Polymeric Nanofiltration Membranes for Desalination & Nuclide Separation

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1. Introduction

Within several decades, global interest in clean water has been significantly increased.[1] In nuclear engineering field, water (or seawater) is used for moderator or coolant, and this is because every nuclear power plant is built close to coastal area.[2] Since nuclear energy is extremely dangerous and unknown territory considering common sense, wastewater treatment coming from nuclear facility is very important and highly focused area.

Among several techniques, membrane based separation has been rising technology due to low energy intensity, high special efficiency, and pressure driven process.[3] To overcome other technology, membrane materials used for separation should possess high permeability (throughput) and high selectivity (process efficiency).[4]

There are several membrane based wastewater treatment techniques, such as microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and forward osmosis. With these various techniques, selection of appropriate operation and membrane is the most important issue in membrane separation community.

In this work, we describe the nanofiltration technique for commercial polymeric membranes to apply desalination and aqueous nuclide separation. Nanofiltration of three different aqueous nuclide solutions is studied to understand the permeation characteristics of the commercial polymeric membranes. We demonstrate that the nanofiltration membranes display decent permeation properties, highly rejecting nuclides considering their salt rejection at room temperature conditions.

2. Main title

Nanofiltration membrane performance was evaluated with a lab-made crossflow test unit shown in Fig. 1.

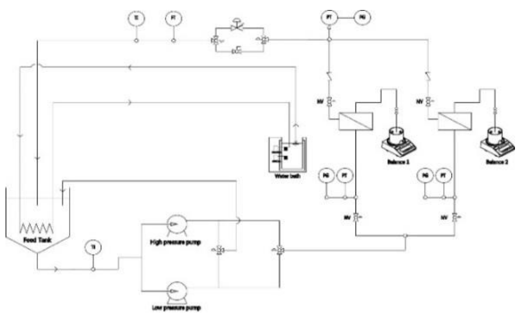

Fig. 1. Schematic diagram of the nanofiltration system. (TI: temperature indicator, FT: flow transmitter, PT: pressure transmitter, PG: pressure gauge, and NV: needle valve)

Fig. 2 shows desalination data for 35,000 ppm of NaCl aqueous solution under 30 bar at room temperature. For the feed reservoir, the seawater is modeled which indicates the 35,000 ppm (3.5wt%) of NaCl aqueous solution. In Fig. 2(a), the conductivity values are well coincided with the designated value 54.7 mS/cm. After passing nanofiltration membranes (NF90 and NF270), the conductivity values are significantly decreased to 19 mS/cm and 38 mS/cm which are corresponding to 12,400 ppm and 24,300 ppm, respectively. With regard to rejection, they are 82% and 37%, and these are not qualified rejection value as desalination membranes, and much lower rejection comparing to the general reverse osmosis membranes. Flux is calculated by dividing the volumetric rate with membrane area to obtain membrane-area-normalized value. Due to the usual trade-off property coming from the separation membranes, NF90 shows 160 LMH and NF270 shows 210 LMH. Even if the NF270 has high flux, NF90, which shows high rejection, is more appropriate membrane for nuclides separation considering the nuclear engineering area.

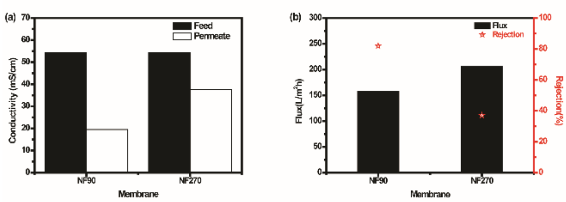

Fig. 2. Desalination results regarding (a) conductivity and (b) flux & rejection from NF90 and NF270 under 30 bar at room temperature.

Fig. 3 shows nuclide separation results for aqueous nuclide solution containing 10 ppm of Cs, Sr, and Co using NF90 nanofiltration membrane under 30 bar at room temperature. Through the solution-diffusion mechanism, the nuclides are rejected from 10 ppm to 1.6 ppm for Cs, 2.2 ppm for Sr, and 3.4 ppm for Co. This significant downgrade of concentration is attributed to the nuclides rejection by polyamide chains and their high affinity to water. The concentration downgrade is corresponding to the rejection of 83%, 78%, and 64%. Similar to the desalination result, nuclides separation also has trade-off property between flux and rejection. Among three different nuclides solutions, aqueous Cs solution describes most stable flux and rejection with narrow error bars. This represents that polyamide based nanofiltration membrane is well-applied to the Cs comparing to other main nuclides. Even higher rejection can be anticipated tuning the feed pressure, and membrane surfaces.

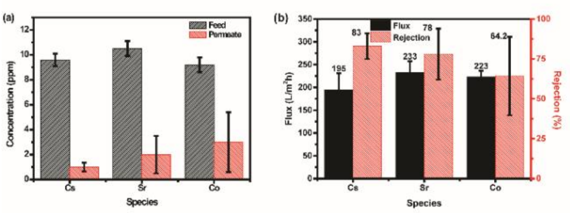

Fig. 3. Nuclide separation results regarding (a) concentration downgrade and (b) flux & rejection from NF90 under 30 bar at room temperature.

Table 1 summarizes desalination and nuclide separation results for NF90 at room temperature.

Table 1. Performance summary of NF90 membrane

	Flux (L/m^2h)	Feed conc. (ppm)	Permeate conc. (ppm)	Rejection (%)
NaCl	158	35,000	12,600	82
Cs	195	9.6	1.6	83
Sr	233	10.5	2.2	78
I	223	9.2	3.4	64

3. Conclusion

This work demonstrates that commercial polymeric membranes, NF90 & NF270, could apply to separation of nuclides. The commercial polyamide based polymeric membranes show high rejection for model seawater and aqueous nuclides solutions (Cs, Sr, and Co) at room temperature. This work on polymeric membranes for nuclide separation leads to an understanding of the behavior of polymeric membranes. Future work using radioactive nuclides and mixed nuclides solution is warranted.

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