Chapter 7
Membrane Distillation for Aqueous Feeds Treatment

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ABSTRACT

Membrane distillation (MD) is a thermally-based membrane operation in which the distillation of aqueous feeds occurs through a membrane. Although first works on MD appeared in the literature in the 1960s, the application of MD has been limited, mainly due to the lack of membranes and modules specifically designed, as well as to the thermal demand. Nevertheless, MD attracted the attention of many researchers, and significant improvements of the MD performance have been achieved. In this chapter, MD features, drawbacks, and possible solutions are presented and discussed.

INTRODUCTION

Membrane distillation (MD) is a thermally-driven membrane operation based on the use of hydrophobic microporous membranes. With respect to pressure-driven membrane operations, liquid water cannot permeate through the hydrophobic membrane and only water vapor and volatile species can be removed from aqueous feeds thanks to a difference of vapor pressure created across the membrane. With respect to conventional distillation units, MD is characterized by lower operating temperatures, with consequent reduction of the energy demand, and by higher compactness, typical of membrane devices. The fact that a distillation rather than a filtration occurs, allows reaching high-purity distillates starting also from highly concentrated feeds, which cannot normally be treated by pressure-driven membrane operations, like reverse osmosis (RO), because of the limitation in the osmotic pressure. Moreover, MD is in principle able to completely reject all non-volatiles present in the aqueous streams, leading to a high purification efficiency also when feeds contain species for which pressure-driven membrane operations do not offer high selectivities (e.g., urea and boron). Based on the above considerations, the interest in MD has significantly grown in the last years and its performance in different fields has been studied. This Chapter aims at giving an overview of the main principles of membrane distillation, main applications, main drawbacks which still limit its full development at large scale, as well as research efforts in progress.

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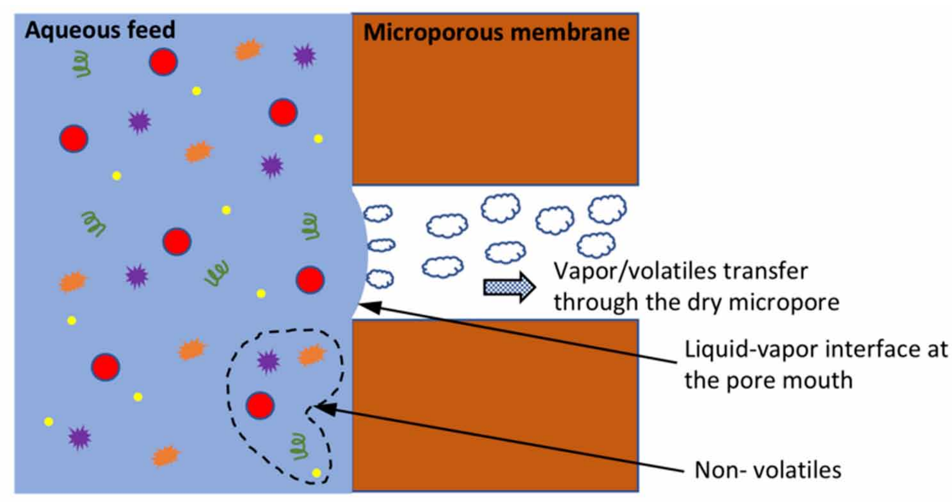
MAIN PRINCIPLES

The core of membrane distillation is the membrane, which has to be hydrophobic and microporous. Typical materials used to prepare the membrane are polypropylene (PP), polytetrafluoroethylene (PTFE), and polyvinylidene fluoride (PVDF). The hydrophobicity is fundamental to avoid the aqueous feed could permeate as liquid through the membrane, while the presence of micropores is needed to establish the liquid-vapor equilibrium. Each micropore acts as an interface, and a well-defined area for evaporation is created. From this interface, the vapor and volatiles migrate through the micropore and reach the other side of the membrane to be, then, recovered. In this way, all non-volatiles present in the feed are retained, therefore allowing the treatment of feeds containing different non-volatile species in the same unit, as sketched in Figure 1.

Figure 1. Liquid-vapor interface at the micropore mouth



It has to be pointed out that, in addition to the membrane hydrophobicity, to carry out MD experiments, it is important to never exceed the so-called Liquid Entry Pressure (LEP), which is the pressure value at which the aqueous feed starts to penetrate the membrane as liquid, no matter its hydrophobic character. The LEP value is directly linked to the membrane hydrophobicity and to the liquid surface tension, while it is inversely proportional to the membrane pore size.

The MD process is characterized by a simultaneous transfer of mass and heat. Both depend on the boundary layers and the membrane resistance.

In particular, while the boundary layers resistances are affected by the fluid dynamics, the membrane resistance is a function of the membrane properties. Specifically, the mass transfer encounters three main resistances in the membrane:

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