Potentialities and limits of Membrane Distillation and related technologies

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Membrane separation techniques have gained a fundamental role in solving problems related to the separation, concentration and/or purification of chemical species from liquid solutions or gaseous mixtures. Among the wide variety of membrane operations, membrane contactors are relatively new membrane devices that are becoming increasingly relevant. In particular, membrane distillation (MD), appeared as a new promising technology for wastewater treatment and desalination, as it may be potentially cost-effective by utilizing low-grade waste heat or renewable energy sources. Among the other advantages of the MD is the case of remembering the reduced footprint of the plant, the low capital costs compared to conventional distillation processes and the almost total absence of flux limitations due to concentration polarization. Unfortunately, the MD permeate flux is a few times lower than that obtained in reverse osmosis (RO). With the aim of achieving a zero-liquid discharge in desalination, the concept of membrane crystallization (MCr) has been introduced by Drioli and his colleagues in recent times. This new salt water treatment technology shares the same separation/concentration mechanism with MD. It is considered as an extension of MD because it concentrates the solution up to the supersaturation state to recover valuable ions from feed solution. As well as for MD, the driving force of MCr is not significantly affected by the concentration polarization phenomenon. This implies that high recovery factors and concentrations can be reached in MCr operations, as opposed to RO. Only in recent years the supply of membranes and/or membrane modules for MD has become more pronounced and differentiated. Although membrane fouling is not a crucial problem in MD, temperature polarization and membrane pore wetting are critical issues. The former is inevitable and can be mitigated mainly by changing the fluid dynamics of the system while the latter can primarily be reduced or completely prevented by choosing appropriate fluid dynamics conditions and suitable membrane materials, as is evident from experimental observations involving LiCl with PVDF-based membranes. In this respect, the occurrence of wetting in crystallization tests with PVDF-based membranes was attributed to the interaction between the positively charged Li and fluoropolymers. While MD/MCr applications make an important contribution to salt water management by enabling the production of fresh water and the recovery of precious salts, there is still a long way to go before these technologies can become widespread. Further research efforts should be addressed to the study of optimized membrane configurations and membrane materials. MD performance confirms the need for a customized hardware, i.e., high porosity hydrophobic membranes with appropriate thickness and made by low-heat conductive polymers in order to reduce the amount of waste energy.

New amorphous perfluoropolymers, mixed matrix and ceramic materials are becoming available. Moreover, clear protocols and comparison indexes for the choice of the best materials and operative conditions, accurate modeling for an easy scale-up or scale-down, and significant multidisciplinary research efforts are needed and might contribute to the development of the technology.

Further progresses in these operations will be related to the understanding of plasmonic phenomena. In particular, control and minimization of temperature polarization might be improved.

Relevant bibliography

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