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Incorporation of Aquaporins into Membranes for Water Desalination

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Introduction

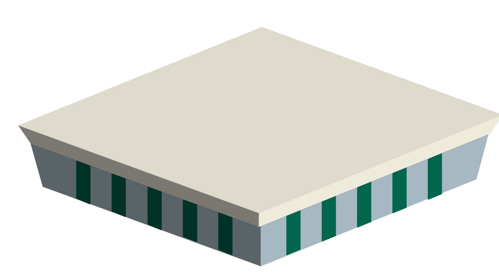
- Desalination of non-traditional water sources (seawater and brackish water) is more vital than ever due to the increasing scarcity of traditional water sources.
- About 1.6 billion people suffer from economic water scarcity, meaning they do not have the means to access water, regardless of whether it is physically available (1).
- Thermal vs membrane processes for desalination: membranes are cost-effective and less energy intensive (2).
- Thus, it is important to develop novel membranes for desalination to provide an economical way of obtaining greater water supply and quality.

Objectives

- Develop a biomimetic membrane using RsAqpZ - a membrane that mimics the function of RsAqpZ-containing lipid bilayer.
- Create biomimetic reverse osmosis (RO) membranes with high salt rejection and/or flux.

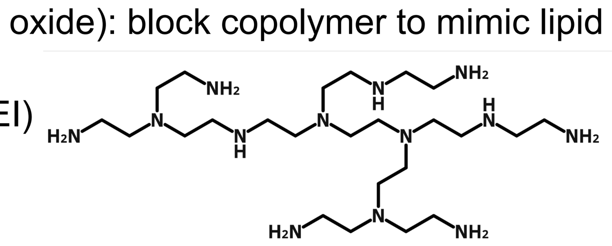
Background

Thin-film-composite membranes:
- Nanofiltration (NF) membranes:

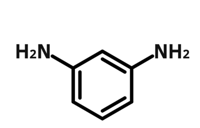


- Reverse osmosis (RO): most common membrane for desalination
- Aquaporin-Z (AqpZ): a protein channel in *E. coli* with quick and highly selective water transport (3).

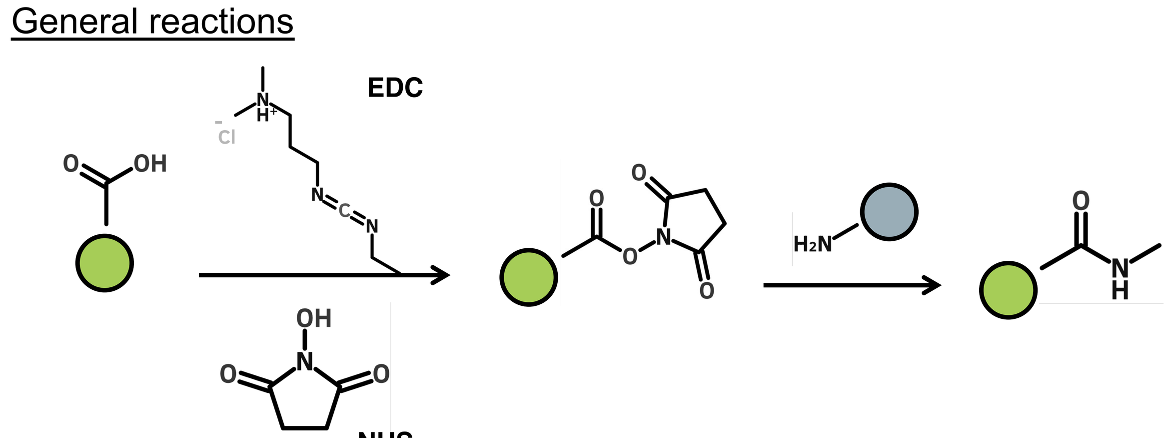
Biomimetic membranes:
- Poly(butadiene)-b-poly(ethylene oxide): block copolymer to mimic lipid bilayer
- Branched polyethyleneimine (PEI)

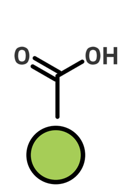
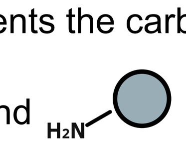


- m-Phenylenediamine (MPD)



General reactions

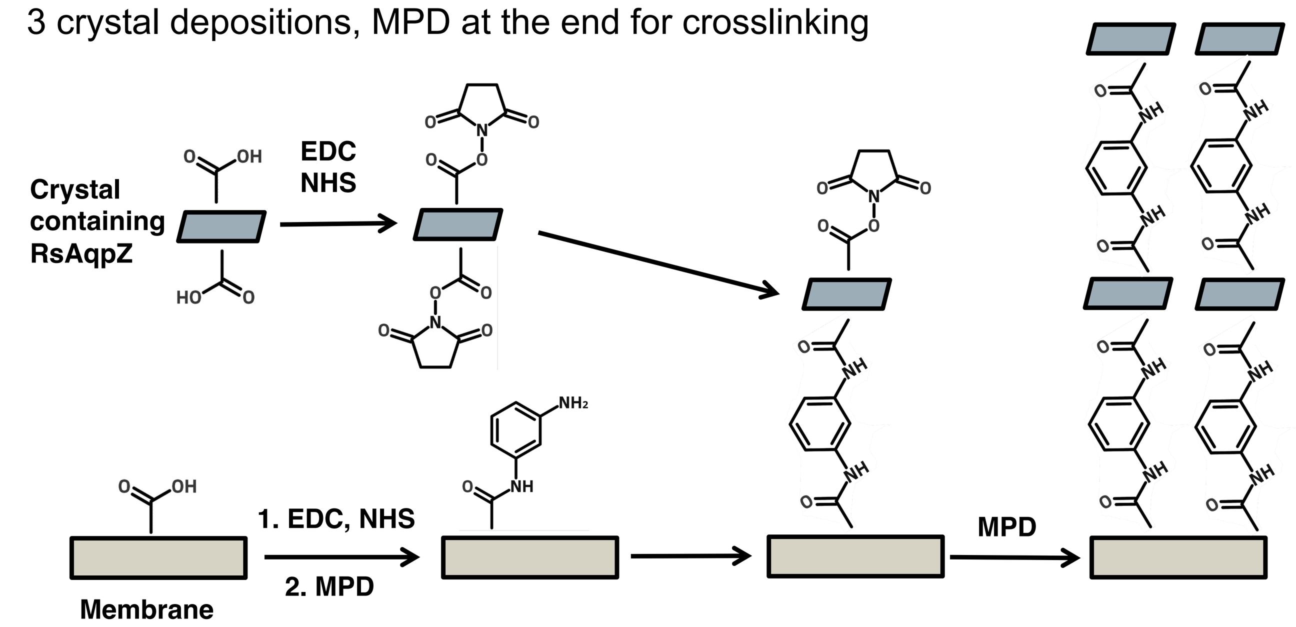


where  represents the carboxylic acids on the membrane surface and on the crystals, and  is the amine (PEI or MPD)

Methods

Crystal Deposition with PEI
- PEI on membrane, crystals on PEI (3 repetitions), then EDC NHS as the last step for crosslinking

Crystal Deposition with MPD
- MPD on membrane, EDC NHS on crystals
- 3 crystal depositions, MPD at the end for crosslinking



Equations

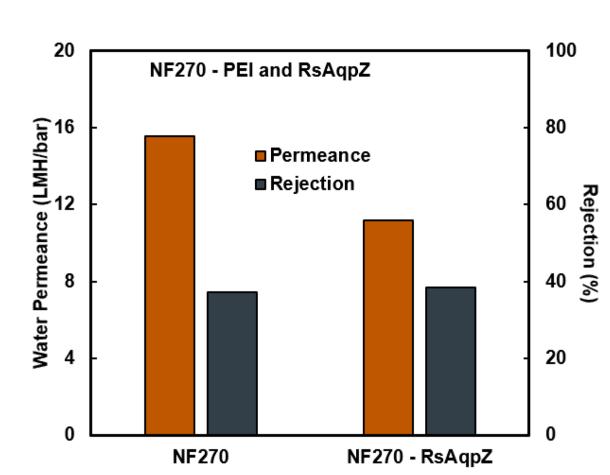
$$J_w = A(\Delta p - \Delta \pi) \qquad J_w = \frac{1}{Area \times t}\left(\frac{m_f}{\rho} - \frac{m_i}{\rho}\right)$$

$$R_{apparent} = \left(1 - \frac{c_{sl}}{c_{so}}\right) \times 100\%$$

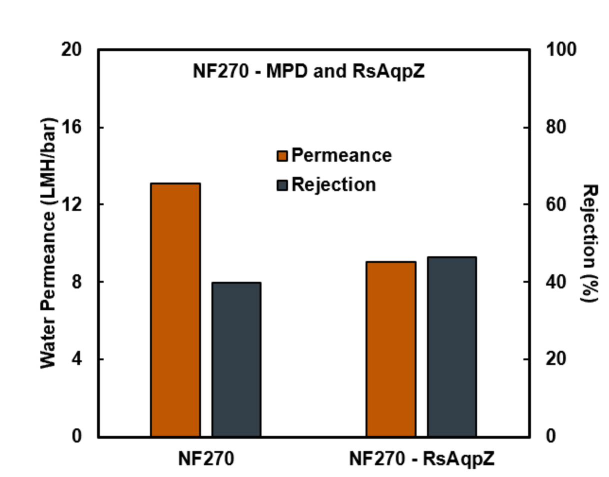
- A: water permeance (LMH/bar)
- Δp: pressure drop (bar)
- $\Delta \pi$: osmotic pressure difference (bar) across the membrane.
- $Area$: membrane area (m^2)
- t: time (hr)
- m_f: final mass of permeate (g)
- m_i: initial mass of permeate (g)
- ρ: fluid density (g/L).
- $R_{apparent}$: apparent rejection of membrane (%)
- c_{sl}: permeate concentration
- c_{so}: feed concentration

Results

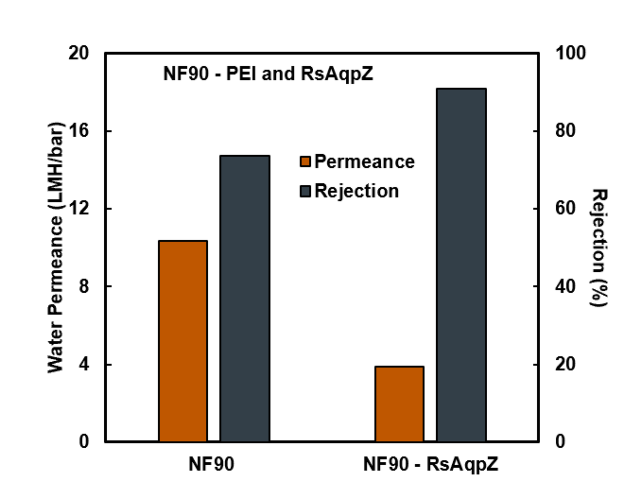
NF270 – PEI and RsAqpZ



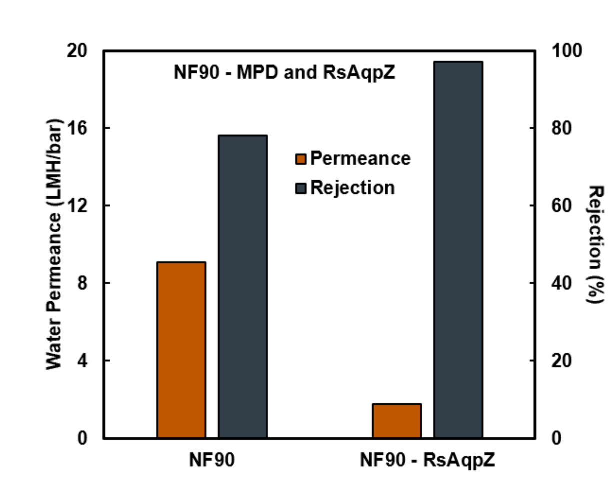
NF270 – MPD and RsAqpZ

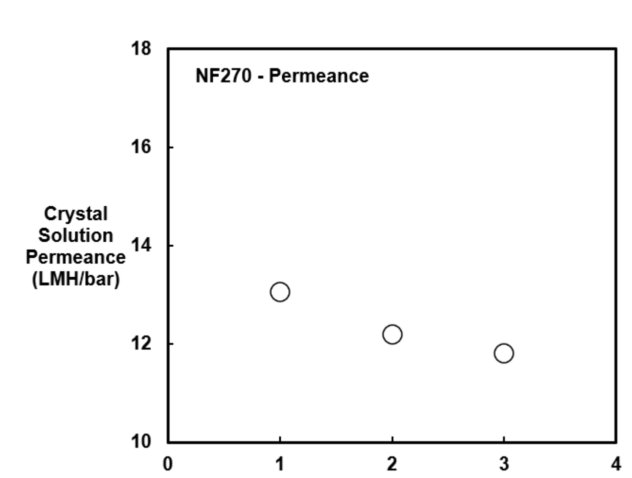


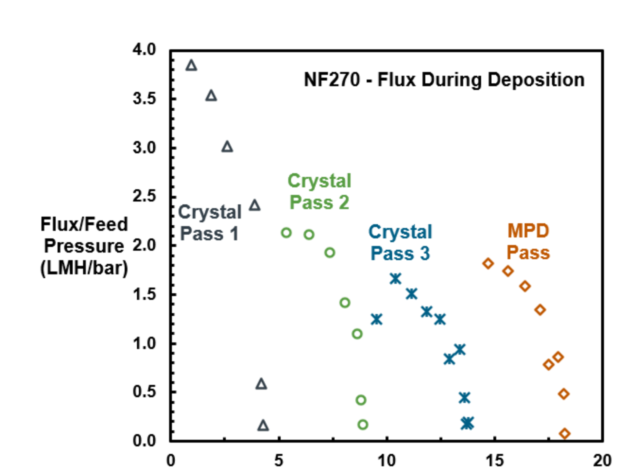
NF90 – PEI and RsAqpZ

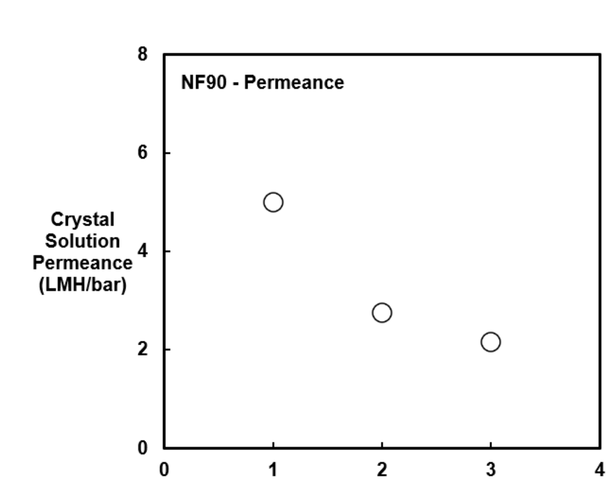


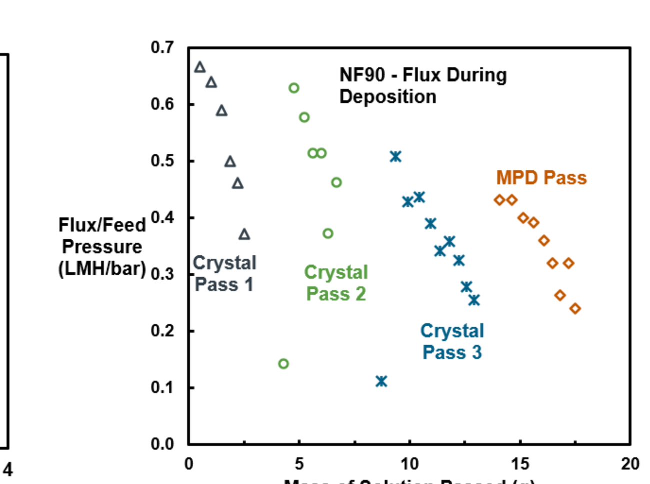
NF90 – MPD and RsAqpZ



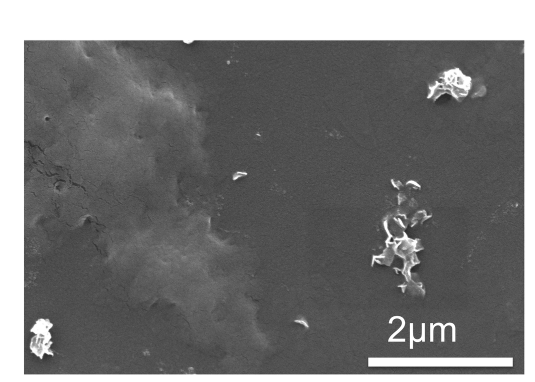




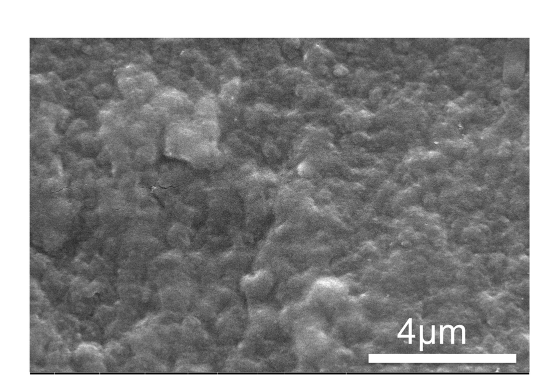




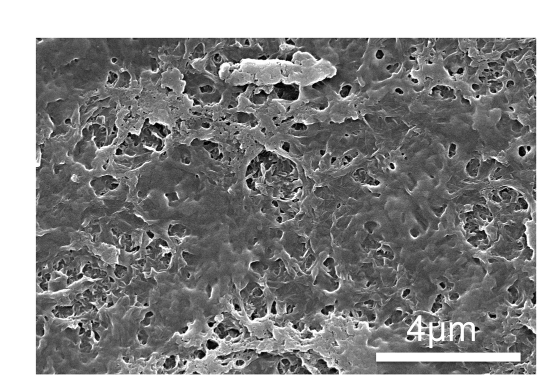
NF270 After PEI and Crystals



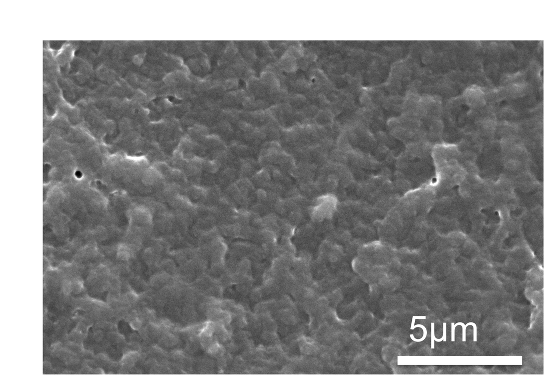
NF270 After MPD and Crystals



NF90 After PEI and Crystals



NF90 After MPD and Crystals



Conclusion

- Crystal deposition increased rejection and lowered permeance, regardless of which membrane (NF270 or NF90) and which amine (PEI or MPD) were used

PEI:
- Good rejection of about 90.9% for NF90 however, ideal rejection is in high 90s

MPD:
- Nearly ideal rejection of about 97.1% for NF90

Challenges
- NF90 has high rejection but large drop in permeance
- NF270 is a good candidate for permeance but rejection is not high enough
- Crystal deposition with MPD resulted in higher rejection than with PEI, but also lower permeance

References

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(2) Ahdab, Y. D.; Lienhard, J. H. Chapter 41 - Desalination of Brackish Groundwater to Improve Water Quality and Water Supply. In *Global Groundwater*; Mukherjee, A., Scanlon, B. R., Aureli, A., Langan, S., Guo, H., McKenzie, A. A., Eds.; Elsevier, 2021; pp 559–575.
(3) Calamita, G. The Escherichia Coli Aquaporin-Z Water Channel. *Molecular Microbiology* **2000**, *37* (2), 254–262.

Acknowledgements

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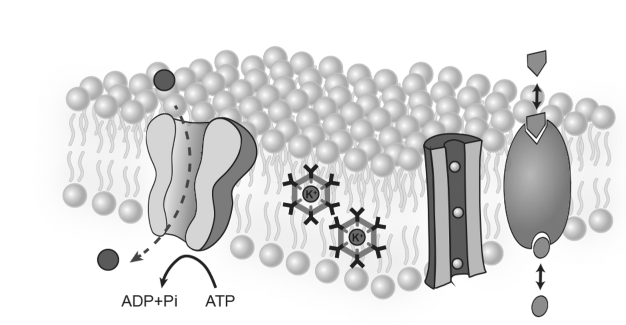

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