Selective Ion-Exchange Membranes for Electrodialysis Pretreatment of Brackish Water for High Water Recovery Reverse Osmosis

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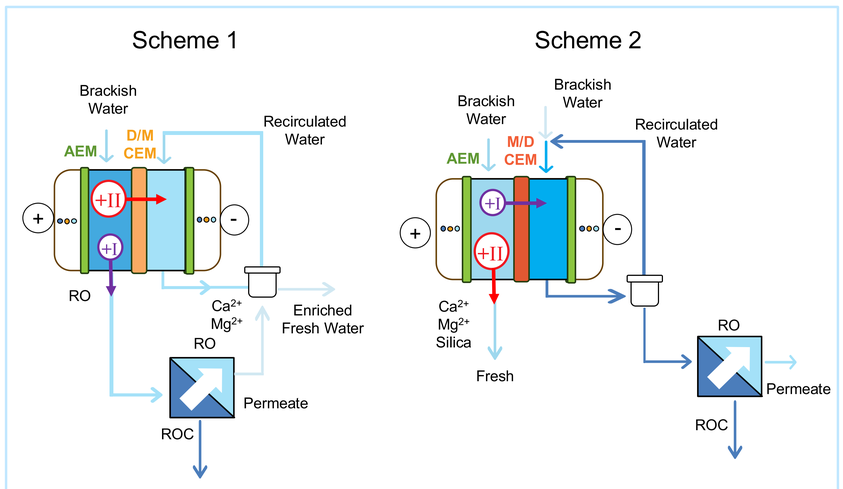
Valent-selective ion exchange membranes (IEMs) can enable high-recovery Reverse Osmosis (RO) desalination by reducing scaling and improving water recovery efficiency.

BACKGROUND AND RATIONALE

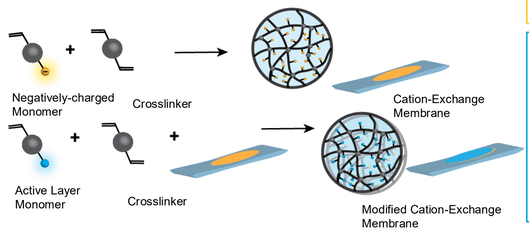
- Brackish water reverse osmosis (BWRO) desalination is limited by mineral scaling, restricting water recovery to 50–85%.
- Conventional pretreatment (pH adjustment, antiscalants) and alternative methods (ion exchange, solvent extraction) remove scale-forming ions but require extensive chemicals and are energy-intensive.
- Electrodialysis (ED) with monovalent/divalent-selective IEMs (M/D IEMs) can enable high water recoveries by selectively removing divalent ions before BWRO.
- Currently available M/D IEMs suffer from low selectivity, high resistance, and poor stability.
- The overall goal of this project is to develop selective ion exchange membranes for removal of scale forming divalent ions.

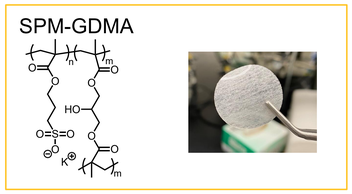


Schematic diagrams of novel treatment schemes coupling valent selective ED with high recovery RO desalination. Scheme 1: divalent selective electrodialysis; Scheme 2: monovalent selective electrodialysis.

METHODOLOGY

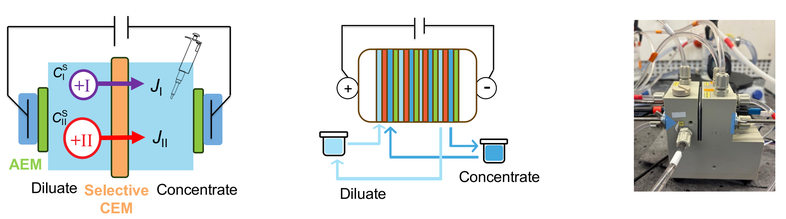
Membrane Synthesis





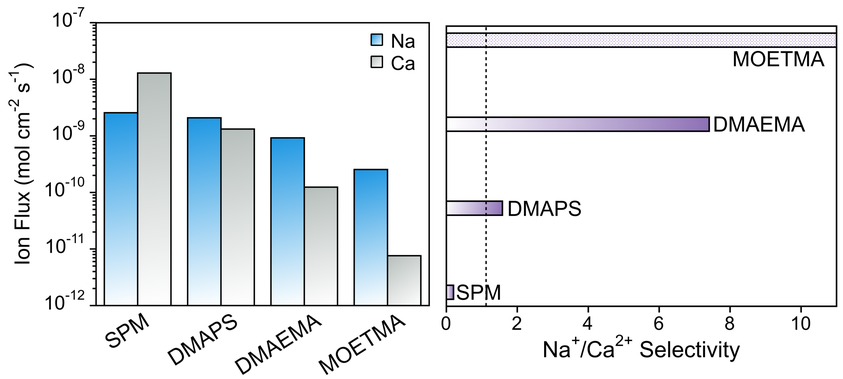
Schematic illustration of cation-exchange membrane synthesis using a negatively charged monomer (SPM) and a crosslinker (GDMA). This figure also depicts the surface modification of the cation-exchange membrane with a zwitterionic monomer (DMAPS), a positively charged monomer (MOETMA), or an uncharged monomer (DMAEMA), along with the crosslinker (GDMA).

Ion Transport Characterization



Left: Schematic of membrane setup for ion transport characterization and selectivity measurements. Middle: Schematic of bench-scale electrodialysis setup with membrane stack. Right: Photo of bench-scale electrodialysis cell.

PRELIMINARY RESULTS



Na^+/Ca^{2+} flux (left) and selectivity (right) of synthesized membranes obtained from electrodialysis. Experiments were conducted using a mixed salt solution of 25 mM NaCl + 25 mM $CaCl_2$ and constant current density (1.6 – 3 mA/cm²).

NAWI CONNECTIONS

Period of Performance: 24 months

Challenge Area/Topic Area: Materials & Manufacturing

TO1: Innovation in Desalination Pretreatment Systems.

NAWI Leverage: The feasibility of this process will be determined through a technoeconomic analysis (TEA) in collaboration with NAWI's WaterTAP.

KEY FINDINGS AND CONCLUSIONS

- We synthesized cross-linked membranes with different functional monomers and tested their ability to separate Na^+ and Ca^{2+} ions in electrodialysis (ED).
- Bench-scale ED experiments revealed that the base cation-exchange membrane exhibits poor Na^+ selectivity (Na^+/Ca^{2+} = selectivity 0.2) under relevant brackish water conditions.
- The three novel membrane chemistries (DMAPS, DMAEMA, MOETMA), which will be used to modify the base CEM surface, demonstrated significantly enhanced Na^+ selectivity, with selectivity values of 1.6, 7.4, >8, respectively.
- Future work will include tuning the membrane's water content and functional monomer concentration to further enhance selectivity while maintaining good cation flux.

REFERENCES

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