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Membrane Distillation: Principles, Applications and Perspectives

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Abstract

Membrane Distillation (MD) is a membrane-based operation able to give 100% theoretical ions rejection and to efficiently work with high concentrated brines. Both features make MD of interest for the purification of wastewater, the production of ultra-pure water and the concentration of brines produced in desalination. MD, also integrated with other membrane operations, can be a valuable way to improve the performance of separation processes.

Keywords Membrane distillation; Wastewater treatment

Introduction

MD is a thermally-driven membrane operation where the vapor molecules evaporate from the feed thanks to a difference of vapor pressure created across the membrane. Through the evaporation it is possible to produce a pure distillate and to concentrate the feed. The membranes employed are hydrophobic and porous. Polymeric membranes made of polypropylene (PP), polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE) are the most used, although some studies on zeolite and ceramic membranes have been also carried out. If compared to conventional distillation units, MD is able to work with smaller footprint and lower operating temperatures. Typical operating temperatures are around 50°C-80°C and waste heat or renewable sources, like solar energy, can be used to heat the feed. If compared to pressure-driven membrane operations, MD operates at lower pressures (usually at atmospheric pressure) and is able to treat high concentrated streams, due to the lower effect of concentration polarization on its performance. Its potentialities have been proven for many types of separations, as well documented by the huge amount of papers published in the field [1-24].

Main Principles and Applications of Membrane Desalination

There are four main configurations of MD, that differ in the way the difference of vapor pressure is created and the distillate recovered (Figure 1). Direct Contact Membrane Distillation-DCMD (Figure 1a) is the simplest one, using a cold stream to promote the difference of temperature across the membrane; in this case vapor condenses directly into the cold stream. Air Gap Membrane Distillation-AGMD (Figure 1b) presents an air gap in which the vapor diffuses before condensing. Sweep Gas Membrane Distillation-SGMD (Figure 1c) uses a sweep gas to remove the permeating vapor, while Vacuum Membrane Distillation-VMD (Figure 1d) applies vacuum. In both cases, the vapor is liquified in an external condenser.

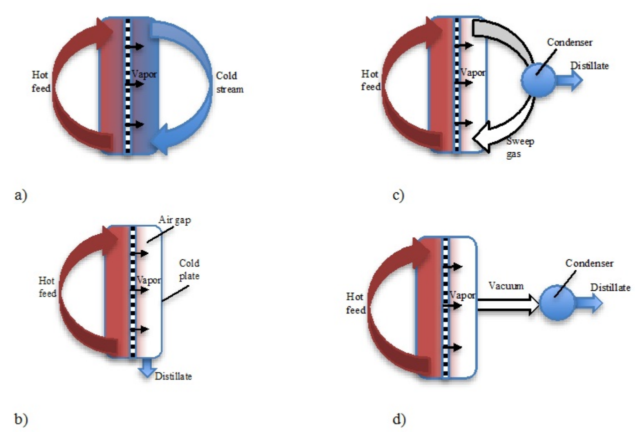

Figure 1: Simplified schemes of MD configurations: a) DCMD; b) AGMD; c) SGMD; d) VMD.

The efficiency of the MD is strongly dependent on the membrane properties. To make the process happening, it is essential to work with hydrophobic membranes. Pore size should be of the order of few microns and has to be chosen with the objective of working with reasonable fluxes and high Liquid Entry Pressure (LEP), to reduce the wetting risk. A typical value of pore size is around 0.2 μm. High porosity values should be preferred, for both enhancing the flux and reducing the heat loss by conduction through the membrane matrix, particularly for DCMD. Thickness plays also an important role, influencing the flux, the mechanical resistance and the heat loss by conduction.

Being a thermally-based process, the efficiency of MD is often evaluated in terms of Gained Output Ratio (GOR), that gives information on how much of the supplied heat has been used for the evaporation (useful heat).

MD finds application in different sectors, as summarized in Table 1.

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Concentration and purification of wastewaters (dairy effluents, olive mill wastewaters, textile effluents, etc.)
Desalination
Treatment of gas produced waters
Treatment of waters contaminated by toxic compounds, like boron, arsenic, uranium, fluoride, etc.
Treatment of brines and high-concentrated waters
Treatment of radioactive waters
Ultra-pure water production
Fruit juice concentration
Dehydration of solid particles

Table 1: Some fields of application of MD.

Conclusion and Future Perspectives

MD has a good potential for the purification and concentration of streams and the growing number of researches on MD clearly documents the interest in the field. It is expected that improvements in the membrane properties and the development of membrane modules specifically designed will drive the application of MD at large scale.

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