Produced Water: Environmental Issues and Technological Solution

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- **Introduction**
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- **Aim of this Study**
- **Membrane Distillation (Novel Solution)**

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  MD Configurations.

  Benefits of MD technology.

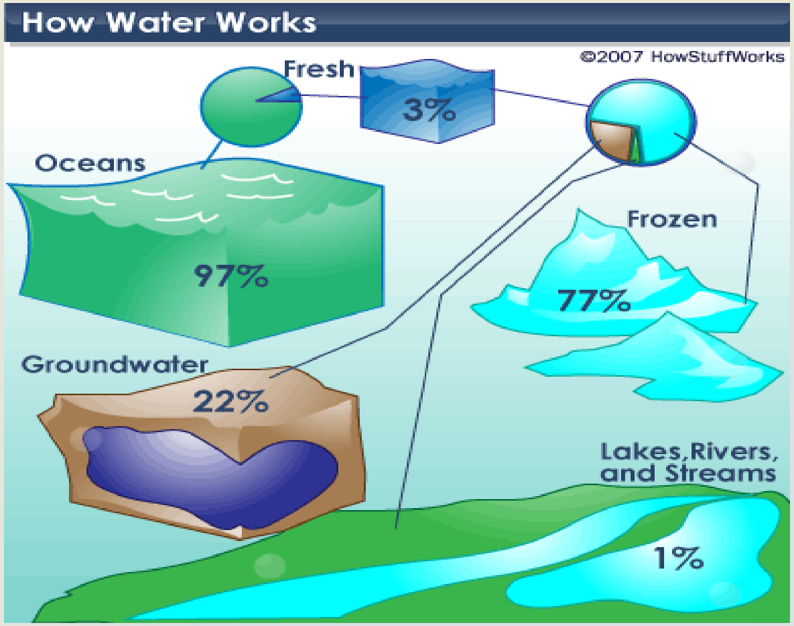
- **Materials and Methodology**
- **Major Finding**

  The permeate flux and the pore size effect.

  Effect of operating parameters.

- **Conclusion**

Introduction



What is the Produced Water ?

- Produced water is water from underground formations that is brought to the surface during oil or gas production .
- it includes injected water, which is derived from surface water or seawater.

Size of the problem

- Produced water is composed of dispersed oil, dissolved organic compounds, heavy metals and natural radioactive minerals.

- Produced water is the largest volume by-product in the oil production industry.

- At the lowest level of production, three barrels of produced water is generated with every one barrel of oil produced.

Management Options

- Injection of produced water into the same formation.
- Discharge to the environment.
- Treatment to meet the quality required for beneficial uses such as drinking water and irrigation (<1%).

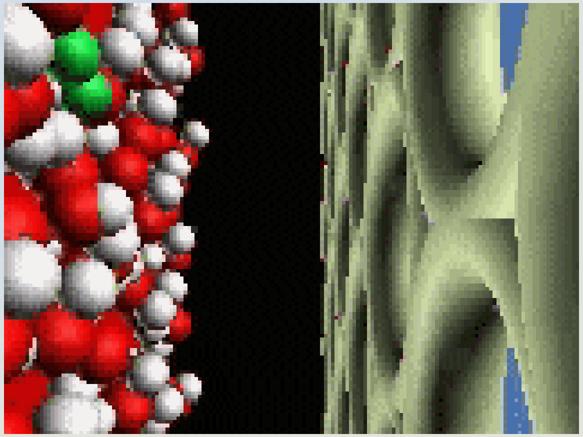
- **Aim**

To treat produced water with minimum energy consumption, and produce high quality permeate.

Novel Solution

What is Membrane Distillation (MD)?

MD is a thermally-driven separation process, in which only vapour molecules are able to pass through a porous hydrophobic membrane.

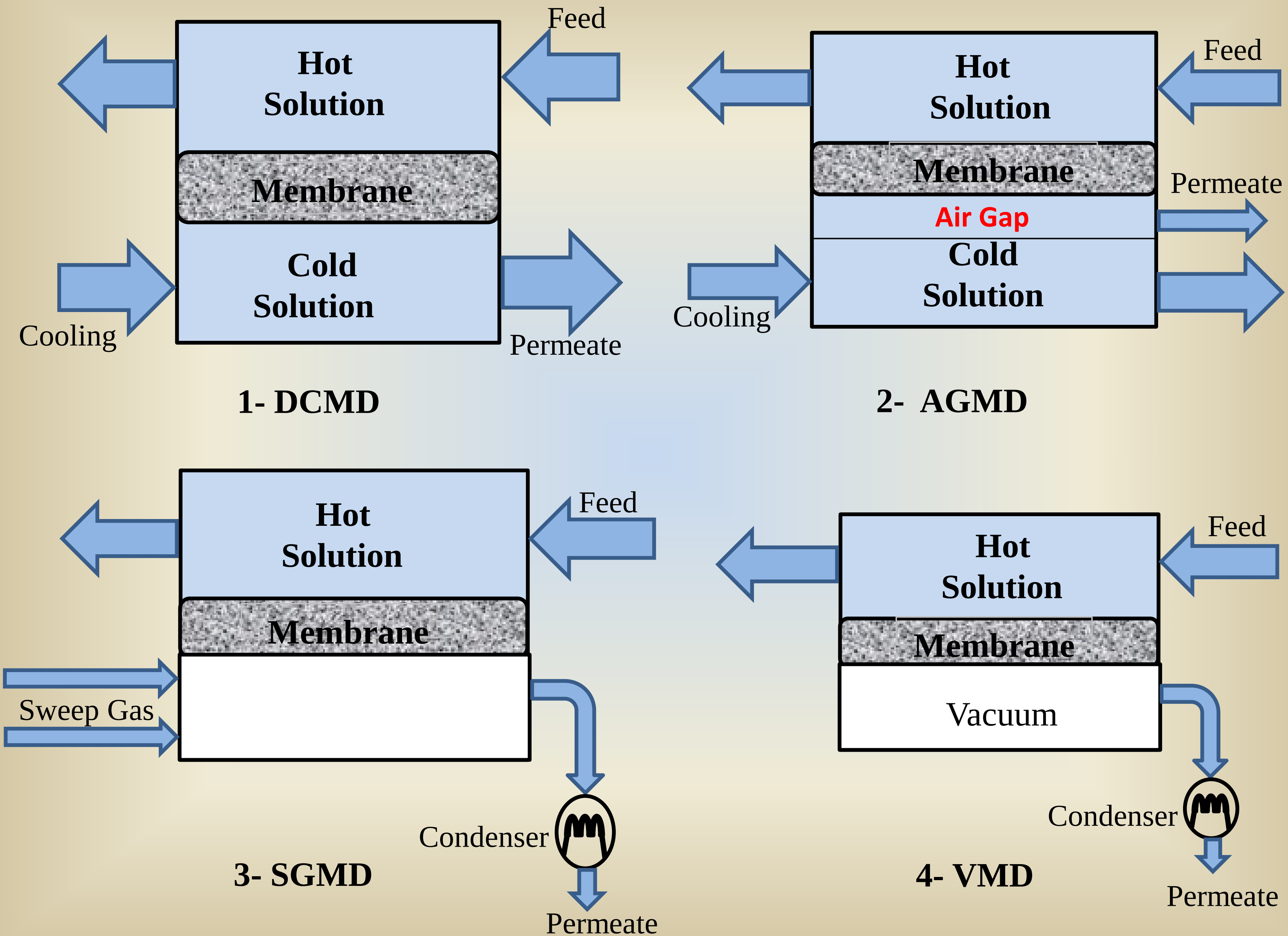


The vapour is moved by the pressure difference across the membrane to the permeate side and condenses.

Membrane Distillation Configuration:

In terms of permeate collection and driving force generation, MD technology can be classified into four categories:

1. *Direct Contact Membrane Distillation (DCMD)*
2. *Air Gap Membrane Distillation (AGMD)*
3. *Sweeping Gas Membrane Distillation (SGMD)*
4. *Vacuum Membrane Distillation (VMD)*


Feed
Hot Solution
Membrane
Cold Solution
Cooling
Permeate
1- DCMD
Feed
Hot Solution
Membrane
Permeate
Air Gap
Cold Solution
Cooling
2- AGMD
Feed
Hot Solution
Membrane
Sweep Gas
Condenser
Permeate
3- SGMD
Feed
Hot Solution
Membrane
Vacuum
Condenser
Permeate
4- VMD

MD benefits:

- Low operating temperatures in comparison to those encountered in conventional processes.

- The hydrostatic pressure encountered in MD is much lower than that used in pressure-driven membrane processes like reverse osmosis (RO).

- Fouling is not a problem compared to other membrane processes (the membrane pore size is relatively large).

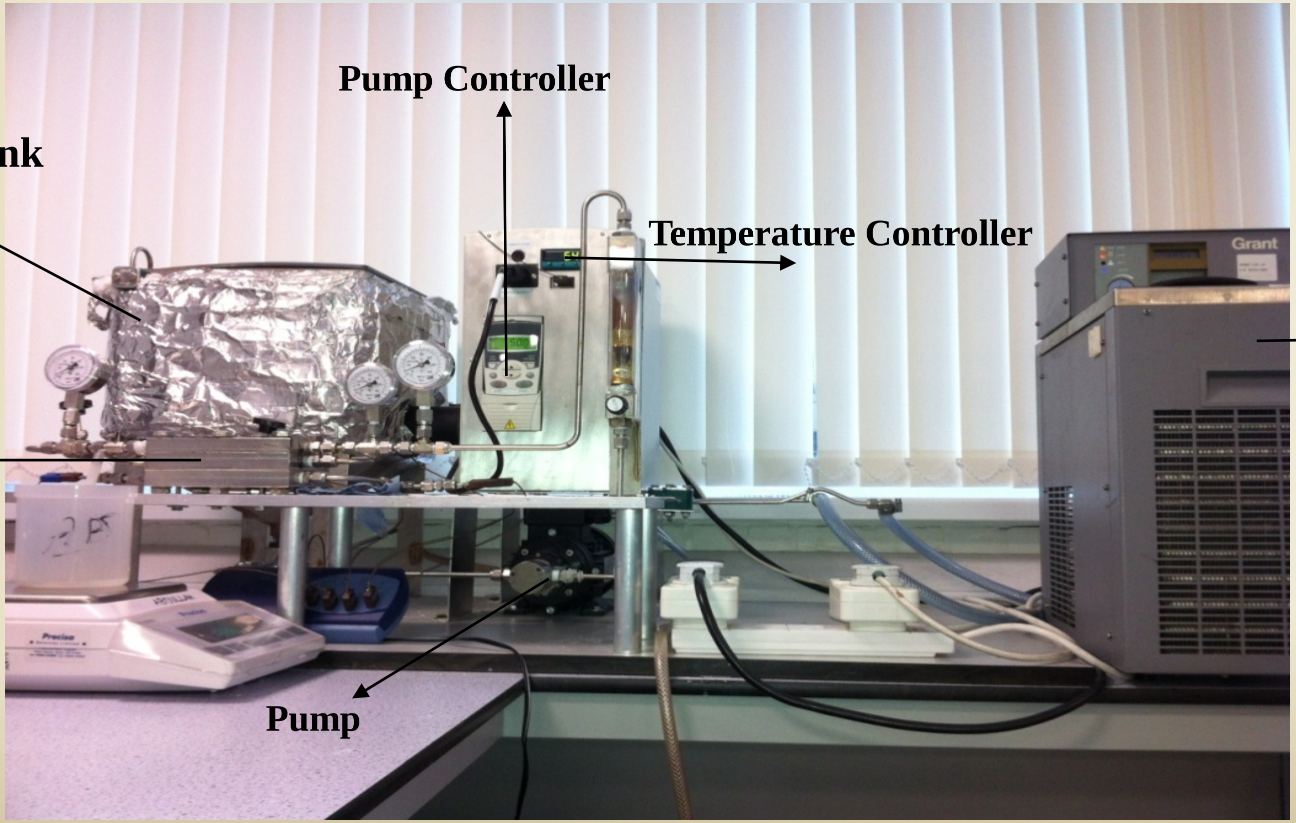
- The MD system has the feasibility to be combined with other separation processes to create an integrated separation system.

Materials And Methodology

- **Membrane:**

Three PTFE flat sheet membranes (0.2, 0.45 and 1.0 μm) : microporous and hydrophobic.

- **Experimental procedures:**



Produced water

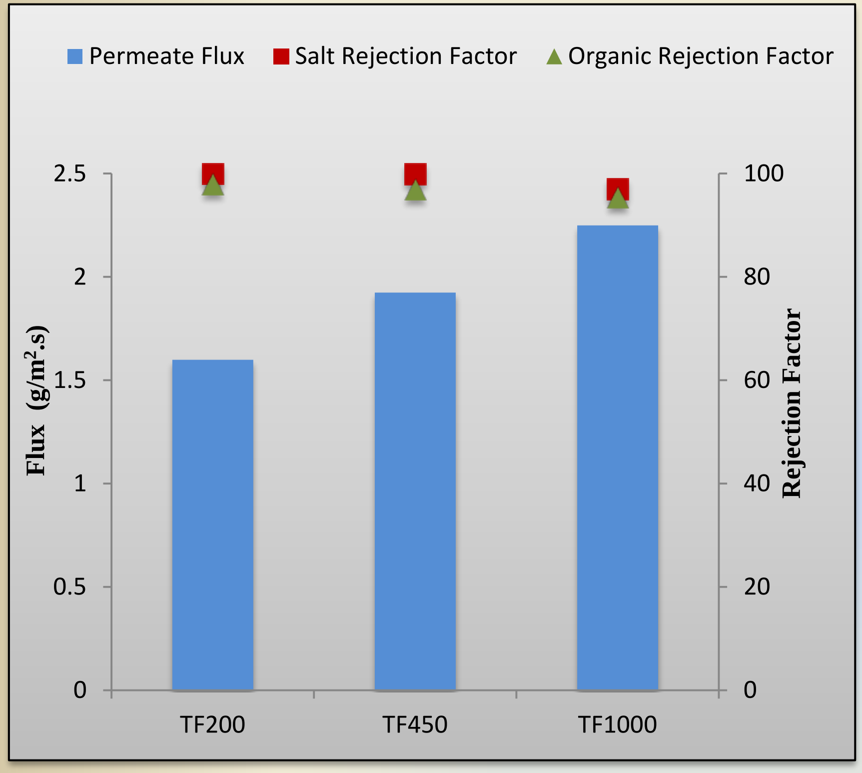
- *Produced water was treated at different operating conditions and different membrane pore sizes (0.2, 0.45 and 1 µm).*

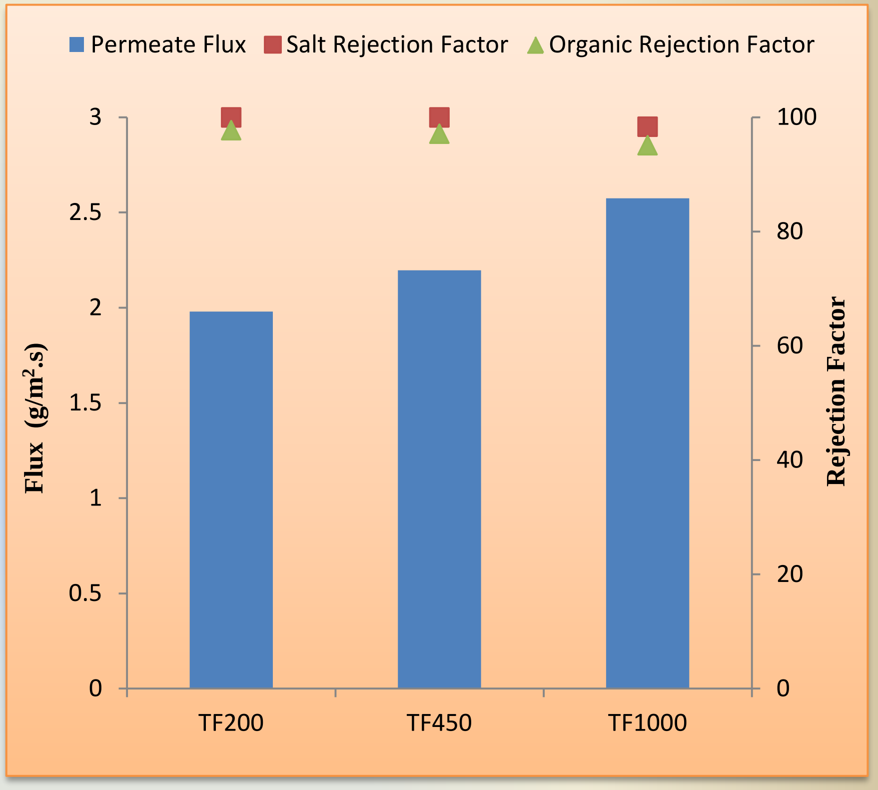
Feed Flow Rate (l/min)	coolant temperature (°C)	Feed temperature (°C)
0.5, 1.0, 1.5 and 1.89	5, 10, 15, 20 and 25	40, 50, 60, 70 and 80

- *One operating parameter was changed, while other parameters were kept constant.*

Results

•The permeate flux and the pore size effect:





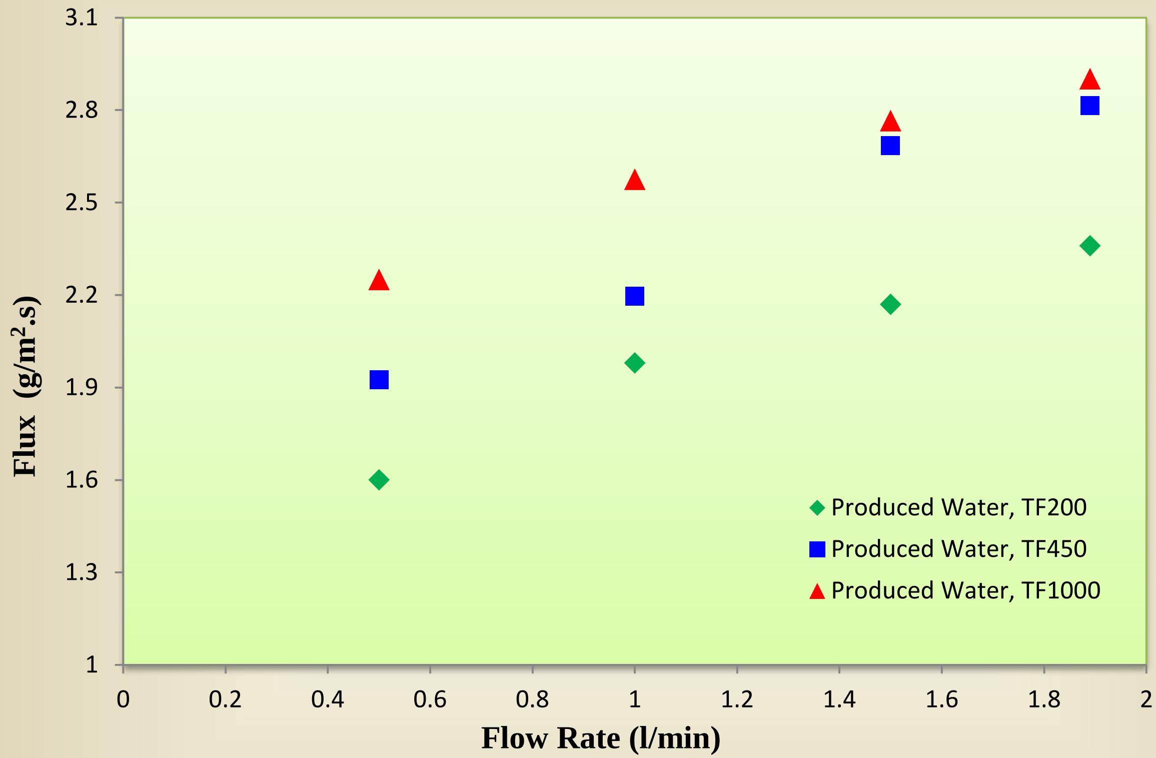
At T= 50 °C, F= 0.5 l/min

At T= 50 °C, F= 1 l/min

- The permeation flux increases when the pore size increases.
- The rejection factors for the salt and organic decreased with increasing pore size.
- Salt and organic rejection for TF200 and TF450 is more stable than TF1000.

- # Effect of operating parameters

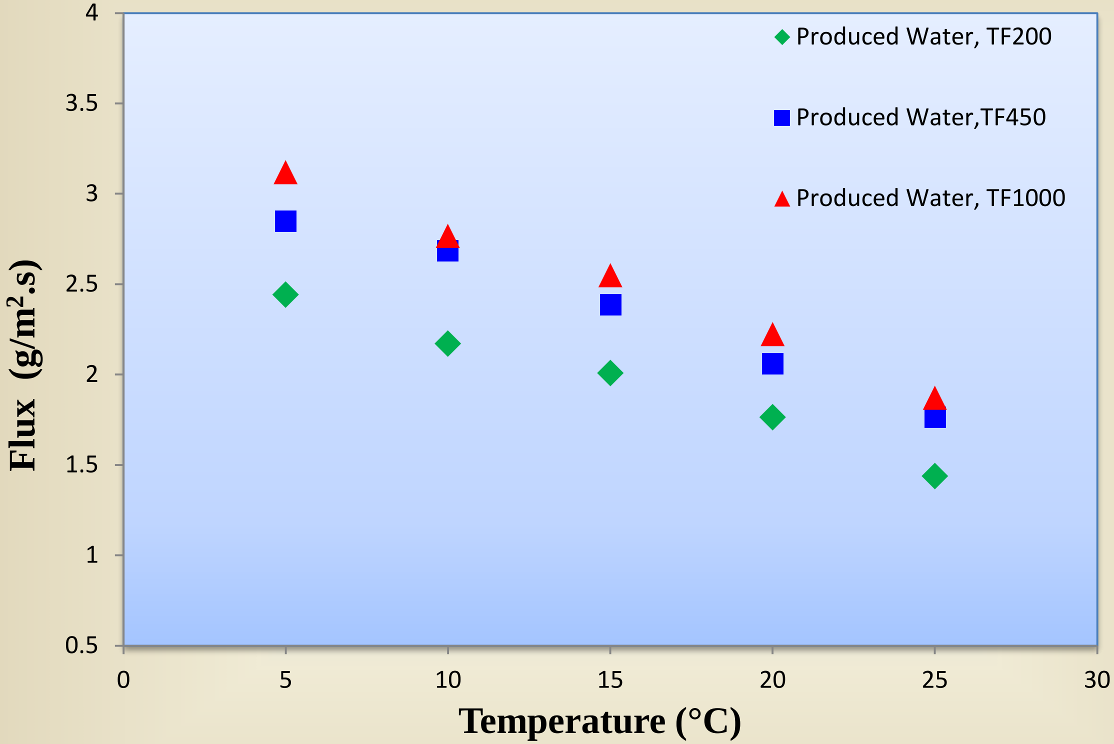
I. Flow Rate Effect



- As the flow rate increases, the permeate flux rate increases.
- Linear relationship exists between the investigated flow rate range and permeate flux.
- The increase in the feed flow rate will reduce the effect of temperature polarization and concentration polarization.

• Effect of operating parameters

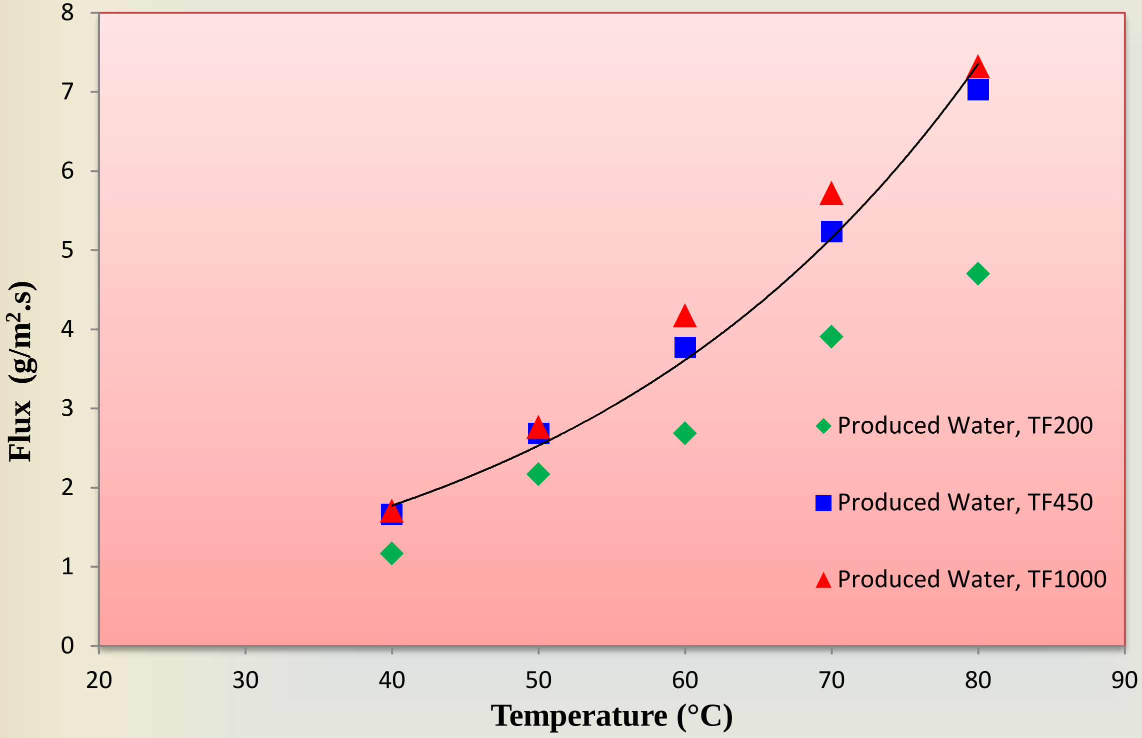
II. Coolant temperature effect



- The permeate flux declined gradually when the coolant temperature increased.
- increasing the coolant temperature leads to an decrease in the vapour pressure difference across the membrane.

- # Effect of operating parameters

III. Feed temperature effect



- the permeate flux is greatly affected by the feed solution temperature.
- an exponential increase in permeate flux with feed temperature due to the exponential increase of the vapour pressure with temperature (exponential increase in the driving force).

Conclusions:

- AGMD is promising technology for the treatment of produced water. Also, it is expected to be a cost-effective process for produced water treatment.

- When the pore size increases, the permeate flux increases due to the enhanced mass transfer in the pores.

- The rejection factor decreases with the increasing the pore size.

- The permeate flux is found to be directly proportional to the feed temperature and the feed flow rate. However, it is inversely proportional to the coolant temperature.

- The feed temperature has the most significant influence on the trans-membrane flux, followed by the feed flow rate.

- it is desirable for the AGMD process to be operated at the highest allowable feed temperature and flow rate to maximize the permeate production and minimize the energy consumption ratio.

Thank you!

• Energy Consumption