Application of Modified Membranes in Drinking Water Treatment

Flávia Vieira da Silva[*1], Natália Ueda Yamaguchi[1], Angélica M. Salcedo Vieira[2], Maria Teresa Pessoa de Amorim[3], Carlos José Tavares[4], Célia Regina Granhen Tavares[1], Rosângela Bergamasco[1]

[1]Department of Chemical Engineering, State University of Maringá, Av. Colombo, 5790, Campus Universitário, Maringá, Brazil. flaviaeq@yahoo.com.br
[2] Department of Food Engineering, State University of Maringá.
[3] Department of Textile Engineering, University of Minho.
[4] Center of Physics, University of Minho.

This paper presents filtration results obtained with commercial acetate membrane with a pore diameter of 0.45 μm, unmodified and modified with TiO_2, bearing in mind drinking water treatment. The experimental filtration set-up that was used consisted in the gravitational filtration system, whereas the accomplished tests that were endured consisted of hydraulic permeability of the modified and unmodified membranes, treatment of polluted water with *E. coli* bacterium, color removal, turbidity and free chlorine. The results of hydraulic permeability showed similar flux for all membranes at the end of the experiments, between 25 and 30 $kg \cdot m^{-2} \cdot h^{-1}$. The retention results for color, turbidity and *E.coli* bacteria are comparable.

1. Introduction

Water is an essential resource for life and good health, but its availability is decreasing day after day. This scarcity is mainly due to the demographic expansion, the sources contamination and degradation, and its irrational utilization. Moreover, the consumption of unmodified water leads to infectious diseases like diarrhoeic ones and others faecal-oral in nature (Arnal et al., 2001).

Tam et al. (2007) cited membrane separation processes as a suitable process for water treatment, since they can provide an absolute barrier for bacteria and viruses, besides removing turbidity and color. Most membrane processes are pressure-driven and require pumps to promote the trans-membrane pressure, resulting in high energy consumptions. Alternatively, membrane processes can be designed to operate with gravity as the driving force. However, this kind of research is scarce in the scientific literature. Peter-Varbanets et al. (2009) listed a few known membrane processes that use gravity as driven force for water treatment, such as the LifeStraw Family from Vestergaard Frandsen (LifeStraw, 2008).

The fouling in membrane filtration limits the application of this process because cleaning and frequent substitution of membranes are required, increasing the costs

involved. Essentially, fouling is a major constraint during separations using membranes. Its occurrence leads to a decline in the membrane permeability and can occur either by the deposition of a new layer onto the membrane surface (cake filtration) or by intermediate, total or internal porous blocking (Hermia, 1982), besides mechanisms as spacer clogging and adsorptive fouling. These several modes of porous blocking are due to the size and shape of the solid/solute in relation to the distribution of the membrane pore sizes.

Chemical modification of membrane surface using the deposition of titanium dioxide technique on its surface is of special interest. It aims to reduce the hydrophobic interactions between membrane surface and water solutes, the main cause of fouling (Morão et al., 2005). However, titanium dioxide could also act as a foulant once it forms a thin film onto membrane surface, so flux and resistance variations should be observed.

The aim of this paper is to present the results obtained in a gravitational filtration system operating with commercial acetate membrane unmodified and modified with TiO_2 thin film on its surface, for the application in drinking water treatment.

2. Materials and Methods

2.1. Membrane Modification

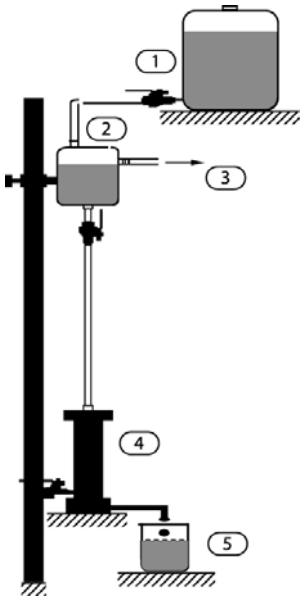
Cellulose acetate microfiltration membrane (pore diameter=0.45 μm) was purchased from Advantec. The immobilization of titanium dioxide onto membranes has been made by deposition of titanium dioxide films at room temperature by pulsed-frequency d.c. reactive magnetron sputtering from a high purity Ti target in $Ar/O_2/N_2$ atmosphere. The conditions of titanium dioxide deposition are shown in Table 1, and can be obtained in more detail elsewhere (Tavares et al., 2010). Original membrane is identified as M, while the modified membranes as identified as M01 and M02.

2.2. Gravitational filtration system

The modified and unmodified membranes were evaluated in the gravitational filtration system presented in Figure 1.

Table 1: Conditions of titanium dioxide deposition on membranes surface

Membrane	Ti cathode current(A)	Deposition time (h)
M01	0.5	6
M02	0.35	8



1= General tank
2= Lung tank
3= Bypass
4= Filtration module
5= Permeate

Figure 1. Scheme of the gravitational filtration system

2.3. Evaluation of unmodified and modified 0.45 µm membranes

The evaluation of the 0.45 µm membranes was performed in 5 steps:(1) Compression determination of initial permeated flux using deionized water. (2) Initial bacteriological assay, which consisted in an evaluation of *E. coli* removal using a suspension prepared to contain $1.0x10^5$~$1.0x10^6$ CFU/100mL. (3) Assays with tap water to determine the permeate flux and to monitor color and turbidity. (4) Final bacteriological assay, performed as described in step (2), to evaluate the *E. coli* removal capacity of membranes at the end of its use (5) Determination of final permeated flux using deionized water.

Table 2: Characteristics of tap water used in step (3).

Parameter	Value
pH	7.80
Color (UC)	4.93
Turbidity (UT)	1.15

2.4. Total resistance to tap water and contaminated water filtration

A plot of total resistance as function of time was constructed for the tap water assays (and for both bacteriological assays. The total resistance is defined as follows in Equation (1), as adapted from Duclos-Orsello et al. (2006).

$$R_t = \frac{\Delta P}{\eta J} \quad (1)$$

Where: R_t= total resistance (m^{-1}); ΔP= pressure applied in the membrane (Pa); η= kinematic viscosity of water (Pa.s); J= permeate flux ($kg.m^{-2}.h^{-1}$).

3. Results and Discussion

The obtained curves corresponding to the initial and final permeated fluxes with deionized water are presented in Figure 2 for all tested membranes.

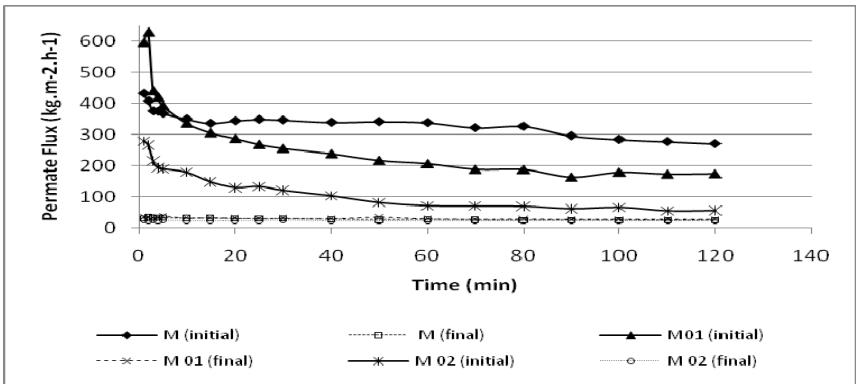


Figure 2: Permeated fluxes with deionized water

M01 and M02 presented a lower stabilized flux in comparison to the original membrane. Similar results were already reported (Mansourpanah et al., 2009). The observed fouling percentages were 90.04, 87.36 and 50.91, respectively to M. M01 and M02. The permeated flux data of contaminated water for the modified and unmodified membranes are shown in Figure 3. Moreover, the total resistance data in function of time is depicted in Figure 4.

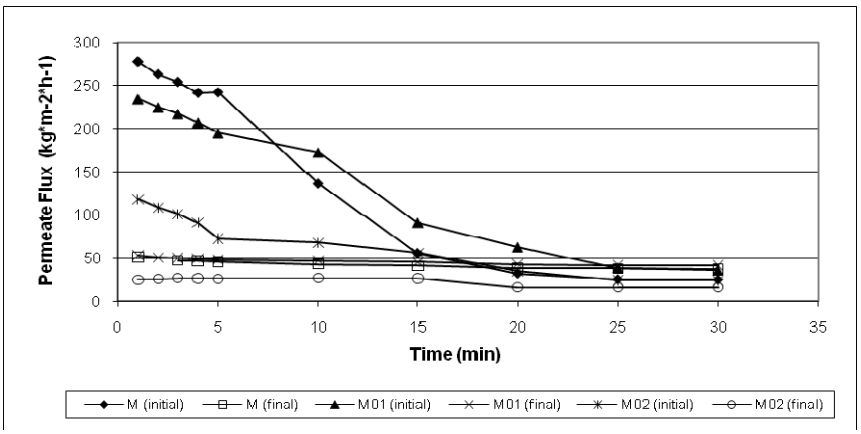


Figure 3: Permeated fluxes with contaminated water

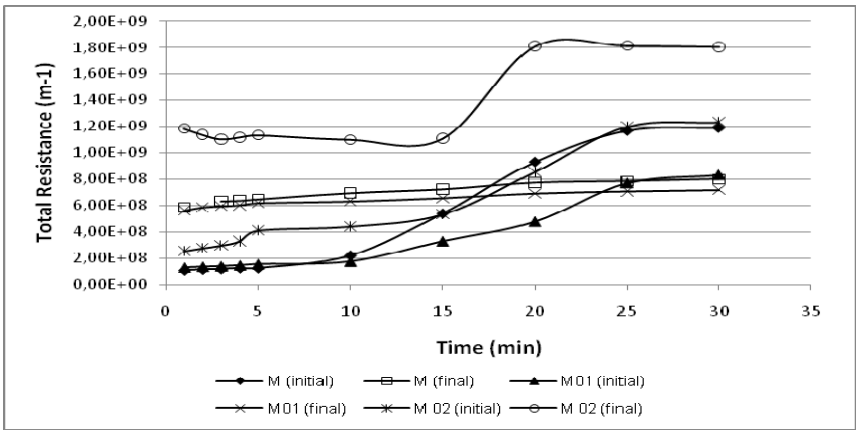


Figure 4: Total resistance as function of time for contaminated water

According to Figure 3, the stabilized flux was the lower than the stabilized flux observed for M01 and virtually equal to the stabilized flux obtained for M02. The total resistance (Figure 4) versus time curves were quite linear due to the fact that fouling occurs through a combination of different fouling mechanisms and has similar effects on both membranes (Duclos-Orselo et al., 2006). The obtained curves for the permeated flux of tap water are depicted in Figure 5, and the total resistance is shown in Figure 6.

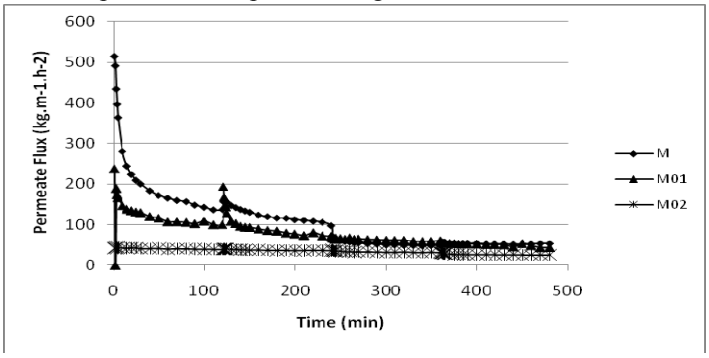


Figure 5: Permeated fluxes for the assays with tap water

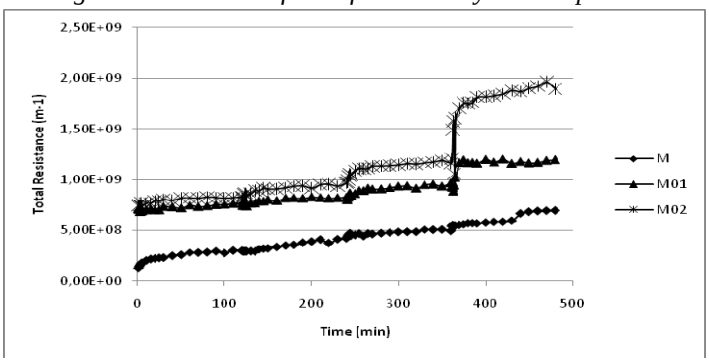


Figure 6: Total resistance as function of time for tap water

It was noticed that the TiO_2 deposition increased significantly the resistance of the membrane, and this effect increased with deposition time (Figure 6). All tested membranes (unmodified and modified) exhibited a bacteriological removal of 100% of the bacterium charge, both at the initial and final bacteriological assays. Moreover, the presented membranes removed 100% of color and ~80% of turbidity during the testing with tap water. Similar results were obtained by Ribeiro *et al.* (2007).

4. Conclusions

It is possible to conclude that the application of a gravitational module with membranes modified through TiO_2 immobilization in the conditions of M01 could be an alternative for the decontamination of potable water with superior quality, due to reduced fouling, lower cake resistance, besides the excellent removal of bacteriological and physical parameters.

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