IDA WORLD CONGRESS 2015

DESALINATION & WATER REUSE

Renewable Water Resources to Meet Global Needs

IMPROVED BORON REJECTION USING THIN FILM NANOCOMPOSITE (TFN) MEMBRANES IN SEAWATER DESALINATION

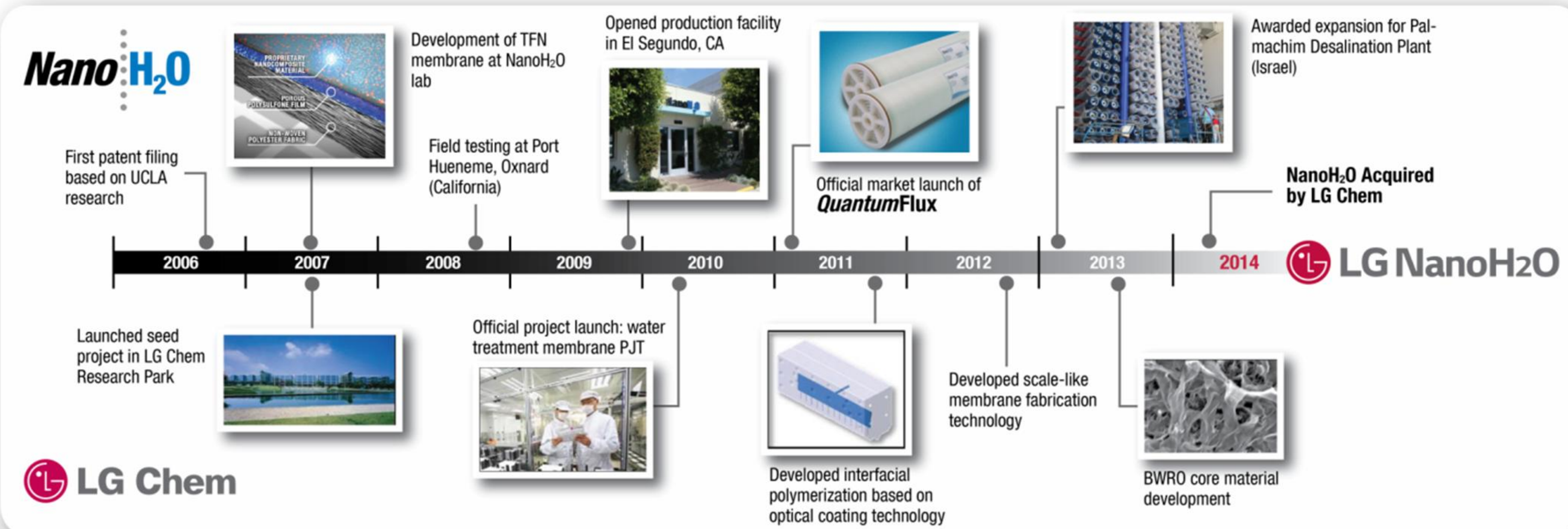
Simon Bae

15WC: 51678

ABOUT LG NanoH2O

- **Mission**
  - To provide customers with the most innovative and highest quality reverse osmosis membrane technology for desalination

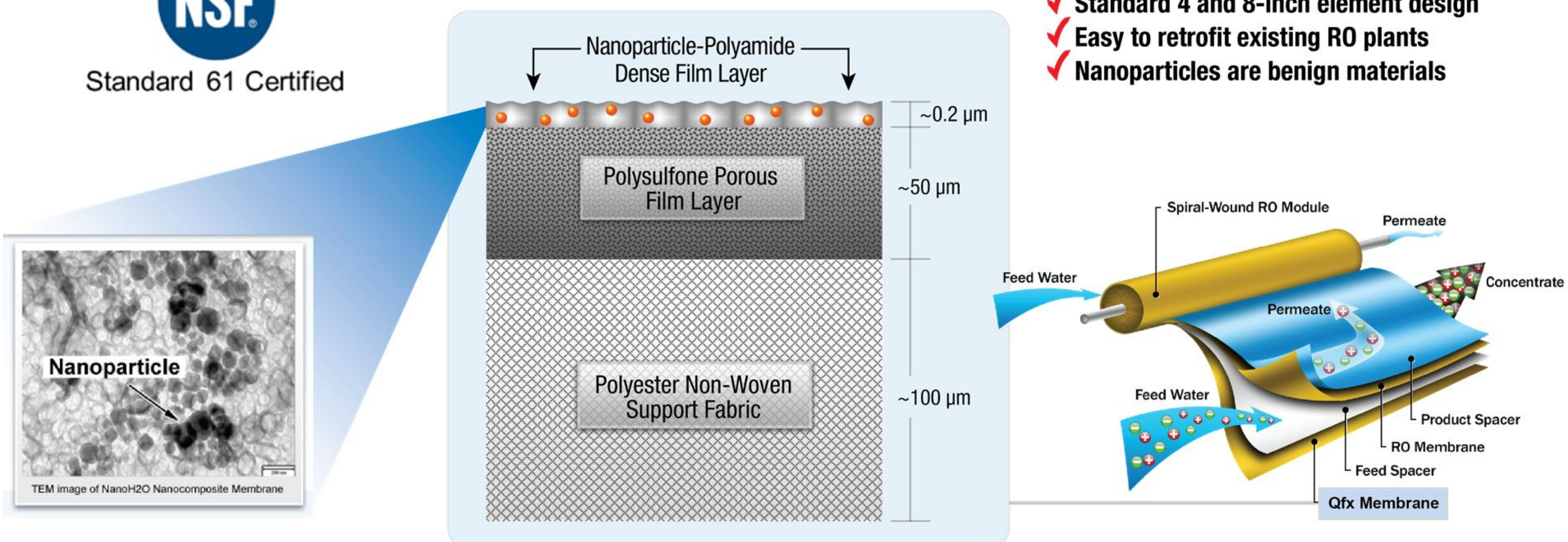
LG NanoH2O TIMELINE



THIN-FILM NANOCOMPOSITE (TFN) MEMBRANE TECHNOLOGY

NSF Standard 61 Certified

- ✓ Best-in-class flux and salt rejection
- ✓ Standard 4 and 8-inch element design
- ✓ Easy to retrofit existing RO plants
- ✓ Nanoparticles are benign materials



I. Introduction

BORON REJECTION IN SEA WATER DESALINATION

- ✓ Drinking water requires less than 2.4 ppm boron (World Health Organization).
- ✓ However, certain applications still have stringent boron requirement less than 1 ppm.
- ✓ Typical SWRO membranes achieve over 99% salt rejection.
- ✓ However, element boron rejection remains low at 85% - 95%.
- ✓ Typical methods to improve boron rejection:
  - Alkalization of feed solution (pH adjustment)
  - Post-treatment of the first pass RO permeate in the second pass

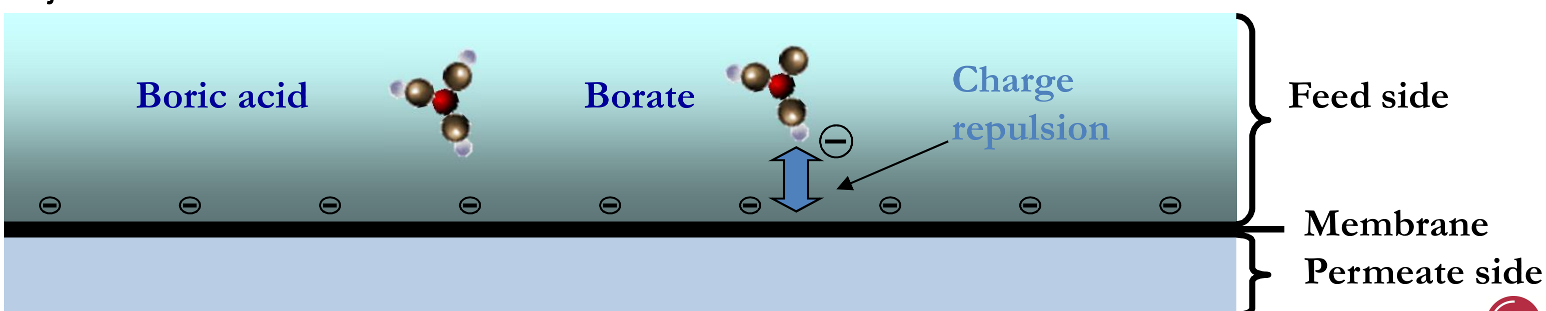
BORON TRANSPORT MECHANISM

Nano H2O

- ✓ In natural conditions, boron exists in form of boric acid (H_3BO_3) and Borate ($H_2BO_3^-$).
- ✓ Ionic equilibrium of boric acid is represented as below, where *pKa1* is approx.8.6 in typical sea water.

$$H_3BO_3 \xleftrightarrow{K_{a1}} H_2BO_3^- + H^+,\ pK_{a1} = -\log_{10}\frac{[H_3BO_3]}{[H_3BO_3][H^+]}$$

- ✓ RO membranes has relatively lower rejection of boric acid while they can remove borate ions efficiently mainly due to the charge repulsion.
- ✓ Typical seawater pH ranges between 7.0 – 8.0 and most of boron exists as boric acid → Lower boron rejection.



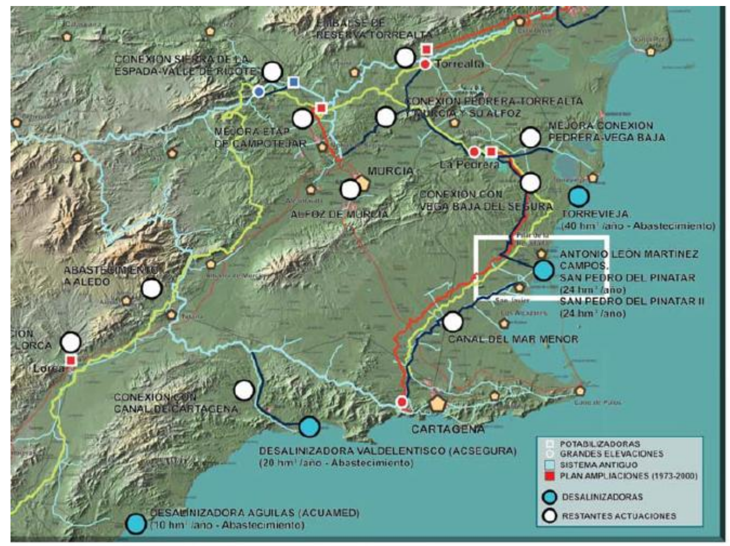
LG Chem

II. Project Background

PROJECT OVERVIEW

Nano H$_2$O

- Objective: Verify boron removal performance of Thin Film Nanocomposite membrane
- Test Site: San Pedro del Pinatar II Desalination Plant, Township of El Mojon, Murcia, Spain
- Test Period: Sep. 2014 to Dec. 2014



LG Chem

SAN PEDRO DEL PINATAR II SWRO PLANT

NanoH2O

End-User:	MCT
Location:	Murcia, Spain
Commissioned:	Feb. 2015
Recovery:	45%
Plant Capacity:	65 MLD (12,000 GPM)
No of Trains:	9

San Pedro del Pinatar 2 Desalination Plant

PILOT UNIT – START UP OPERATING CONDITIONS

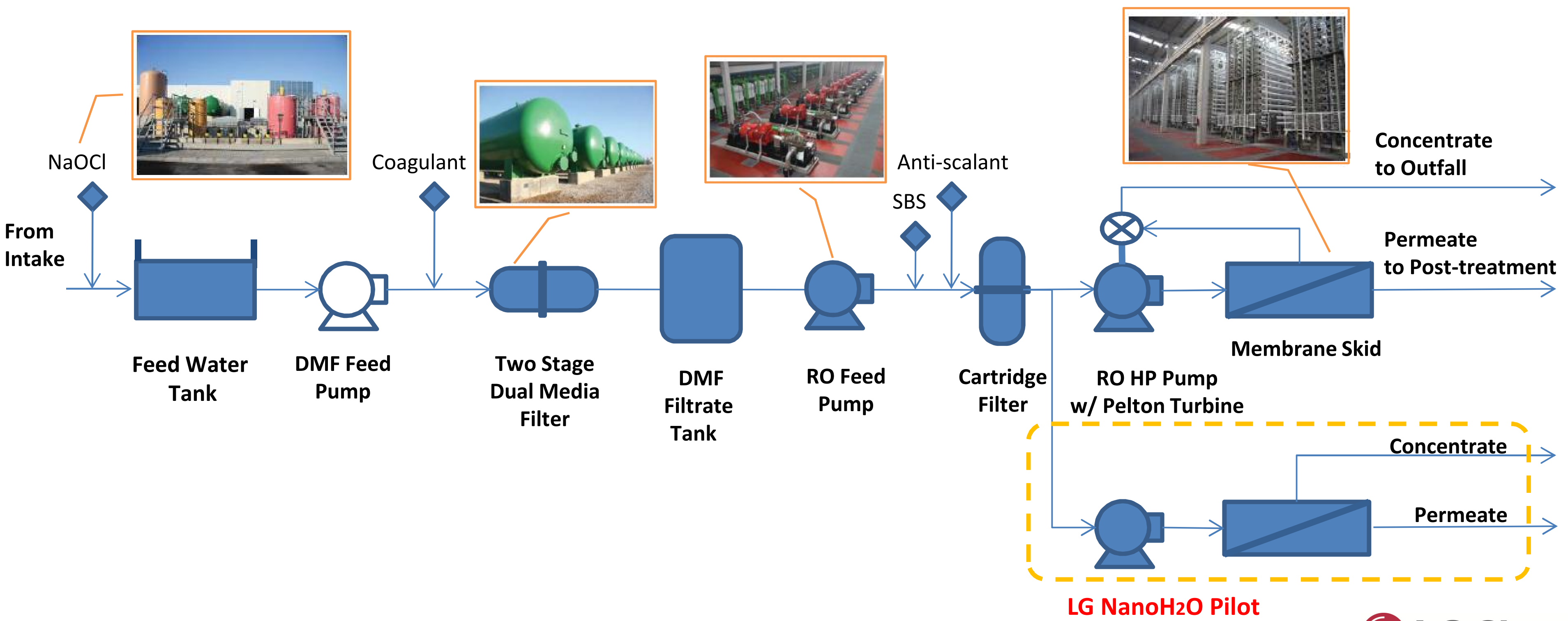
Nano H2O

Feed Flow:	6.6 m^3/h
Brine Flow:	3.6 m^3/h
Permeate Flow:	3.0 m^3/h
Pilot Unit Configuration:	Single Pressure Vessel, 7 elements
Feed Temperature Range:	Up to 27.5 ºC
Membrane Model:	LG SW 440 SR

Pilot Test Equipment

SAN PEDRO DEL PINATAR II SWRO PLANT

NanoH2O



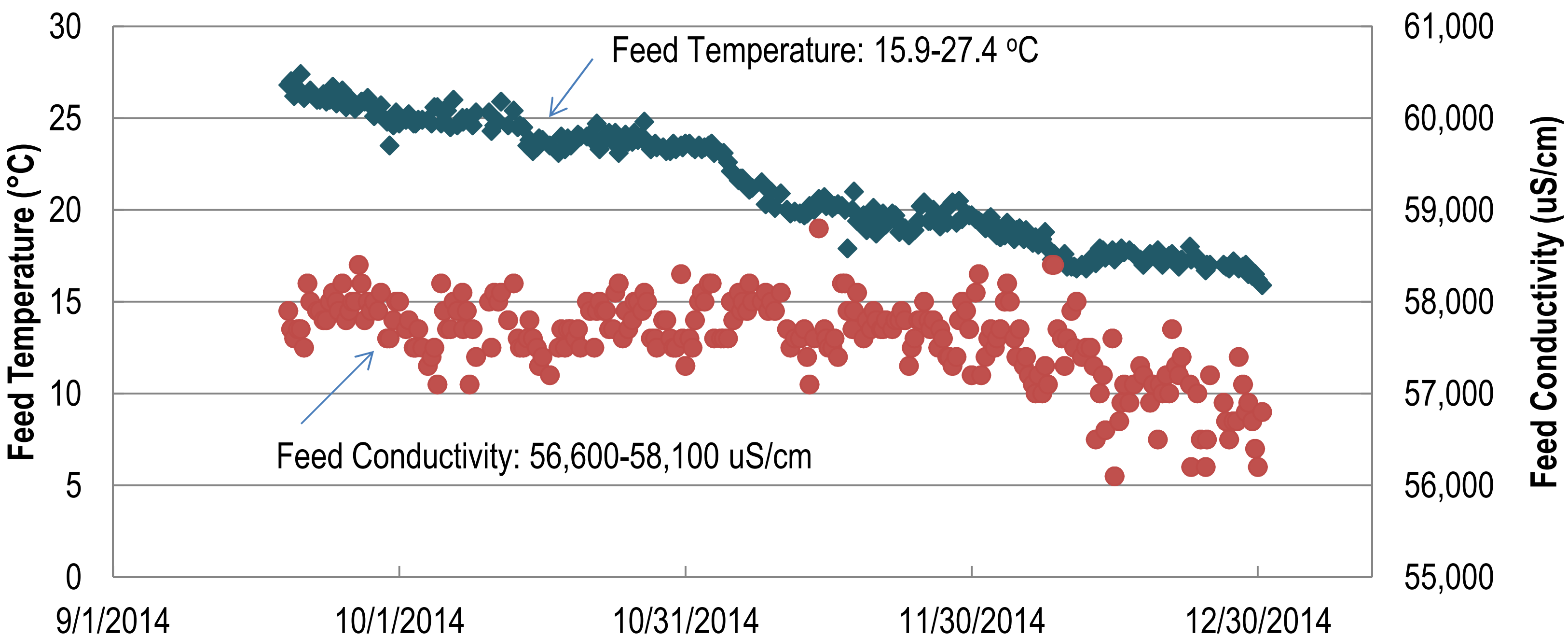
LG Chem

NanoH2O

IV. Results and Discussions

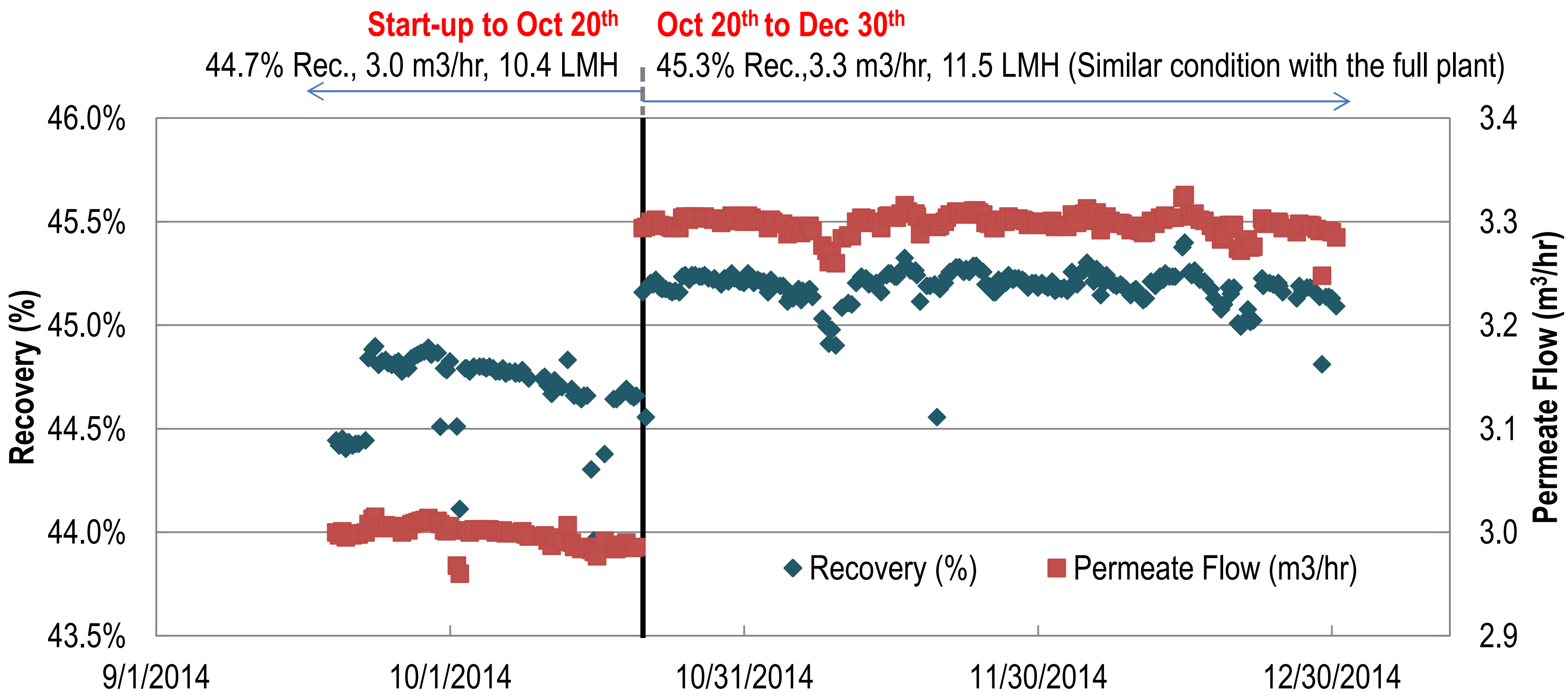
LG Chem

FEED WATER CONDITION

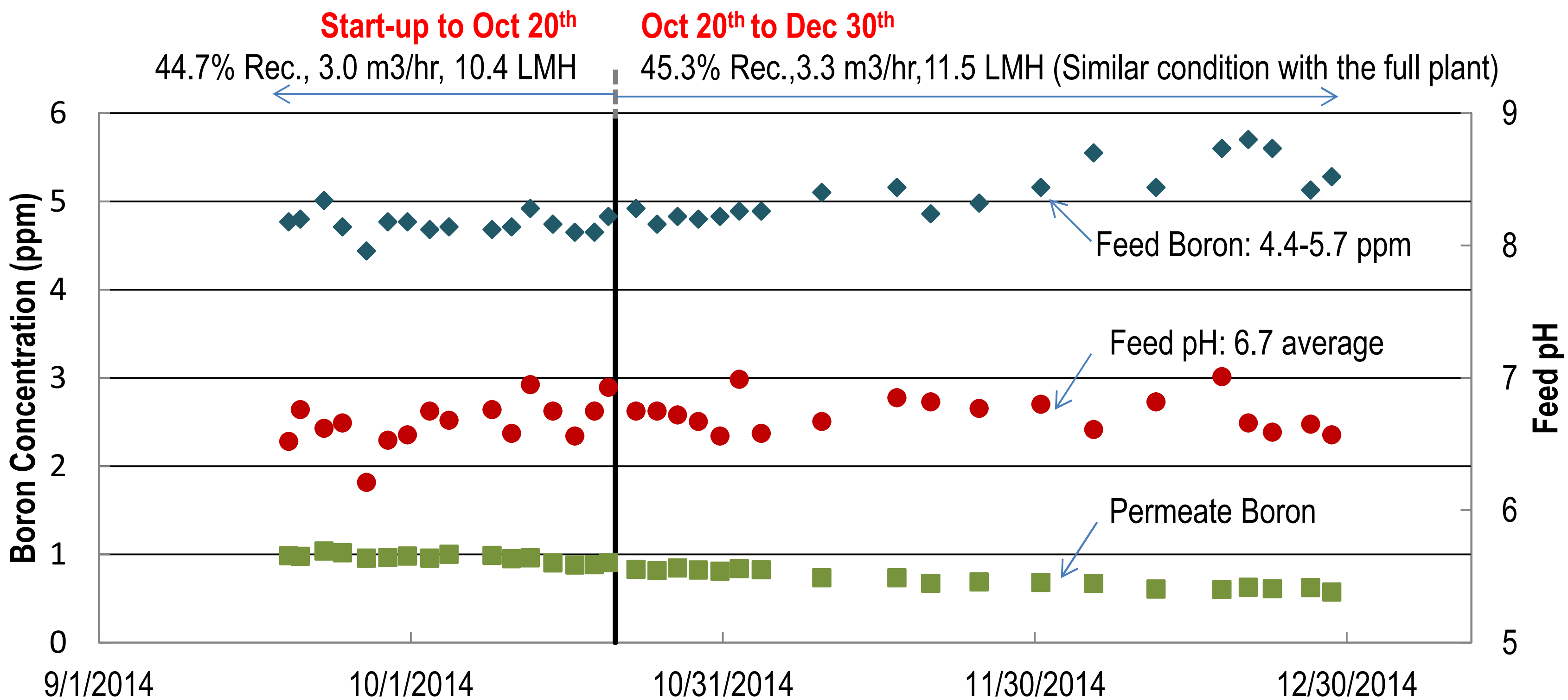


OPERATING CONDITIONS

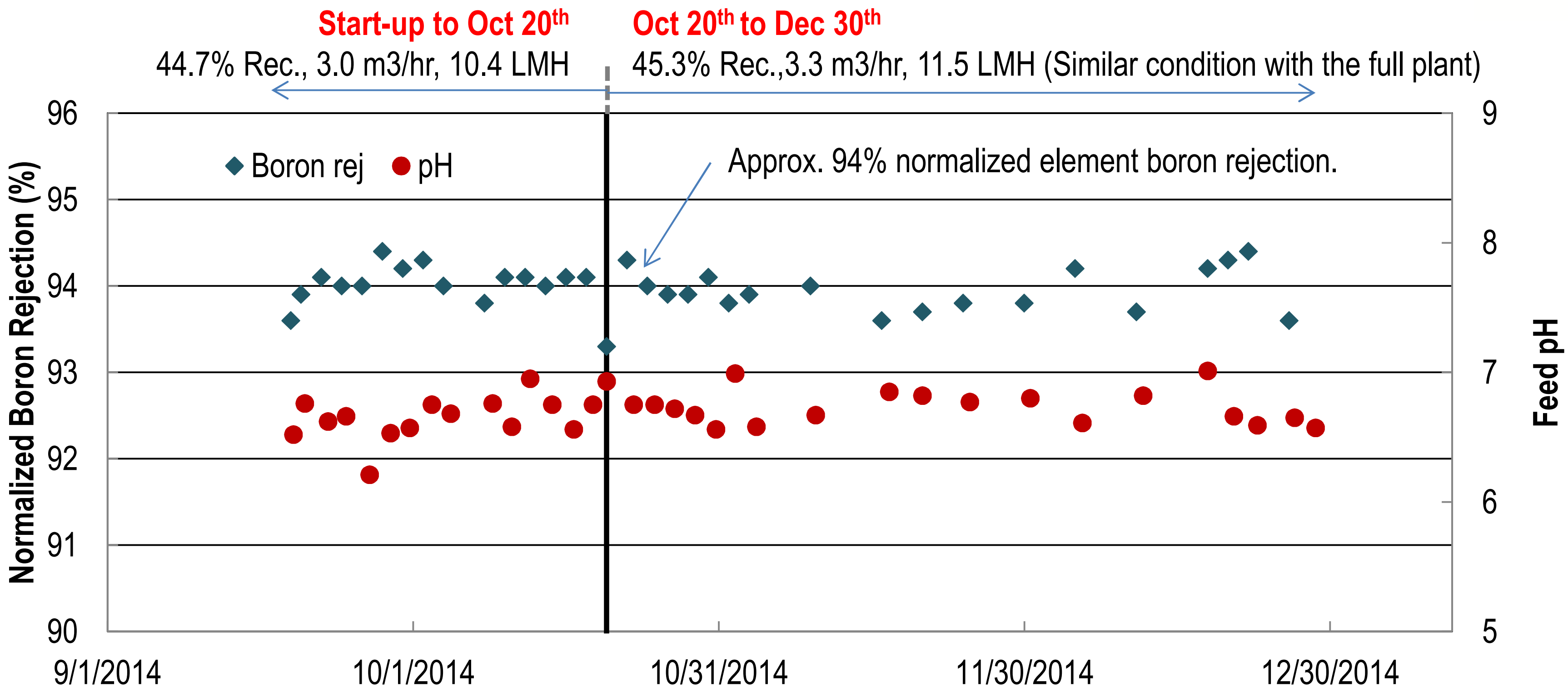
NanoH2O



BORON REJECTION PERFORMANCE



NORMALIZED ELEMENT BORON REJECTION

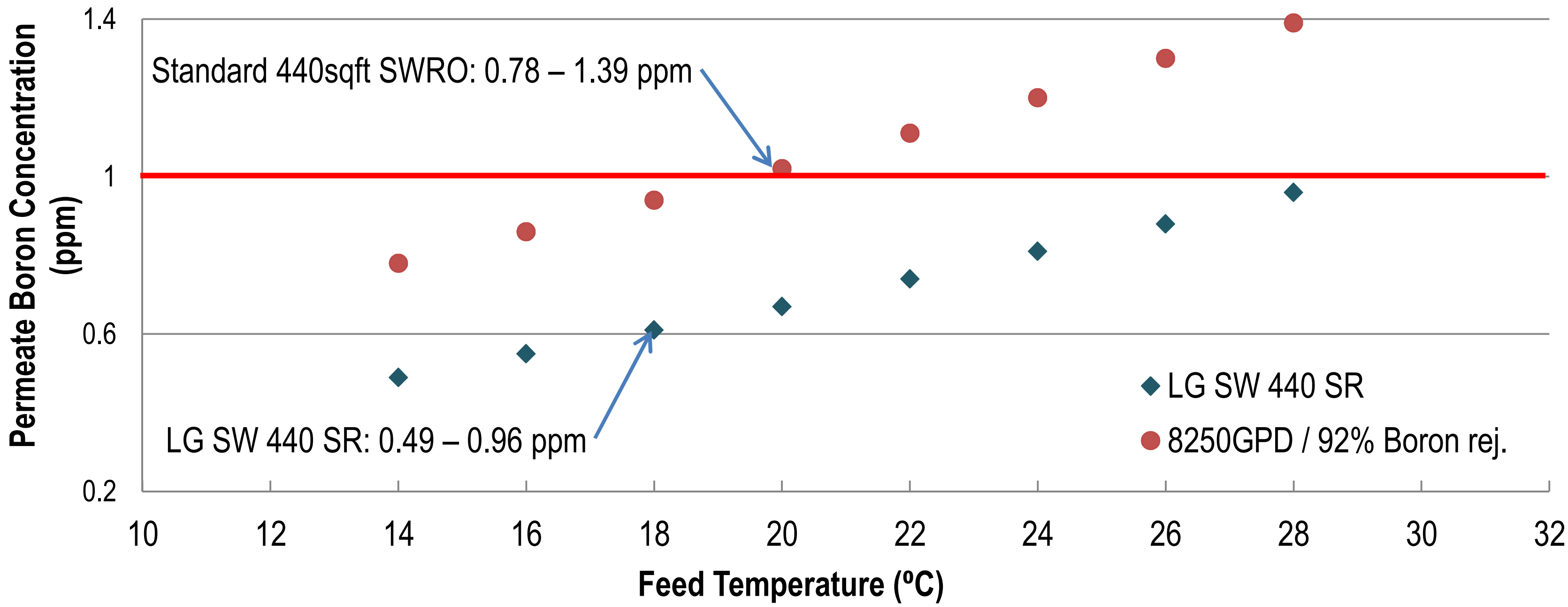


* Boron rejection normalized using LG NanoH2O's Q+ software under standard SWRO element test condition: 800 psi, 32,000 ppm NaCl, 5 ppm Boron, 8% recovery, pH 8, and 25 C

COMPETITIVE ANALYSIS

Nano H_2O

✓ LG SW 440 SR vs Commercially available 440sqft SWRO Membrane (8,250gpd / 92% Boron rej.)



* Operating Condition: 10MLD Capacity, 40k ppm SW, 5ppm Boron, pH 6.7, 45% Rec., 11.5lmh Ave. flux

- Design Configuration: 100 PV's (7) 440 sqft SWRO

LG Chem

COST BENEFIT ANALYSIS – SAN PEDRO II PINATAR PLANT

NanoH2O

- ✓ With standard 440-sqft SWRO (8,250 gpd, 99.80% salt rejection., 92% boron rejection.) membrane
  - pH adjustment up to 8 is required at temperature above 22 ºC *, to achieve less than 1 ppm permeate boron

- ✓ Estimated Annual Caustic Cost at San Pedro del Pinatar II Plant

Production Capacity	65 MLD
Recovery	45%
Raw Feed	144 MLD
Caustic Dosing to Adjust pH 6.7 to 8.0	25 mg/l
Daily Caustic Consumption	3,600 kg
Caustic Chemical Cost	$0.5/kg
Daily Caustic Cost	$1,800
Annual Caustic Cost **	**$219,000**

* Calculated using LG NanoH2O's Q+ Projection Software
** Assuming 33.3% of the time temperature exceeds 22 ºC

LG Chem

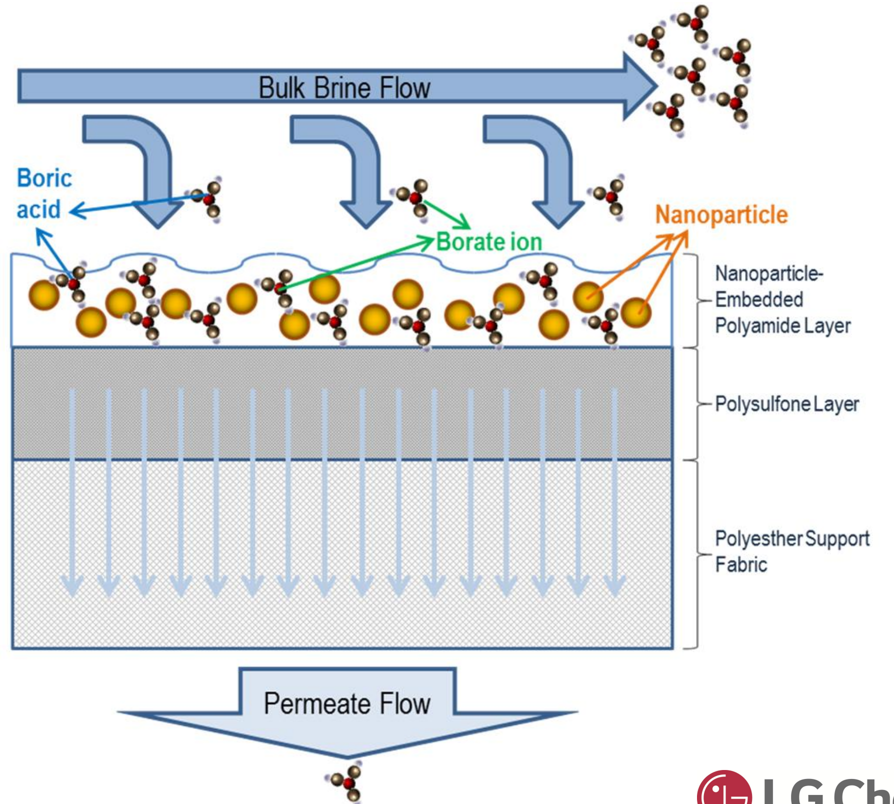
V. Conclusion

ENHANCED BORON REJECTION MECHANISM USING NANOTECHNOLOGY

1. Binding of the boron
2. Boron sites become saturated due to the binding effect
3. Lowered boron concentration gradient (ΔC) between the membrane and concentrate*
4. Lowered ΔC promotes less boron transfer from brine to permeate
5. Results in enhanced boron rejection of Thin Film Nano-composite (TFN) membranes

$$* Q_S = B \,.\, S.\, (C_{fc} - C_p)$$

- Q_S: Salt Flow
- B: Salt Diffusion Coeff.
- S: Total membrane area
- $(C_{fc} - C_p)$: ΔC = Concentration Gradient



CONCLUSIONS

Nano H2O

- ✓ Boron removal performance of TFN membrane was verified form the pilot test at San Pedro del Pinatar II.
- ✓ TFN SWRO membrane could achieve less than 1 ppm permeate boron under all the operation conditions without pH adjustment.
- ✓ TFN SWRO membrane could achieve a normalized boron rejection of 94%.
- ✓ With the high boron rejection of TFN membranes, operation cost saving associated with chemical (caustic) dosing can be obtained ($220k in case of San Pedro del Pinatar II).

ACKNOWLEDGEMENT

- David Kim-Hak (co-author)
- Mike B. Dixon (co-author)
- Esther Lorenzo Jaudenes (co-author)
- San Pedro del Pinatar II Desalination Plant
- AYESA
- Mancomunidad de Canales del Taibilla (MCT)