Optimization of FO System for the Utilization of RO Brine

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Climate Change

Global Warming

Increase in Surface Temperature

Increase in Sea Level

lack of water

too much water

Seawater

DROUGHT

FLOOD

Contaminated water

Desalination

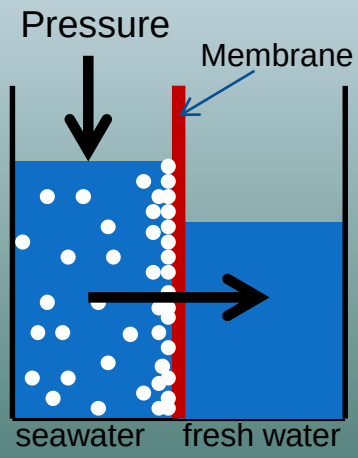
SCARCITY OF POTABLE WATER

Water Purification

Application of Membrane

Energy Issue

Reverse Osmosis



- high pressure requirement
- energy intensive
- simple mechanism

Scarcity of Energy Resource

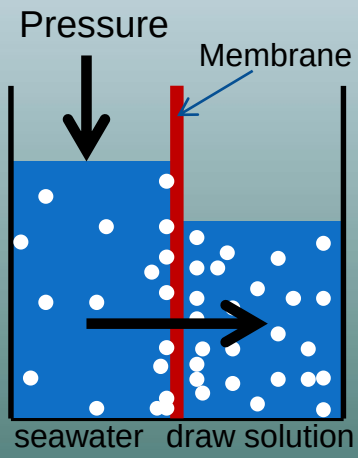
FLOOD

LifePack and HydroPack (Energy Drink)

DROUGHT

Desalination

Forward Osmosis

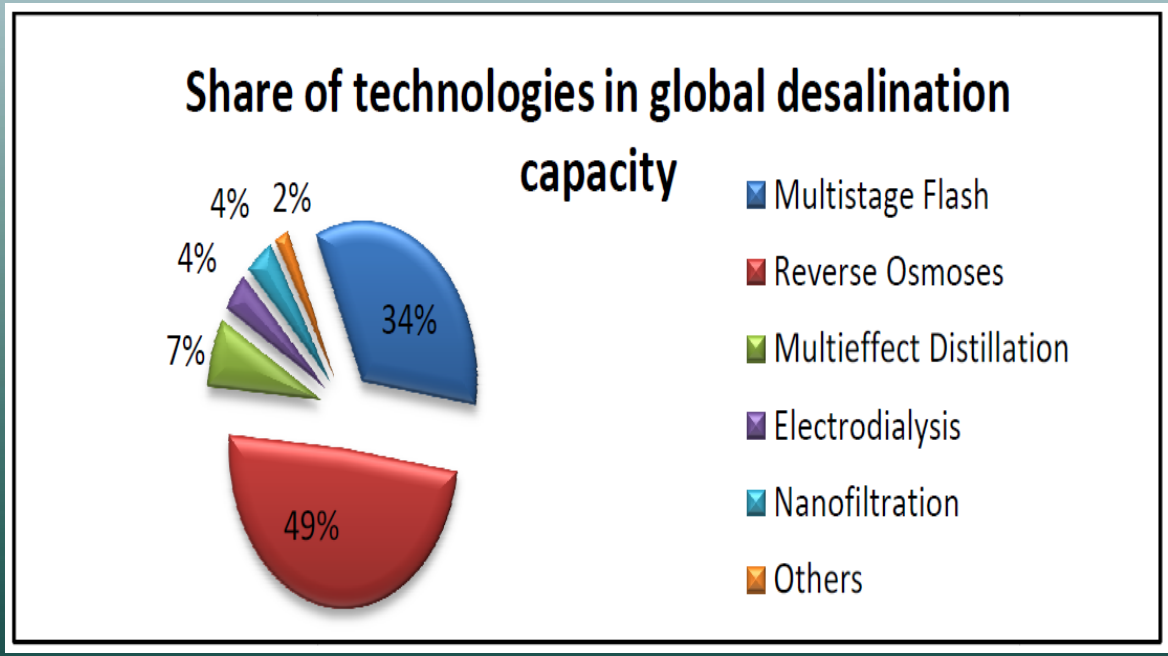


- no pressure needed
- osmotic gradient
- low membrane fouling
- internal concentration polarization
- DS recovery (Distillation)

FO cannot be used as a sole system for desalination

Reverse Osmosis

The strongest decrease in water production cost was achieved for operation of reverse osmosis processes. This strong decrease was due to technological improvements of membranes, economy of scale, improvement of pre-treatment options and the application of energy recovery systems.



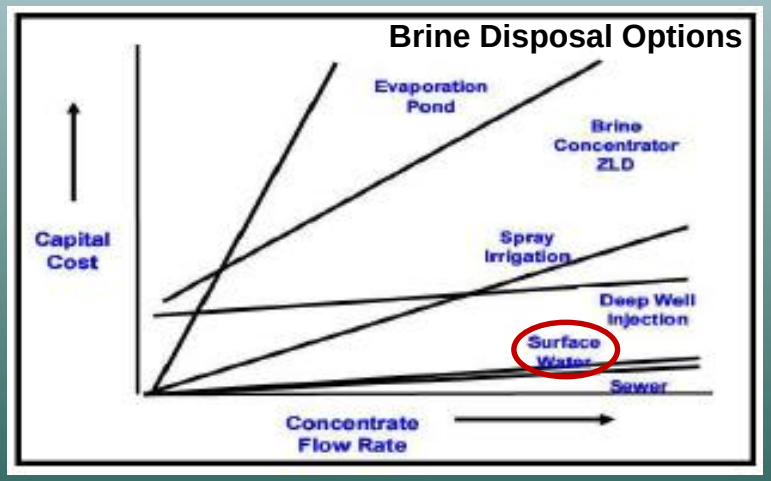
Forward Osmosis

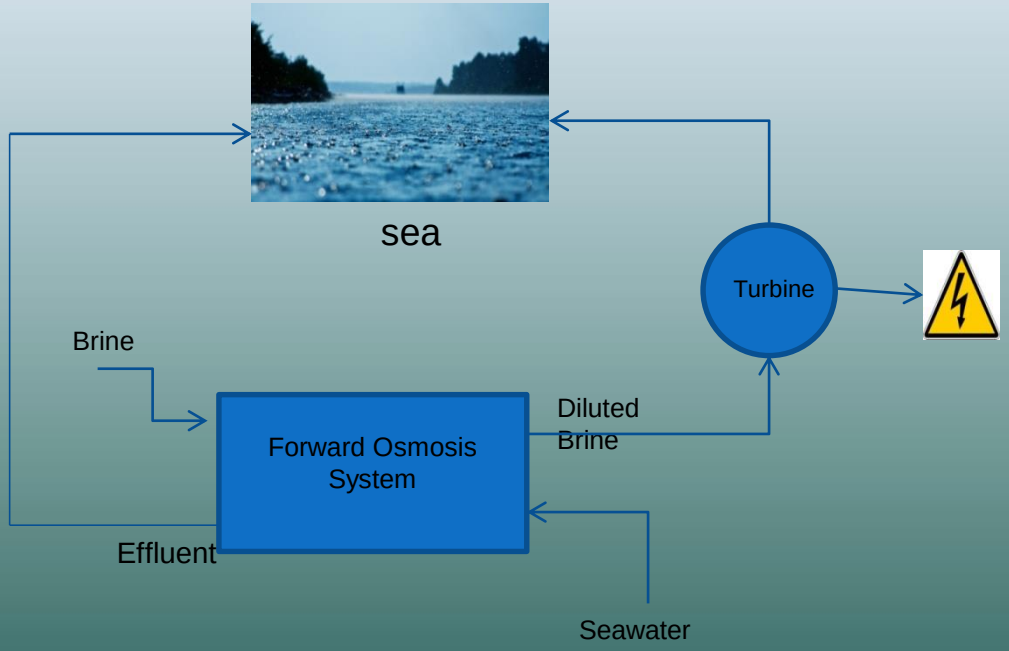
Combination of RO and FO is being proposed as an effective system for Desalination

How?

Major Challenges of Desalination

1.Land usage
2.Energy Consumption
3.Brine Discharge



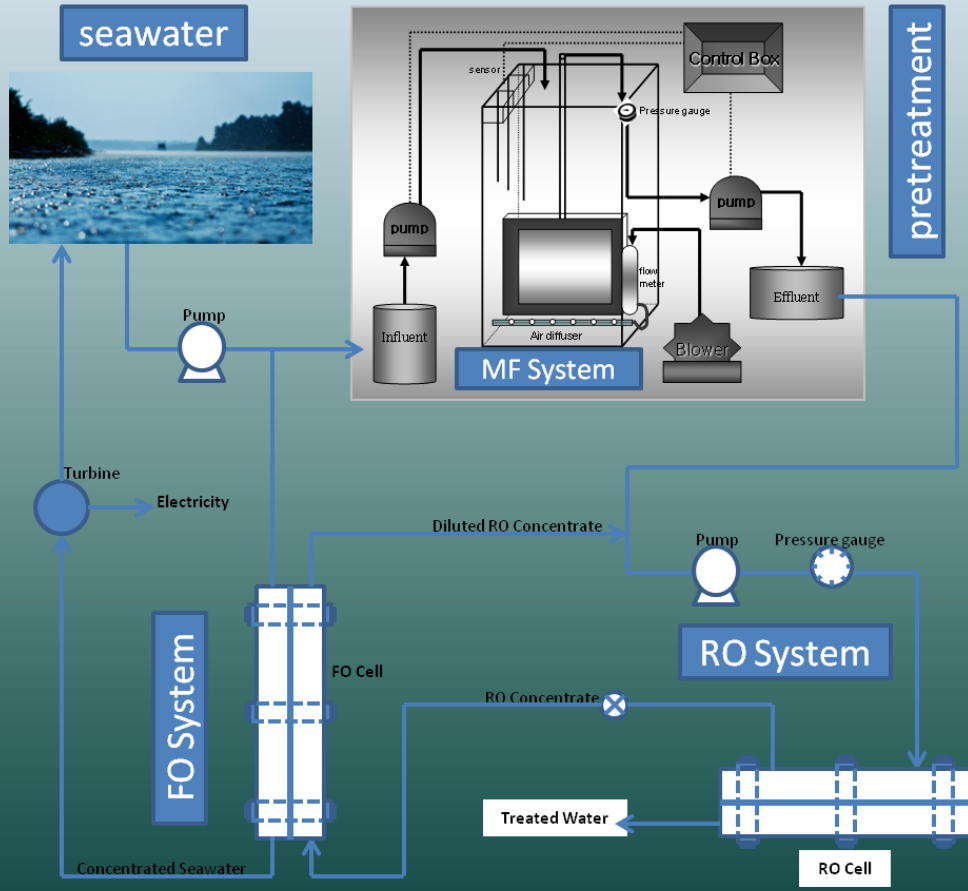


Environmental impact:

Increased salinity and temperature cause local problems – reduces vitality and biodiversity

Seawater Desalination

application forward osmosis to recover energy from SWRO concentrate

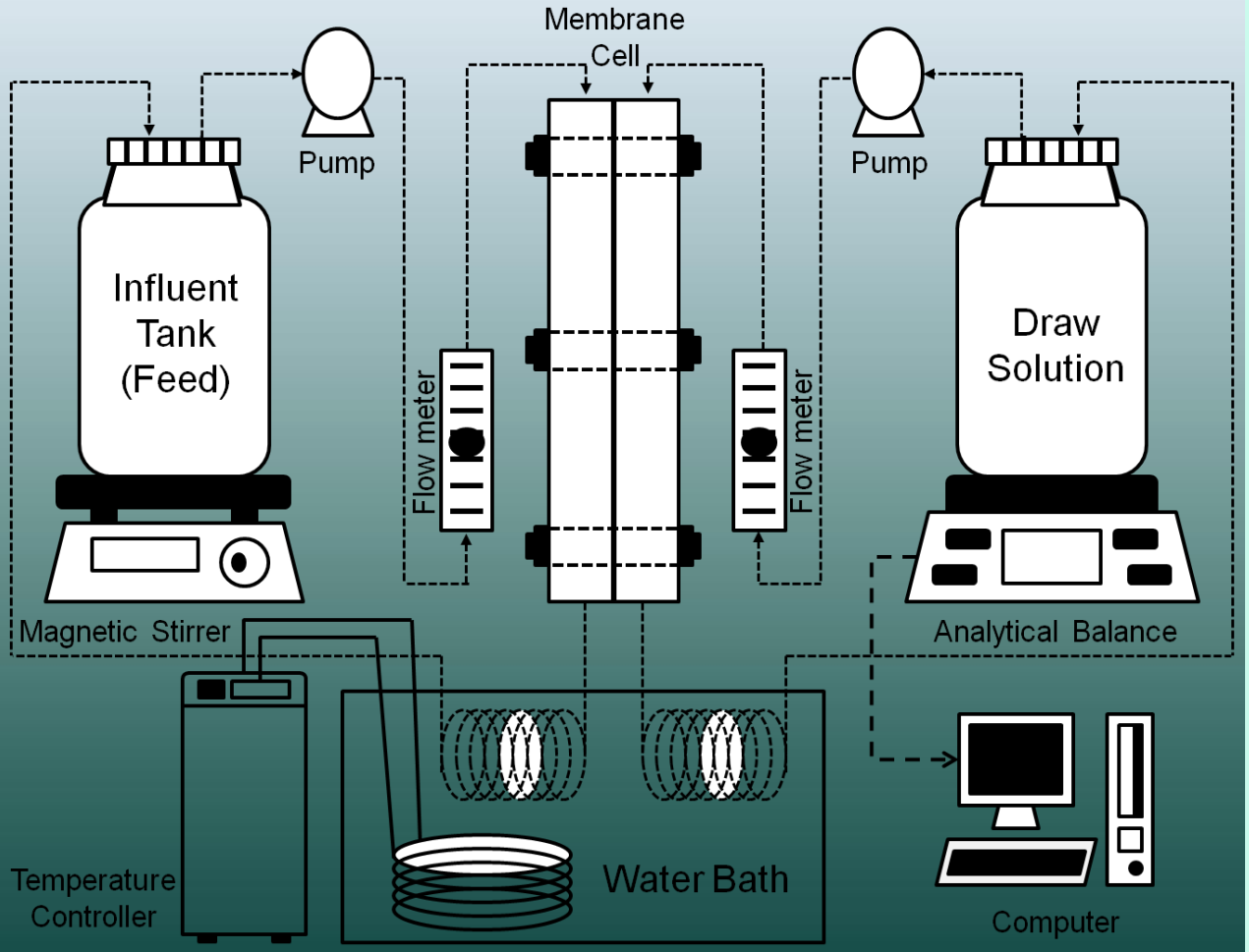


Objectives

- to maximize the permeate flux while lowering the reverse solute flux
- to optimize the operating condition of Forward Osmosis system by minimizing the effect of internal concentration polarization

Energy recovery from SWRO concentrate

Experimental Set-up



FO membrane (HTI):
0.0065 m^2 (CTA)

Feed: Synthetic Seawater

Draw Solution: NaCl
50, 75, 100 and 200 g/L

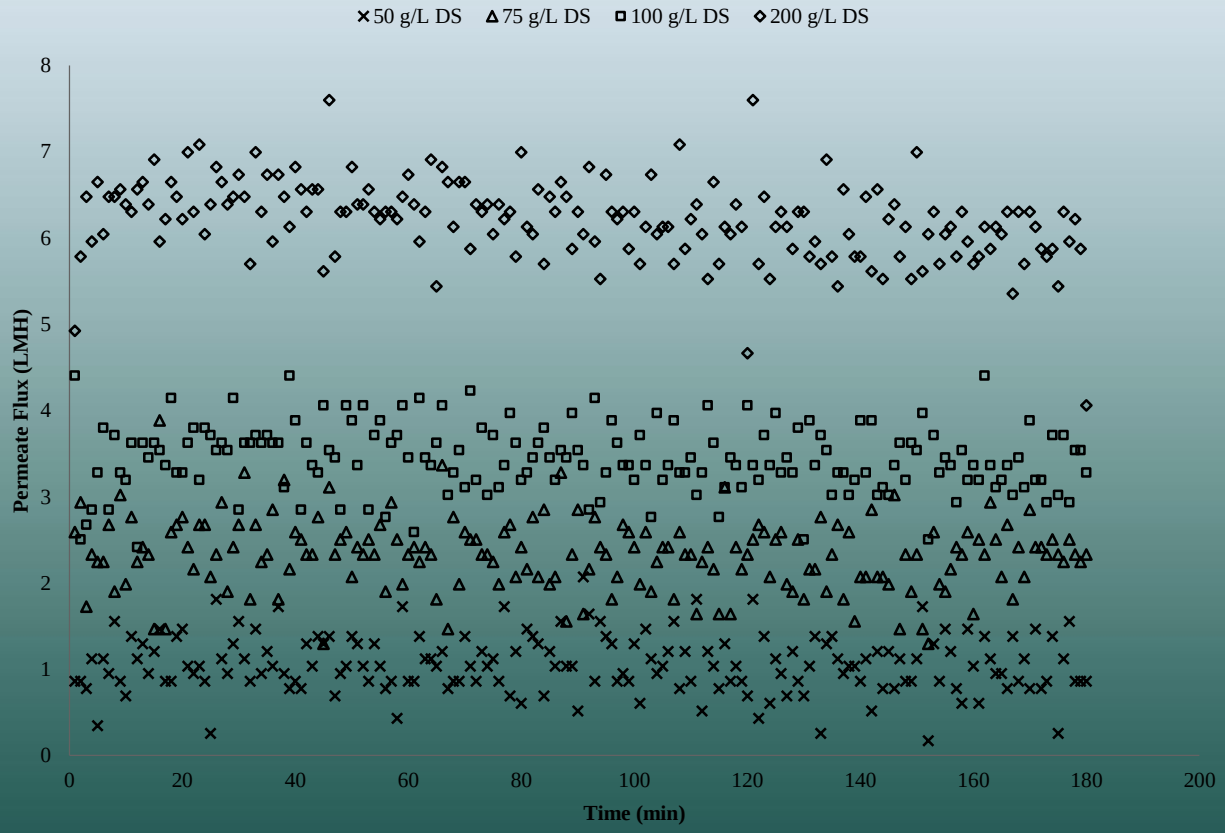
Temperature: 25°C

Influent Flowrate:
0.2 L/min

- Feed Salinity
- Permeate Flux
- Membrane Fouling (SEM and EDX)

Labscale Forward Osmosis System

Comparison of fluxes at different draw solution concentrations



Average Permeate Flux

50 g/L: 1.0721 LMH

75 g/L: 2.3175 LMH

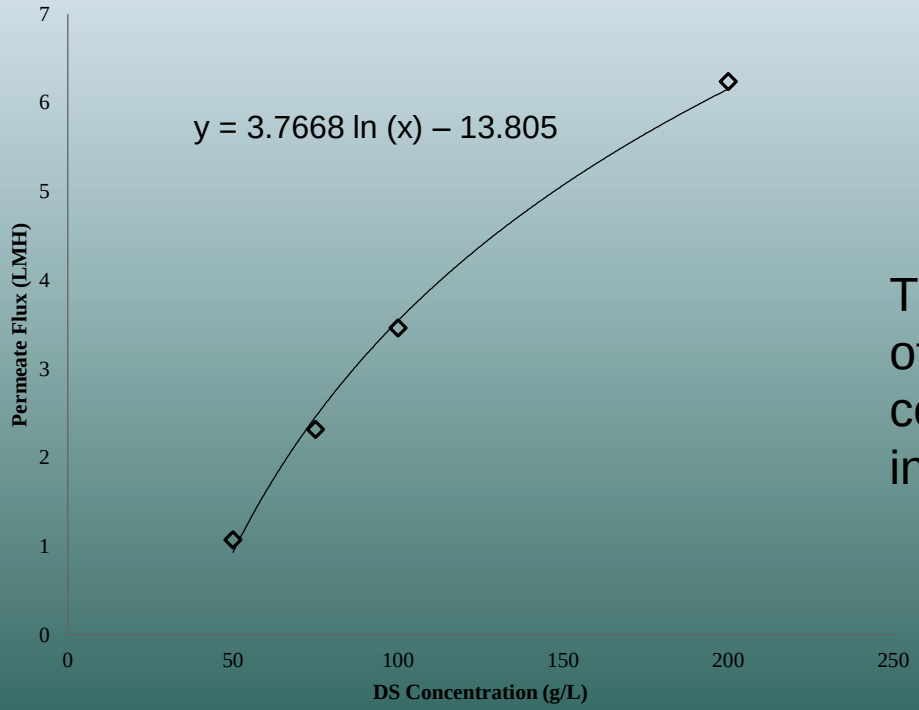
100 g/L: 3.4598 LMH

200 g/L: 6.2355 LMH

↑ Brine Concentration
↑ Permeate Flux

Permeate Flux (LMH)

Average flux at different draw solution concentrations

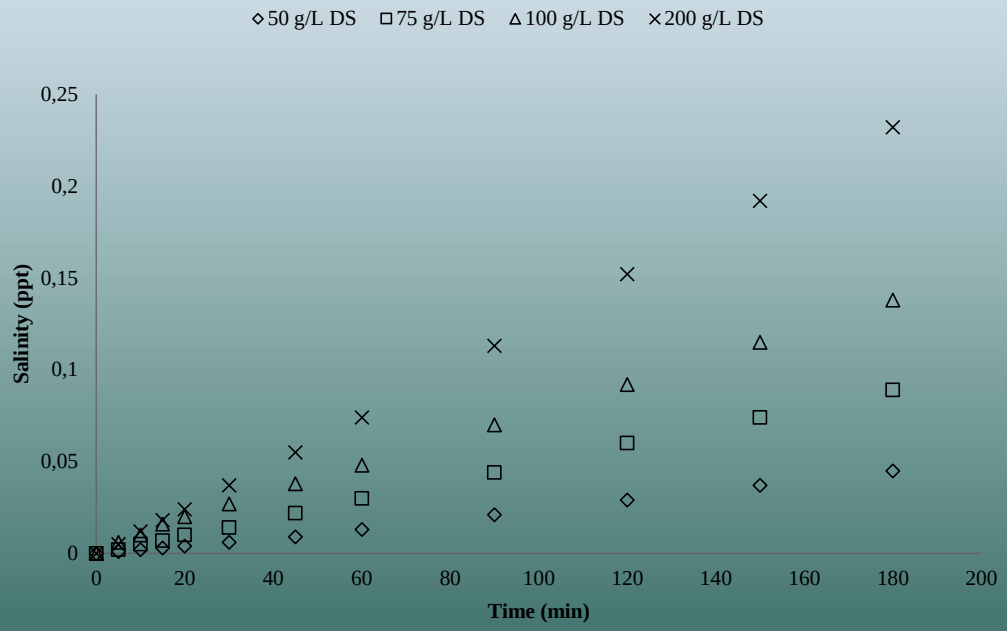


↑DS concentration
↓ Δ permeate flux

This could be attributed to the tendency of the membrane to be fouled at high DS concentration resulting to an increase in internal concentration polarization.

It was found that increasing the DS concentration increases the permeate flux, however, the increase in DS concentration also increases the transport of solute across the membrane.

Increase in salinity at different draw solution concentrations

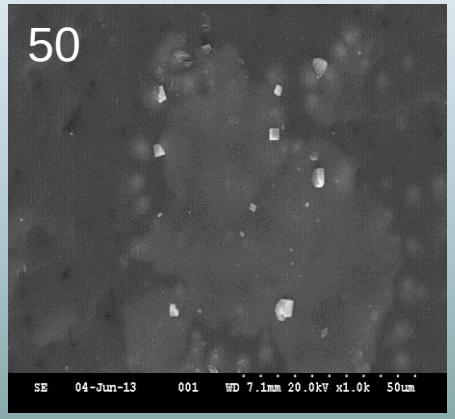


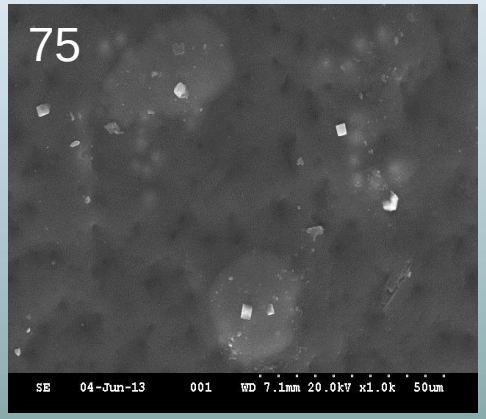
↑ Brine Concentration, ↑ Feed Salinity

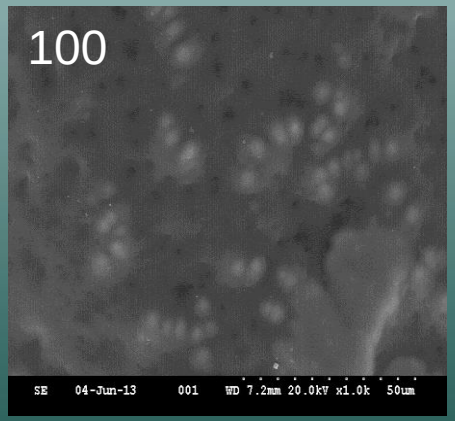
Low DS concentration:
solutes from the draw solution could enter to the pores of the membrane's support layer and easily diffuse back to the draw solution side

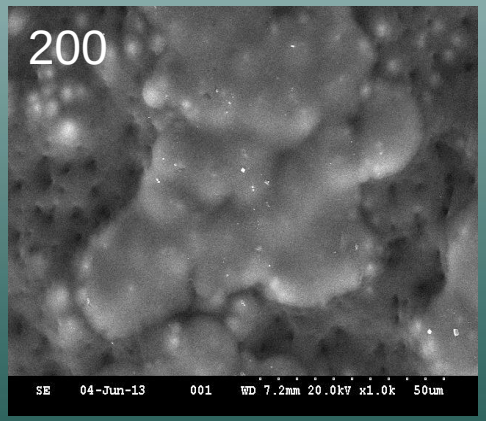
High DS concentration:
deposition of salts in the support layer could be severe, making it difficult for the solutes to diffuse back to the draw solution side, which also blocks the passage of the water from the feed side.

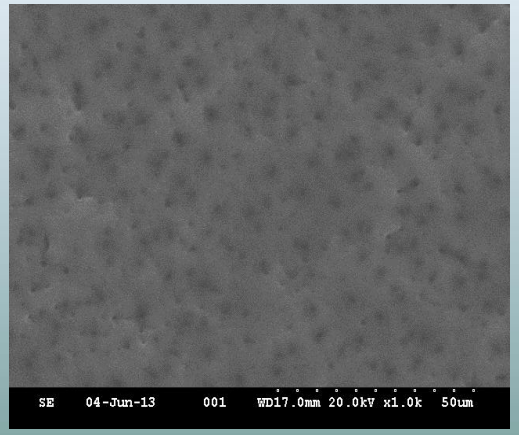
SEM and EDX Analyses











virgin membrane

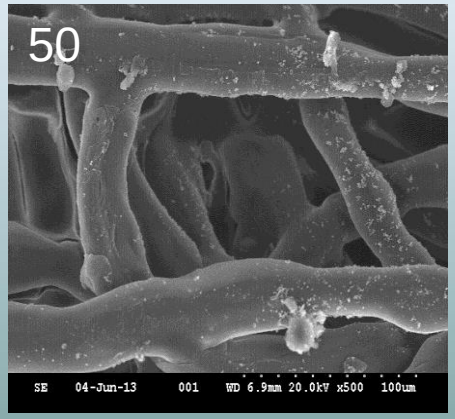
	50	75	100	200
Na	38.03	36.04	35.08	34.76
Cl	61.97	63.96	64.92	65.24

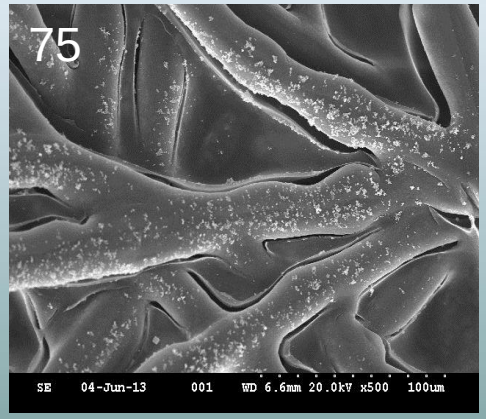
EDX (% Composition)

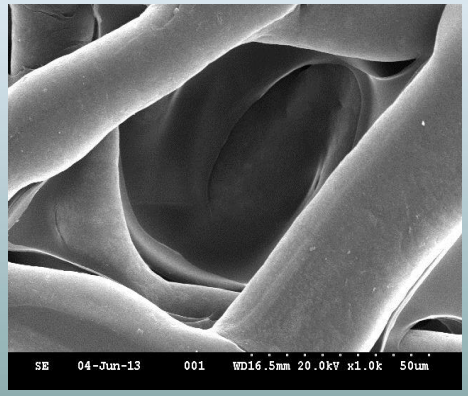
It was proven that the composition of foulants at elevated salt concentration triggers pore blocking that prevents passage of water from the feed side to the draw solution side.

Feed Side (Seawater)

SEM Images

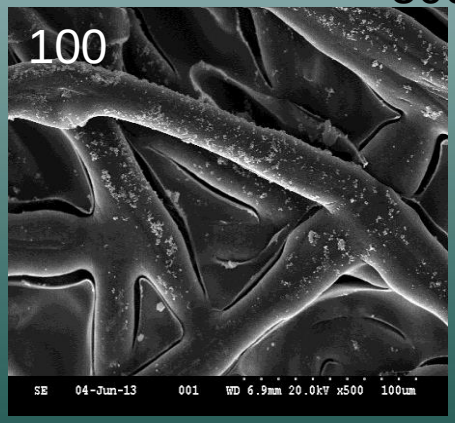


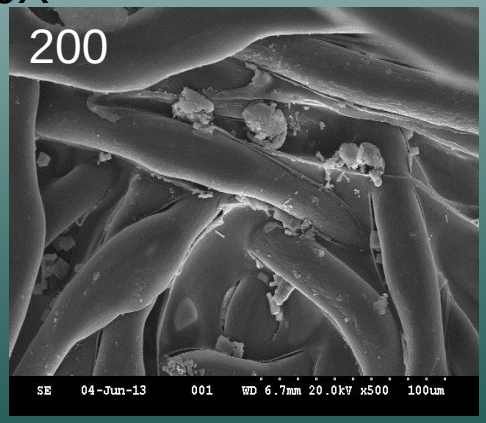




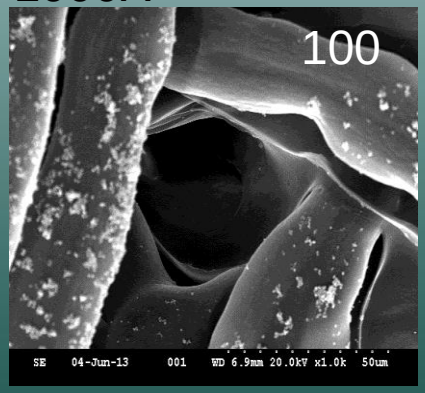
virgin membrane

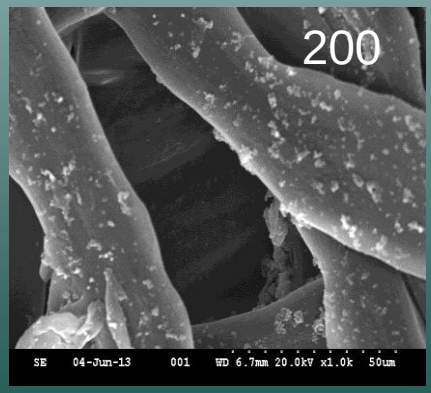
500X





1000X





Salt deposition causes internal concentration polarization that lowers the transport of water across the membrane and increases the diffusion of salts to the feed side, which resulted to the low change in permeate flux and high reverse solute flux.

Draw Solution Side (Brine)

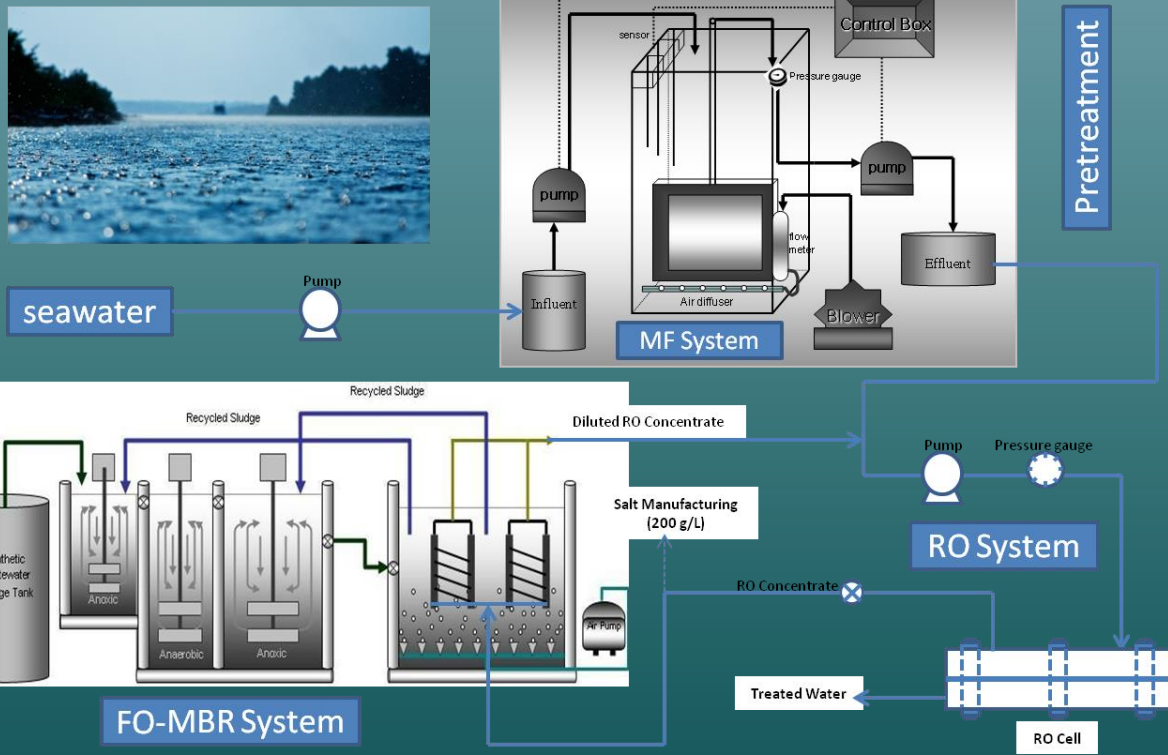
Conclusions

Performance of the labscale FO system was evaluated by investigating three important parameters: permeate flux, reverse solute flux and membrane fouling

- Increasing the draw solution concentration increases permeate flux, which compensates the increase in reverse solute flux.
- Highest permeate flux was recorded at the highest DS concentration but recorded the lowest rate of water transport or the change of permeate flux with respect to DS concentration, which was caused by high internal concentration polarization at elevated salt concentration.
- Membrane fouling was severe at 200 g/L DS concentration, while others showed similar fouling propensity.
- 100 g/L was the most suitable DS concentration that can be used in FO process to minimize internal concentration polarization with an optimized permeate flux and reverse solute flux of 3.46 LMH and 0.24 mol/m^2hr, respectively.

On-going Study

Feasibility of Lab-scale Membrane Filtration System for Seawater Desalination and Wastewater Treatment



Objective: to design an integrated filtration system suitable for water purification

THANK YOU…

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