A NOVEL HYBRID FORWARD OSMOSIS-NANOFILTRATION TECHNOLOGY FOR SEAWATER DESALINATION

New Shi Lin Serene, Wee Lay Kit
Mentors: A/P Ng How Yong, Tan Chien Hsiang

ABSTRACT AND INTRODUCTION

Currently, reverse osmosis (RO) is the main technologies used for seawater desalination which has high energy requirements. There is a need to develop novel technology to lower the energy requirement for seawater desalination. In this project, a dual salt technology was proposed for the FO process, to harness the strengths of both salts.

AIM AND HYPOTHESIS

This project aims to develop a novel hybrid forward osmosis (FO) - nanofiltraton (NF) technology for seawater desalination and to propose a suitable dual salt draw-solute in optimal proportion. It is hypothesized that a dual salt draw solution will perform better than a single salt draw solution in terms of achieving a higher water flux in FO and salt rejection in NF.

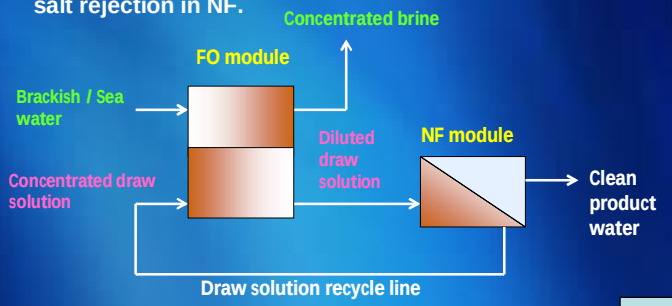

Fig 1: Schematic diagram of the FO and NF process

MATERIALS AND METHODS

- Lab-scale FO cell measures water flux of draw solutes
- FO Feed solution: 0.6M NaCl (simulates seawater)
- FO Draw solutions (40g/L to 120g/L) :
  - $MgCl_2$-$MgSO_4$ (3:1, 1:1, 1:3)
  - Na_2SO_4-$MgSO_4$ (3:1, 1:1, 1:3)
- Lab-scale NF cell
- NF Feed solution: diluted draw solution from FO process

RESULTS AND DISCUSSION

STEP 1: Short listing Combinations

STEP 2: Selecting Best Combination

STEP 3: Optimizing salt proportion

Step 4: Testing Water Quality

	2-pass Seawater RO	2-pass FO-NF
Hydraulic pressure (1st-pass), bar	60	40
Hydraulic pressure (2nd-pass), bar	20	10
Net energy consumption, kWh/m³	3.10	2.29

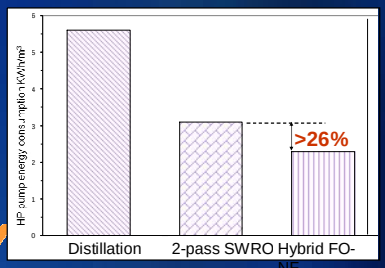

Fig 5: Comparison of energy consumption of RO and FO-NF

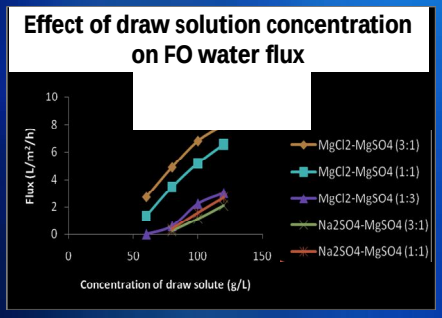

Fig 2: Graph of FO water flux against draw solution concentration

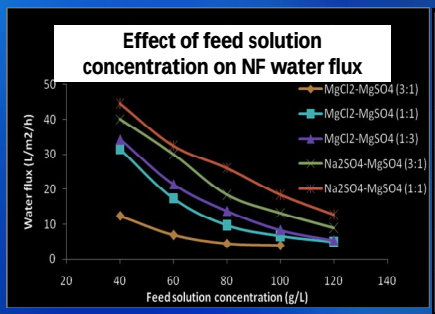

Fig 3: Graph of NF water flux against feed solution concentration

Dual-salts Draw Solute	Salt Ratio	Draw Solution Concentration (g/L)	1st Pass Permeate Conductivity (µs/cm)	2nd Pass Permeate Conductivity (µs/cm)	WHO Conductivity Guideline (µs/cm)
$MgCl_2$-$MgSO_4$	3:1	120	62640	626	500
$MgCl_2$-$MgSO_4$	1:3	120	16350	164	
$MgCl_2$-$MgSO_4$	1:1	120	27400	274	
Na_2SO_4-$MgSO_4$	3:1	120	9405	94.1	
Na_2SO_4-$MgSO_4$	1:1	120	18760	188	

Fig 4: Table for prediction and comparison of water quality

- $MgCl_2$-$MgSO_4$ (3:1) and $MgCl_2$-$MgSO_4$ (1:1) yielded high FO flux
- Na_2SO_4-$MgSO_4$ yielded low FO flux

∴ $MgCl_2$-$MgSO_4$ → more ideal dual salt draw solute combination.

- As proportion of $MgCl_2$ ↑ FO flux↑ NF flux ↓
- As proportion of $MgSO_4$↑ FO flux↑ NF flux ↓

∴ Considering both FO and NF, 1:1 → Optimal proportion

- Most second-pass permeates meet WHO guidelines
- 1:1 produced 274µs/cm

∴ 1:1 $MgCl_2$-$MgSO_4$ → Comparable to drinkable tap water

CONCLUSION

The FO-NF process is a recyclable process with a low energy requirement and high salt rejection. A dual-salt draw solute is recommended to achieve high water flux in FO and salt rejection in NF. $MgCl_2$-$MgSO_4$ (1:1) is proposed to be the optimal dual salt draw solute. FO-NF is a promising alternative technology for seawater desalination to produce drinkable product water that meets the WHO drinking water guidelines.

FURTHER RESEARCH

Additional improvements can be made to the membrane structure such as to make the porous layer as thin as possible while not compromising membrane stability

ACKNOWLEDGEMENTS

We would like to extend our utmost gratitude to our mentors, Ass. Prof Ng How Yong, Mr Tan Chien Hsiang as well as Ms Emily Li for providing us with much guidance and concern throughout the course of the project.

REFERENCES

[1] Batchelder, G.W. Process for the demineralization of water. US Patent 3, 171,799, 1965.
[2] D.N. Glew, Process for Liquid Recovery and Solution Concentration, US Patent 3,216,930, 1965.