Membrane Distillation Crystallization Hybrid Process for Zero Liquid Discharge in QAFCO Plant

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Motivation

Liquid discharge

- Harbor-Bosch process
- Wastewater
- Multi-stage flash desalination process
- Brine
- Process water
- Seawater

Objective

The outmost goal is to demonstrate

- ❑ Effective process for zero-liquid discharge (**ZLD**) of all processed water or wastewater from QAFCO facilities.
  - Membrane distillation crystallization (**MDC**) hybrid process
  - To Concentrate and minimize the volume of wastewater/brine streams
    - To from **solid** through crystallizer unit.

Introduction

Membrane distillation (MD

Based on thermal gradient created across a microporous hydrophobic membrane.

Super-hydrophobic MD membranes

- ❑low surface energy
- ❑very rough surface
- ❑High liquid entry pressure

Vapor Mass transfer is influenced by

- ❑Operating conditions
- ❑Membrane properties

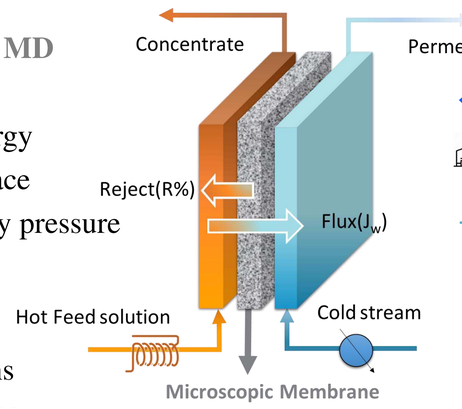


Fig.1: Direct contact membrane distillation (DCMD)

Advantages

- Easier operating conditions
- Least capital and land for the plant
- Coupled with low grade or alternative renewable source of energy

Limitation

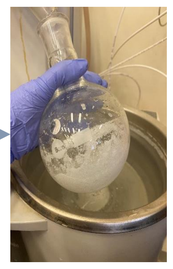
- ❑Membrane wetting
- ❑Temperature polarization effect

Experimental approach

Crystallization

Fig.3: Rotary evaporator

Rejected WW



Operated at 60°C, 140 rpm

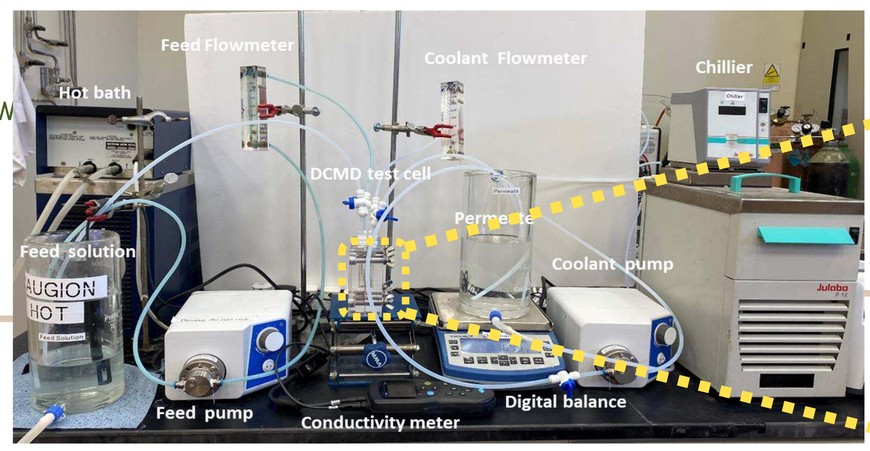
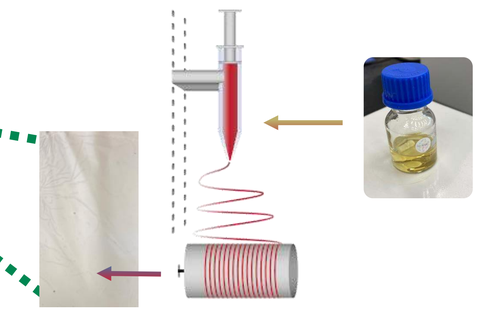


Fig.2: Direct contact membrane distillation (DCMD) experimental setup

DCMD Test cell

Water Recovery

Electrospinning technique



Results

Electrospun MD membrane

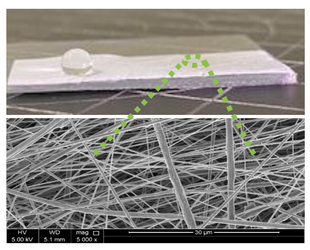


Fig.4: SEM image of PVDF nanofiber electrospun membrane (ENM) .

Table 1: Mechanical and chemical characteristics of PVDF nanofiber electrospun membrane (ENM)

Thickness (mm)	Young's Modulus (MPa)	Tensile Strength (MPa)	Max load (N)
1.2	92.33	19.21	23.06
Elongation at fracture (%)	**Melting temperature (°C)**	**Crystallization temperature (°C)**	**Contact angle (°)**
118.32	170	139	141.64

Membrane distillation Process

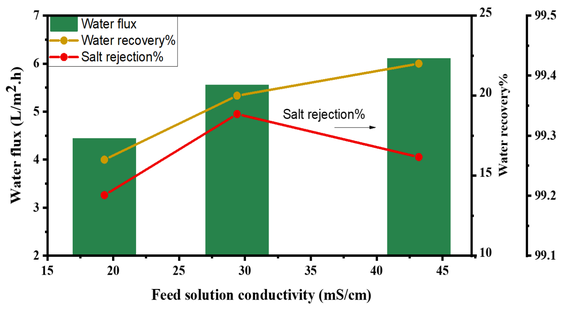


Fig.5: (a) DCMD behavior at different feed conductivity. Hot bath temperature (70°C±1), chiller temperature (20°C±1) and feed flowrate (1 L/min).

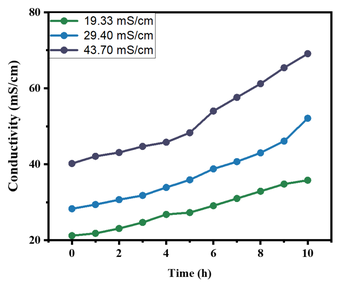


Fig.6: Conductivity changes at different feed conductivity. Hot bath temperature (70°C±1), chiller temperature (20°C±1) and feed flowrate (1 L/min).

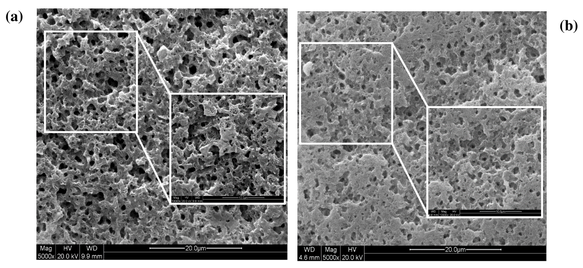


Fig 7: SEM images of active layer surface of Polyvinylidene fluoride (PVDF) MD membrane. (a) Origin, (b) after six convective MD tests at different feed solution. Physical cleaning applied prior each MD test.

Crystallization

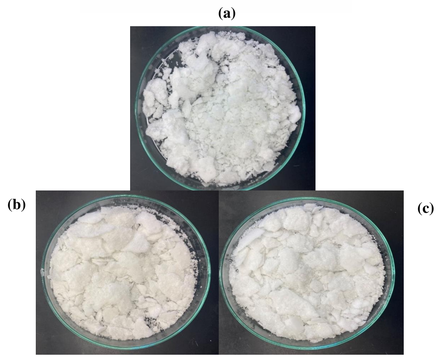


Fig.8: Formation of Crystallized solids by rotary evaporator at initial conductivity(mS/cm) (a) 19.33, (b) 29.4and (c) 43.7,

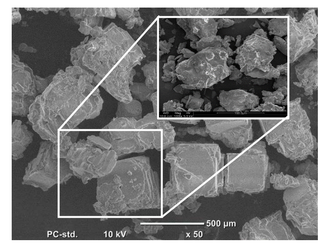


Fig.9: SEM images of obtain crystallized solids

Significance

MDC hybrid process

- Minimum water discharge into the sea from QAFCO facilities
- Sustainable ammonia & urea production
- Cost effective meth

Conclusions

- PVDF ENMs have stable mechanical and chemical properties
- For super-hydrophobic PVDF ENMs , WCA should be greater than 100°, in order to be tested in DCMD process
- Optimum feed solution conductivity of 29.4 mS/cm, recovered 22% of water and rejected 99.3 % of feed solute.
- Crystallization process was performed by using extremal low temperature crystallizer unit.

Acknowledgement

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