2015 Membrane Technology
CONFERENCE & EXPOSITION

USING THIN FILM NANOCOMPOSITE (TFN) BRACKISH WATER REVERSE OSMOSIS MEMBRANES TO PROVIDE GREATER CONFIDENCE FOR NDMA REMOVAL

Dr Mike Dixon

LG NanoH_2O

America's Authority in Membrane Treatment
AMTA
American Membrane Technology Association
Improving America's Waters Through Membrane Treatment and Desalting

American Water Works Association
Dedicated to the World's Most Important Resource™

Summary

1. Introduction to LG NanoH_2O and TFN Membranes
2. Membranes and Organic Micropollutants (OMs)
3. Nitrosamines (NDMA)
4. Nitrosamine Removal by TFN Membranes
5. Summary and Conclusions

1. Introduction to LG NanoH_2O and TFN Membranes

Mission

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

Quick Facts

- Licensed original technology in 2005 from University of California, Los Angeles
- Intellectual property includes 43 patents and patent applications
- Headquarters, manufacturing and R&D facility located in Los Angeles, California, USA
- Approximately 100 employees
- Membranes installed in over 400 plants across 40 countries, producing more than 300,000 cubic meters per day of fresh water
- **In April 2014, LG Chem acquired NanoH_2O**

LG NanoH2O

LG Group

Management Philosophy

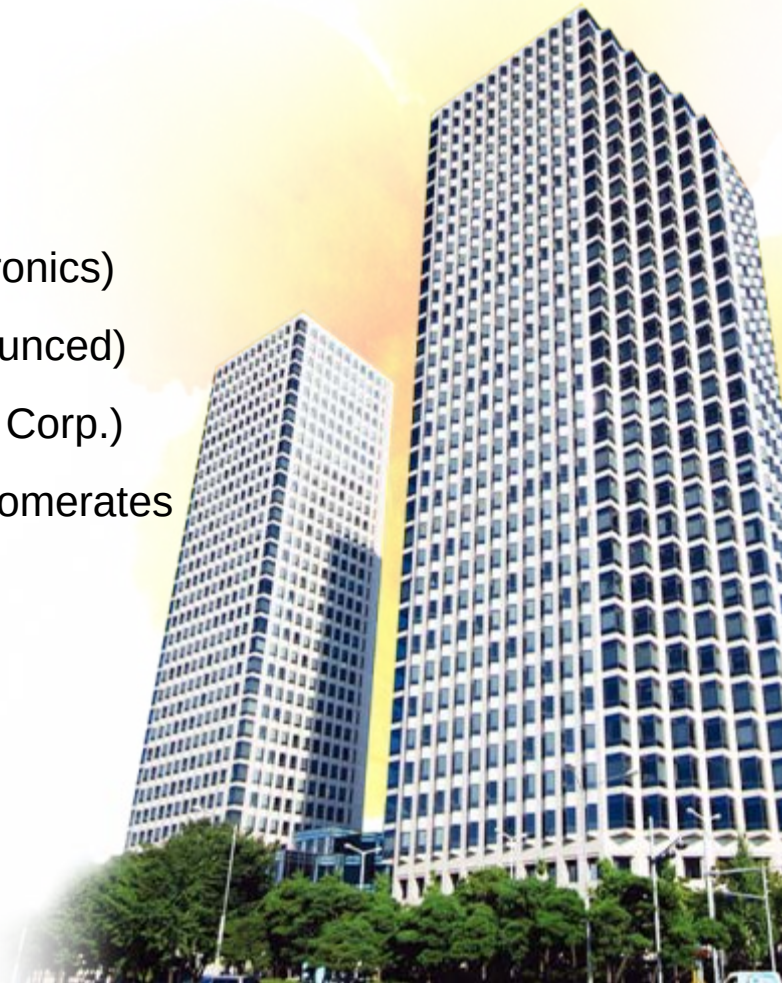
- Creating value for customers
- Management based on esteem for human dignity

History

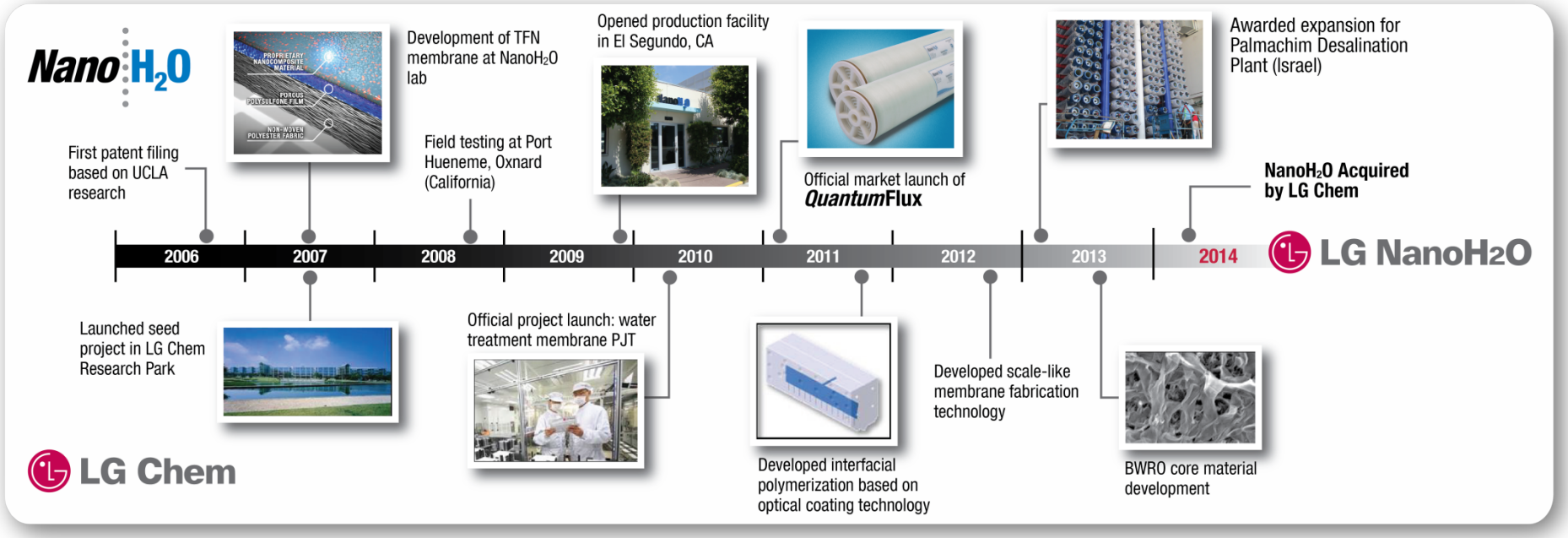
- 1947: LG founded by establishing Lak Hui (Lucky) Chemical Industrial Corp. (now LG Chem)
- 1958: Established Goldstar Co., Ltd. (now LG Electronics)
- 1995: Lucky Goldstar renamed as LG (new CI announced)
- 2003: Launched the holding company structure (LG Corp.)
- 2005: LG and GS divided as two independent conglomerates

Sales in 2013: USD 103 Billion

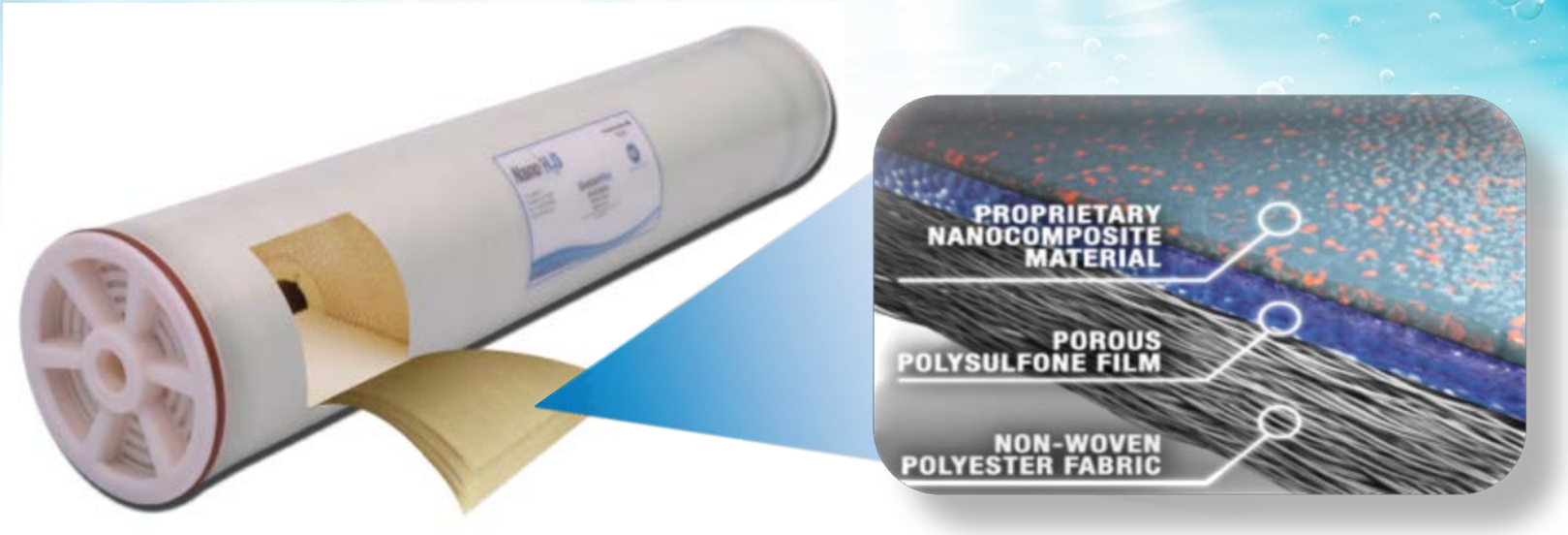
Workforce: 226,400 employees



Our History


NanoH2O
PROPRIETARY NANOCOMPOSITE MATERIAL
POROUS POLYSULFONE FILM
NON-WOVEN POLYESTER FABRIC
Development of TFN membrane at NanoH2O lab
Opened production facility in El Segundo, CA
Awarded expansion for Palmachim Desalination Plant (Israel)
First patent filing based on UCLA research
Field testing at Port Hueneme, Oxnard (California)
Official market launch of QuantumFlux
NanoH2O Acquired by LG Chem
2006
2007
2008
2009
2010
2011
2012
2013
2014
LG NanoH2O
Launched seed project in LG Chem Research Park
Official project launch: water treatment membrane PJT
Developed scale-like membrane fabrication technology
Developed interfacial polymerization based on optical coating technology
BWRO core material development
LG Chem

Thin-Film Nanocomposite Membrane Technology



- ✓ First RO membrane innovation in 25 years
- ✓ 50-100% more permeable than existing polymer technology
- ✓ Improves best-in-class salt rejection
- ✓ Drop-in replacement for existing membranes
- ✓ 16 Patents / 27 Applications in 11 Countries

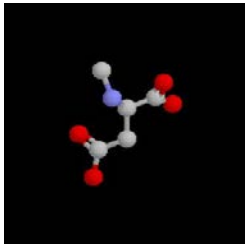
LG NanoH2O

How is TFN Membrane Technology Different?

- Nanoparticles are embedded in the surface of the polyamide membrane to boost flux without causing loss of rejection.
- High flux TFN membranes use less energy
- Surface can be ‘tuned’ for either high flux or high rejection
- TFN cleans the same as Thin-Film Composite (TFC)
- TFN has the same chlorine resistance as TFC

2. Membranes and Organic Micropollutants (OMs)

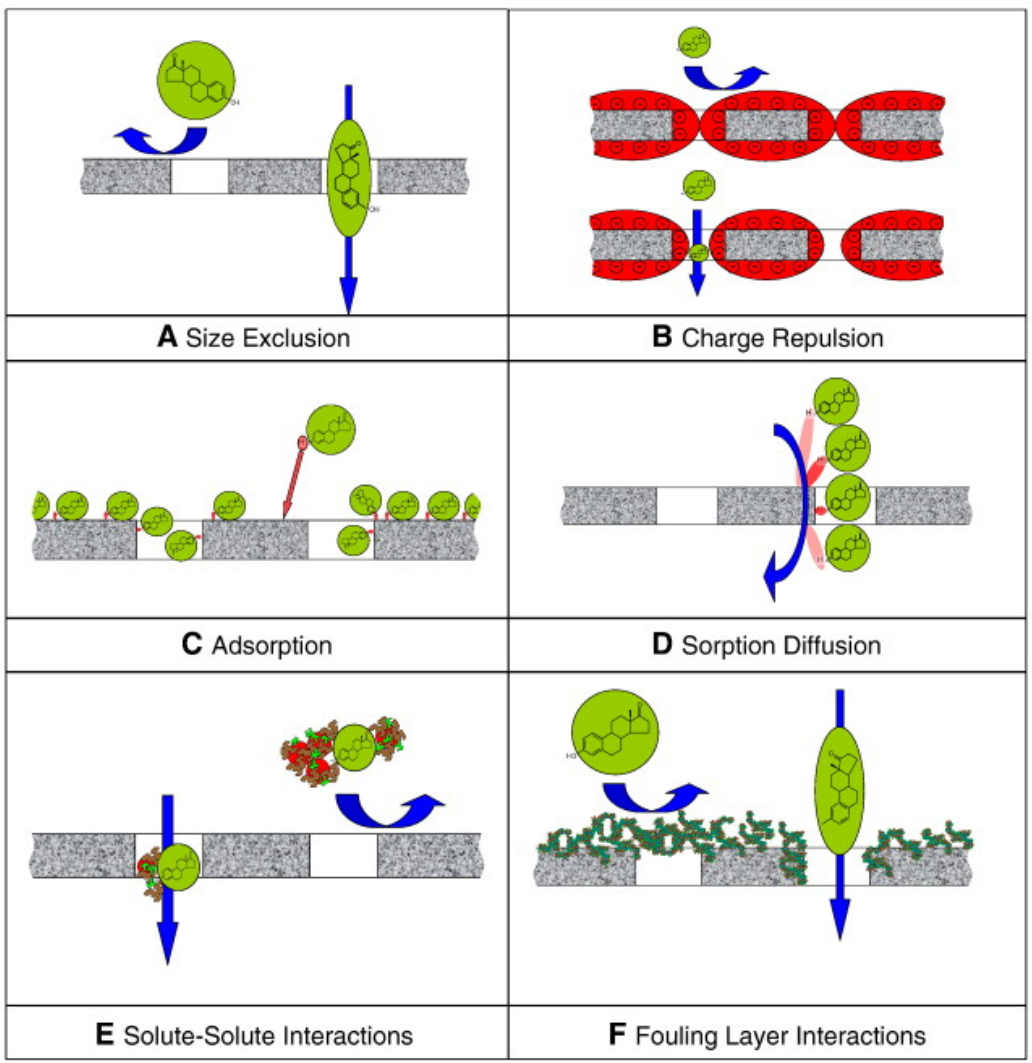
MWCO
salt rejection
Charge &
hydrophobicity
porosity
roughness



MW
molecular size,
Charge &
hydrophobicity
feedwater chemistry

LG NanoH2O

Organic Micropollutant Removal Mechanisms



Schäfer et al., (2011) Advances in Colloid and Interface Science, 164(1–2)

Determining Removal Efficiency

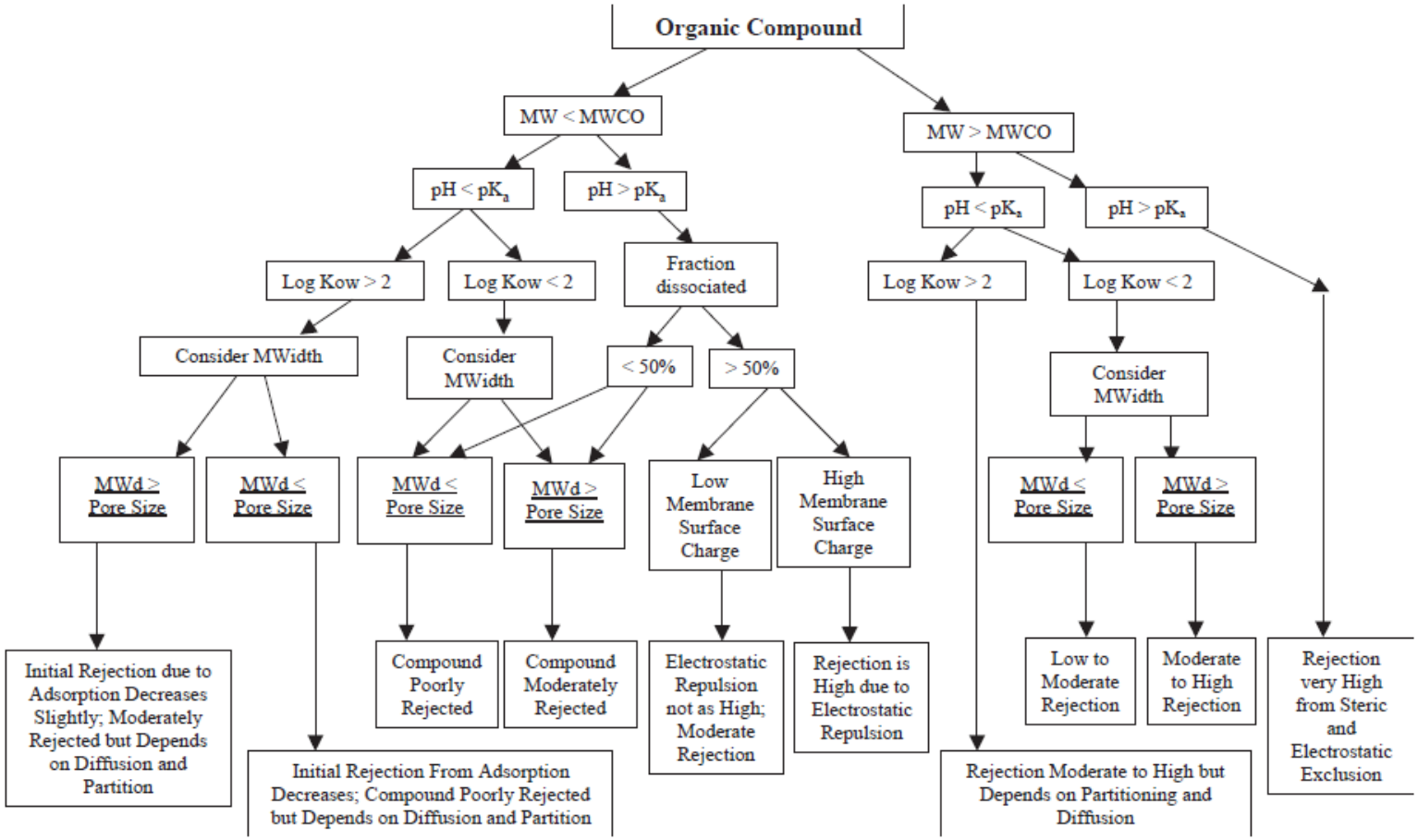
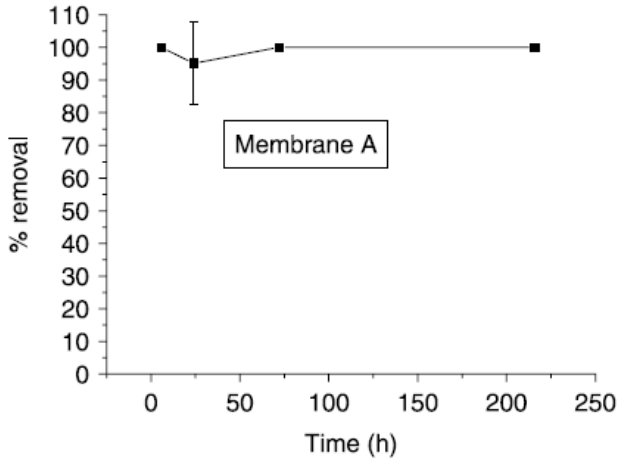


Fig. 1. Rejection diagram for organic micropollutants during membrane treatment based on solute and membrane properties.

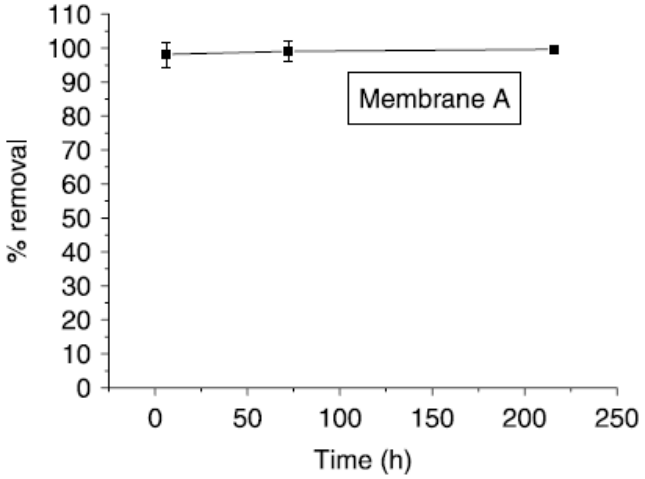
Bellona et al., (2004) Water Research, 38

Removal of OMs by RO

- Microcystin
  - 1000Da
  - 1+ charge



- Cylindrospermopsin
  - 415Da
  - No charge



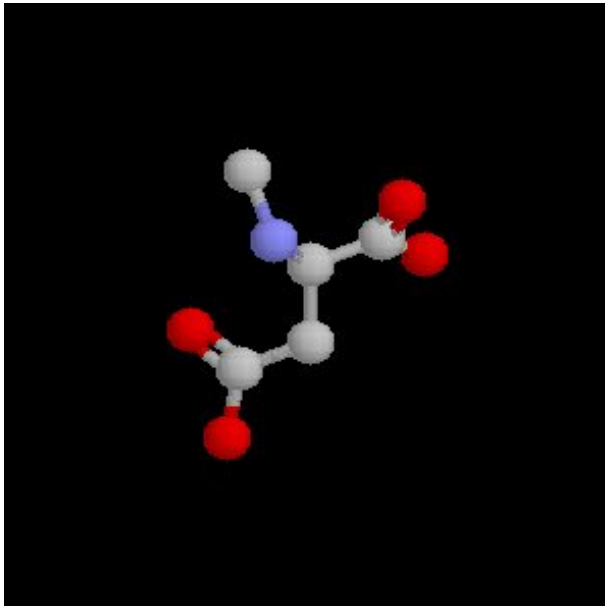
Dixon et al., (2010) Water Science and Technology, 61.5

Typical rejections of OMs by RO

- The good…
  - Microcystin 99%+
  - Ibuprofen 98%
  - 17b-estradiol 80-95%
- The bad…
  - Geosmin/MIB ~70-90%
  - 1,2 dioxane ~10-20%
  - NDMA ~40-60%

3. Nitrosamines (NDMA)

- N-Nitrosodimethylamine (NDMA)
- Family of 8 nitrosamines
- Suspected carcinogen
- Potent hepatotoxin
- NDMA MW= 74Da
- No charge
- Commonly found in bacon, beer, tobacco smoke and WATER



LG NanoH2O

Causes and Occurrences

- Causes in Water Treatment:
  - leaching from polyethylene pipe
  - byproduct of the chloramination process
  - incorrect dosing of polyDADMAC
  - Insufficiently treated reuse water

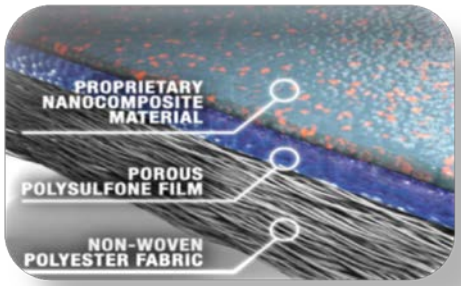
- California Department of Public Health (CDPH) notification level (NL) =10 ng/L.

- CDPH found 30 public drinking water wells with NDMA above the NL of 10 ng/L – 26 in Los Angeles

Mitigation Technologies

- Activated Carbon – fairly ineffective, 15days before breakthrough
- TFC Reverse Osmosis - 40-60%
  - MW is less than MWCO of most membranes
  - 74Da for NDMA compared with ~100Da for RO
  - Uncharged molecule

What about Thin Film Nanocomposite RO???

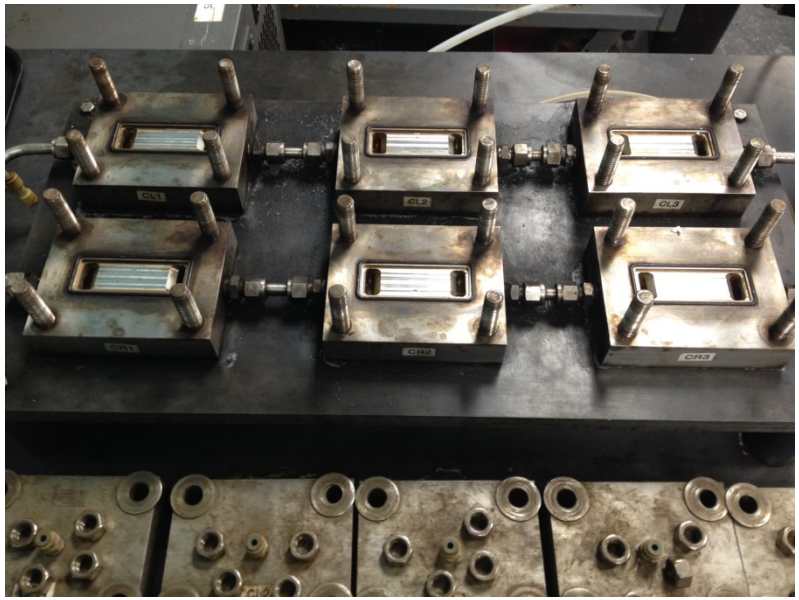


4. Nitrosamine Removal by TFN

- Method- comparison of 2 membranes

  Qfx BW TFN -versus- Ind. Standard BW TFC

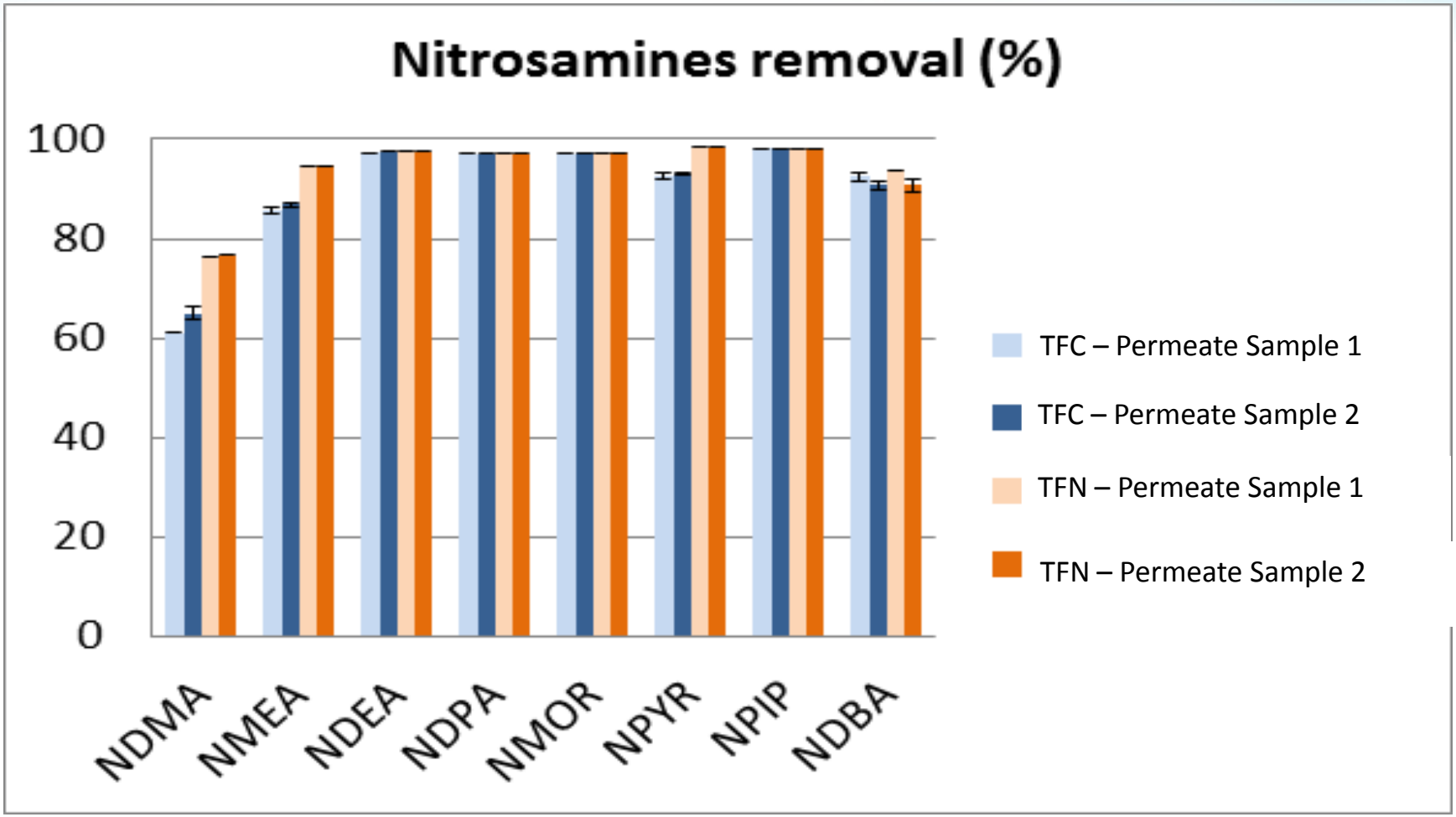
  - 26.25GFD/99.7% –versus- 26.25GFD/99.5%
  - @ 2000ppm, 225psi, 15% Recovery, 25C
  - Bench Test – 3 coupons each
  - 24hr pre-stabilization
  - 150hr experiment



LG NanoH2O

Results

- 16% higher NDMA removal for TFN vs TFC



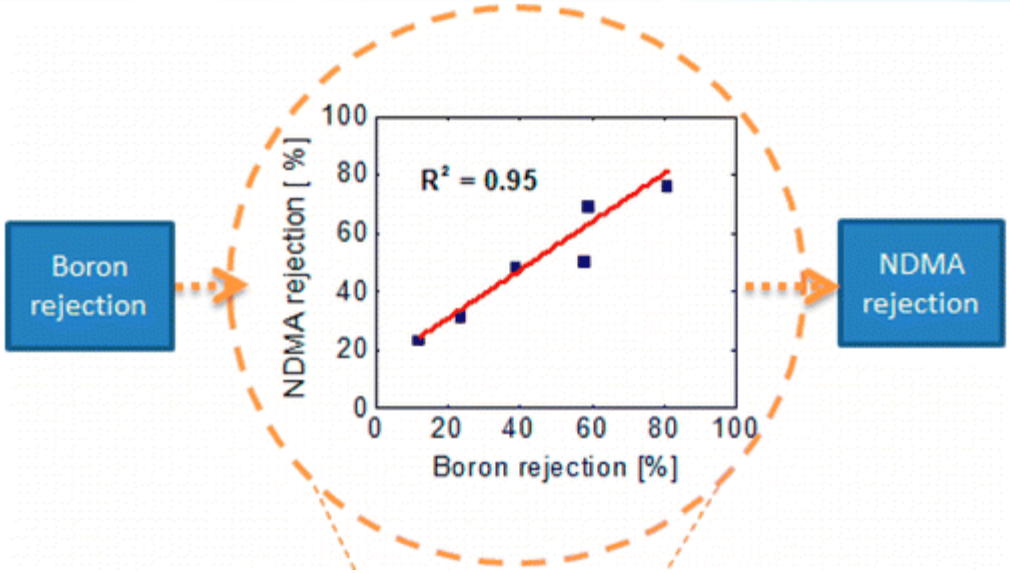
Discussion

- Fujioka et al., found 45-70% removal of NDMA by TFC
- Our study was at similar test conditions and found 78%
- 8% higher removal with TFN

- Full Plant studies in the literature (10-70% removal):
  - El Segundo West Basin Water Recycling Plant (USA)
  - Scottsdale Water Campus (USA)
  - Bundamba Advanced Water Treatment Plant (Australia)
  - Interim Water Factory 21 (USA)

Fujioka, et al., (2012) Separation and Purification Technology 98, pp.503–51

Boron as a Surrogate



- Tu et al., found a strong correlation between boron and NDMA removal
- Boric acid MW = 62Da vs NDMA = 74Da
- Both uncharged at pH 7

Tu, K.L, 2013 Environmental Science & Technology 47 (12)

5. Summary and Conclusions

1. LG NanoH_2O manufacture TFN membranes with the highest flux for rejection on the market
2. Both RO Membrane characteristics and Organic Micropollutants (OMs) properties determine removal of OMs
3. NDMA is a toxic chemical and is difficult to remove from reuse water with TFC membranes
4. NDMA Removal by TFN was 16% higher than an industry standard TFC at equivalent flux and 8% better than field studies from the literature
5. Boron can be a surrogate for NDMA removal

Thank-you…

- Co-Authors:
  - David Kim Hak *LG NanoH_2O*
  - Wolter Siegers *KIWA Watercycle Research*
  - Dr Emile Cornelissen *KIWA Watercycle Research*