TREATING SUPERFICIAL WATERS WITH RECYCLED MEMBRANES IN MINAS GERAIS

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ABSTRACT

In the context of improving water access to poorer populations, this paper explores the technical feasibility of using low-cost recycled membranes for the successful water treatment of the rivers of Minas Gerais, Brazil. In the first stage, the objective was to recycle, through oxidative treatment, polymer membranes discarded after reverse osmosis and nanofiltration processes, which would be disposed of in landfills. Subsequently, the research evaluated the use of recycled membranes in surface water treatment. Membrane performance before and after recycling was investigated by measuring the water flow in tangential-axial flow, at bench and pilot scales. Experimental results indicated that recycled membranes can be used in processes analogous to ultrafiltration, with satisfactory flow performance and scale resistance behavior. Tests have shown that recycled membranes operated steadily in water treatments under 0.5 to 1 bar pressure. Low pressure is regarded as favorable for the purpose of minimizing energy costs. The scale of the recycled membrane was removed through conventional cleaning. The quality of the treated water is similar to that reported in previous works evaluating new spiral modules of commercial ultrafiltration membranes. The permeate produced from the raw water treatment samples from the Doce, Paraopeba, and Velhas rivers using the recycled membranes obeyed the Brazilian potability standards for the following analyzed parameters: apparent color, turbidity, Escherichia coli, and heterotrophic bacteria.

Keywords: Access to water. Water treatment. Recycled membranes.

1. INTRODUCTION

The recycling of composite polymer membranes, which at the end of their useful life would be disposed of in landfills, gained increasing interest in academic and industrial environments (Lawler et al., 2015; Landaburu-Aguirre et al., 2016). The recycling technique used in this experiment consisted of immersing the membranes in a commercial solution of sodium hypochlorite pH 11 (NaClO) for 2.7 hours (~ 300,000 ppm·h) (Coutinho de Paula et al., 2017). In terms of water permeability, based on the new reverse osmosis (RO) membrane, which is 3.0 L · h-1 · m-2 · bar-1, the membranes oxidized with NaClO showed an increase from 27 to 39 times, while salt rejection decreased from ~ 96% to 15.5% (Coutinho de Paula et al., 2017). Thus, this work explores the feasibility of using recycled reverse osmosis and nanofiltration membranes to successfully treat the waters from the Minas Gerais rivers. The results indicate the low-cost recycled membranes potential to favor the population's access to water, especially in rural areas or in emergency situations.

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2. MATERIAL AND METHODS

The performances of discarded membranes and recycled membranes were investigated in bench and pilot scale tests, through cross-flow water permeation measurement. The procedures for the chemical cleaning of the membranes were evaluated according to Coutinho de Paula et al., 2017. The operation of water treatment by recycled membranes was repeated for three different sources of raw water from Minas Gerais rivers, namely: Rio Doce, Paraopeba, and das Velhas. No pretreatment was used for the river waters. The cleaning of the recycled membranes was performed at room temperature under immersion involving 0.1% (m/m) NaOH plus 0.2% (m/m) HCl for 2 hours at each stage. The physical-chemical parameters were analyzed according to APHA (2017).

3. RESULTS AND DISCUSSION

The performance of the pilot test using a recycled spiral-wound membrane in relation to the normalized permeate flux decline at 25° C at a flow rate of 3.2 L · min-1, at 1 bar pressure, over 24 continuous hours of permeation, is shown in Figure 1. A non-accentuated permeate flow decline occurred in the first hours of operation, due to concentration polarization and/or scaling (pie-crusting), as expected in this type of operation. It was observed that after about three hours of operation, the flow became stable (~ 16 L·h-1·m-2).

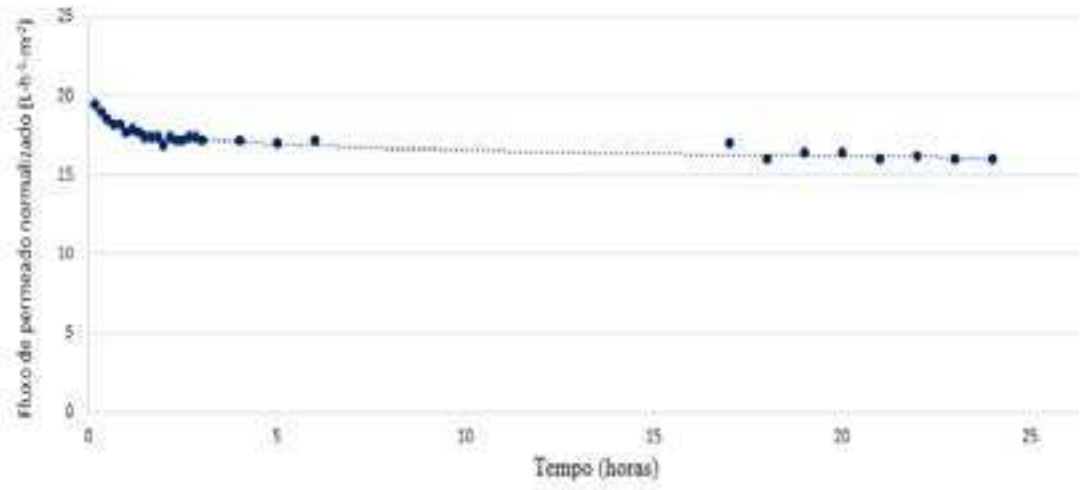

Figure 1 - Experimental results of normalized permeate flow at 25° C (L · h-1 · m-2) in function of time (24h of continuous permeation) of the Doce River water, pH ~ 7 in pilot test (membrane recycled with NaClO, flow rate 3.2 L · min-1, pressure of 1 bar).

Table 1 shows the results of the physical-chemical analyses of the analyzed parameters for the Doce River raw and treated water samples, according to APHA (2017).

Table 1 - Comparison between the results of the analyzed parameters for the Doce River raw water and water treated with recycled polymer membranes.

PARAMETER	UNIT	RAW WATER	TREATED WATER	REMOVAL (%)
pH	-	7.48	7.42	-
Electrical Conductivity	S·cm-1	196.9	192.5	-
Apparent Color	uH	113	1.9	98.3
Turbidity	NTU	10.5	0.11	99.0
TOC	$mg \cdot L^{-1}$	10.8	6.78	37.2
COD	$mg \cdot L^{-1}$	26.4	15.3	42.0
Total Nitrogen	$mg \cdot L^{-1}$	9.985	< 1	90.0
Alkalinity	mg $CaCO_3 \cdot L^{-1}$	26.97	15.93	40.9
Total Coliform	MPN·100 mL^{-1}	> 2.419,2	< 1	100
Escherichia coli	MPN·100 mL^{-1}	> 2.419,2	< 1	100
Heterotrophic Bacteria	CFU·mL-1	> 5.700	< 1	100

MPN = Most probable number
CFU = Colony-forming unit
Source: authors.

The evaluation of the efficiency of the recycled membrane indicates significant reductions in the apparent color and turbidity of the treated water compared to raw water, as well as the complete removal of microbiological parameters, which shows the added value of using recycled membranes. The monitored parameters for the permeate were kept at approximately constant values during the operation time. The physical-chemical analyses of the raw water samples from the Paraopeba and Velhas rivers, as well as their treated waters, showed similar results.

4. CONCLUDING REMARKS

The recycled polymer membranes showed similar performance and characteristics to the processes with low-pressure membranes. The result proved that recycled membranes can be applied to surface water treatments under a pressure of 0.5 to 1.0 bar. Low pressure is regarded as favorable for the purpose of minimizing energy costs. The chemical cleaning adopted proved to be effective for removal of scale and consequent recovery of the recycled membrane permeability. The quality of treated water is similar to that reported by several authors who have evaluated brand new commercial ultrafiltration (UF) spiral-wound modules. The permeate produced from the treatment of different raw waters of the rivers using the recycled membranes obeyed the Brazilian standards of potability for the following analyzed parameters: apparent color, turbidity, Escherichia coli and heterotrophic bacteria.

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