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The Opportunities and Limitations of Electromagnetic Field (EMF) for Scaling Control

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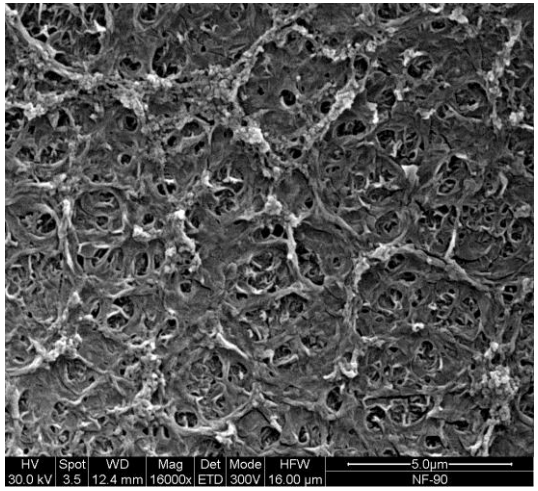
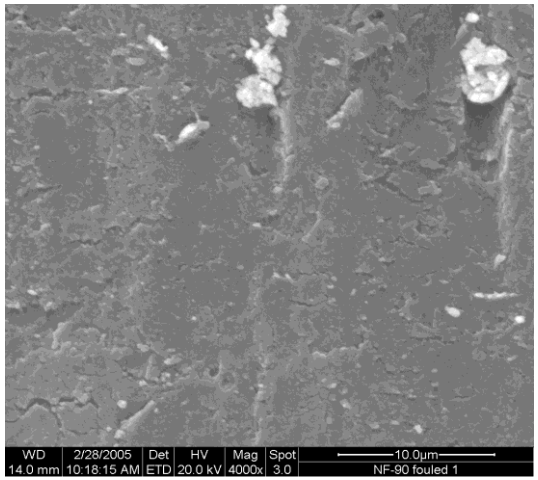
NM STATE

Scaling in Water Systems

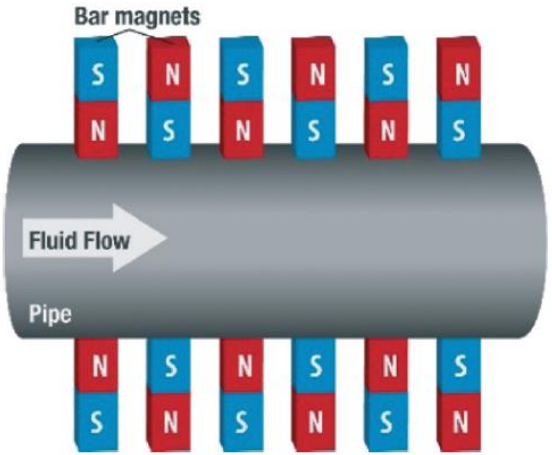




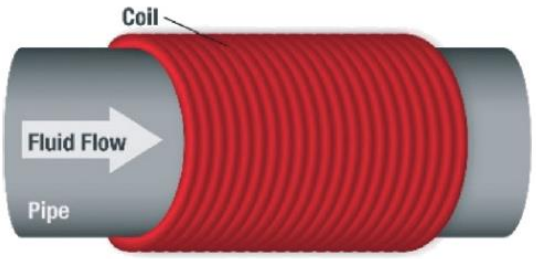
Scaling in Water Systems

- Loss in performance and economics
- Chemical treatment
  - Addition of scale inhibitors
  - Chemical softening
  - Ion-exchange
  - Chemical cleaning
- Handling, storage, and management of chemicals
- Environmental and health impacts

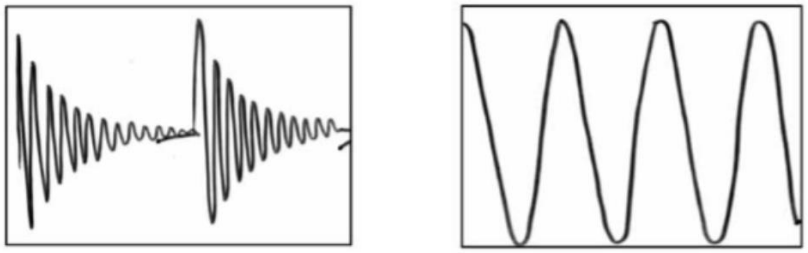
Non-chemical Scaling Control – Electromagnetic Field (EMF)



(a) Permanent magnets



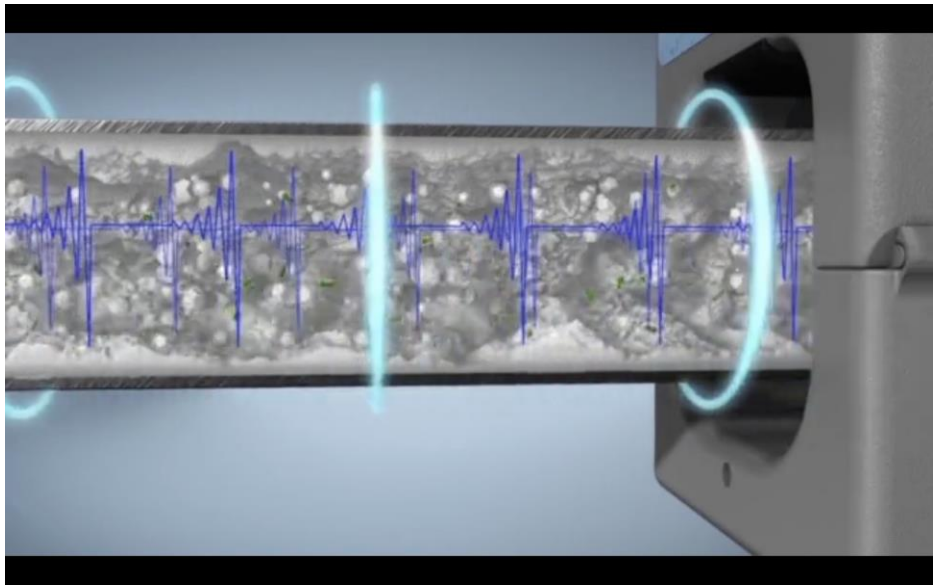
(b) Solenoid coil



(c) Schematic representations of wavesforms

Pilot Testing of EMF on RO Scaling Control during Brackish Groundwater Desalination at BGNDRF

- Two types of EMF devices tested
  - HydroFLOW: induce an electric signal of ±150 kHz in the liquid inside of a pipe on which they are installed. A specialized transducer connected to a ring of ferrites performs the electric induction

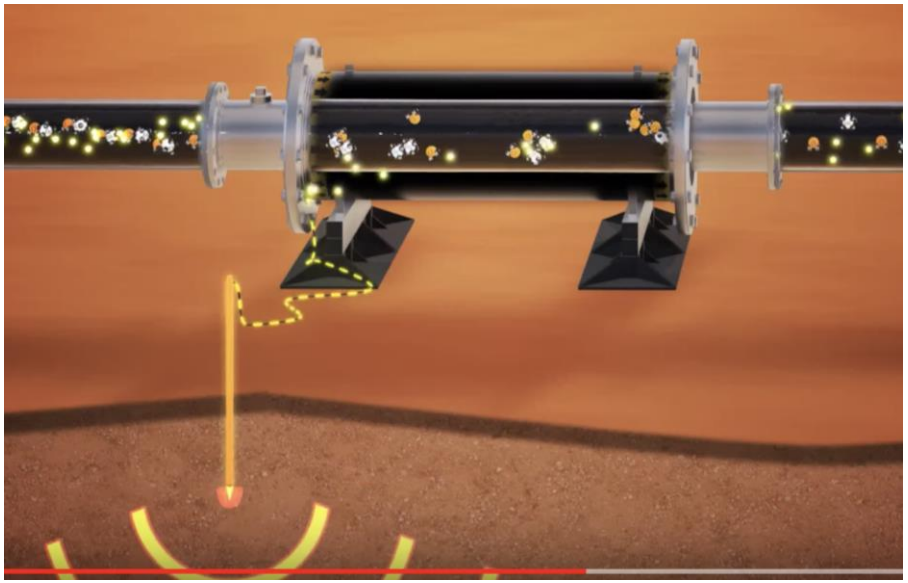


Pilot Testing of EMF on RO Scaling Control during Brackish Groundwater Desalination at BGNDRF

- Two types of EMF devices tested
  - HydroFLOW: HS48 was installed in the metal pipeline before the cartridge filter and S38 was installed in the inlet of the RO vessel.

Pilot Testing of EMF on RO Scaling Control during Brackish Groundwater Desalination at BGNDRF

- Two types of EMF devices tested
  - Eco1st Separation Enhancer: an inline fluid ionization system using electrochemical ionization principles. It induces EMF into the flowing fluid and discharges electrons from the molecules exist in the water. The free electrons will then be routed and drawn to a dedicated earth ground.



Pilot Testing of EMF on RO Scaling Control during Brackish Groundwater Desalination at BGNDRF

- Two types of EMF devices tested
  - Eco1st Separation Enhancer: installed before the cartridge filter of a 2-stage RO system.

Feed Water Quality

- Two types of groundwater used

Water quality parameter	Unit	Well 1	Well 2
Temperature	℃	21.3	27.0
pH	pH unit	7.74	7.17
Electrical conductivity	µmhos/cm	1840	6440
Total dissolved solids	mg/L	1260	5850
Langelier Saturation Index	SI	0.44	0.55
Total alkalinity (as $CaCO_3$)	mg/L	147	244
Chloride	mg/L	36	521
Sulfate	mg/L	723	3200
Total hardness (as $CaCO_3$)	mg/L	233	2550
Calcium	mg/L	66	501
Magnesium	mg/L	16	316
Potassium	mg/L	4.7	2.1
Silicon dioxide	mg/L	21.5	20.8
Sodium	mg/L	305	650
Strontium	mg/L	1.9	8.1

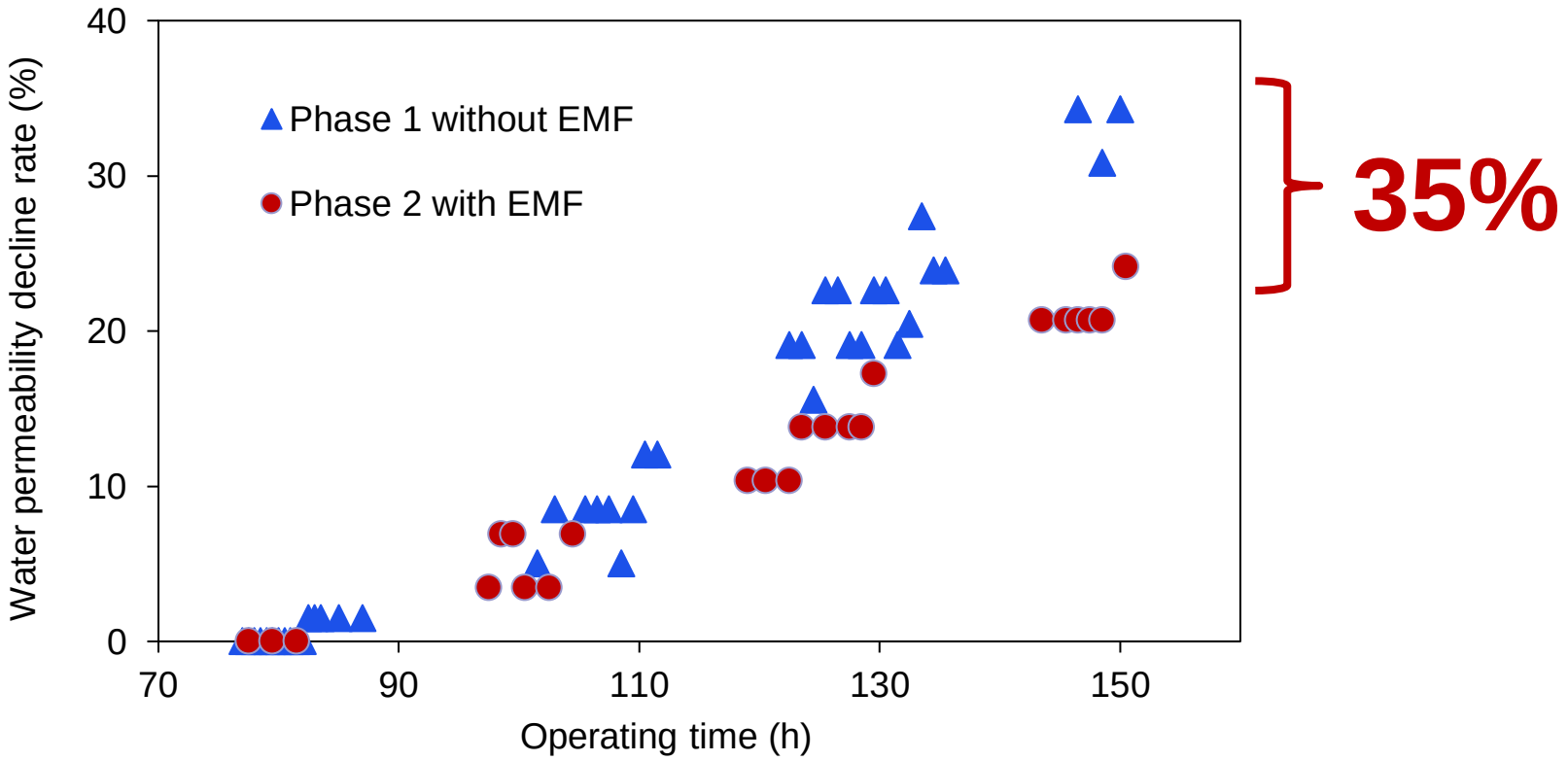
RO Scaling Simulation

- Scaling indices for the RO system based on the ROSA modeling: Well 2 water at 50% water recovery

Parameter	Feed Water	Concentrate
Langelier Saturation Index	1.07	1.80
Stiff & Davis Stability Index	0.69	1.16
Ionic Strength (Molar)	0.14	0.29
$CaSO_4$ (%Saturation)	105	238
$BaSO_4$ (%Saturation)	174	352
$SrSO_4$ (%Saturation)	71	150

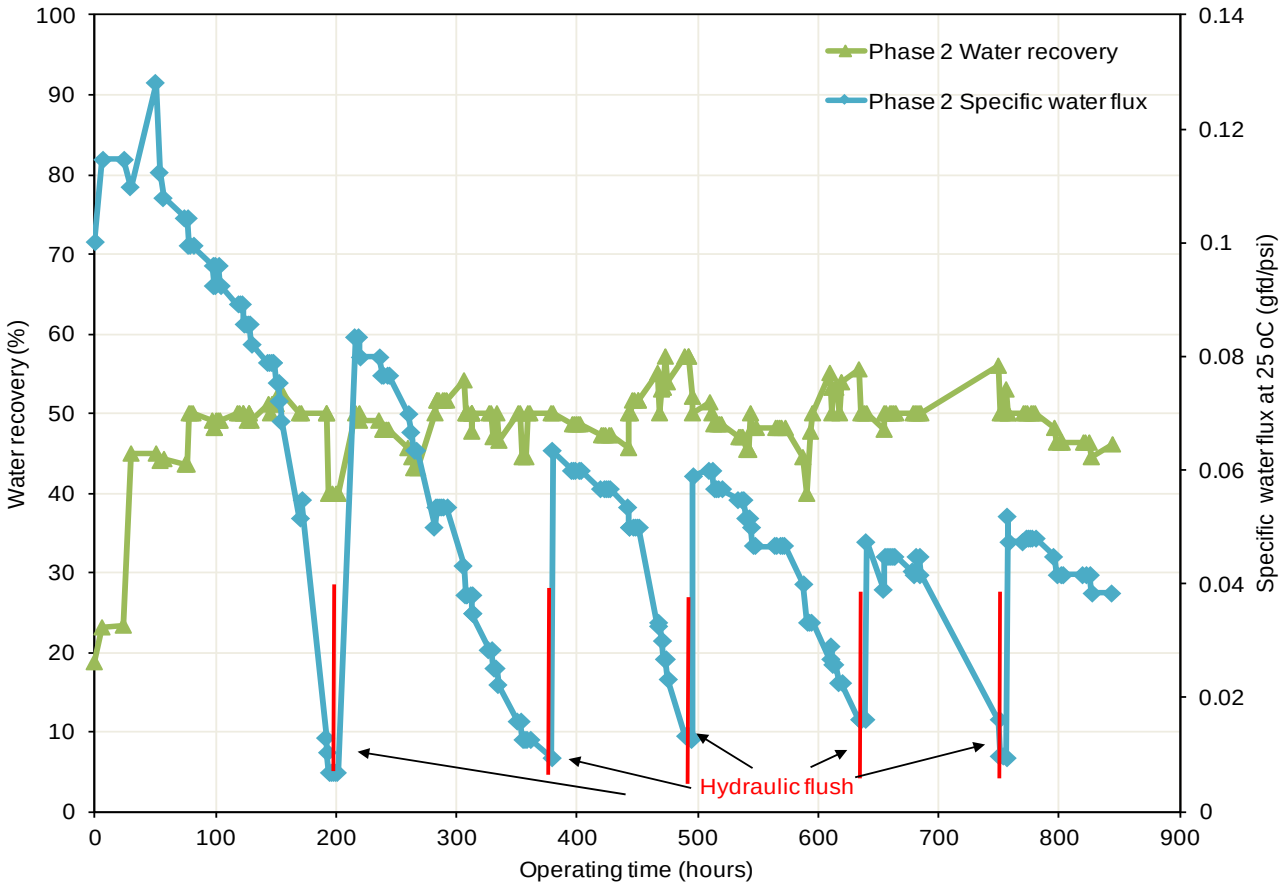
Pilot Testing Results - HydroFLOW

- Membrane flux decline during 150 hr desalination of Well 2 water at 50% water recovery without antiscalant



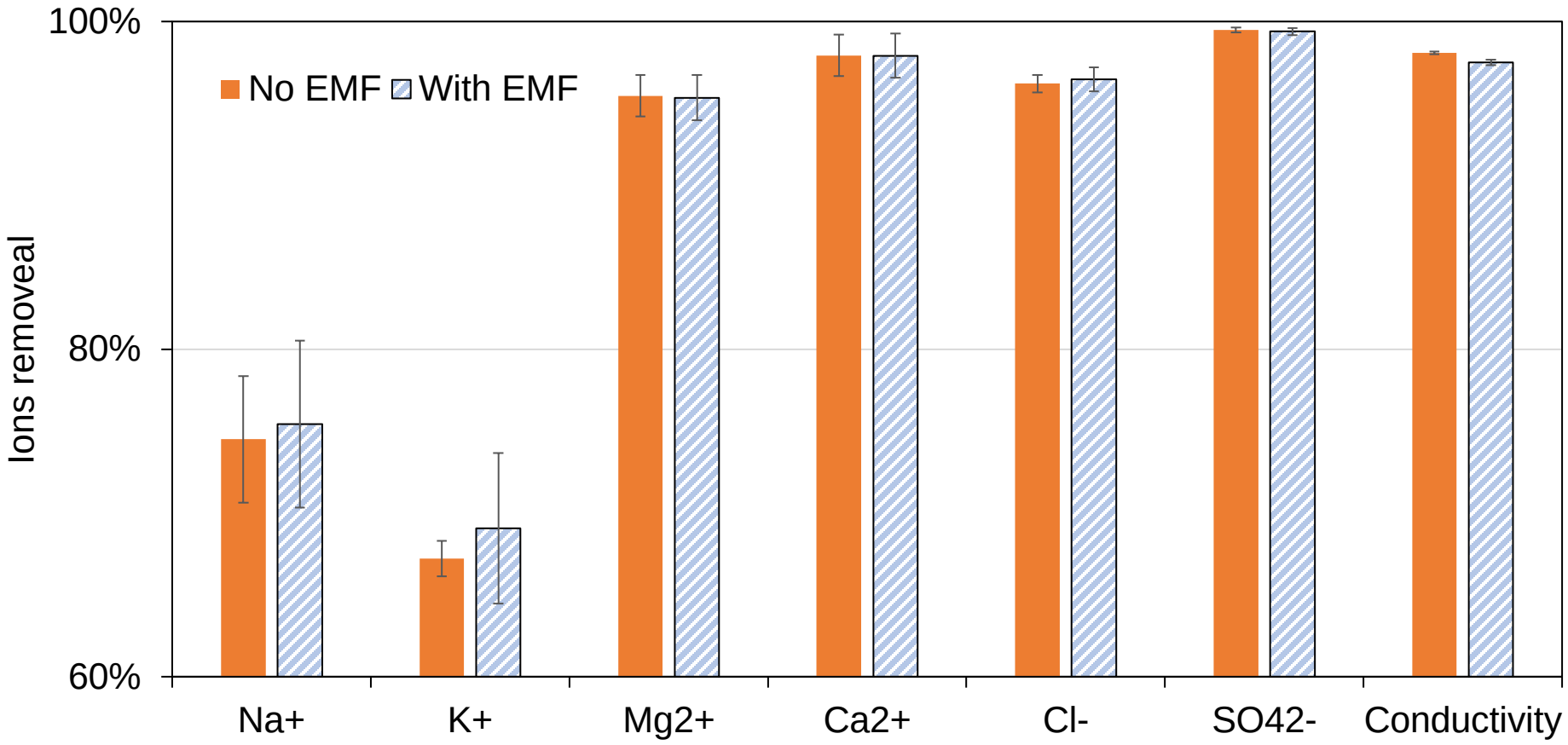
Pilot Testing Results - HydroFLOW

- EMF + Hydraulic flushing partially restore membrane perforn

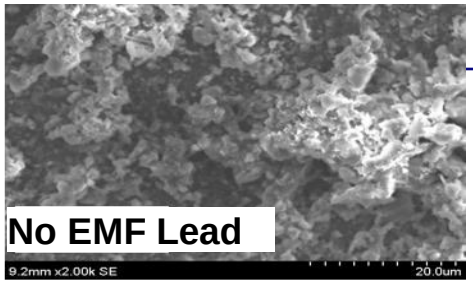


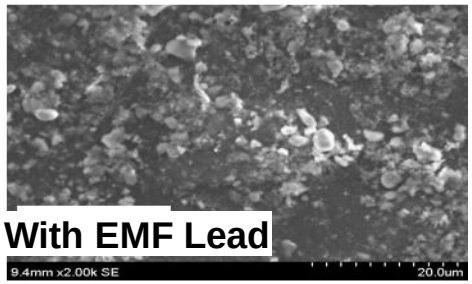
Pilot Testing Results - HydroFLOW

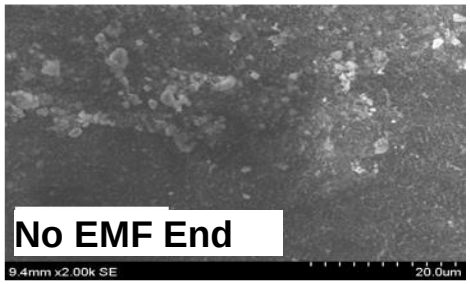
- Product Water Quality

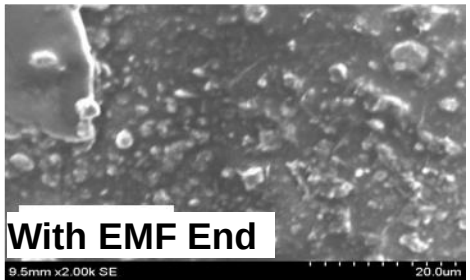


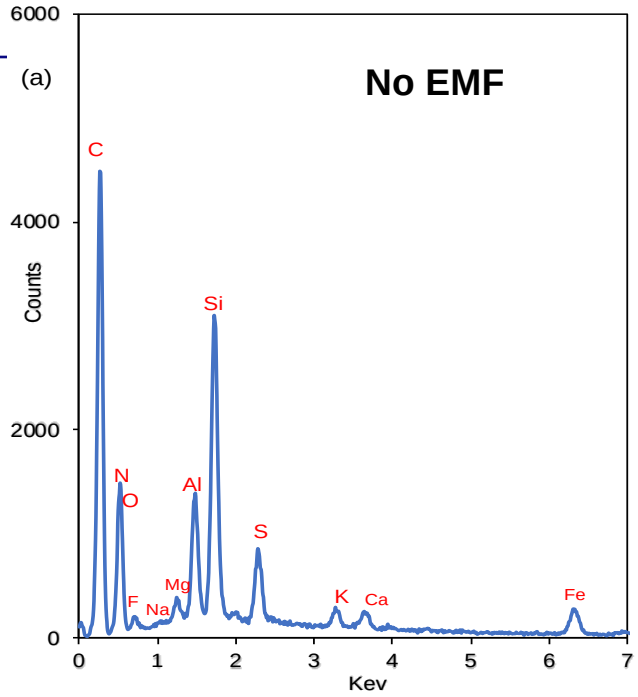
Pilot Testing Results - HydroFLOW

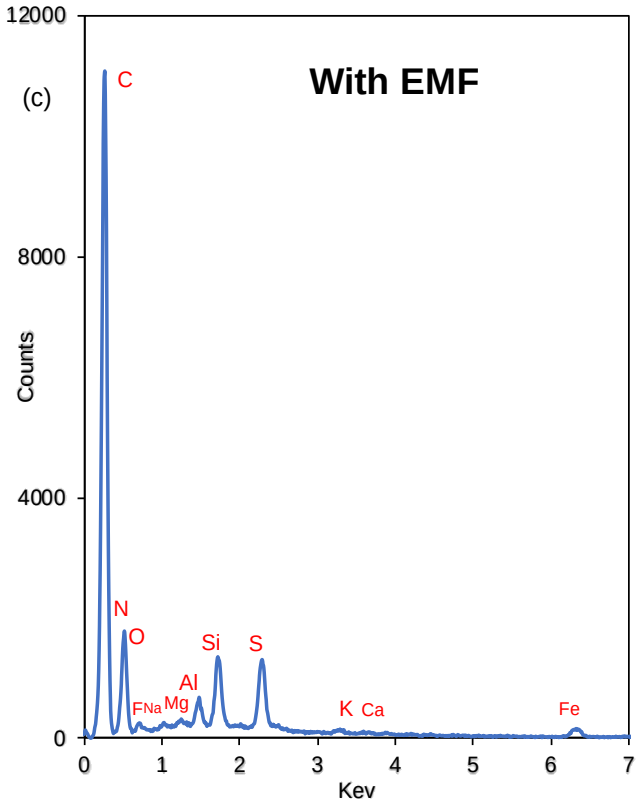










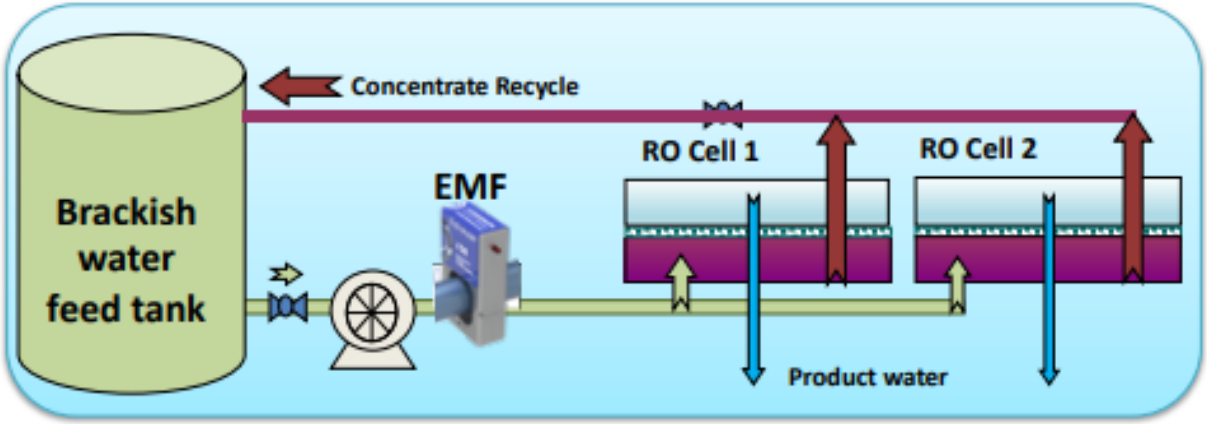


Pilot Testing Results

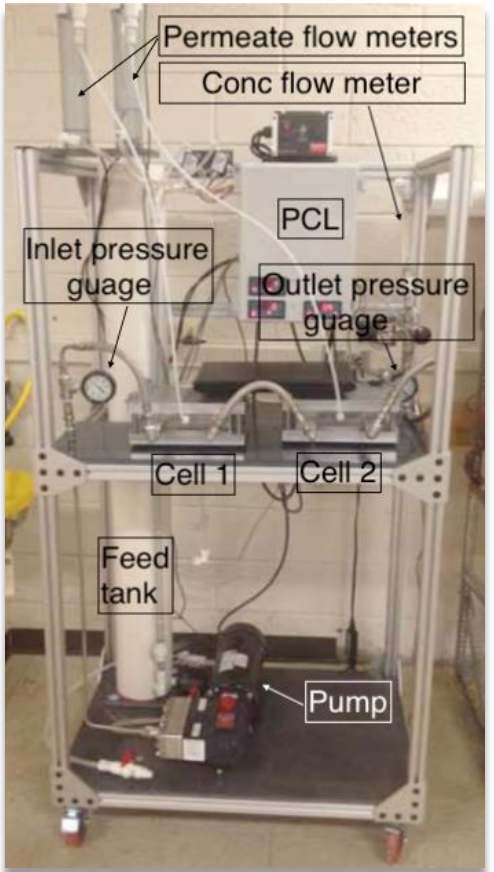
- Clean up the scales in the water pipelines

Bench-Scale Testing

- Impact of EMF on RO membrane fouling and scaling during treatment of secondary effluent and brackish water

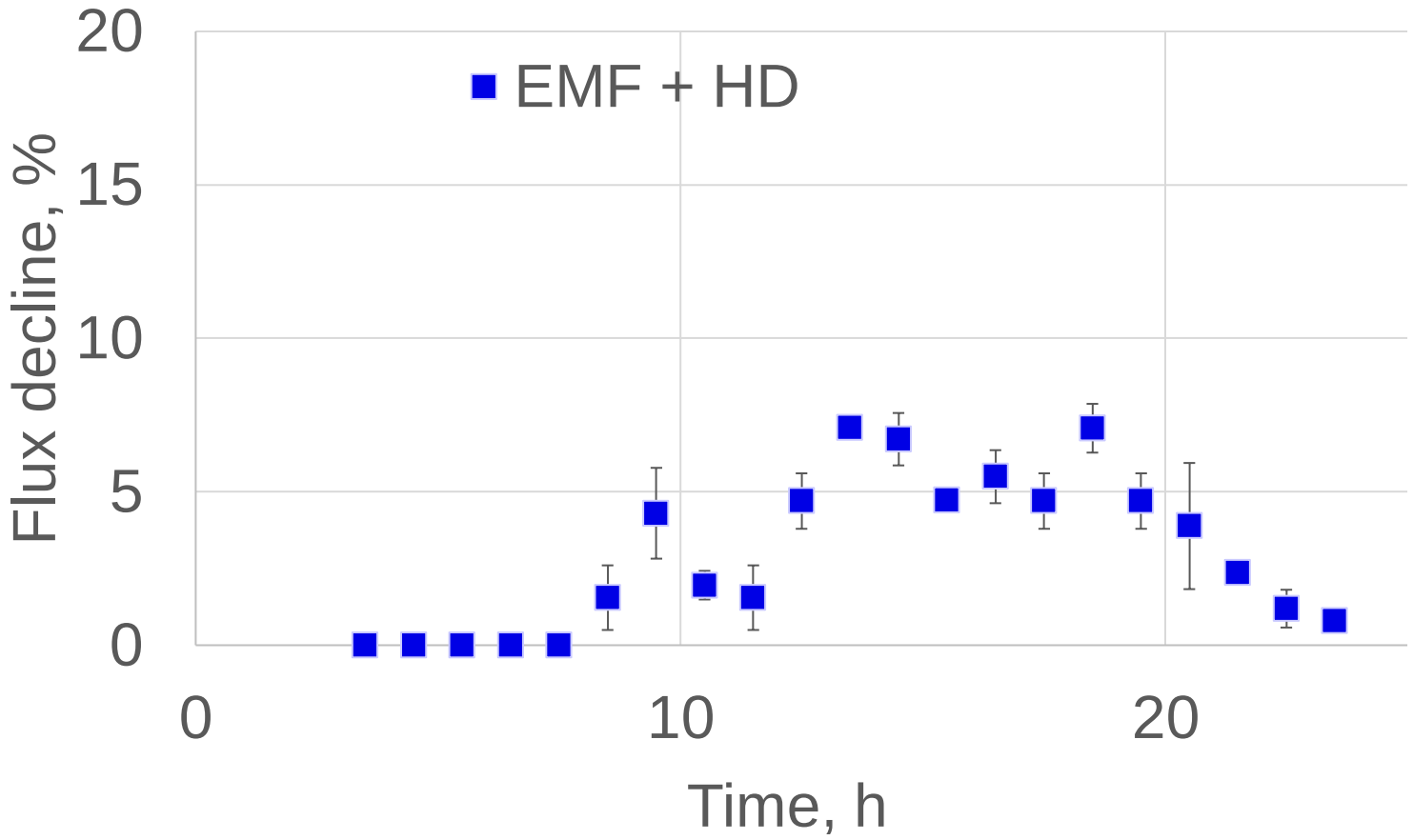


Schematic Diagram



Bench Testing – Secondary Effluent

- EMF + hydraulic flushing can control membrane fouling



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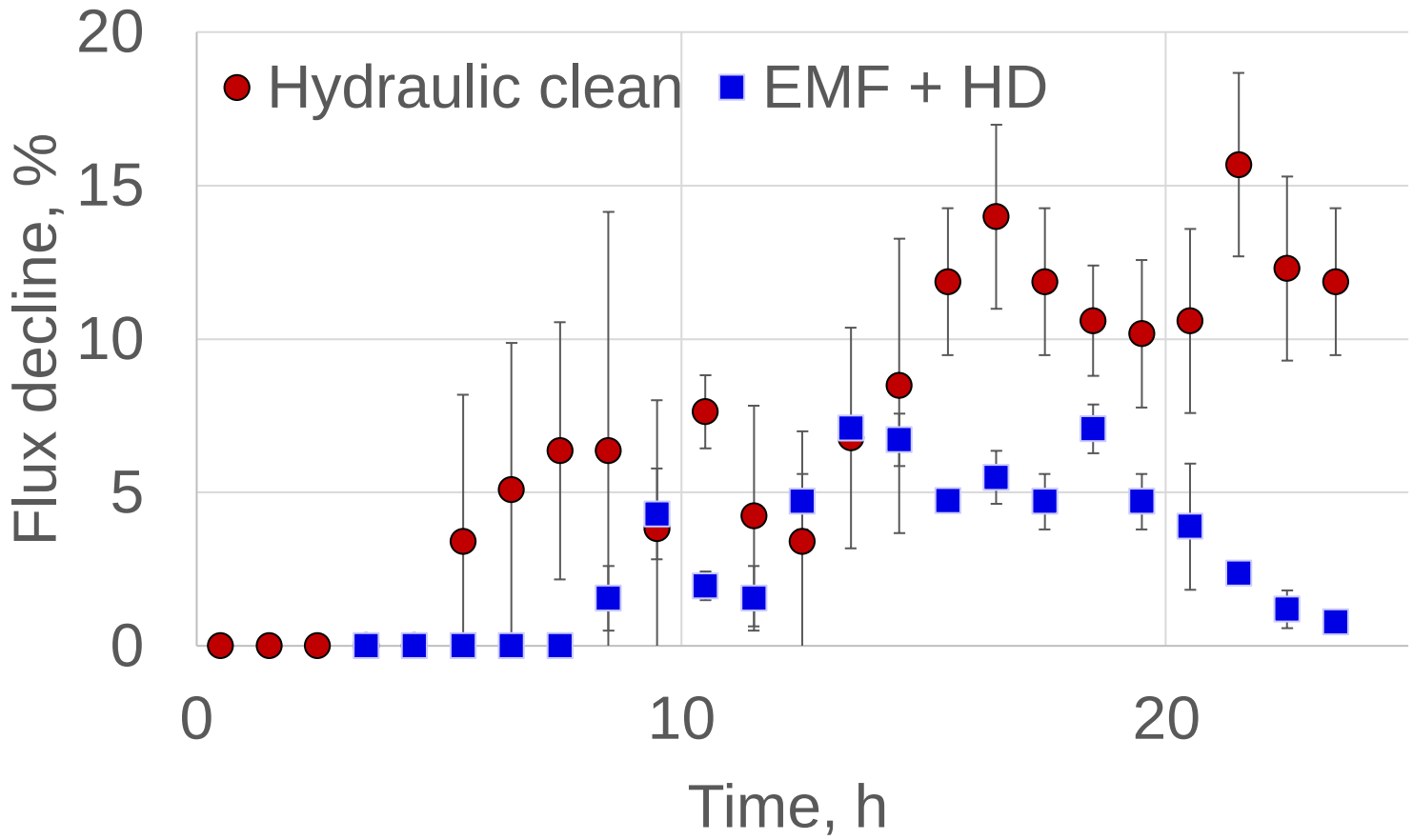
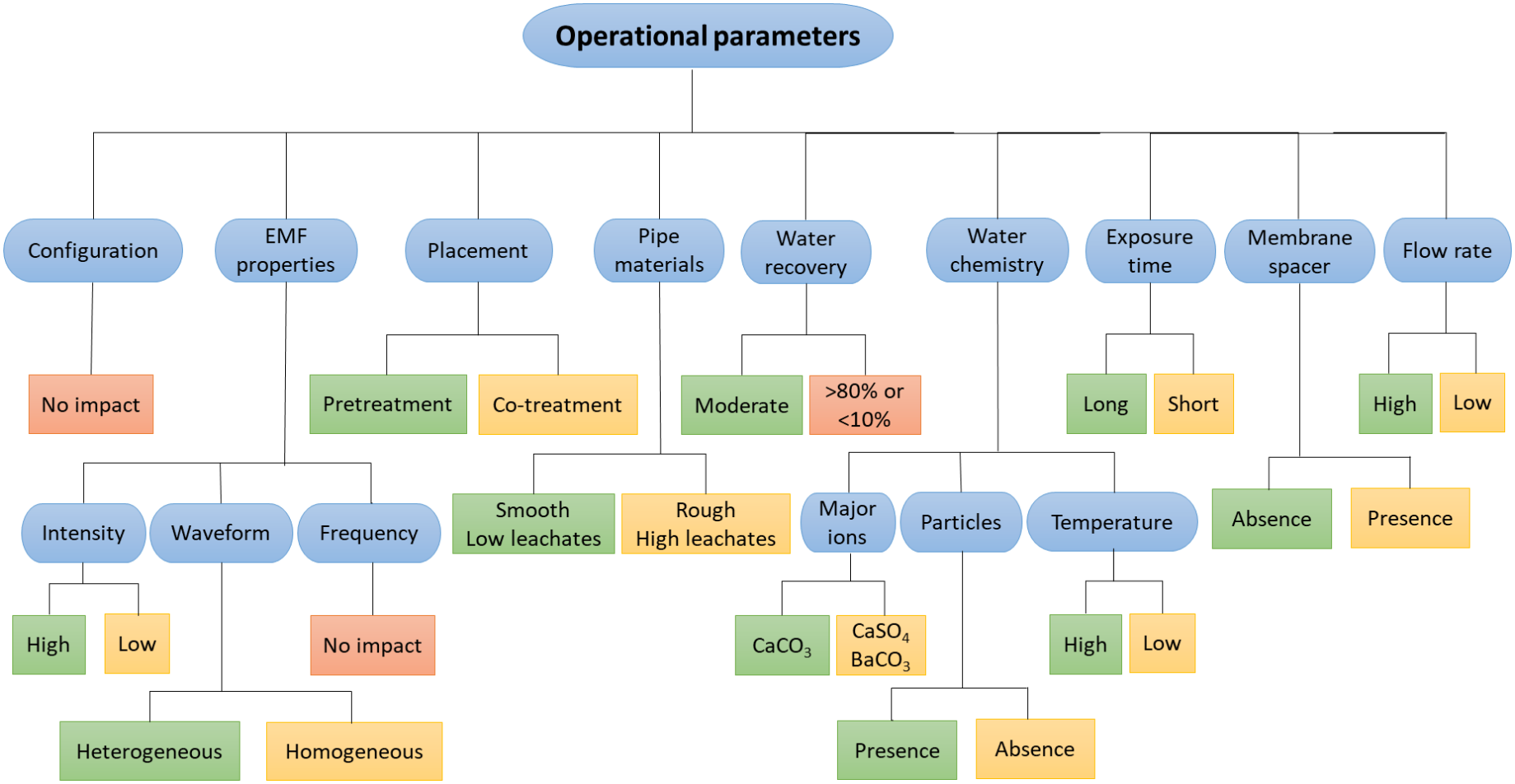


Factors Affecting EMF Effectiveness

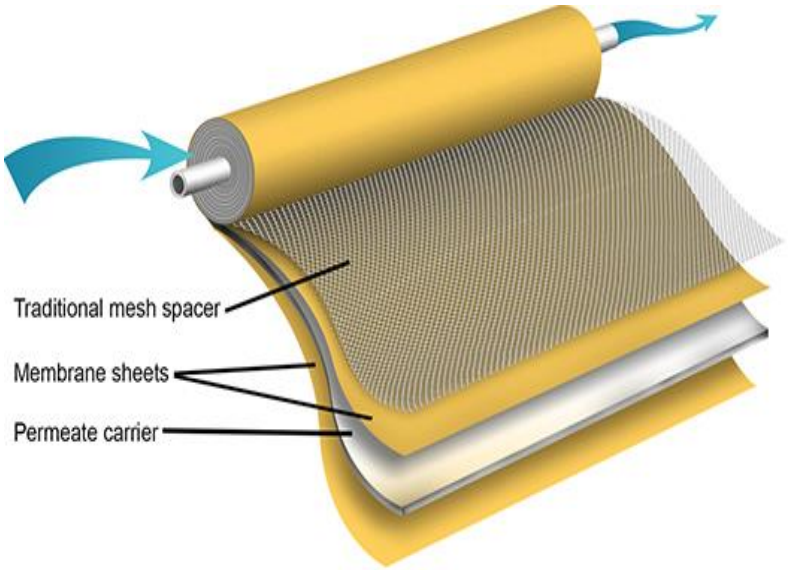


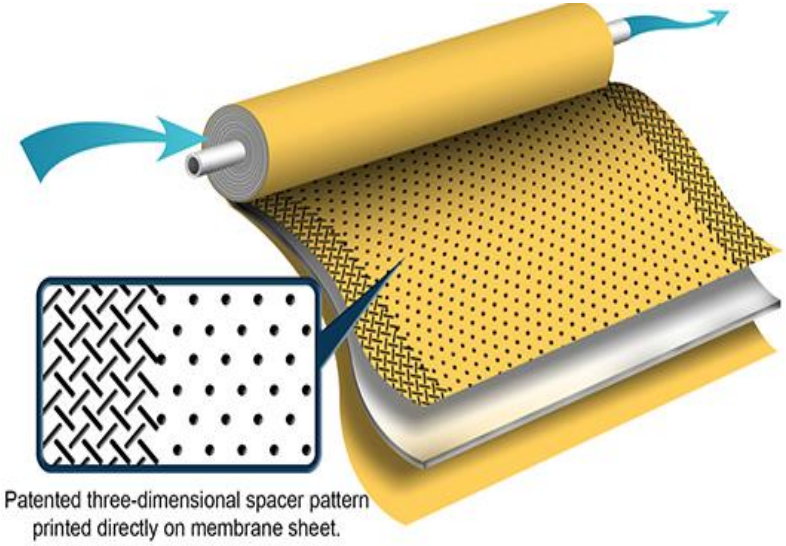
Summary

- EMF requires no or low energy.
- EMF pretreatment can significantly reduce chemical costs, energy, and negative environmental impacts of chemical treatment.
- Reduce initial membrane scaling and fouling by 30-40%.
- Periodic hydraulic flushing + EMF can recover RO membrane performance by removing the foulants loosely accumulated on membrane surface and flow channels.
- Work at moderate water recovery.
- Promote bulk precipitation, spacer design is critical.

Future work

- Evaluate the combination of EMF with 3D printed open flow channel RO membranes to achieve high recovery



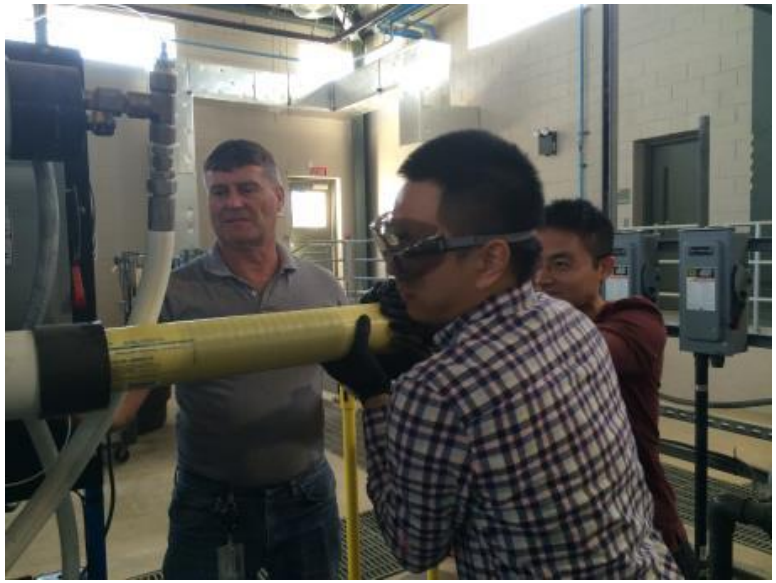


Future work

- Molecular dynamics simulations to gain insights into how the applied electromagnetic fields effect the motions of ions in the fluid. Develop methods to compute polarizabilities, net atomic charges, and force-field simulations on molecular interactions between ions and membranes.
- Sensors to monitor the induction time and particle motions.

Acknowledgements

- Bureau of Reclamation
  - BGNDRF
  - DWPR funding
- El Paso Water
- AquaMembranes
- HydroFLOW
- Eco1st



Thank you!

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