Energy and Sustainability Center

Effects of Salinity and Feed Temperature on Permeate Flux of an Air Gap Membrane Distillation Unit for Sea Water Desalination

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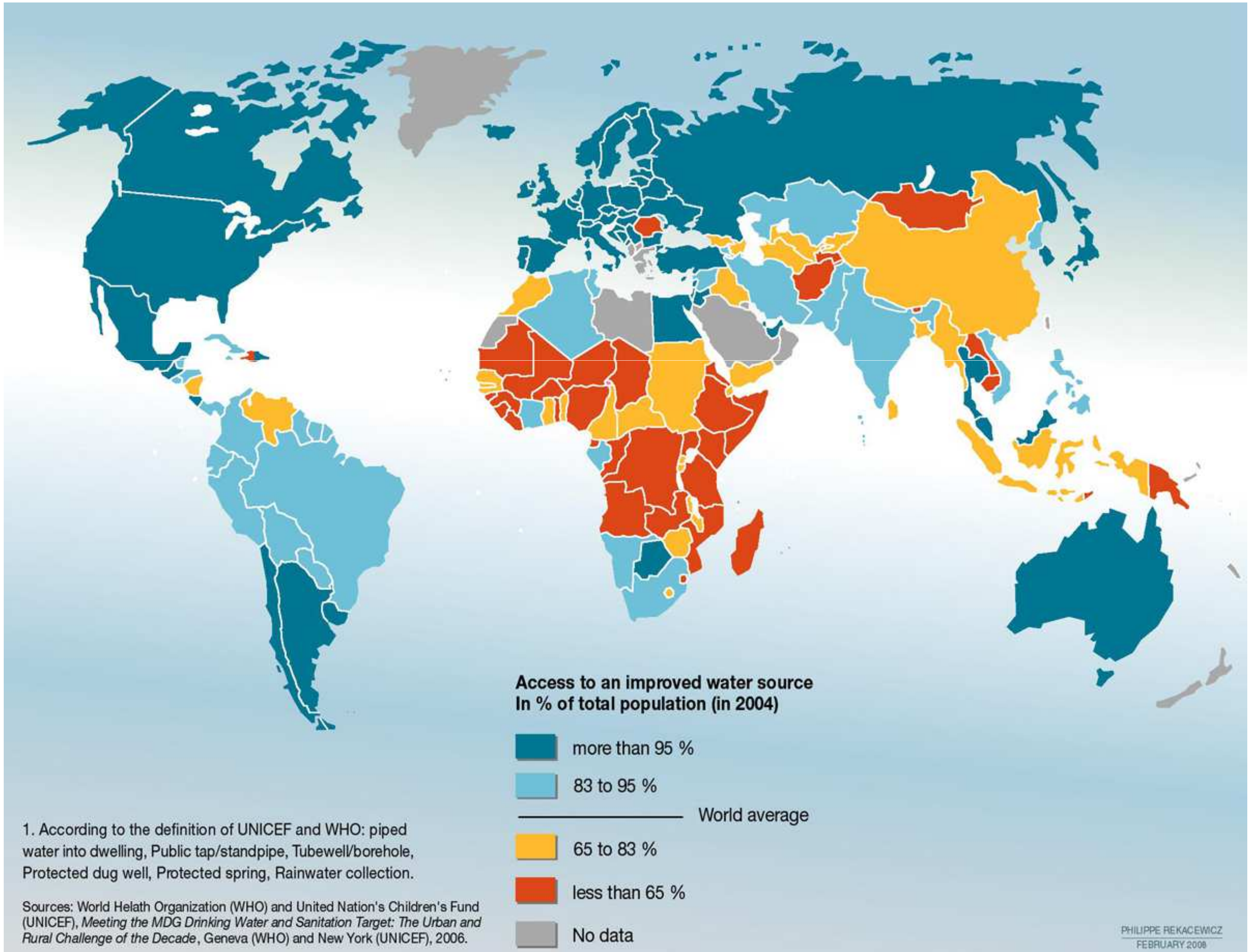
Water issues

- Roughly 80% of the world population live in developing countries.
    - o 1.3 billion lack access to water
    - o 2.6 billion deprived of electricity
    - o 84% in rural regions
        - o (44% Africa and 38% Asia)

- Lack of access to potable water and high cost of purification pose a major challenge.

Water stressed regions



Problem statement

Humanity's Top Ten Problems for next 50 years

1. **ENERGY**
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

2003	6.3	Billion People
2050	8-10	Billion People

Source: Professor Smalley, Rice University

Membrane Distillation (MD)

Advantages:

1. Low operating pressures than RO
2. Can treat high salinity brines
3. Requires less space than others
4. Minimal reactions membranes/feed solutions
5. Low operating temperature < feed boiling point – waste heat, solar, wind, geothermal

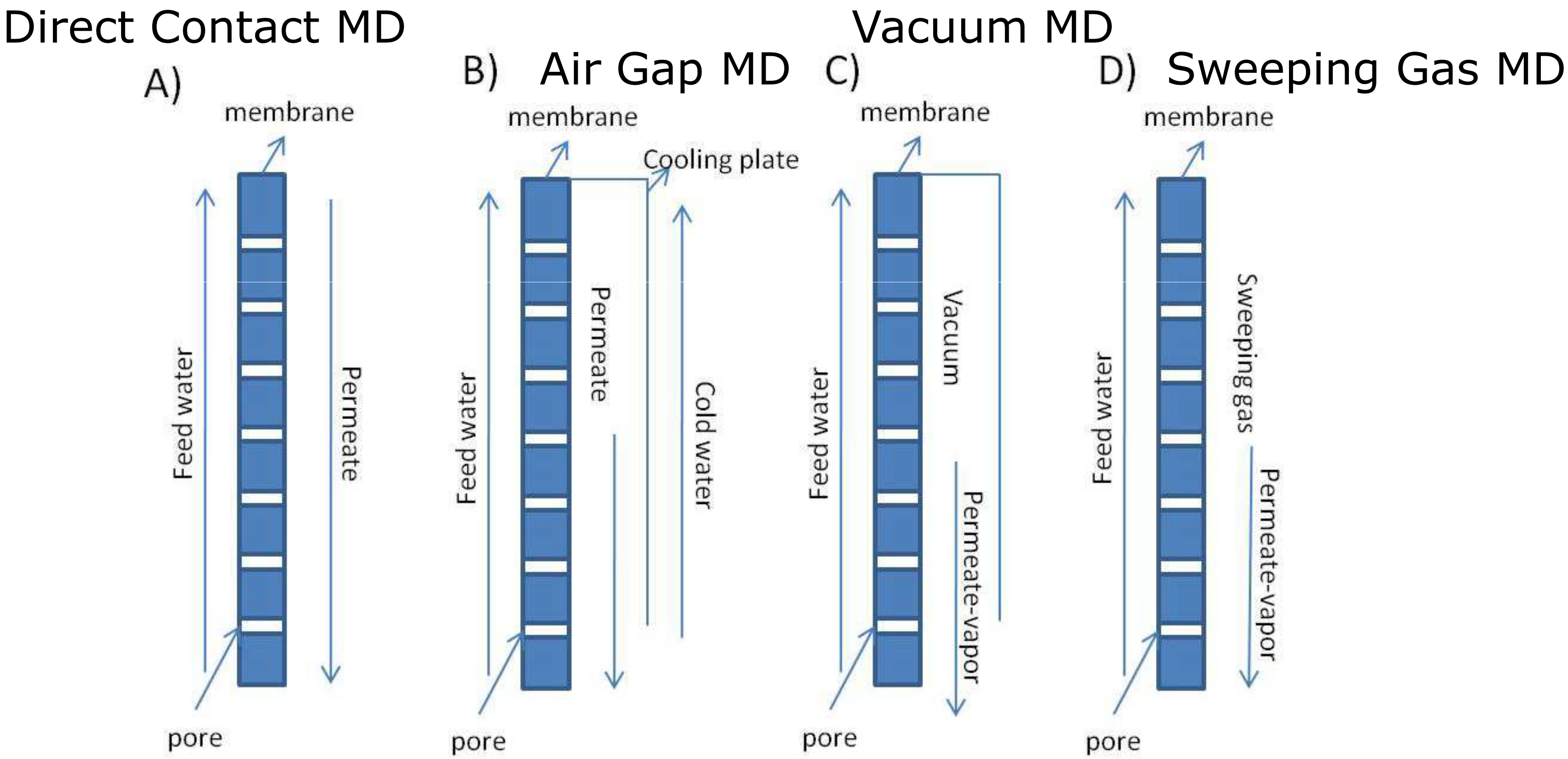
Disadvantages:

1. Low permeate flux than RO
2. Dependence on feed concentration, temperature
3. Fouling, Membrane deterioration

OBJECTIVE

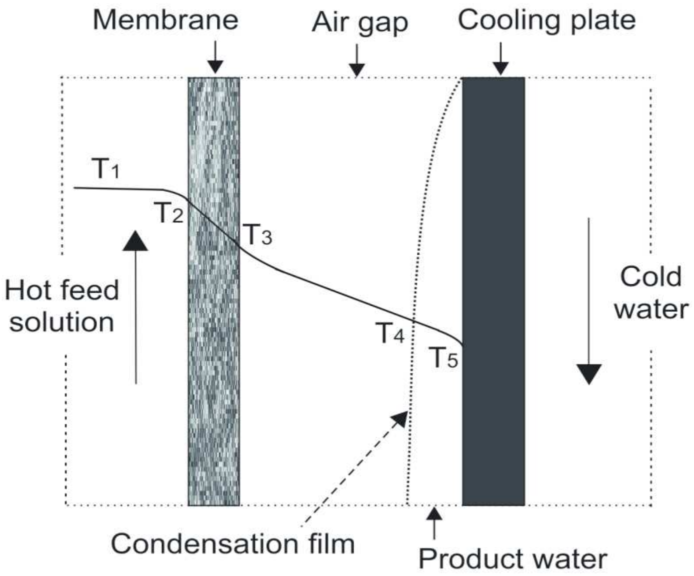
- Distillation of seawater using affordable technology – renewable energy or waste heat.

MD Introduction



MD module

- Scarab AB AGMD unit
  - o $2.8m^2$ membrane area
  - o PTFE & PP materials
  - o Parallel cross-flow

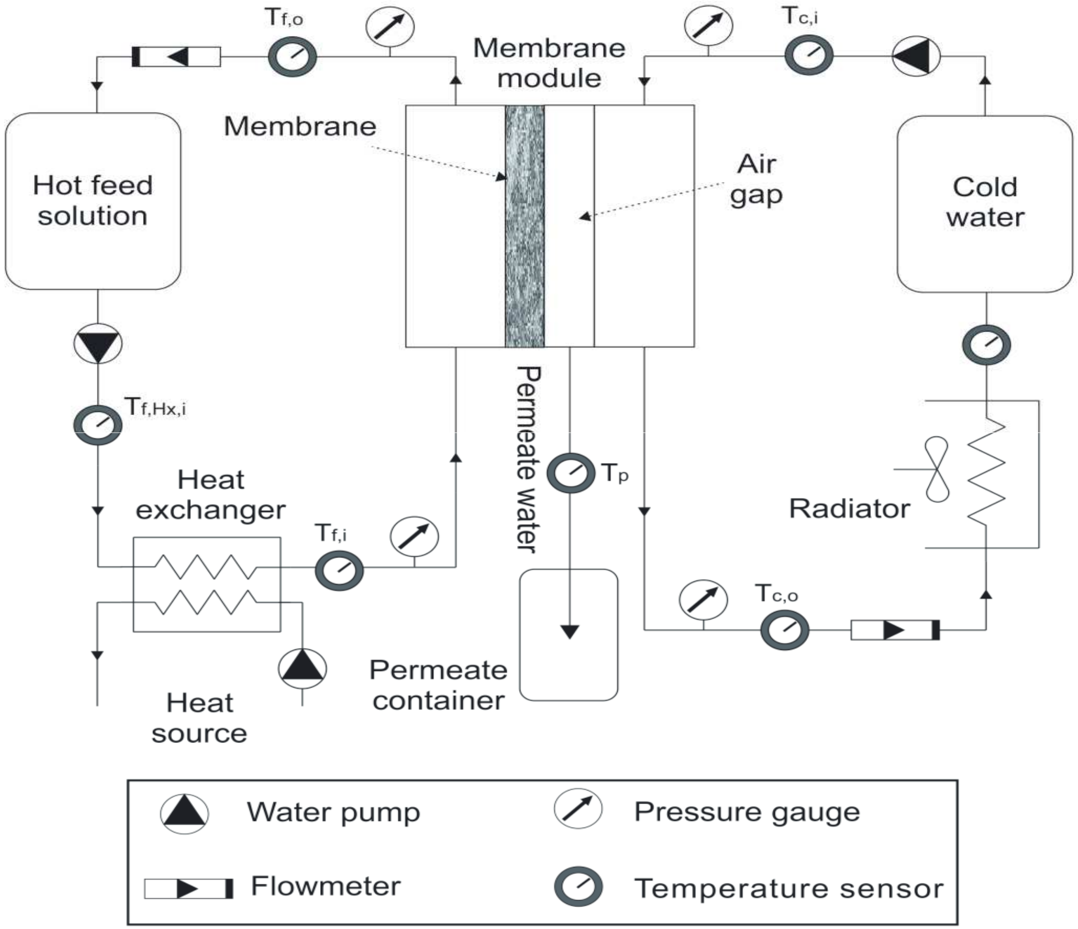


MD Objective

Characterize a Scarab AB MD unit

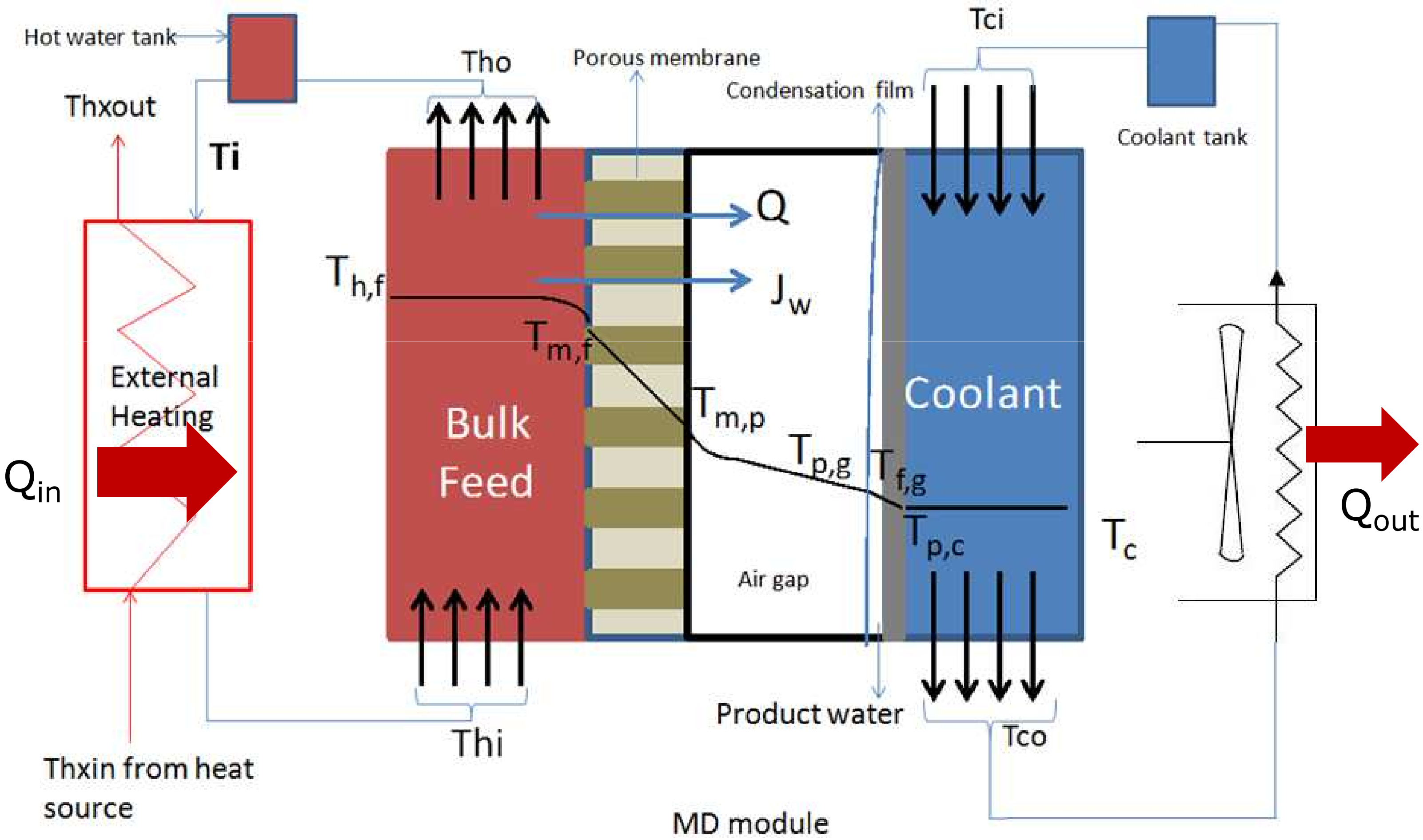
- Test MD unit within operating limits
  - o Effect of hot side temperature (T_h)
  - o Effect of cold side temperature (T_c)
  - o Effect of Salinity (C)
  - o Effect of temperature drop across membrane (ΔT)
- Thermal energy required to produce water

Membrane Distillation (MD) Schematic



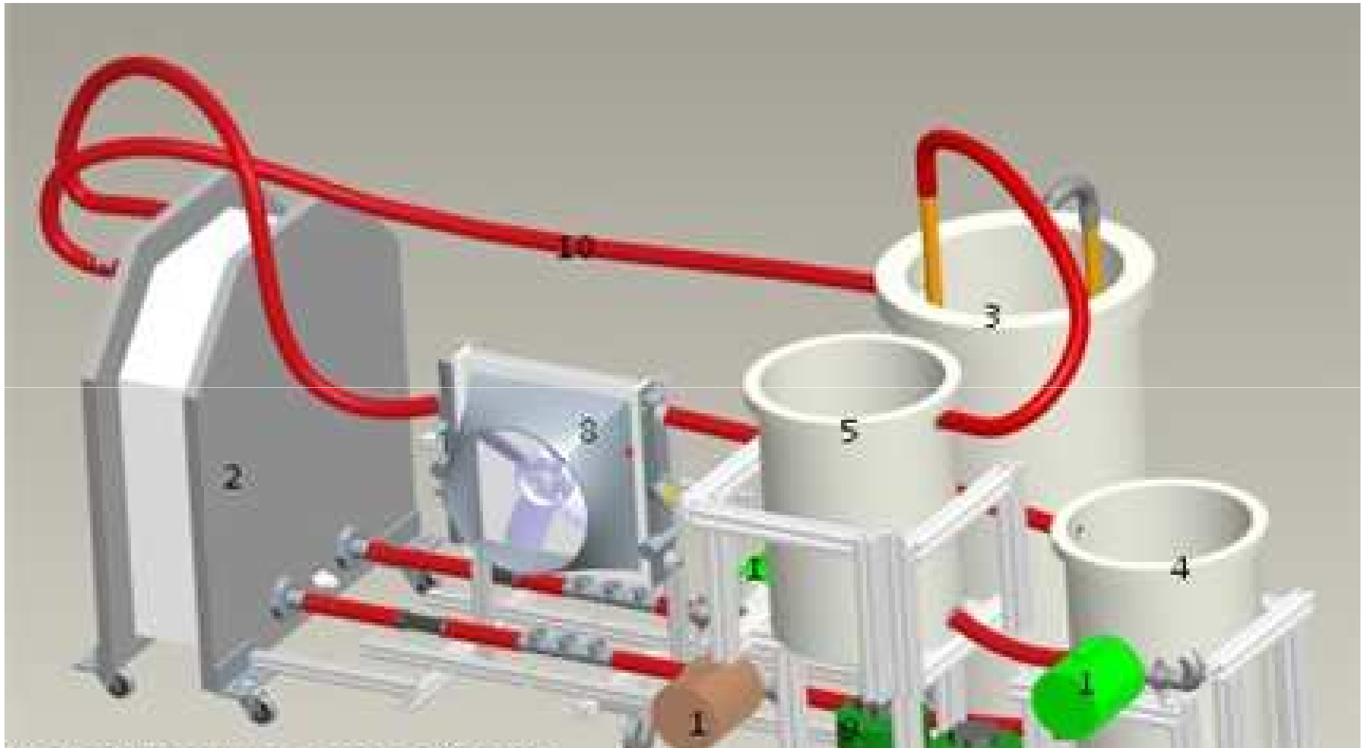
Heat rate: $Q=m_h*C_p*(T_{fi}-T_{f,Hx,i})$

Membrane Distillation (MD) Schematic



Heat consumption rate: $Qin=m_h*C_p*(T_{hi}-T_i)$

Test facility



1. Circulation pumps, one for each circuit;
2. Membrane module
3. Warm water tank with heaters; 4. Cold water tank
5. Expansion tank; 6. Monitoring instruments and transducers
7. Plate heat exchangers on warm water side; 8. Air to liquid heat exchanger
9. Voltage regulators to vary pump speed; 10. Flexible hose

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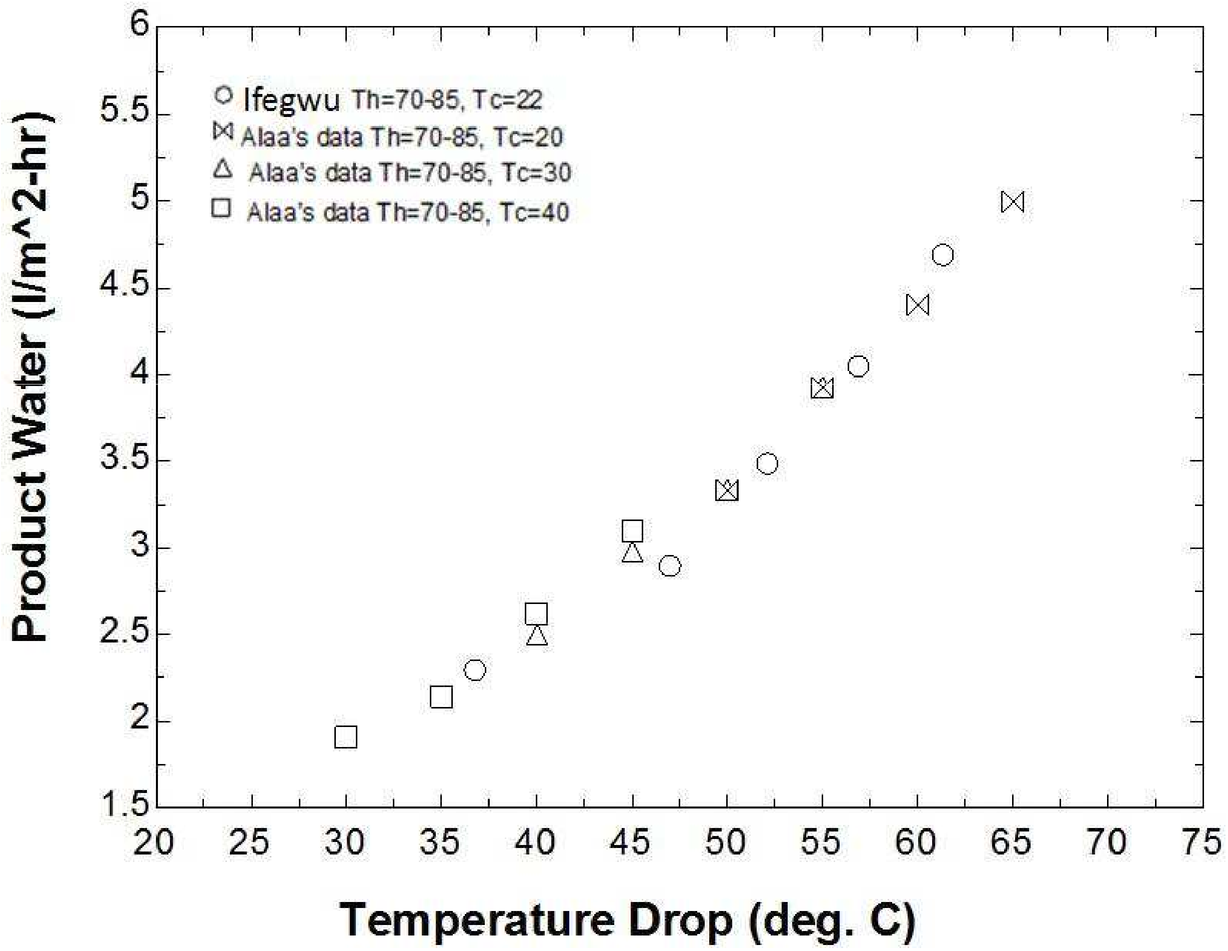
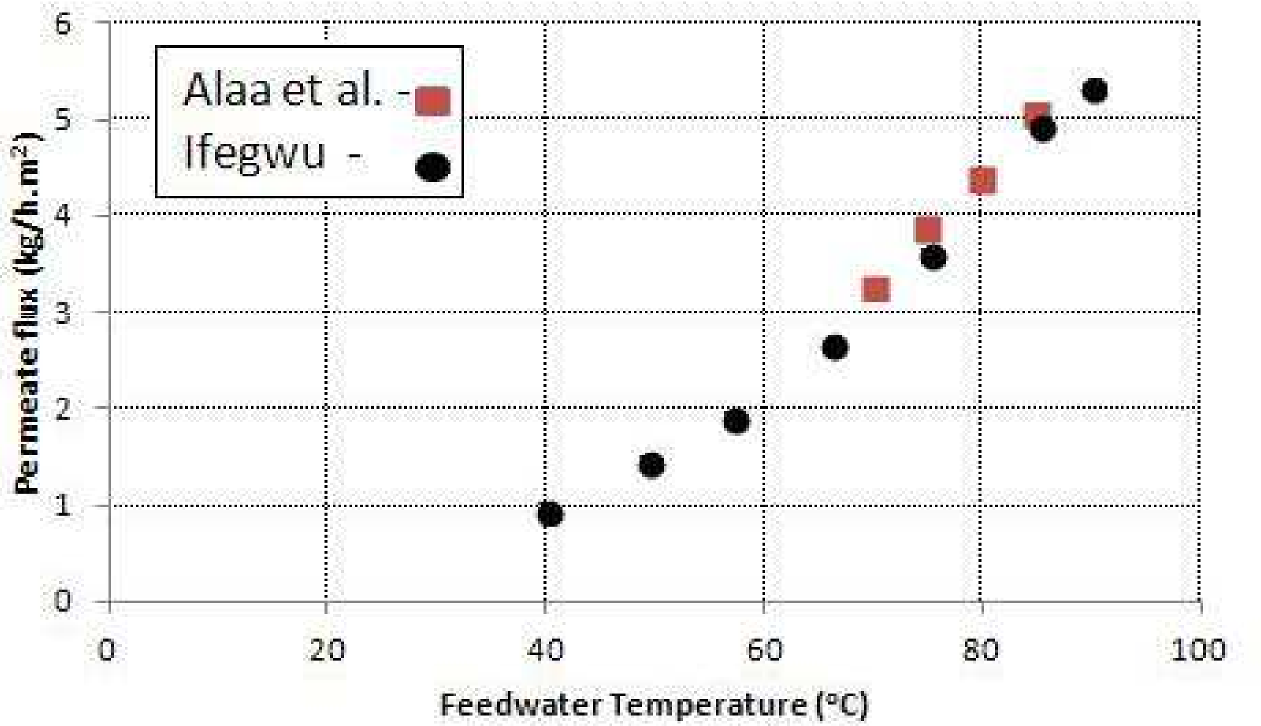
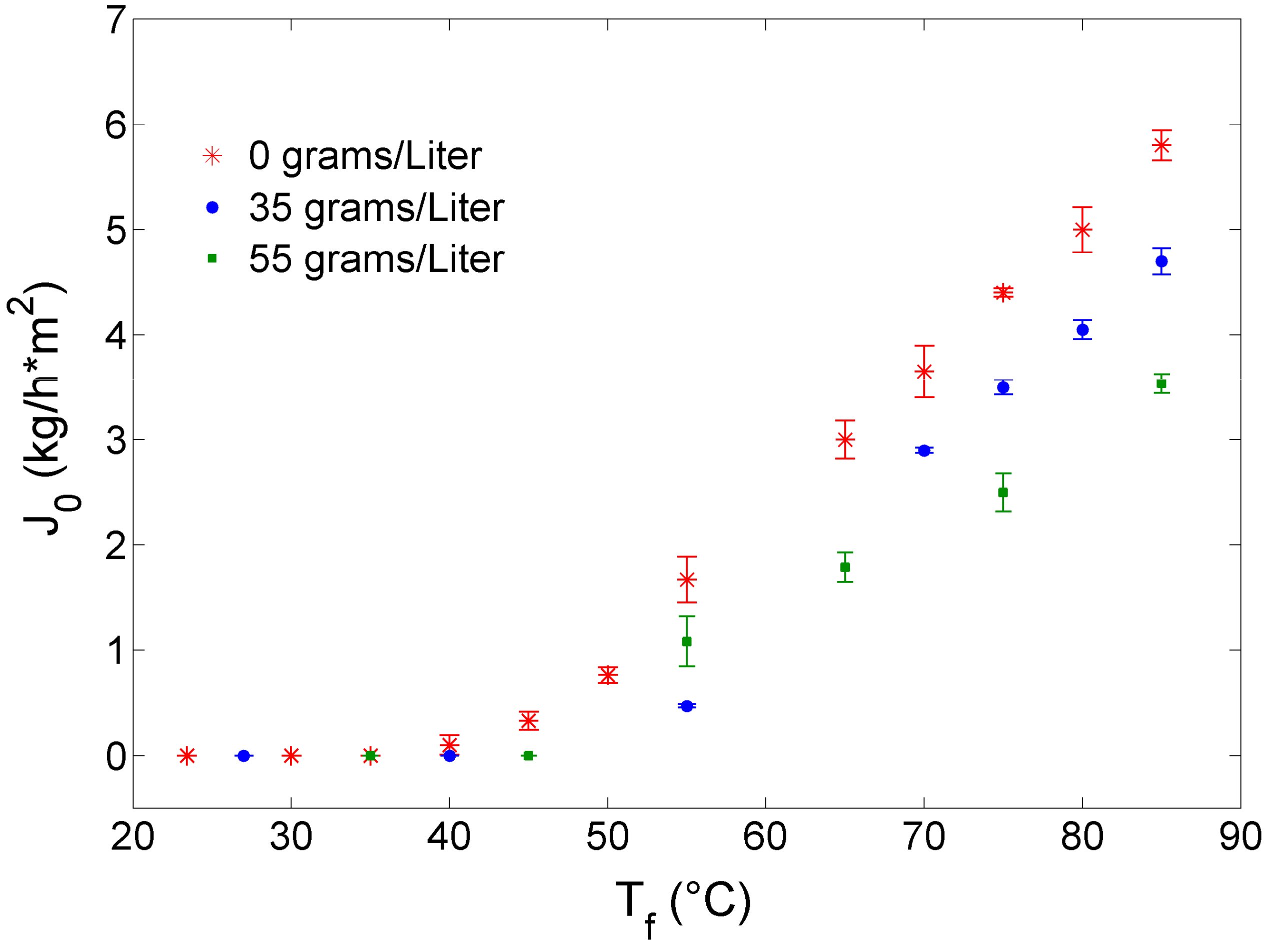
Results Comparison



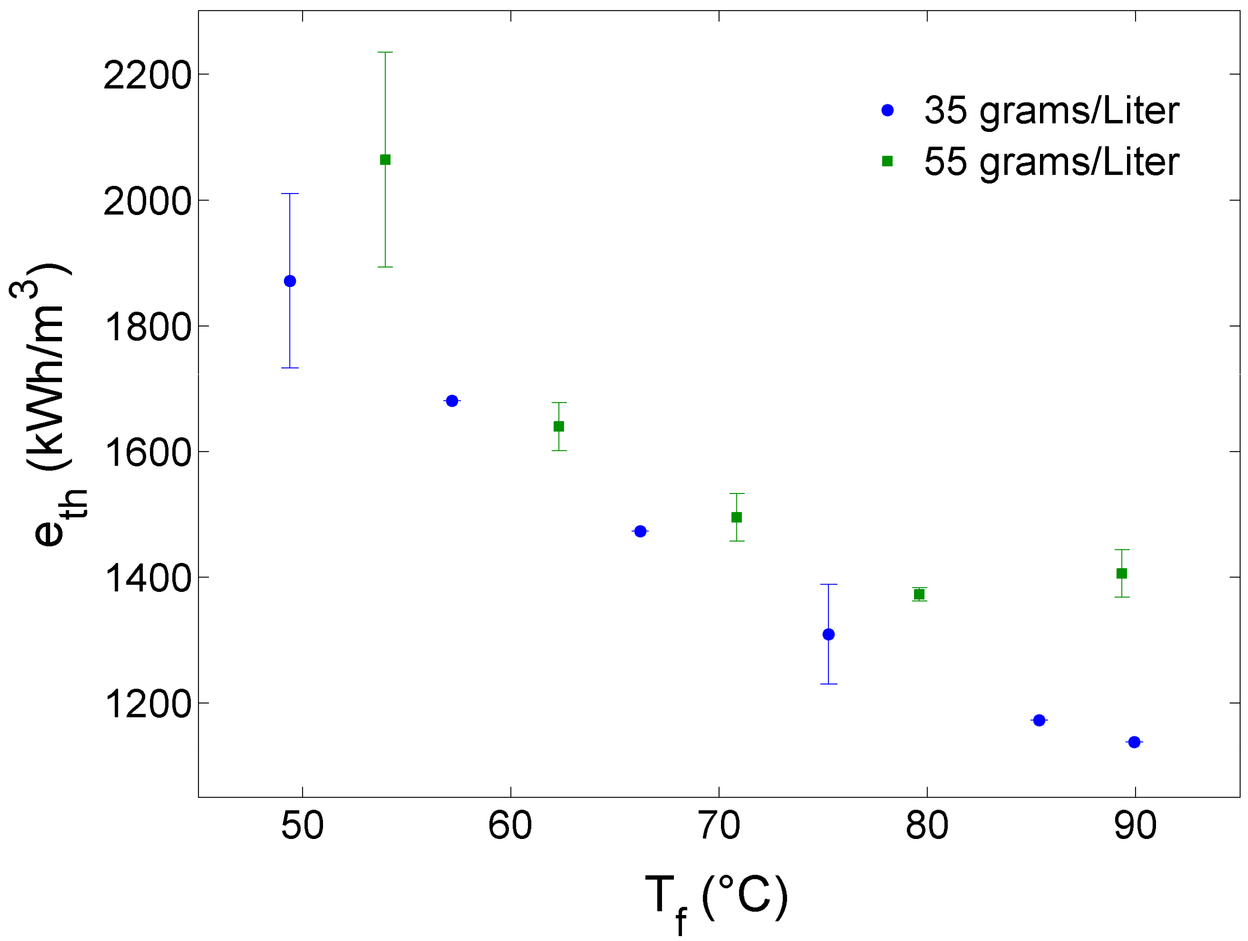
Effect of feed water temperature



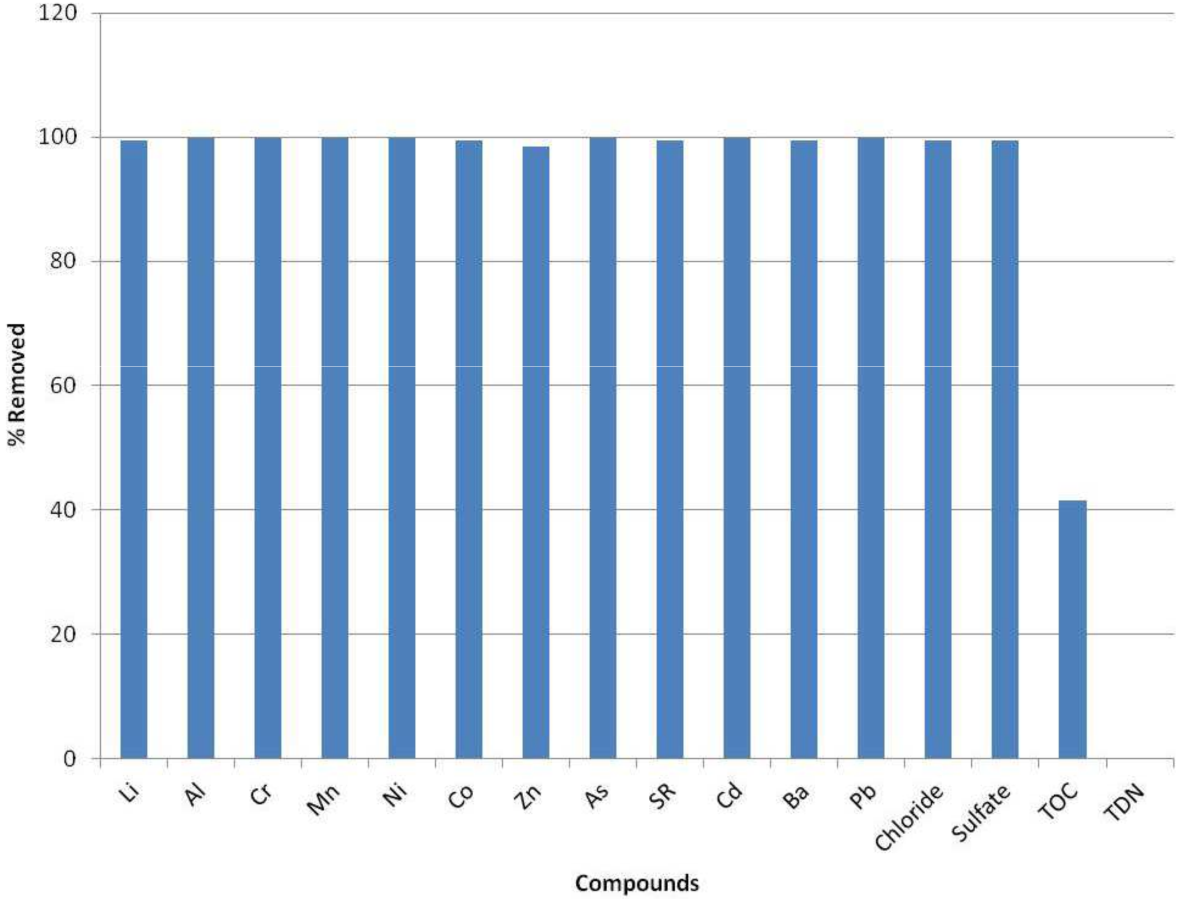
Permeate flux vs. feed Temperature



Specific Energy Consumption



Contaminant removal



Distillate Quality

	Concentration Before	Concentration After	EPA (maximum allowable contaminant level)	Units
Li	674	3.9		Ppb
Al	2898	2.4	50 to 200	Ppb
Cr	4776	4.8	100	Ppb
Mn	713	1	50	Ppb
Ni	5080	5.6		Ppb
Co	22	0.11		Ppb
Zn	185	2.8	5000	Ppb
As	273	0.57	10	Ppb
Sr	12039	76		Ppb
Cd	86	0.16	5	Ppb
Ba	48	0.27	2000	Ppb
Pb	368	0.53	0; action level =15	Ppb
Chloride	680mM	3.7mM	250 mg/L	
Sulfate	28mM	0.148mM	250 mg/L	
TOC	123 μM	72 μM		
TDN	29 μM	31 μM	1mg/L or 10mg/L	

Conclusions

1. Increased temperature increases permeate flux (raises vapor pressure gradient)
2. Increased salt concentration reduces permeate flux (reduction in vapor pressure gradient) and increases specific energy consumption
3. Required low grade heat allows for use of waste heat, solar and other renewable sources