Membrane distillation treating a petrochemical reverse osmosis concentrate

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Abstract
This study investigated the applicability of Direct Contact Membrane Distillation (DCMD) process for the treatment of a petrochemical industry effluent, intending to recover water from the concentrate produced by reverse osmosis (RO). In DCMD, the experiments were accomplished with a feed and permeate-inlet temperature of 60 °C and 20 °C, respectively. Four commercial microporous hydrophobic flat-sheet membranes made of polytetrafluoroethylene (PTFE), with or without a support layer, laminated or not with butylated hydroxyanisole (BHA), having different thickness, pore size, effective porosity and contact angle, were evaluated. All evaluated membranes presented a very satisfactory water recovery ratio (~90%), getting high rejection factors (above 99.5%) for all analysed parameters and producing a high-quality water having a very low electrical conductivity (around 2 µS cm^{-1}). The membrane with BHA in its composition presented the lowest permeate flux decay that occurred gradually along the experimental runs, representing a productivity loss of only 14% for a water recovery ratio near 90%. These results indicate that this membrane has a low propensity to fouling and scaling when treating a wastewater with characteristics like the ones evaluated in this work.
Keywords: Membrane Distillation; Petrochemical Wastewater; Reverse Osmosis; RO Concentrate.

1. Introduction

In an effort to make water reuse possible, contemporary researches have been devised to consolidate membrane filtration technologies as effective processes to remove organic and inorganic contaminants (soluble or not) from wastewater (Davood Abadi Farahani et al., 2016). As part of these techniques, the Reverse Osmosis (RO) is already a firmly established technology for wastewater treatment and even to produce potable water. RO practical application has evolved to a largely conventional procedure thanks to its efficient removal capabilities, notably to meet the water quality patterns required by the industry (Padaki et al., 2015). However, despite the RO development, there are still disadvantages and some environmental problems associated to this issue, especially considering the huge amount of concentrate that results from the RO process.

The so-called Reverse Osmosis Concentrate (ROC) is the byproduct of this procedure, containing persistent organic and inorganic pollutants, as well as other noxious factors. Therefore, the appropriate management and disposal of ROC has become a significant matter in water recovery practices, insofar as the concentrate produced in a RO plant contains all rejected contaminants in a much higher proportion. The inadequate discharge of that reverse osmosis' derivative is extremely harmful to the environment, and above all, it causes a meaningful loss of water resources a situation that claims for a totally integrated effluent treatment, including the ROC to the water cycle, preventing any risk of contamination (Shanmuganathan et al., 2016).

This work will highlight the potentials of using DCMD to a petrochemical industry ROC. The results should emphasize the best conditions for water recovery from a real petrochemical reverses osmosis concentrate.

2. Materials and Methods

This work was carried out to the treatment of a RO concentrate by membrane distillation according to the experimental setup presented on Figure 1.

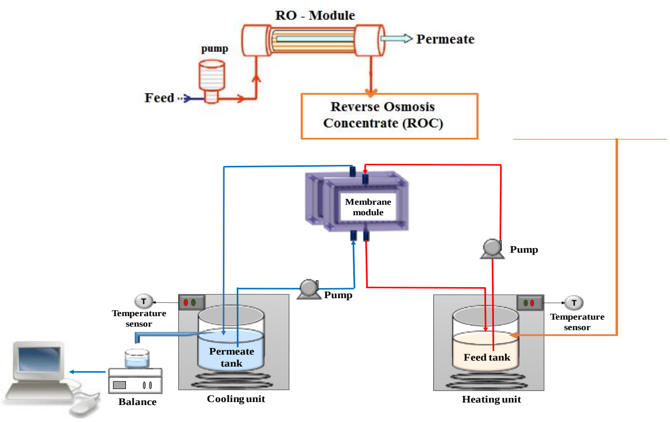

Figure 1. Experimental setup of RO and DCMD.

Table 1. Characteristics of the membranes

Membrane specification	Membranes			
	M1	M2	M3	M4
Material	PTFE	PTFE	PTFE	PTFE-BHA*
Support layer	PP	No	No	No
Pore size (µm)	0.2	0.2	0.3	0.3
Thickness (µm)	150-250	72	76	76
Porosity (%)	80	80	85	80
Contact angle (^{0})	120	137	118	>118
Liquid entry pressure (bar)	1.0	> 4.0	>3.8	> 4.0
Model	QL217	Teflon	Standard	BHA

* PTFE with BHA

3. Results and Discussion

3.1 The effect of the water recovery ratio on permeate flux

At Figure 2 is presented the evolution of permeate flux with water recovery ratio (WRR). For all four membranes the initial permeate flux with ROC (Figure 2a) was closed to the one achieved with pure water, but it decreased by increasing the WRR. This drop was more marked for membranes more permeable with pure water, i.e., the thinnest (M2) and the one with the highest porosity (M3). As can be seen in Figure 2b, M3 membrane presented a large and linear permeate flux decline of around 50% until achieving a WRR nearby 90%. The M2 membrane presented a sharp flux decline (nearly 50%) up to a WRR of 40%. After that, the flux remained stable until the end of the experimental run that represents a WRR of ~90%. On the other hand, the thickest membrane (M1) and the one having BHA in its composition (M4) displayed the smallest declines in permeate fluxes, 23% and 14%, respectively, which occurred gradually along the experimental runs.

In fact, a permeate flux drop by rising the WRR was already expected, once the feed volume diminish while the feed solution become more concentrated, raising the solution viscosity and the boundary layer thickness, which, in turn, increase the mass and heat transfer resistances. Likewise, the increase of salinity concentration of feed solution decreases the water vapor partial pressure, by decreasing of the solution activity coefficient (Naidu et al., 2017).

Generally, a reduction of the permeate flux during the ROC treatment can be explained by the increase of solutes concentration in the feed, and also by a more intense concentration polarization effect. Despite this. In addition, according to Naidu (2017), a faster flux decline could be interpreted as a stronger adhesion of foulants on the membrane. In the current work, this behavior was observed for the most permeable membranes (M2 and M3), indicating that they were more affected by fouling and scaling, what can be confirmed by a mass balance of solutes.

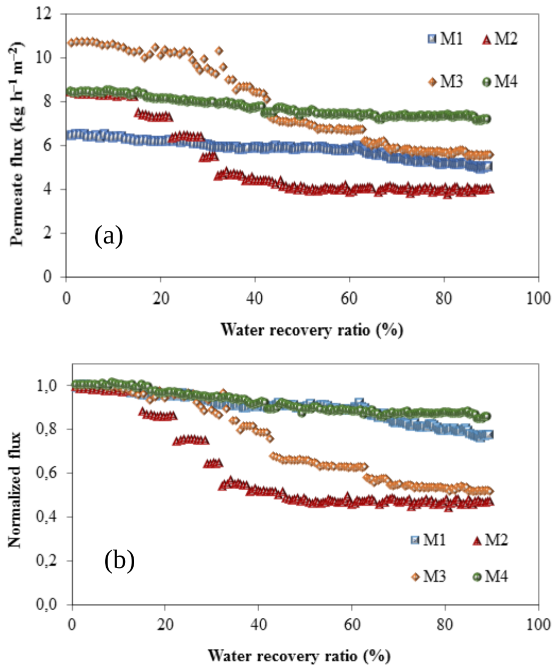

Figure 2. The effect of water recovery ratio on permeate flux. (a) Discrete flux, (b) Normalized flux.

4. Conclusions

All membranes satisfactorily presented a final water recovery ratio near 90% and high rejection factors (above 99.5%) for all evaluated parameters, attaining the requirements for most water reuse and recycling purposes.

For an effluent with the characteristics tested here, the membrane of PTFE with BHA (M4) presented the best results, having a minimum permeate flux reduction even at a water recovery ratio in the order of 90%. Finally, according to the results here observed, it can be considered that the DCMD technique is truly an advantageous and very attractive method to treat the reverse osmosis concentrate of the petrochemical wastewater.

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