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Properties of temperature-responsive polymers as potential driving solutes for osmotic filtration processes

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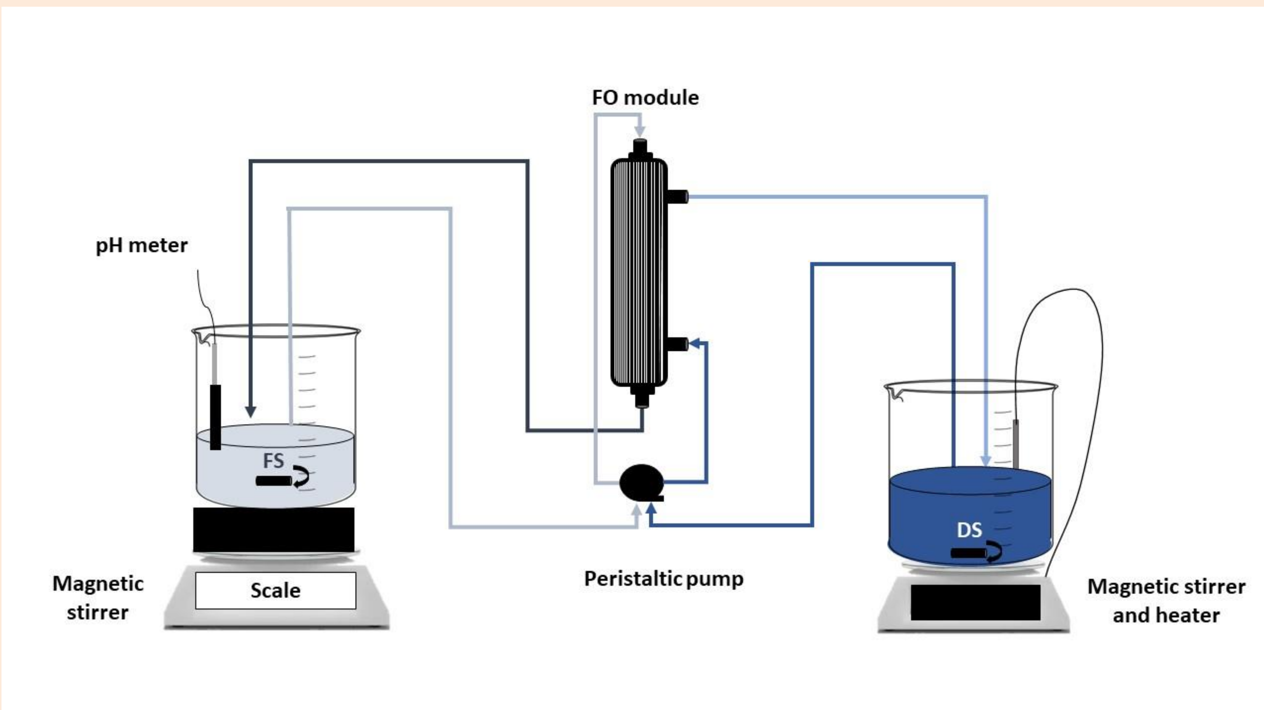
Introduction

Forward osmosis (FO) is a promising technology for efficient water reclamation at low operating costs. It has shown great potential in producing freshwater from seawater, but the regeneration of the diluted draw solution (DS) still holds back further development. Thermo-responsive polymers, especially polyalkylene glycol (PAG) based copolymers with hydrophilic ethylene oxide and hydrophobic propylene oxide units, have shown suitability as DS in FO because they can be regenerated using low-grade heat. Three types of block copolymers Pluronics® (PE 6400, RPE 1740, and L-35) and two different types of random copolymers (Unilube 50MB-26 and Polycerin 55GI-2601) were selected and tested as a DS in a laboratory FO setup using Aqp HFFO lab module.

Materials and methods

- **Membranes**: The Aquaporin Inside® hollow fiber forward osmosis (Aqp HFFO) membranes embedded in a lab- module from Aquaporin A/S (Kgs. Lyngby, Denmark) were used.
- **Feed solution**: DI water **Draw solutes**: PAGs
- **Experimental FO set-up**:



Batch system
Flat-sheet membrane
(A = 0.0180 cm^2)
Flow rate of FS and DS: 120 mL/min
Direction of flow: counter-current

Figure 1: Scheme of the FO process.

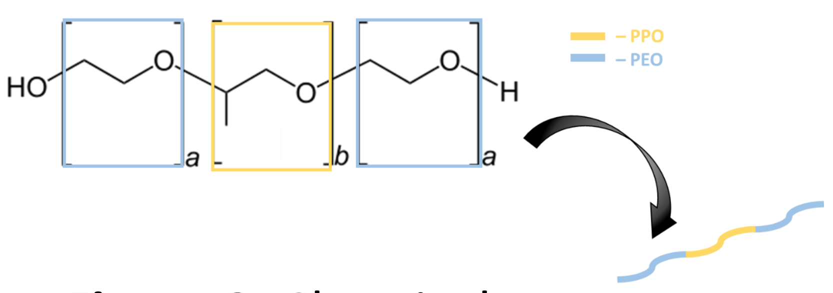


Figure 2: Chemical structure of Pluronics® or block PAGs.

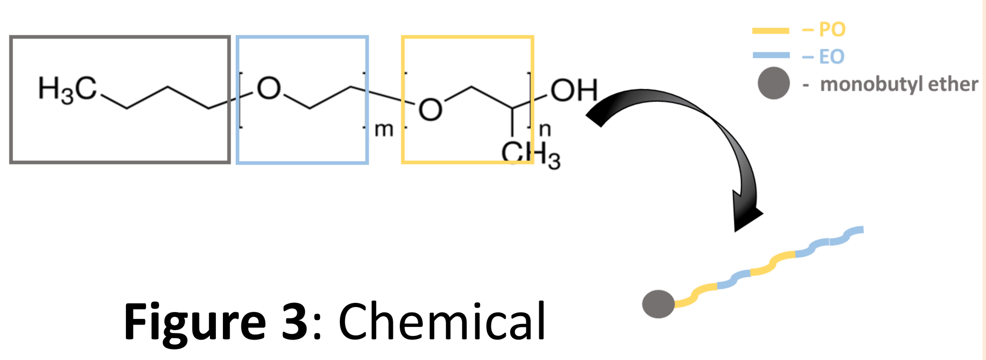


Figure 3: Chemical structure of random PAGs.

Table 1: Characteristics of PAGs.

Type of PAG	Average molecular weight ($gmol^{-1}$)	Structure: Normal (L) Reverse (R)	PEO content (wt%)	LCST (°C) of aqueous solution	Viscosity (mm^2s^{-1})	Product developer
Pluronic® PE 6400	2900	L	40	60 (1 wt%)	952 (23 °C)	BASF SE (Ludwigshafen, Germany)
Pluronic® RPE 1740	2650	R	40	51 (1 wt%)	583 (23 °C)	BASF SE (Ludwigshafen, Germany)
Unilube 50MB-26	2000	/	No information	50 (50 wt%)	310 (20 °C)	NOF Corporation (Tokyo, Japan)
Pluronic® L-35	1900	L	50	73 (1 wt%)	353.8 (25 °C)	BASF SE (Ludwigshafen, Germany)
Polycerin 55GI-2601	2600	/	No information	68 (50 wt%)	560 (20 °C)	NOF Corporation (Tokyo, Japan)

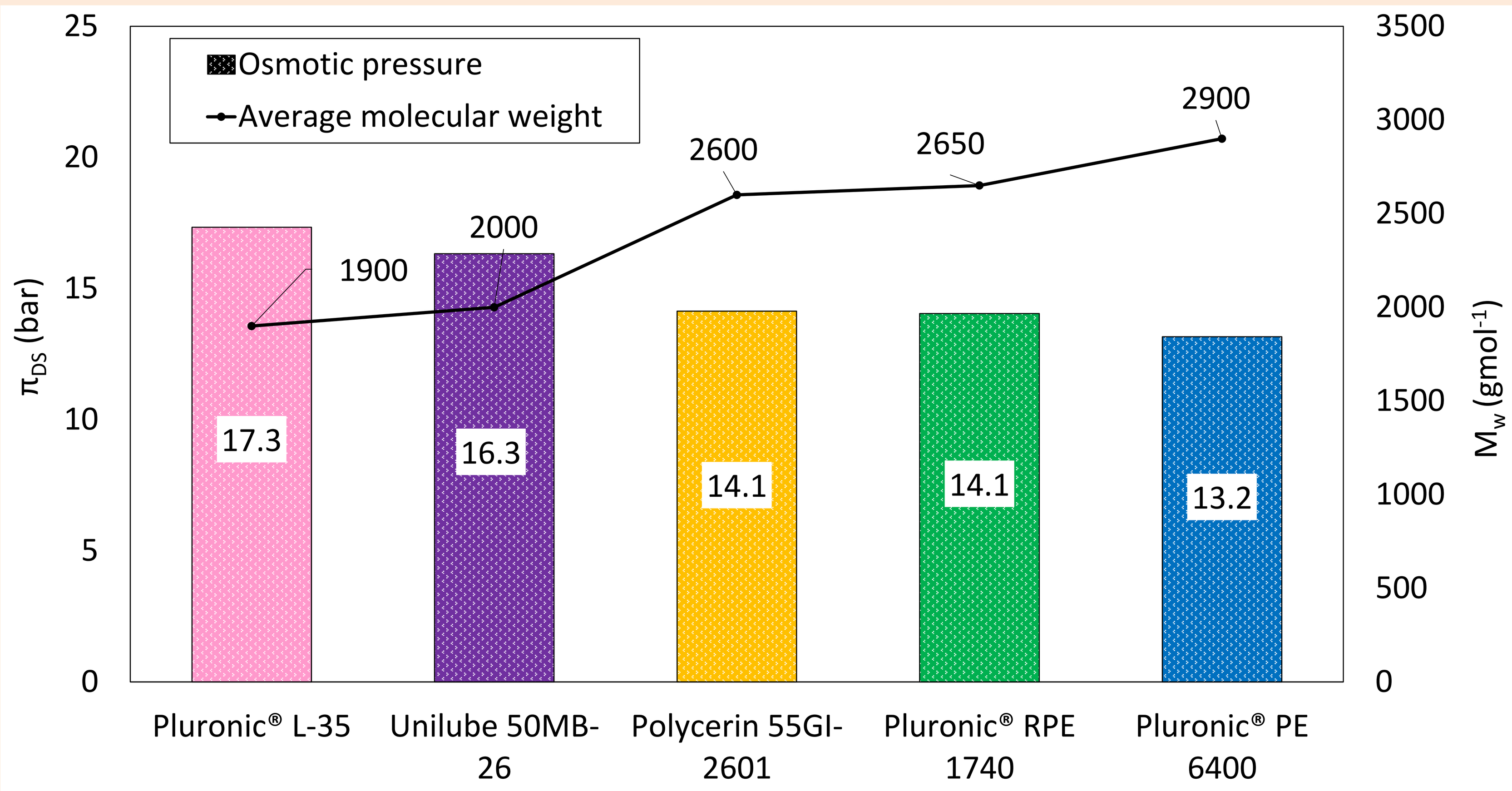


Figure 4: Osmotic pressure of 20 wt% PAG solutions with the corresponding molecular weight.

Results

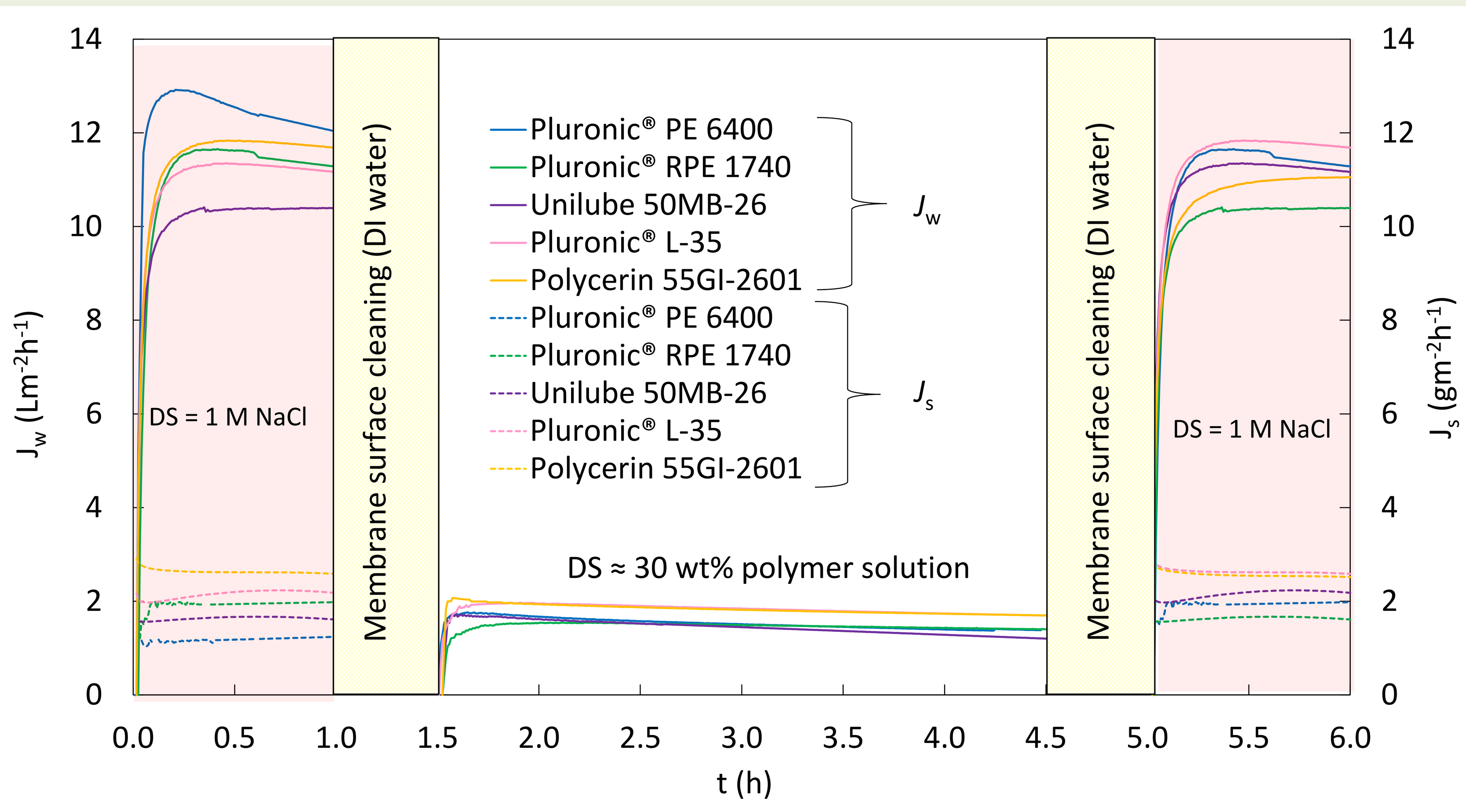


Figure 5: Water flux and reverse solute flux vs time for baseline experiments (1 h) and water flux for FO experiments when using 30 wt% PAG solution (3 h).

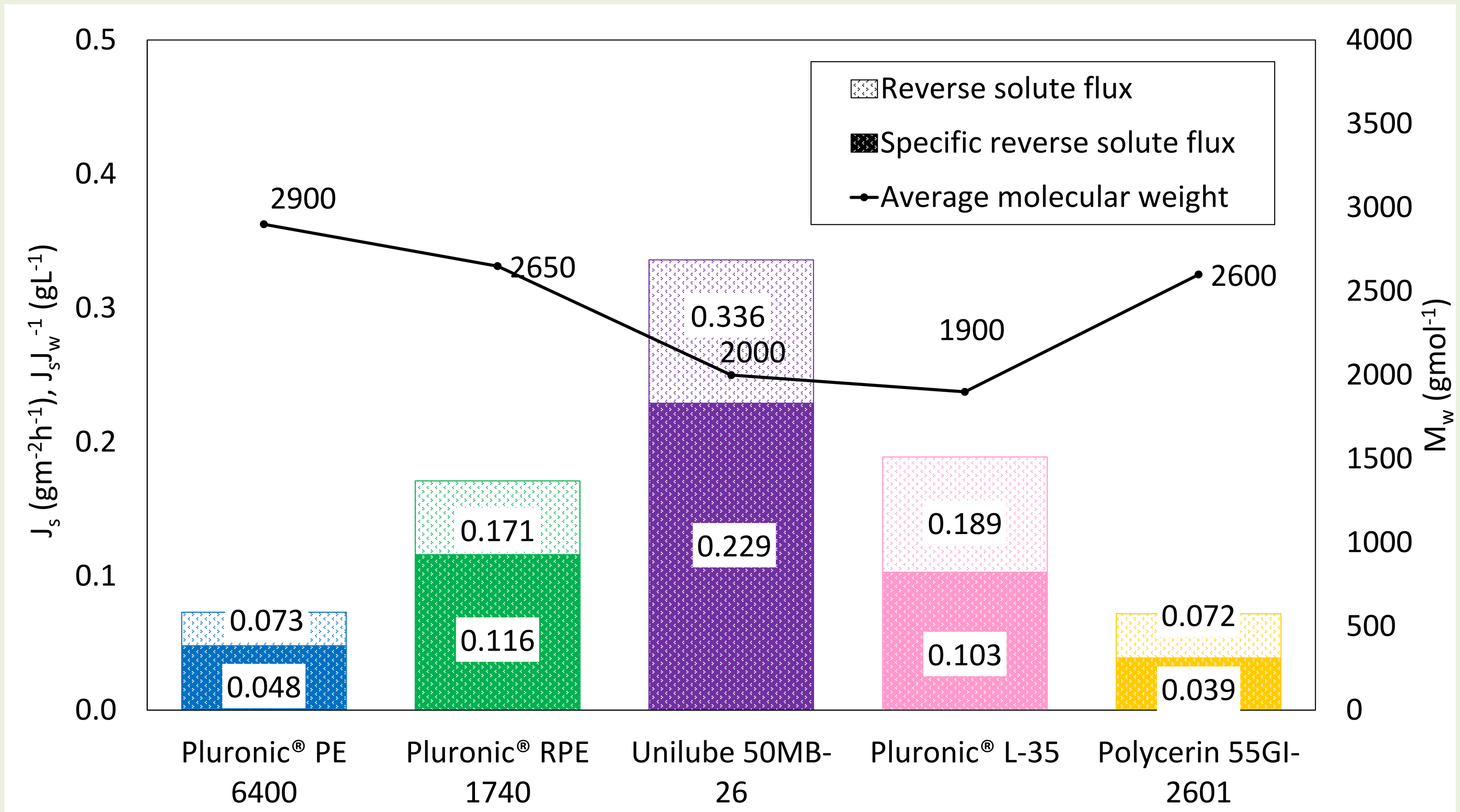


Figure 6: Reverse solute flux, specific reverse solute flux, and average molecular weight data values for each PAG tested.

Acknowledgements

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DESOLINATION

Conclusions

The water flux generated by PAGs varied from 1.5 $Lm^{-2}h^{-1}$ to 2.0 $Lm^{-2}h^{-1}$, and reverse solute flux varied from 0.04 $gm^{-2}h^{-1}$ to 0.4 $gm^{-2}h^{-1}$, strongly depending on molecular weight. The large molecular size of PAGs lowers the tendency to cause leakage through the membrane to the FS, and, therefore, the higher reverse solute fluxes are generated when using a PAG with a lower molecular weight as a DS.