Fouling-Resistant Membranes for Treating Concentrated Brines

Zachary Hendren[1,*], David Jassby[2], David Bollinger[1], and Wenyan Duan[2] • Energy Technology Division (ETD)[1] RTI International, Research Triangle Park, NC • [2]University of California at Riverside, Riverside, CA.

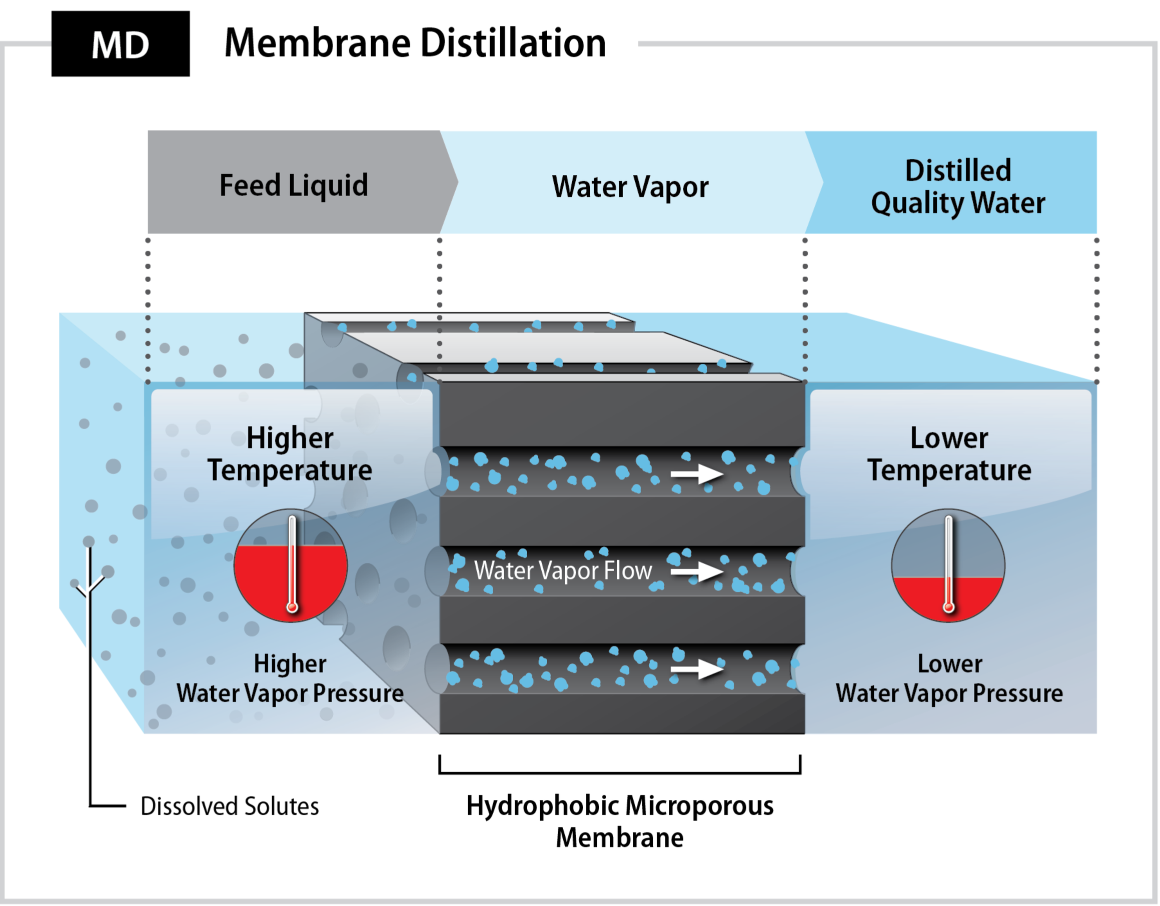


Illustration showing the MD process. The hydrophobic membrane facilitates vapor transport via a temperature differential.

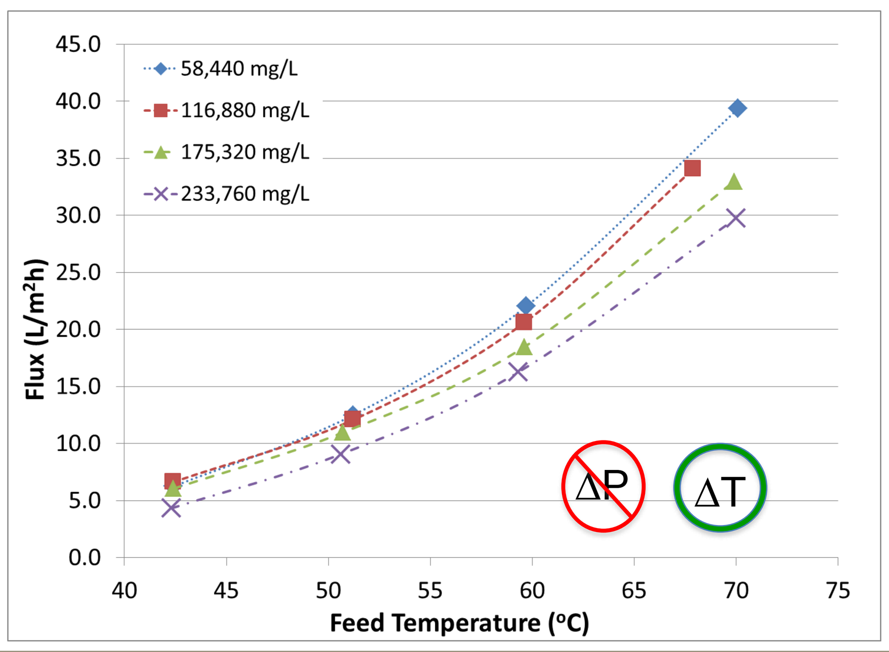
1. Introduction – Concentrated Brines and Water Treatment Challenges

Wastewater Source	Max TDS (ppm)	Additional Key Contaminants
Bakken Oil Play	>300,000	High levels of scalants
Marcellus Shale Play	>280,000	High levels of scalants
FGD Blowdown	>40,000	Heavy metals, Se, Hg, As, + scalants
Coal Wash Wastewater	>30,000	Heavy metals, Se, Hg, As, + scalants

Source:
1.) Mantell, M. (2011). Water resources management: EEPA Hydraulic Fracturing Study Technical Workshop #4. Chesapeake Energy.
2.) Boschee, P. (2014). Produced and Flowback Water: Recycling and Reuse Economics, Limitations, and Technology. Oil and Gas Facilities.
3.) US Environmental Protection Agency. (2009). Steam Electric Power Generating Point Source Category: Final Detailed Study Report
4) Das, B., Prakash, S., Biswal, S. K., & Reddy, P. S. R. (2006). Settling Characteristics of coal washery tailings using synthetic polyelectrolytes with fine magnetite. Journal of the Southern African Institute of Mining and Mettalurgy, 106.

- Wastewater brines generated throughout the fossil fuel life cycle contain high levels of dissolved salts and heavy metals that make up total dissolved solids (TDS).
- TDS in wastewater is among the most difficult of contaminants to remove:
  - High energy consumption/limited recovery;
  - High scaling potential/decreased operation.
- Current practices employ minimal reuse due to the high costs associated with treatment; however these waters are a significant untapped opportunity for reuse and a means for industry to lower their overall water footprint.

2. Our Solution – Electrically Conductive Nanocomposite MD Membranes



MD is particularly suited for high-TDS wastewaters
- Thermally driven process – water recovery and energy use are minimally dependent on salinity.
- High quality product water suitable for reuse/discharge.

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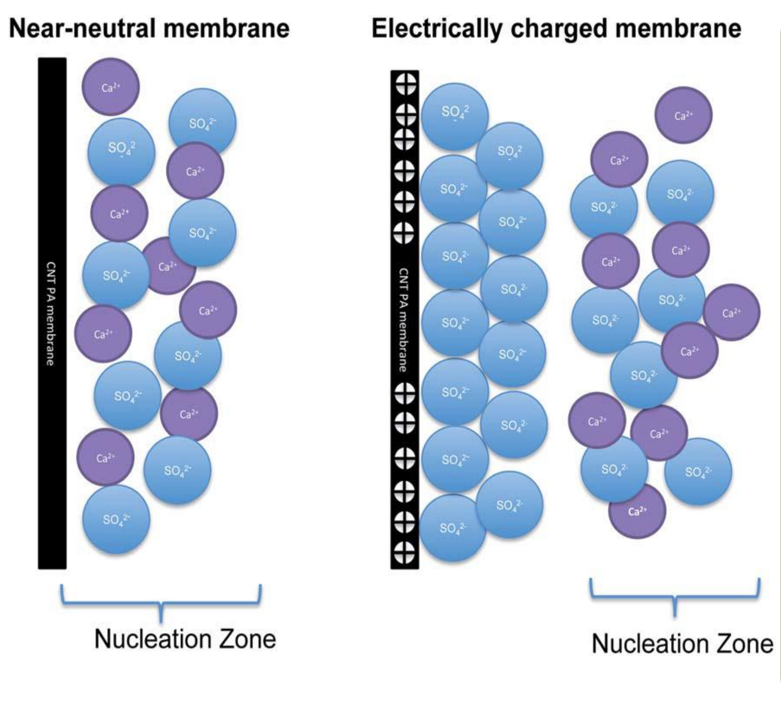
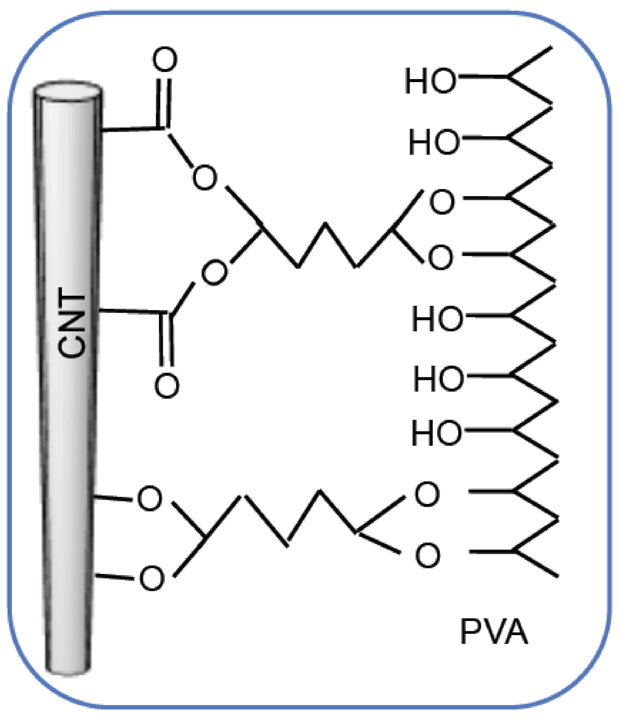


Charged membrane surface alters the mechanism by which scale is formed
- Nucleation zone is "pushed" away from the surface.
- Crystal formation occurs primarily in the diffuse layer away from the membrane.
- Scale growth on the surface is altered.

3. Objectives – Technology Transition from Concept to Developmental Stage

Project Objectives:
- Demonstrate the efficacy of membrane distillation (MD) as a cost-savings technology to treat concentrated brines that have high levels of total dissolved solids (TDS) for beneficial water reuse.
- Develop a novel, fouling-resistant nanocomposite electrically conductive membrane that will reduce the need for chemicals to address membrane scaling due to the precipitation of divalent ions in high-TDS wastewaters.

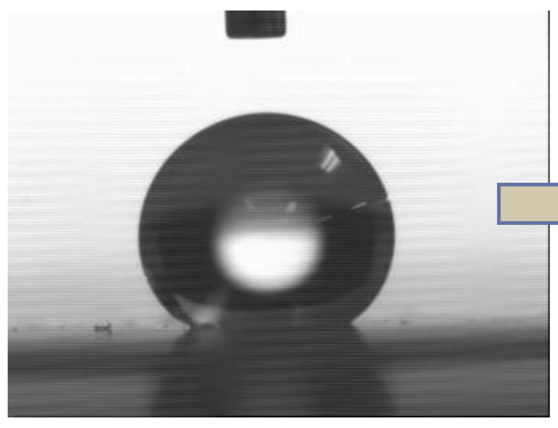
4. Methods – CNT Modification to Develop ECMD Membranes



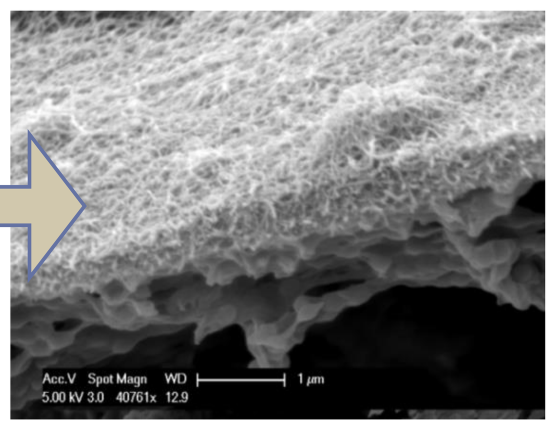
Representation of covalently bonded CNT-MD membrane

- Modification via CNT-OH and polyvinyl alcohol cross-linked atop a MD membrane support.
- Membranes are permanently bonded between the carboxyl groups on the CNTs and the hydroxyl groups on PVA.
- Cross-linking results in reaction that fixes the CNT network to the membrane surface. Porous network leaves original membrane permeability intact.

5. Accomplishments – Successful CNT Grafting to PVDF Membranes



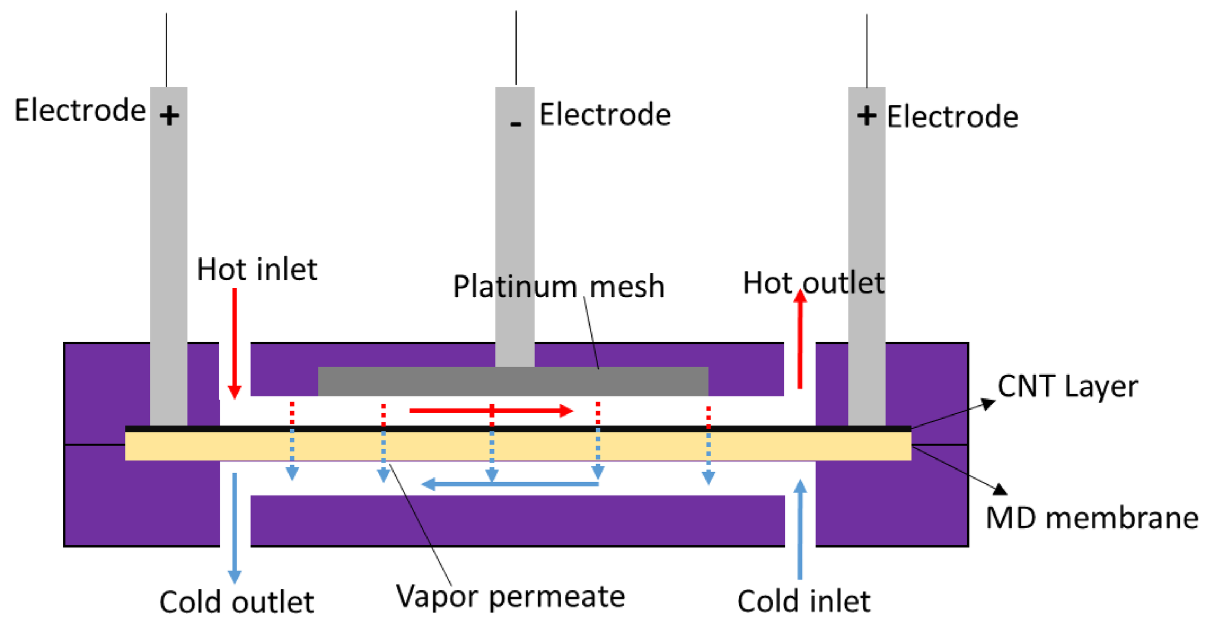
Hydrophobic PVDF membrane



SEM of CNT grafted to PVDF membrane

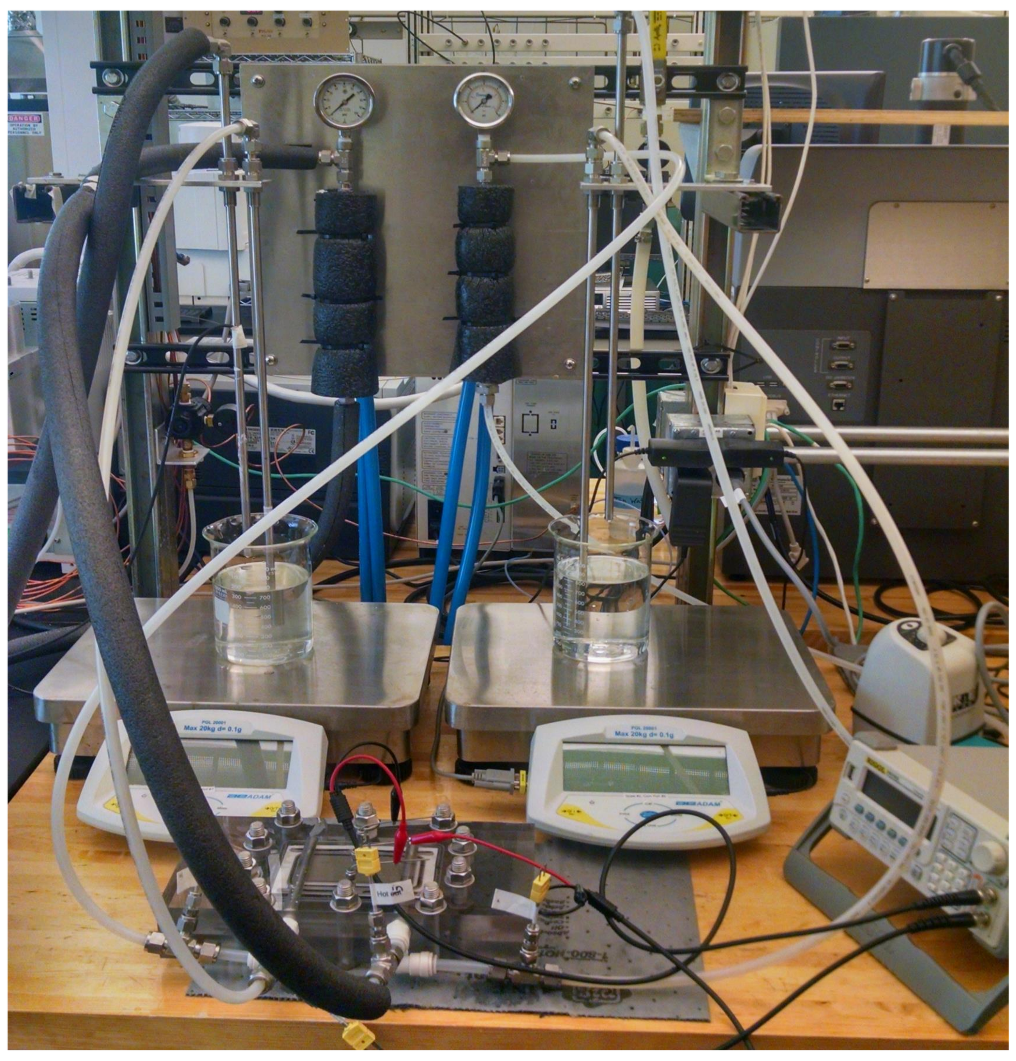
- Smooth and robust:
  - Roughness = 12 ± 2 nm
- High electrical conductivity
  - ~2000 S/m

6. Accomplishments – ECMD Test Cell Design and Fabrication



Schematic representation of the ECMD test cell, electrodes, and CNT modified MD membrane. Arrows indicate flow direction of the hot/cold streams. Dotted arrows represent vapor flux across MD membrane.

7. Project Status – Experimental Setup Complete, Testing In Progress



ECMD Test Bed Experimental Setup

- ECMD test cell leak-tested, commissioned, and connected to power source.
- Experimental test plan to first evaluate synthetic scaling solutions based on salts of calcium, sulfate, strontium, and barium, followed by real high TDS brines.
- Performance targets are to double flux performance time on stream (relative to no applied current) at given scaling condition.

8. Anticipated Impact and Benefits

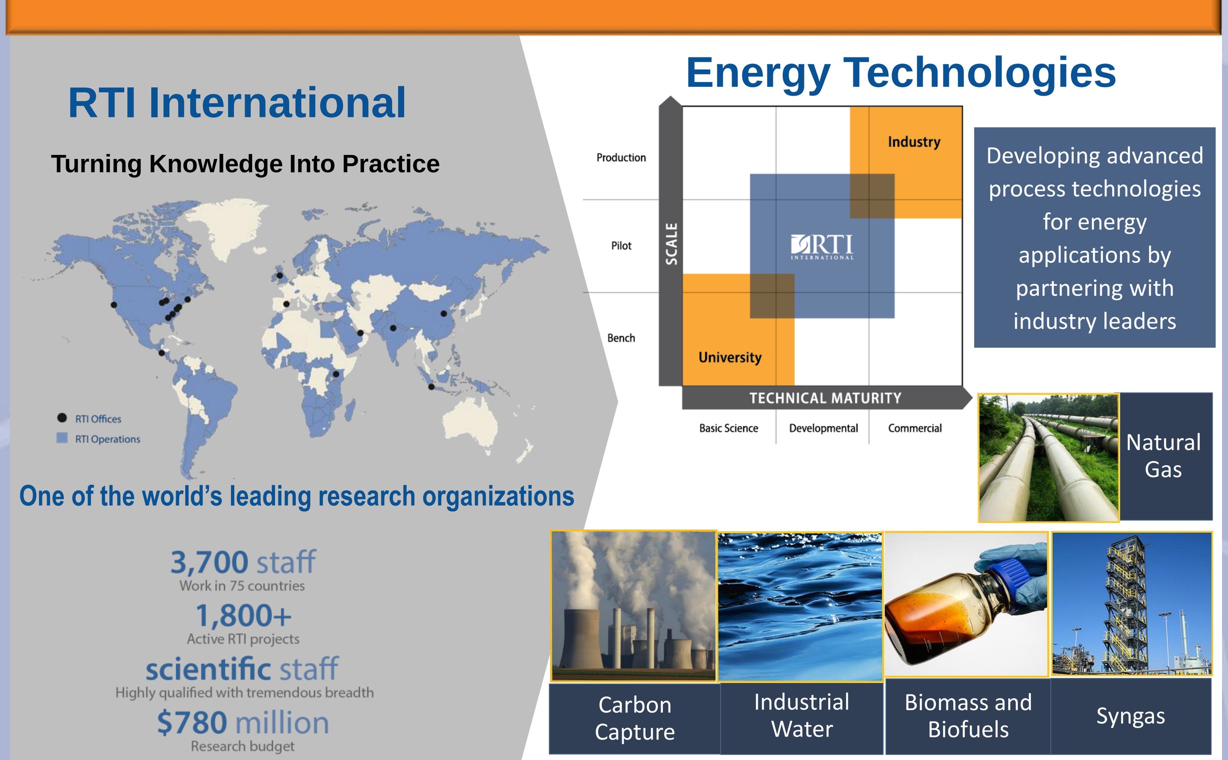
Characteristic	Ion Exchange	Reverse Osmosis (RO)	Electrodialysis Reversal	Crystallization	Membrane Distillation
Energy cost	Low	Moderate	High	High	Moderate
Capital Expenditure	Low	Low/Moderate	Low/Moderate	Very High	Low/Moderate
Plant/unit size	Modular	Modular	Modular	Large	Modular
Pretreatment requirement	Filtration	Extensive	Filtration	Varies	Filtration
Final water TDS	200–500 mg/L	200–500 mg/L	200–1,000 mg/L	<10 mg/L	<10 mg/L
Suitable for 180,000* mg/L TDS wastewater?	No	No	No	Yes	Yes

Commercial (Ion Exchange – Crystallization); Next Generation (Membrane Distillation)

Scale formed on membranes reduces process performance, and requires chemical cleaning that significantly increase treatment costs and reduces reliability. Successfully addressing this challenge would address the operational uncertainty encountered during the treatment of these high TDS wastewaters, and has the potential to make MD a viable treatment option.

Project Period of Performance (2 years)
10/1/2014 to 9/30/2016

9. About RTI



More Information

***Corresponding author**: Zachary Hendren
919.541.6605
zhendren@ rti.org