14.38; NW20: 8.40

(v) stretch (δ) angular deformation in the plane.

3.2.4. Absorption Capacity Analysis

The results showed a strong relationship between the solids content of the resin and its ability to absorb liquids (Figure 6). The absorption values varied from 1.52 to 4.99 g g⁻¹ for RW and between 1.71 to 4.01 g g⁻¹ for tap water. The greatest absorption capacity was obtained for NW10 (4.99 and 4.01 g g⁻¹) in relation to NW20 (2.25 and 2.70 g g⁻¹) and NW30 (1.52 and 1.70 g g⁻¹) respectively. This behavior occurred both for both samples (tap water and RW).

Cellulose acetate fiber has a hygroscopic character (Nomura et al. 1993). However, the resin used has a non-hygroscopic characteristic (Chiantore & Lazzari 1996). In this way, a relationship can be established in the order of the higher the solids content in the resin, the lower the absorption capacity (Figure 6).

3.3 Cellulose Acetate Fiber Filtration System Treatment Performance

In general, the system showed a satisfactory removal of turbidity, color, and suspended solids (Table 2). There was no significant change in relation to the value related to the absorbance of FW compared to RW. This parameter is indicative of the presence of dissolved organic matter (Souza. 2015). Some compounds like humic acid can absorb light at ultraviolet wavelengths. In this sense, the absorbance

result is probably related to the existence of humic materials presents in the RW.

Regarding the pH, it was possible to notice that 66% of the values related to the pH of the RW remained below 7, with an average of 6.64. This can be explained through two variables. Firstly, due to the high respiration rate of organisms present in the RW samples, with the release of carbon dioxide and the consequent formation of carbonic acid, keeping the pH close to neutral (Coral 2009). In addition, these pH values may be associated with the presence of humic materials (Hennemann 2010). After the filtration process, the pH values followed the same behavior as RW, remaining close to neutrality (Table 2).

At the same time, a 62.01% removal for turbidity was identified (Figure 7A). A study conducted by Mulligan et al. (2009) using nonwovens in the column filtration process for surface water treatment achieved turbidity removals in the order of 93%. The difference in removal performance between studies may be associated with the variation of the turbidity concentrations in the RW which was superior (20 to 100 NTU) in studies of Mulligan et al. (2009). In addition, the RW of this study had average turbidity of around 6.83 NTU. These values are considered the next of 5.0, that is values recommended by Ordinance 5/2017 on Consolidation (BRASIL. 2017). Therefore, due to the low turbidity values identified in the RW, the removal process may have been influenced.

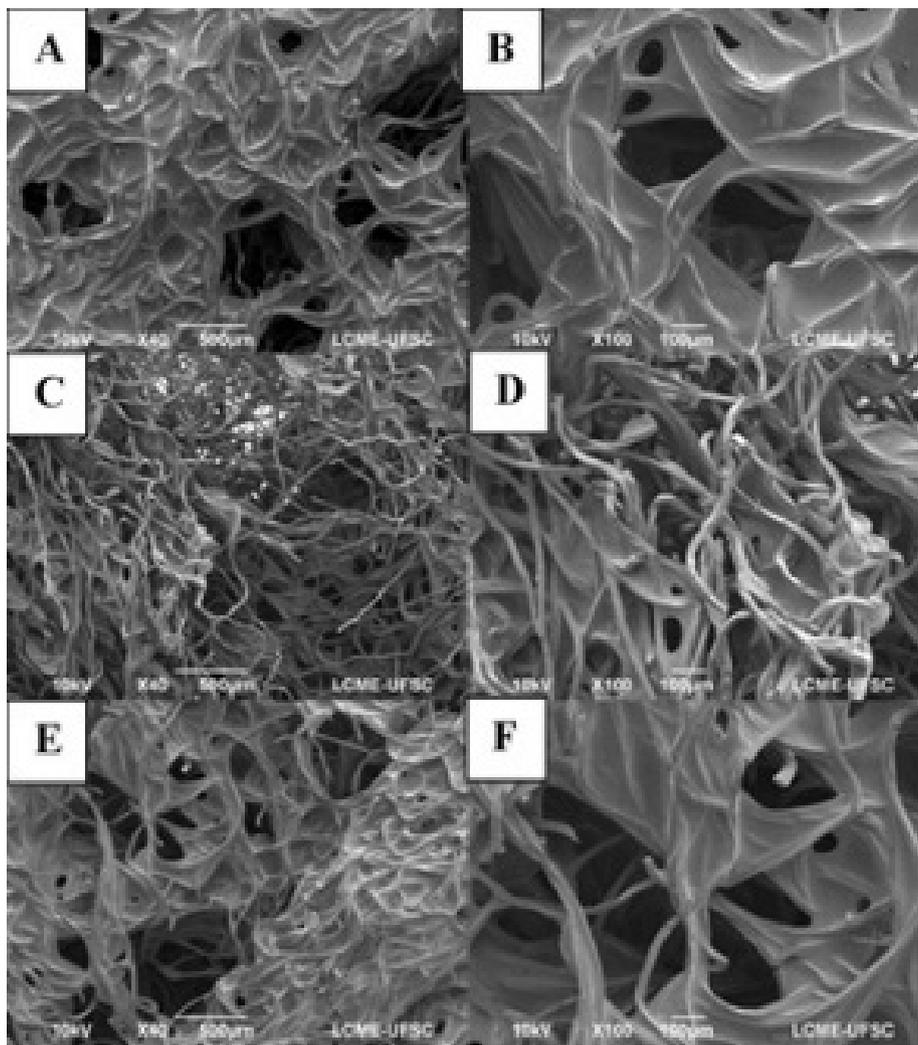


Figure 5 Electron microscope images of consolidated nonwovens. A. NW10 (magnification 40 x); B. NW10 (magnification 100 x); C. NW20 (magnification 40 x); D. NW20 (magnification 100 x); E. NW30 (magnification 40 x); F. NW30 (magnification 100 x).

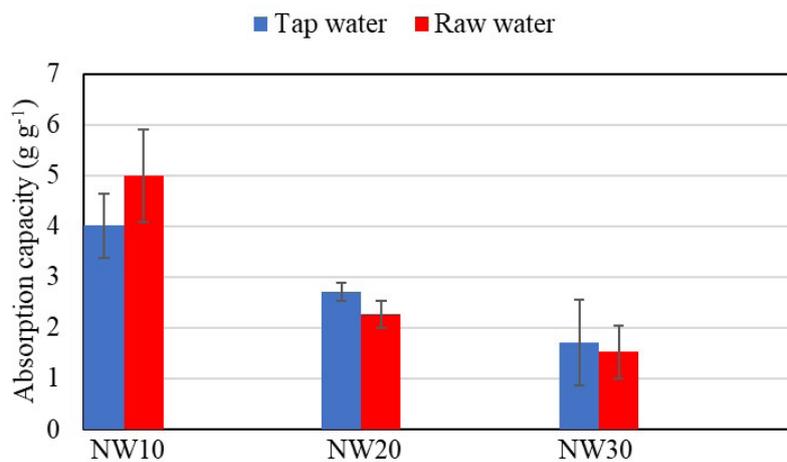


Figure 6 Absorption capacity of the different nonwoven samples.

Table 2 Mean, median values and standard deviation of different contaminants identified in raw water and filtered water.

Parameter n=15	Raw water	Filtered water	Mean removal efficiency (%)
Absorbance (cm⁻¹)			
Mean	0.05	0.06	
Standard deviation	0.01	0.01	–
Median	0.05	0.06	
TOC (mg L⁻¹)			
Mean	8.06	7.64	
Standard deviation	1.11	0.93	5.20
Median	7.94	7.96	
Apparent color (uH)			
Mean	74.90	37.20	
Standard deviation	6.72	6.06	50.36
Median	75.00	36.00	
True color (uH)			
Mean	15.04	14.03	
Standard deviation	2.33	1.60	6.73
Median	14.00	13.60	
pH			
Mean	6.64	6.21	
Standard deviation	0.93	0.80	–
Median	6.70	5.90	
TSS (mg L⁻¹)			
Mean	6.34	2.89	
Standard deviation	3.00	1.21	54.42
Median	5.45	2.87	
Turbidity (NTU)			
Mean	6.83	2.58	
Standard deviation	2.97	1.77	62.01
Median	6.00	2.50	

Note: total suspended solids (TSS); total organic carbon (TOC)

The average removal efficiency of apparent color was 50.36%, while the removal of true color was only 6.73% (Figure 7B). The apparent color removal is associated with suspended material, indicated by turbidity. The low true color removal efficiency was already expected (Figure 7C).

The fact that the true color has a low removal was already expected. This happened because no combination of physicochemical and biological processes was used, since to remove this parameter it is necessary to use chemical coagulation or ozonation (Di Bernardo et al. 1999; Pizzolatti 2014). Regarding TOC, the mean removal efficiency was 5.20% (Figure 7D). This low TOC performance of treatment may be associated with the fact that a large part of TOC usually presents in dissolved form (Aiken 2002). Meanwhile, TSS mean removal efficiency was 54.42% (Figure 7E). Palakkeel Veetil et al. (2021) with synthetic water evaluated the use of nonwovens as a filter

medium, seeking to improve the quality of surface water in a eutrophic lake. The mean removal efficiency obtained by the authors was close to 100%. Probably, the difference in the TSS removal between the studies may be associated with the difference in the concentration of TSS in RW, since in the study by Palakkeel Veetil et al. (2021), RW presented a concentration of about 32.5 mg L⁻¹, while in this study the mean was 6.34 mg L⁻¹.

Table 3 shows the treatment performance regarding the removal of metals. In general, all metals showed concentrations below the maximum permitted values contained in Ordinance 518/2004 (BRASIL, 2004). Higher treatment performance was identified for iron (72.26%), while the removal of copper and cadmium was in the order of 2.12% and 9.61%. The removal of metals was considered satisfactory because it is a filtration system coming from a CBR.

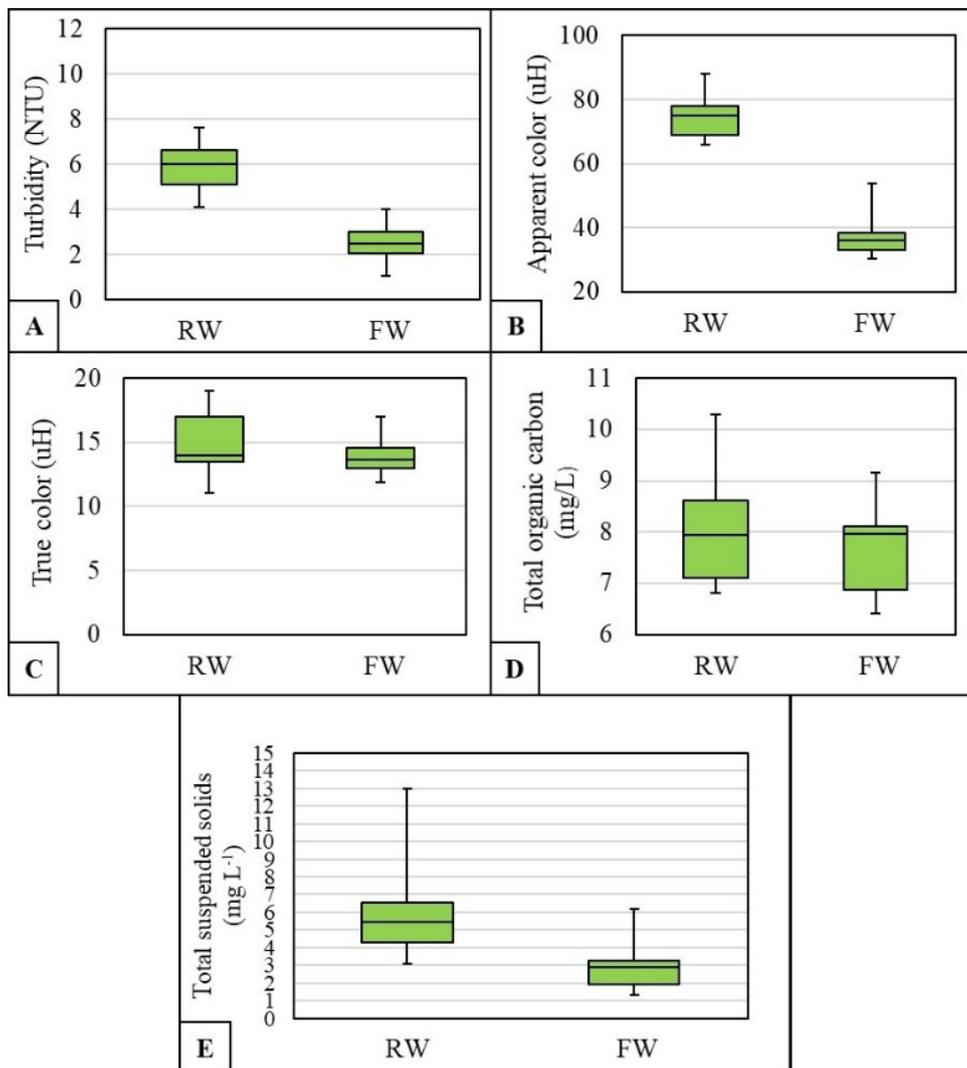


Figure 7 Behavior of the different pollutants identified in raw water (RW) and ed water (FW). A. Turbidity; B. Apparent color; C. True color; D. Total organic carbon; E. Total suspended solids.

Table 3 Mean and standard deviation from heavy concentration found in raw water and filtered water.

Metals	Raw water mg L ⁻¹	Filtered water mg L ⁻¹	Mean Removal efficiency (%)	518/2004 mg L ⁻¹
Iron	1.14 ± 1.92	0.31 ± 0.13	72.26	0.3
Copper	-0.51 ± 0.01	-0.50 ± 0.01	2.12	2
Cadmium	-0.35 ± 0.13	-0.32 ± 0.17	9.61	0.005

The presence of nicotine in both RW and FW has not been identified. This behavior was not expected. The average dose of nicotine per filter cigarette is around 11.9

mg (Carey et al. 2010). Since the filter element of the system is CM from CBR is noted that there was no detachment of nicotinic residues during the filtration process.

3.4 Ecotoxicological Test

The toxicity test showed that there was no release of toxic material from the NW to the water sample during the filtration process. Therefore, according to the results obtained in relation to the non-detection of nicotine and the low presence of heavy metals in filtered water, it is noted that the concentrations of metals found were not sufficient to influence the development of *D. magna*. The nicotine is highly toxic to *D. magna*, it interrupts the neurotransmission at the neuromuscular junction (Chen et al. 2018; Vlasceanu et al. 2015).

4 Conclusion

Based on the monitoring of a cellulose acetate filtration system coming from cigarette residues, it is concluded that:

- Nonwoven made from a resin containing 10% solids showed better encapsulation and cohesion between the fibers, greater uniformity of the fiber layer, in addition to a smoother surface and better absorption capacity (4.99 g g⁻¹ for Raw Water and 4.01 g g⁻¹ for Tap Water) in relation to samples with 20 and 30 solids content for making the filter element;
- The filtration system removed 62.01%, 54.42%, 50.36%, 6.73% and 5.20% for turbidity, TSS, apparent color, true color and TOC respectively;
- The removal of heavy metals was 72.26%, 9.61% and 2.12% for iron, cadmium and copper respectively, keeping within the Brazilian standards for surface water;
- Nicotine concentration was below the detection limit and there was no toxicity to *D. magna* after 48 h of exposure in a sample without dilution.

The filtration system proved to be a viable technology to be used in the surface water pre-filtration process, especially in the cases of rural areas, outlying areas of cities and settlements.

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Author contributions

Ana Silvia de Lima Vielmo: conceptualization; formal analysis; methodology; validation; writing–original draft; writing – review and editing; visualization. **Ailton Borges Rodrigues:** methodology; validation. **Eduardo Volkart da Rosa:** methodology. **Dayane Gonzaga Domingos:** writing – original draft. **Juliana Barden Schalleberger:** writing – original draft. **Maria Eliza Nagel-Hassemer:** supervision.

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Conflict of interest

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