Increasing Water Recovery and Reducing Membrane Scaling Using Innovative Electromagnetic Field (EMF) and 3D Printed Membranes

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INTRODUCTION

Desalination of non-traditional water resources, such as brackish water, seawater, reclaimed water, can provide opportunities to meet increased freshwater demand, enhance water security. Membrane fouling and scaling are the major challenge for successful implementation of membrane desalination technologies, and result in low water recovery, high energy demand and chemical uses, and large volume of concentrate for disposal. In this study, we developed an innovative High Recovery Reverse Osmosis (HRRO) process to reduce membrane fouling and scaling, and to enhance the overall desalination efficiency. The system employs an electromagnetic field (EMF) and 3D printed RO membranes to retard membrane scaling, enhance water recovery, reduce chemical consumption and energy demand, and increase membrane life time. The bench-scale testing demonstrate that the EMF provides an effective pretreatment to control membrane scaling during desalination of a challenging brackish groundwater. The feed groundwater for this study was from Well #2 in Brackish Groundwater National Desalination Research Facility (BGNDRF), Alamogordo, NM, which was primarily $CaSO_4$-type water with a total dissolved solids concentration of 5,850 mg/L and hardness of 2,550 mg/L as $CaCO_3$.

SELECTION OF OPTIMAL DESIGN

- **Chemical-free Pretreatment Using Electromagnetic Field (EMF)**
- **3D Printed Membranes with Open Channel Spacers**

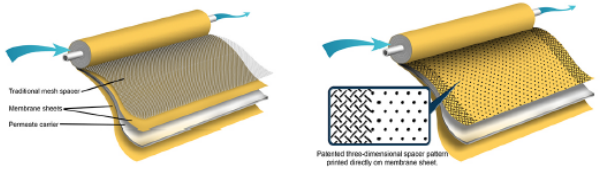

Fig. 1. Comparison of RO membranes with conventional feed spacer (left) and 3D printed spacer technology (right) (Source: Aquamembranes.com)

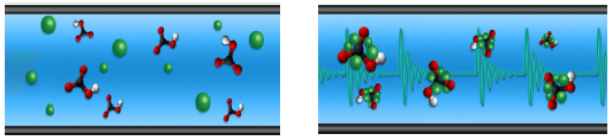

Fig. 2. Comparison of water molecule arrangement in a pipe without EMF (left) and with EMF (right) (Source: Hydroflow-usa.com)

MATERIALS

- Hydranautics low pressure RO Membranes ESPA-DHR, using traditional mesh spacer and 3D printed spacers
- EMF is a residential level water conditioning that performs the electric induction and induces an electric signal of ±150 kHz to feedwater.

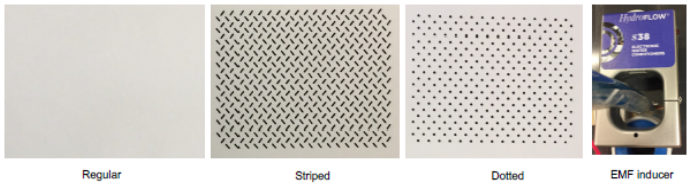

Fig. 3. Regular flat-sheet membrane (left), 3D printed membranes (middle) and EMF inducer (right)

PROTOTYPE DESIGN AND CONSTRUCTION

- Test units – two rectangular plate-and-frame cells, dimensions of 14.6 cm × 9.5 cm × 0.86 mm (34 mil)
- Effective membrane area of 139 cm^2 per unit
- Cross-sectional flow area of 0.82 cm^2
- Test cells and tubing made of stainless steel for the proper induction of EMF.

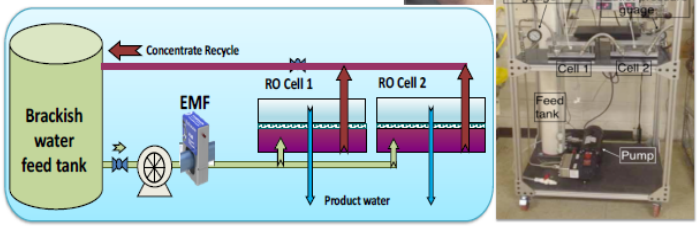

Fig. 4. Schematic diagram (bottom left), bench scale high recovery RO system (right) and test unit cell (top left)

RESULTS

- Pure permeate water flux (PWP) and salt rejection were tested for the 3 different membrane configurations

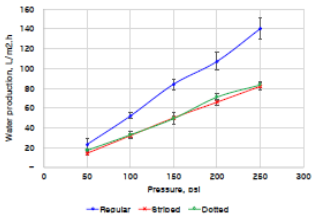

Fig. 5. PWP of different membranes

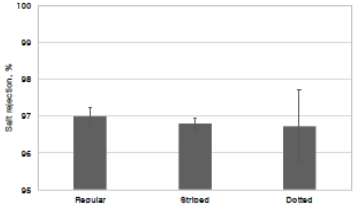

Fig. 6. Salt rejection of the membranes with 1,500 mg/L NaCl solution at 150 psi

- Regular membrane had initial higher water production, but faster permeation flux decline
- Regular membrane with EMF took more time to reach the same flux declined as regular membrane without EMF
- Running the system using EMF permitted to reach a higher recovery of 70% than 50% without EMF for regular membranes
- For regular membrane, the EMF reduced the water flux decline rate and significantly improved membrane performance by 57%, when the water recovery was 45%
- EMF did not have significant impact on the striped membranes, due to a higher standard deviation obtained in the experiments.
- Striped membrane tests showed more stable permeation flux than the regular membrane tests.

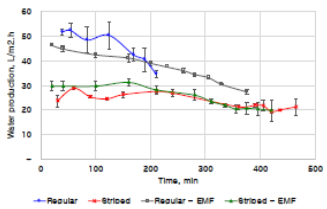

Fig. 7. Water production over time

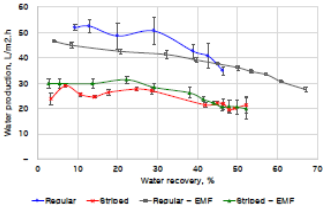

Fig. 8. Water production versus water recovery

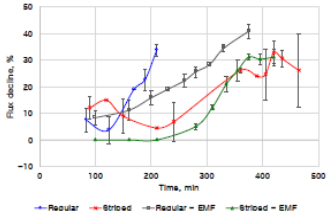

Fig. 9. Flux decline over time

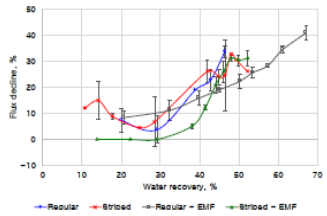

Fig. 10. Flux decline versus water recovery

CONCLUSION

- PWP and salt rejection tests did not show significant difference between striped and dotted membranes
- EMF permitted a higher recovery for regular membrane.
- 3D printed membranes demonstrated capability to reduce fouling and scaling showing more stable permeation flux.

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CONTACT INFORMATION

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