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Properties and membrane distillation performance of polypropylene porous membranes

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Introduction

Membrane distillation [1] is a concentration process that presents some advantages, with respect to the more popular and well established reverse osmosis. This is especially true in the treatment of highly concentrated solutions, where the osmotic pressure can reach values that strongly reduce the process driving force and consequently the water permeation across the membrane. Membrane distillation (MD) is a thermally driven process in which a porous membrane separates two phases held at different temperatures. In most applications one of these phases is represented by a hot aqueous solution, so the vapour molecules flow through the membrane pores and condensate on the cold side of the membrane. No pressure is necessary in MD to promote vapour flow through membrane pores since the driving force is represented by the vapour pressure difference across the membrane. There are at least four different ways to drive the process. One of these (vacuum membrane distillation, VMD) involves the vacuum application on the cold side of the membrane. The success of membrane distillation in a given water purification treatment or solution concentration problem, depends on an optimal combination between membrane material properties and appropriate membrane pore size. Highly hydrophobic and thermally stable polymers such as polytetrafluoroethylene, polyvinylidenefluoride and polypropylene are commonly used for making membranes with small pore size (in the range of tenths of micrometer) that prevent liquid water from pore penetration at relatively low pressure. Membrana^{TM} is a German company that produces a large variety of polypropylene porous membranes with different configurations (e.g. flat sheet, hollow fiber, capillary, tubulet) especially designed for a plurality of applications (microfiltration, contactors, oxygenation, etc.) [2]. Most of these membranes present suitable properties (i.e. highly hydrophobic character, small pore size) for membrane distillation applications. Much attention has been especially paid to hollow fiber and/or capillary membranes but recent trends towards the realization of spiral wound modules [3] motivates also an increasing interest for flat sheet membranes. In this presentation two types of polypropylene flat sheet membranes produced by Membrana (PP1 and PP2EHF) have been characterized through different techniques and their performance has been evaluated in a laboratory scale VMD plant fed with aqueous NaCl solutions. The influence of feed concentration and some process parameters (e.g. feed temperature and vacuum degree) on the distillate flux and salt retention has been studied.

Methods

Scanning Electron (SEM) micrographs of the membrane surfaces (active top layer and support bottom layer) were taken by using a Stereoscan 440 (from Leo) ~~SEM~~ equipment. Pore size distribution of the membrane was evaluated at 25°C by gas-liquid displacement porometry (GLDP) by using a Coulter Porometer II and an increasing air pressure to progressively displace the wetting liquid (Porofil) from the membrane pores [4]. Membrane distillation experiments were carried out with a laboratory plant fed with hot NaCl solutions. A pump provided continuous recirculation of the feed solution with v = 1 m/s, velocity at the top layer membrane surface ($s = 66\ cm^2$) and a pressure: P = 1,1 bar (absolute). Vacuum was applied on the bottom (permeate) side of the membrane and the vapour permeated was condensed by two cooling devices arranged in series. The vapour flow rate was measured by evaluating the volume of condensate every a given run time. Salt retention was calculated through conductivity measurements of both feed and condensate. After each measurement both samples were poured into the feed tank in order to maintain constant the feed concentration.

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Results

Comparison of SEM image reported in Figure 1 reveals profound differences in pore size of the two membranes (PP1 and PP2EHF) as well as in the morphology of the membrane (top layer and bottom support) surfaces.

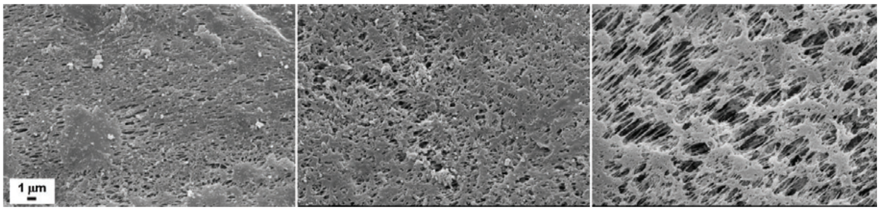


Figure 1. SEM images of polypropylene membrane: a) PP1E, top surface; b1) PP2EHF top surface; b2) PP2EHF bottom surface

These differences between the two membranes can be better observed from pore size distribution curves (Figure 2) determined by GLDP measurements.

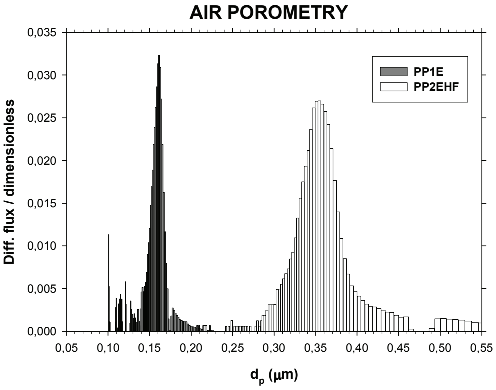
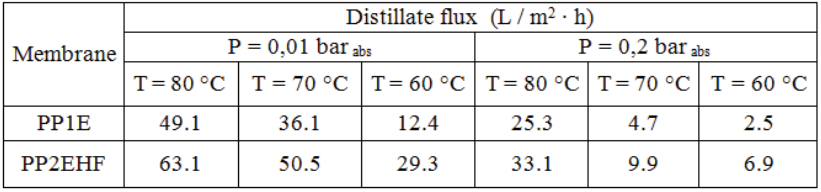


Figure 2. Pore size distribution curves of PP1E and PP2EHF membranes

According to these findings PP2EHF membrane provides a higher distillate fluxes during VMD test carried out at different vacuum degree with hot NaCl solutions (C_{NaCl} = 32 g/L) at various temperature (Table 1). However very high salt retentions were found in all the cases (around 99,98 %).

Table 1. MD performance of PP1E and PP2EHF membrane



Membrane	Distillate flux (L / m^2 · h)					
	P = 0,01 bar$_{abs}$			P = 0,2 bar$_{abs}$		
	T = 80 °C	T = 70 °C	T = 60 °C	T = 80 °C	T = 70 °C	T = 60 °C
PP1E	49.1	36.1	12.4	25.3	4.7	2.5
PP2EHF	63.1	50.5	29.3	33.1	9.9	6.9

Discussion

Two flat sheet polypropylene microporous membranes with different pore size and pore size distribution have been studied for desalting hot NaCl solutions. Distillate flux was found to be strictly dependent on pore size of the membrane as well as feed temperature and vacuum degree while membrane retention was not affected by these parameters.

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