The Innovative Energy Effective Seawater Desalination RO System with Advanced Key Technologies: "Mega-ton Water System"

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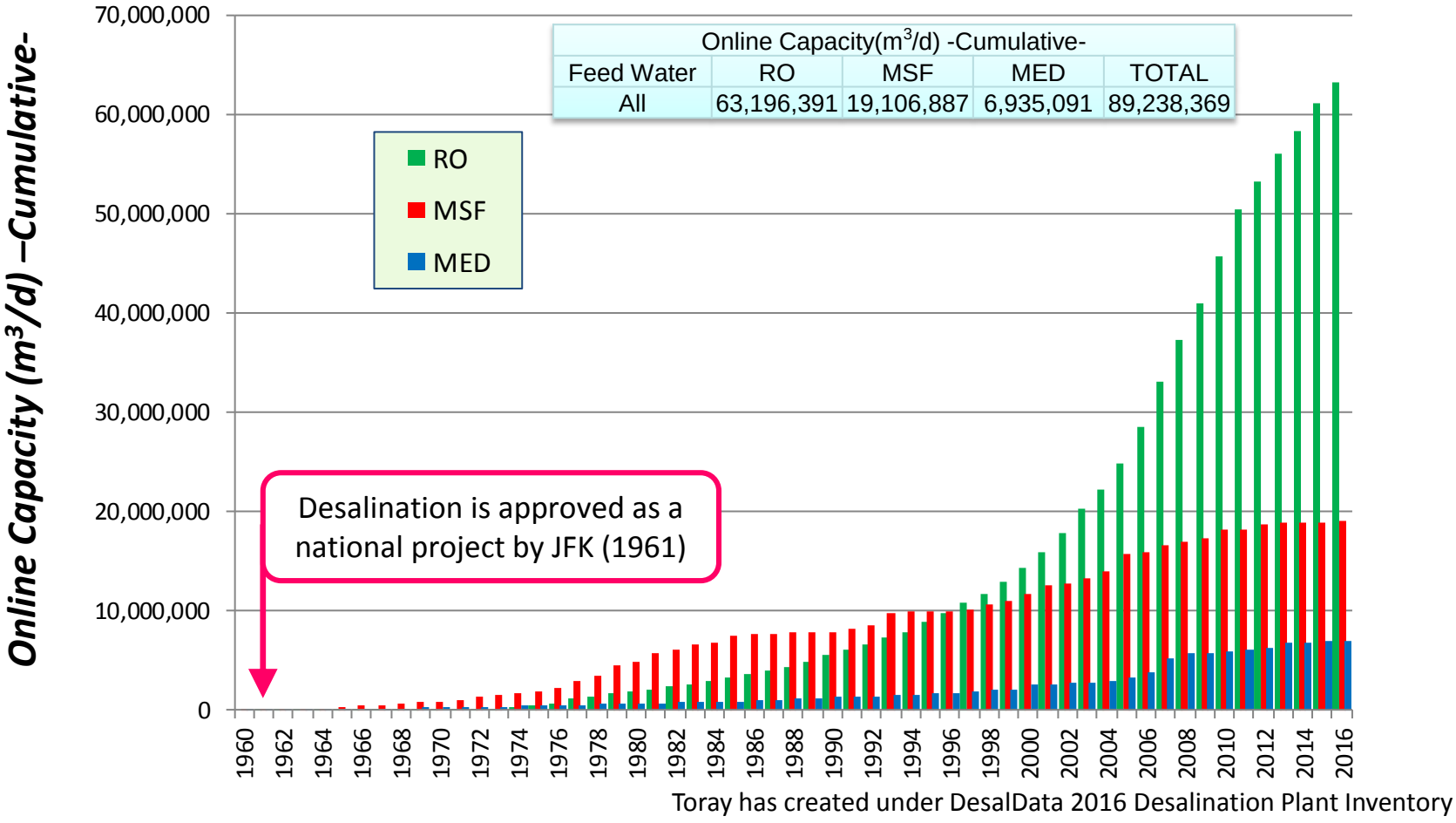
History of desalination plant as capacity of each technology

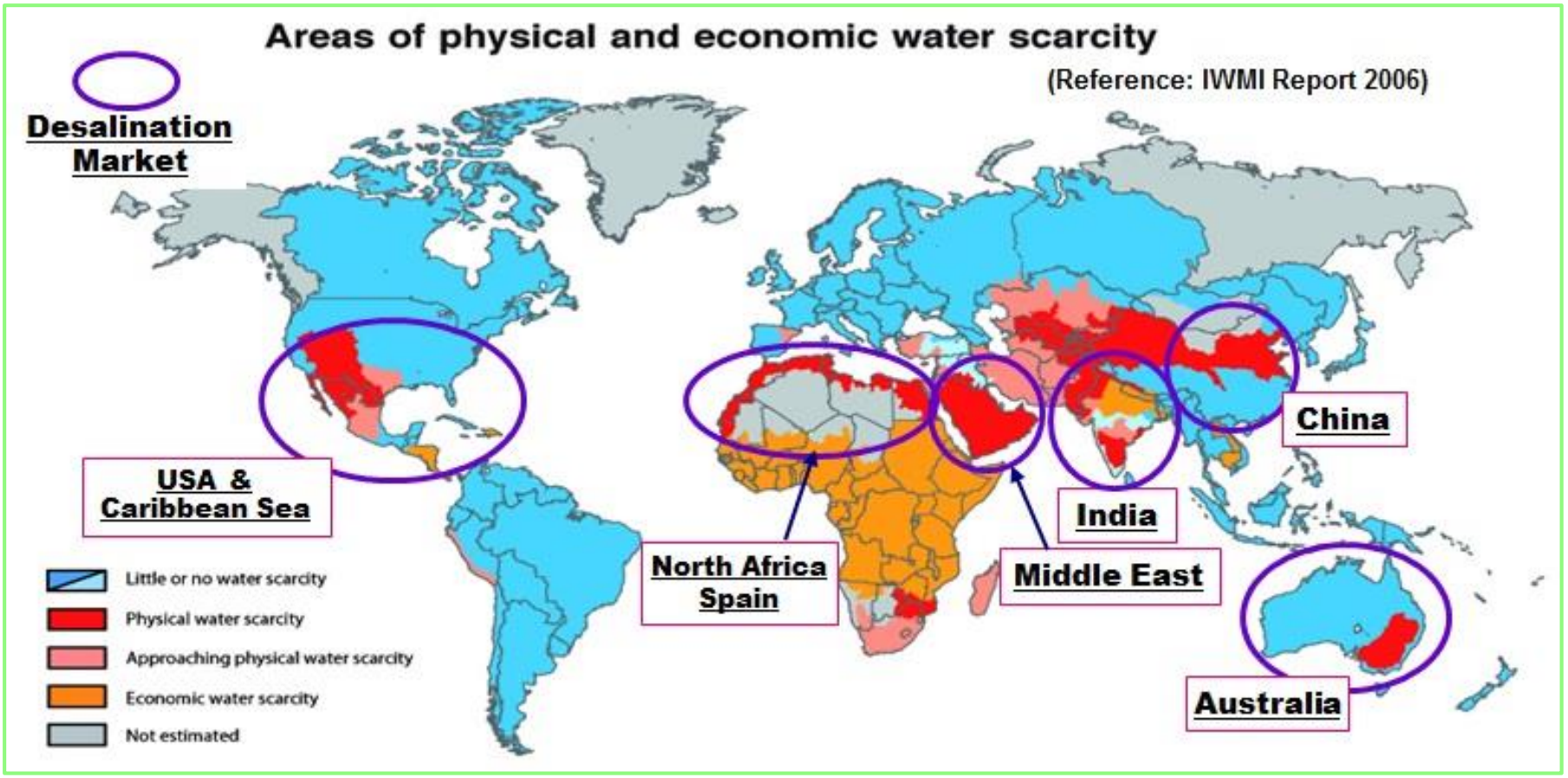


Online Capacity(m^3/d) -Cumulative-				
Feed Water	RO	MSF	MED	TOTAL
All	63,196,391	19,106,887	6,935,091	89,238,369

Toray has created under DesalData 2016 Desalination Plant Inventory

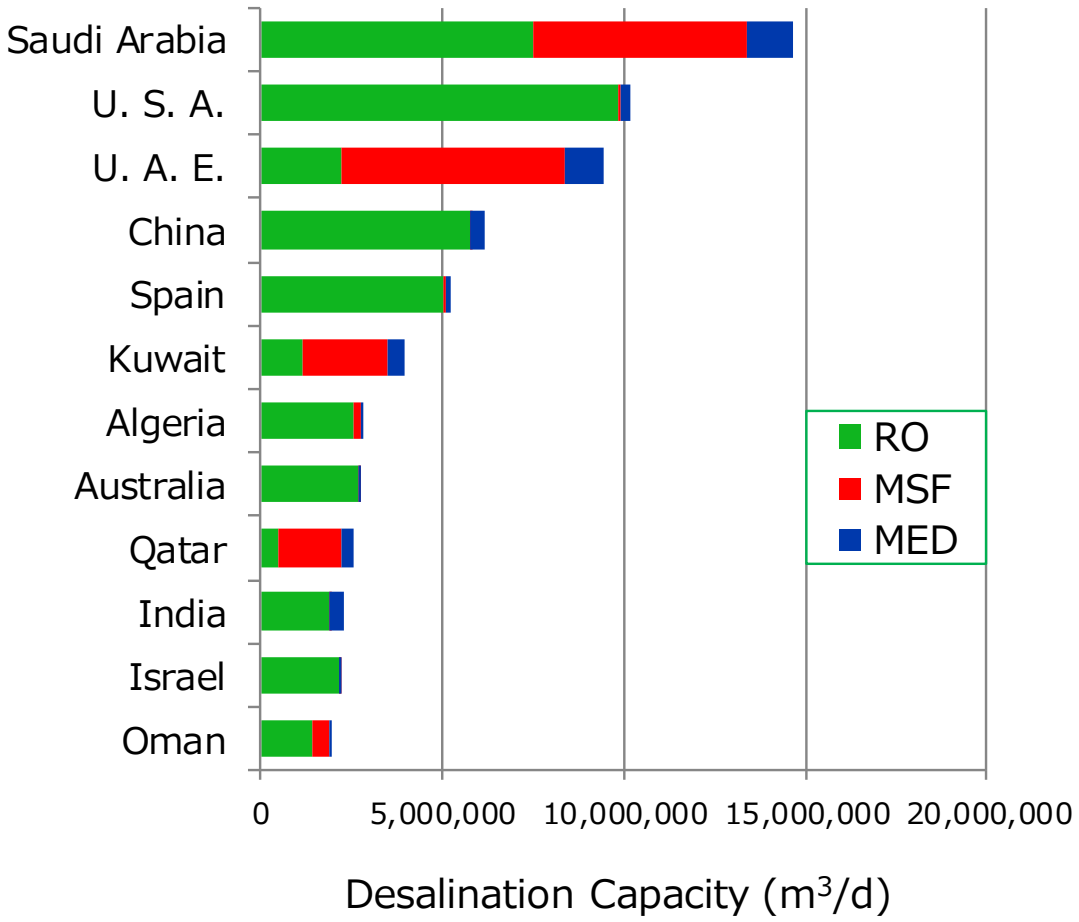
A total capacity of desalination plant has been increasing.
Especially RO become the main technology
A larger plant would be required for the future water demand.

The World Global Desalination Market



Middle East, North Africa, USA & Caribbean Sea, China, India and Australia are the main desalination Market.

Worldwide Desalination Facility by Country



Kingdom of Saudi Arabia is the most important country in worldwide desalination market.

“Mega-ton Water System”

The “Mega-ton Water System” project was implemented as national research in Japan (First Program) that aimed at developing sustainable water treatment core technologies necessary for the 21st century.

- The missions of “Mega-ton Water System”

  1) energy reduction (20%),

  2) water production cost reduction,

  3) low environmental impact (reducing chemical for operation).

- The targeted capacity of the Seawater Reverse Osmosis System (“Mega-ton Water System”) is 1,000,000 m3/d.

Advanced Key Technologies

- Development of innovative low pressure seawater RO membrane

  - with micromorphology analysis of the RO membrane functional layer

  - development of production technology of the innovative RO membrane

- Investigation of the brine conversion low pressure multistage high recovery system

- Monitoring of water Quality on biofouling potential.

  -Measurement of mBFR™ (Membrane Biofilm Formation Rate)

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Structure of RO Membrane and Elements

Functional layer

Crosslinked aromatic polyamide 200 nm

Feed Water Side

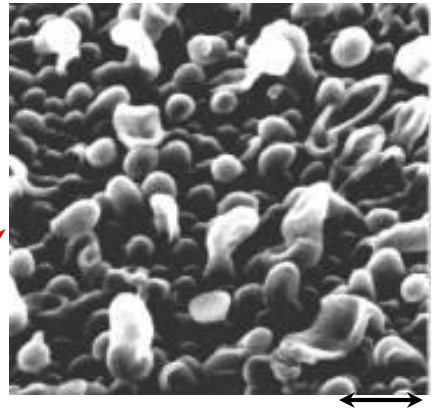
Polysulfone supporting layer 45 µm

non-woven Polyester fabric 100 µm

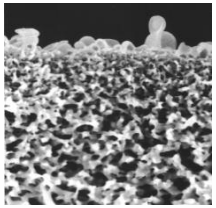
Permeate Side

Structure of RO membrane

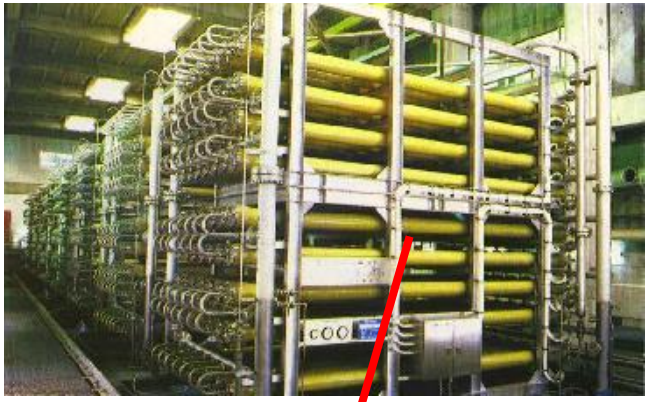
Surface image of RO membrane



200 nm

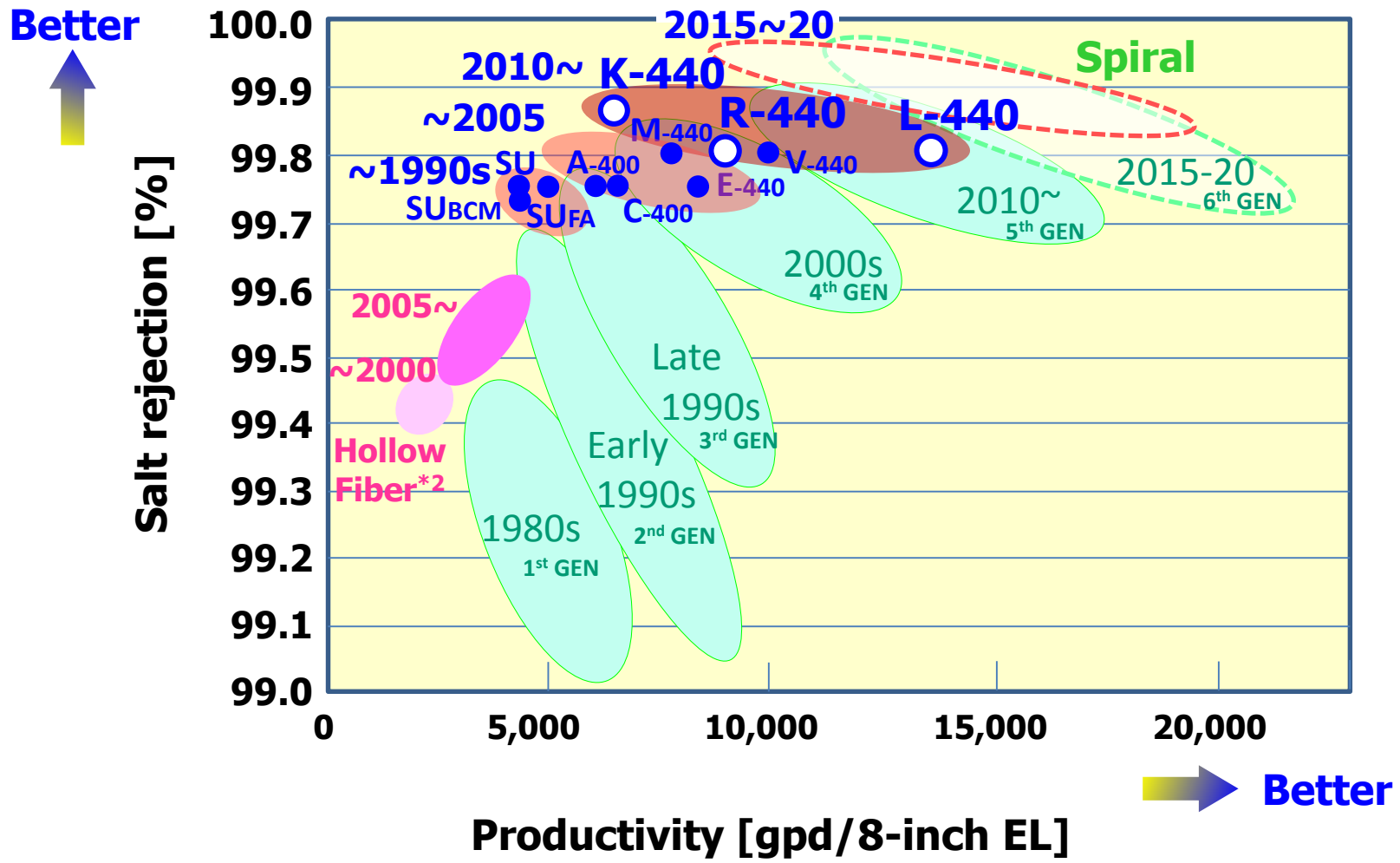


RO membrane units



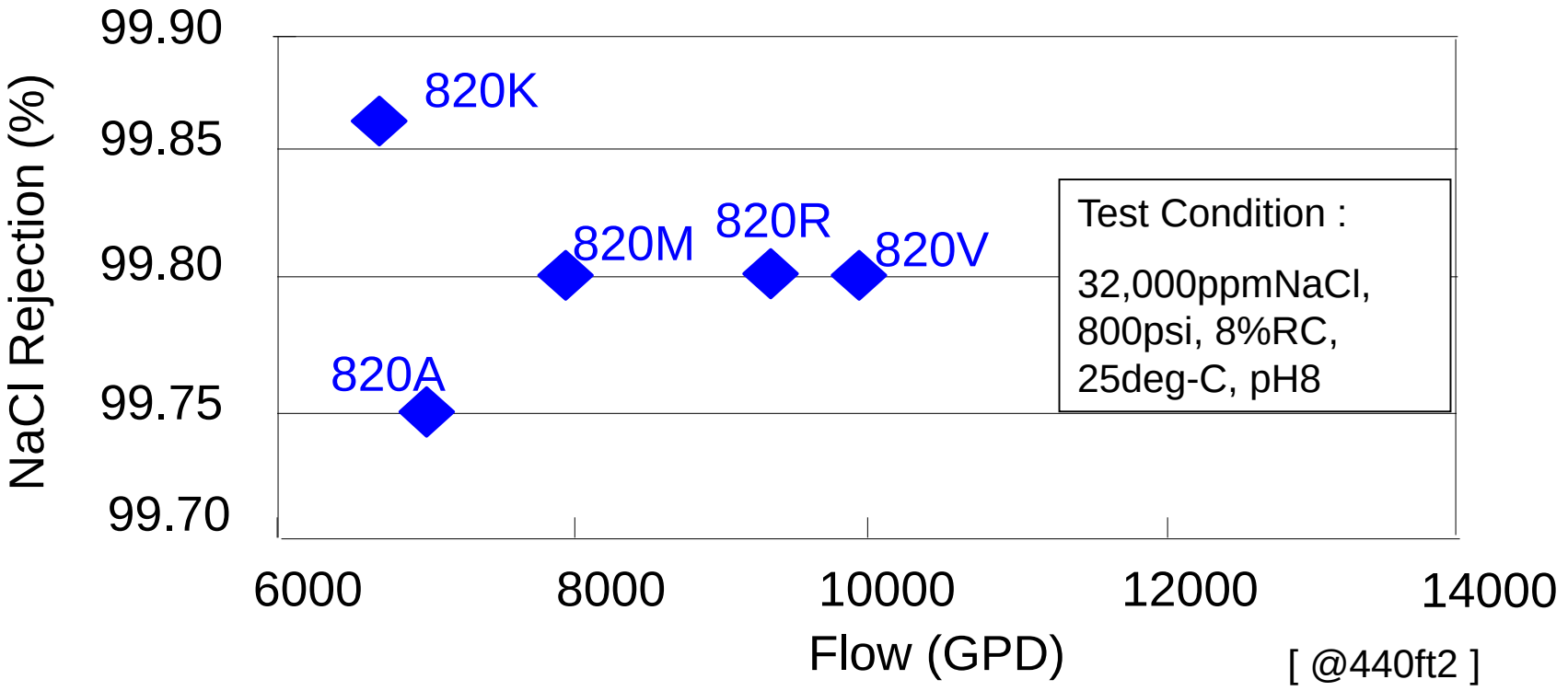
Structure of RO membrane element

Development History of SWRO Membranes



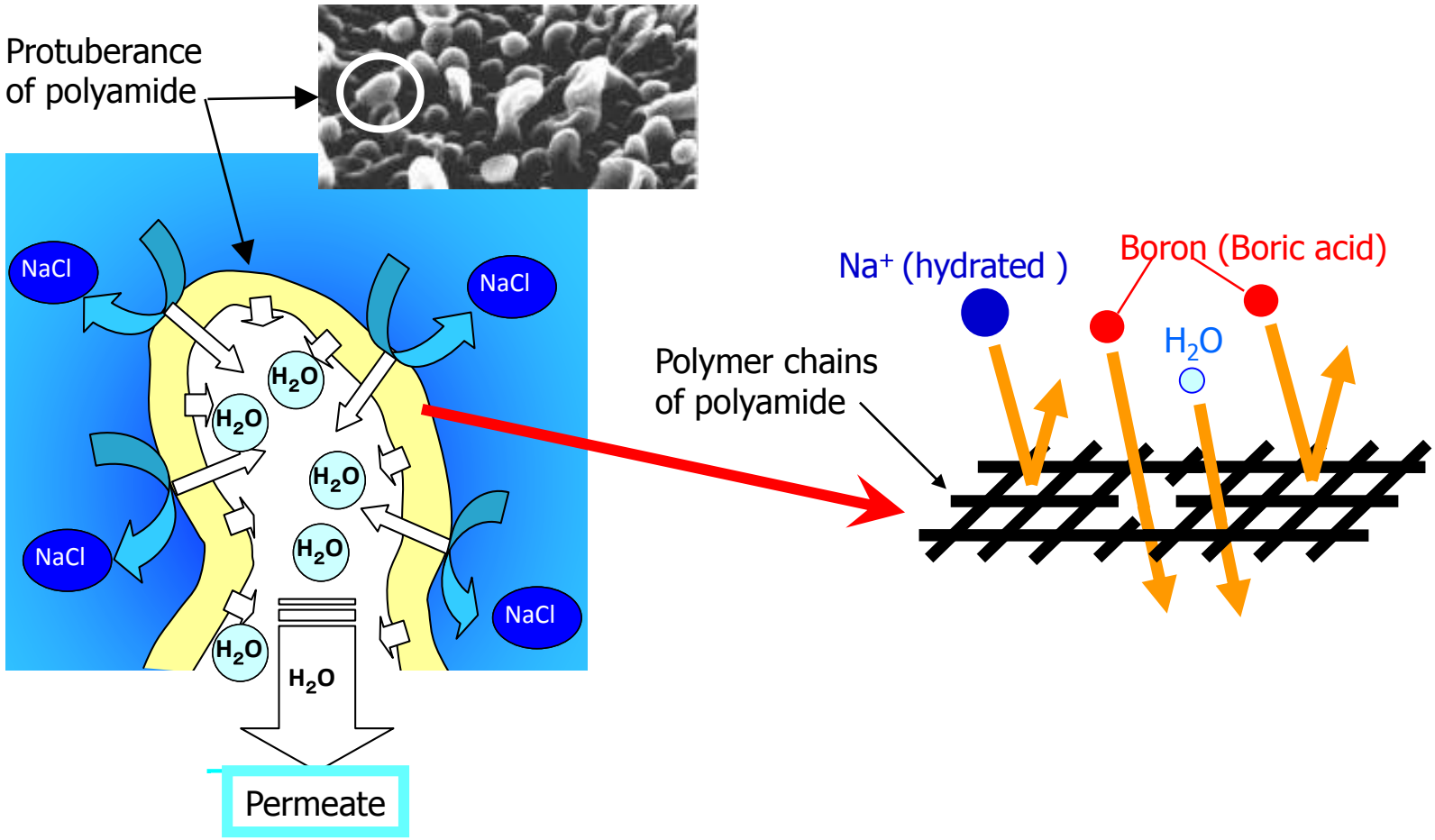
Performance of seawater RO Membrane has been improved by development of membrane materials and micromorphology/

Recent development of SWRO Membranes for conventional plant



Typical conventional SWRO membrane has wide range of Flow and NaCl Rejection at conventional pressure (800psi).

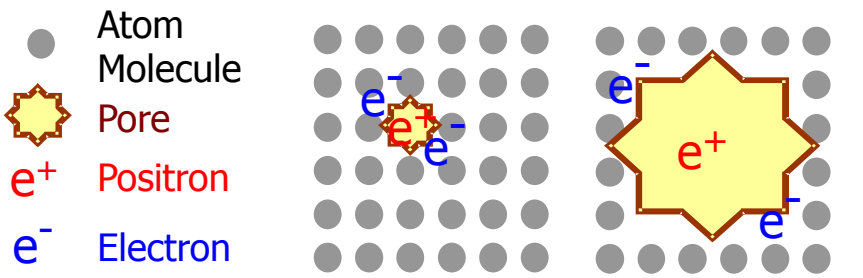
Schematic Diagram of salt Removal and Water permeation through the Protuberance



Water permeate through thin layer of polyamide protuberance.
Salt and Boron are rejected by narrow pores in protuberance.

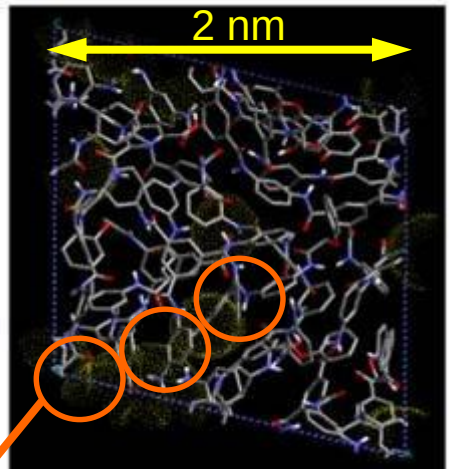
Precise Pore Size Estimation of Cross-linked Aromatic Polyamide

Positron Annihilation Lifetime Spectroscopy(PALS)



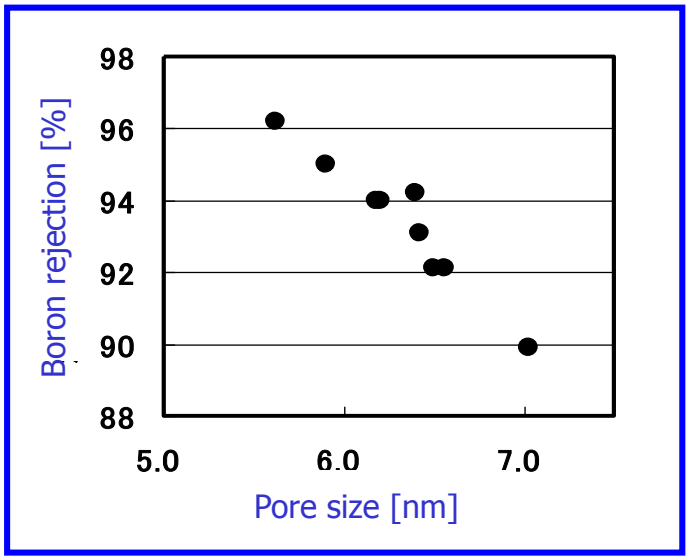
Pore size	Small	Large
Positron Annihilation Lifetime	Short	Long

Confirmation of pore structure with Molecular Dynamics simulation



Estimated as 6-8 A diameter

Relationship of Boron Rejection and Pore Size by PALS



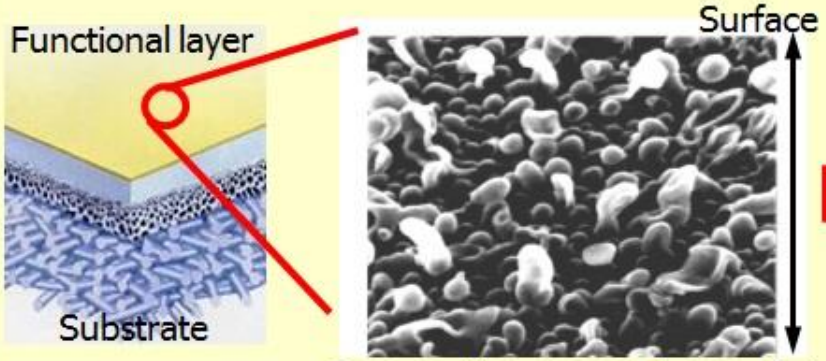
- Pore size of polyamide membrane was estimated by PALS.
- Correlation was observed between pore size and boron rejection.

Technologies for Precise Estimation of "Protuberant Structure"

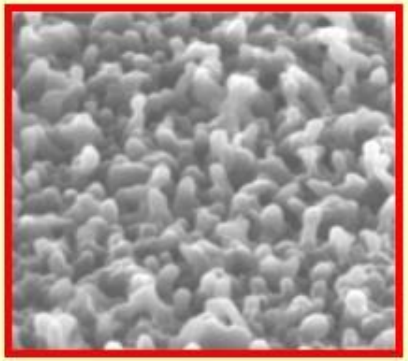
Conventional method

Leading-Edge method

1. Scanning Electron Microscopy (SEM)



Prepared by vacuum freeze drying

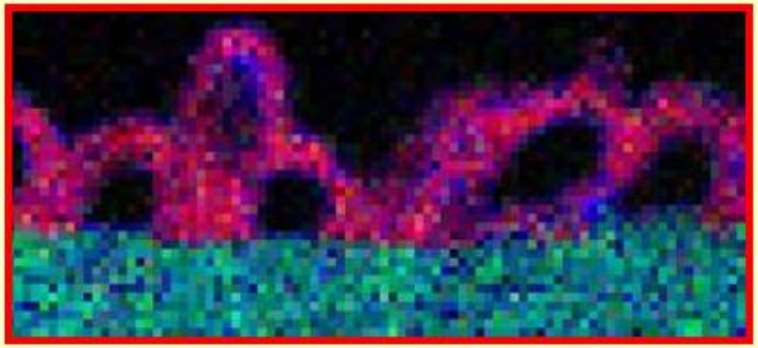


Prepared with pretreatment to keep wet condition

2. Transmission Electron Microscopy (TEM)

Fixed by Polymer Embedding

(N-S-O)

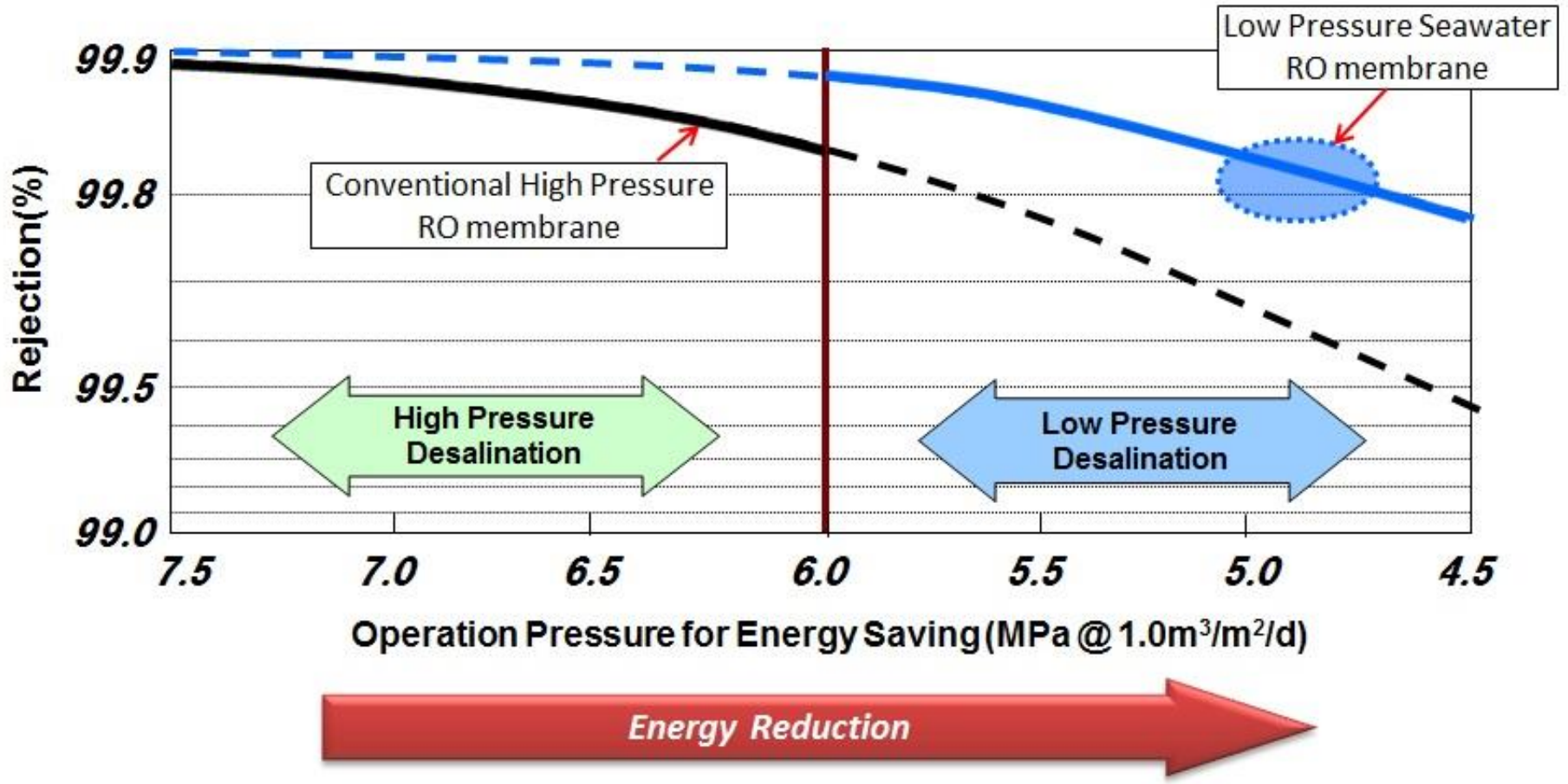


Elemental mapping by STEM-EELS※

※STEM(Scanning Transmission Electron Microscopy), EELS(Electron Energy Loss Spectroscopy)

Structure of protuberance was estimated by SEM and TEM with new technology .

Comparison between Conventional High pressure and Innovative Low Pressure Seawater RO Membrane



Innovative SWRO membrane will achieve lower operating pressure and energy reduction.

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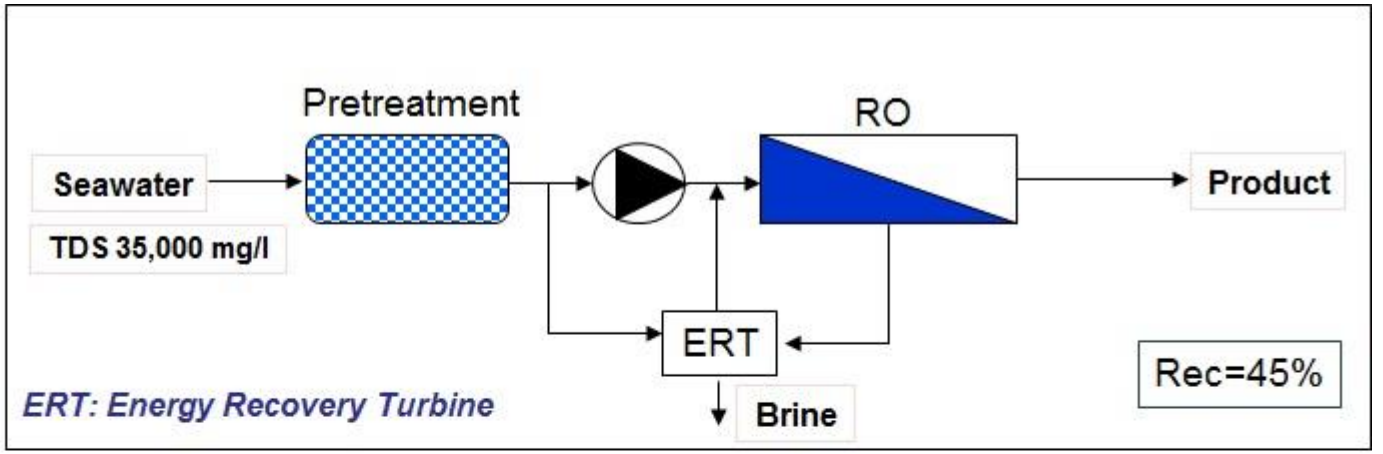
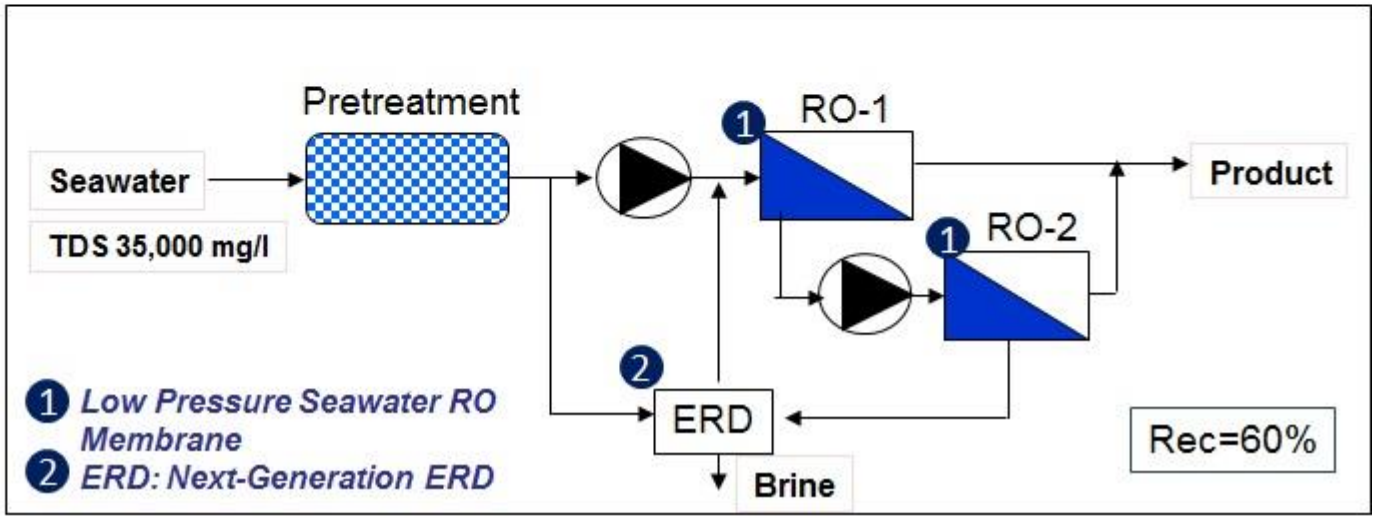
Comparison of Flow Diagram for Conventional System and LMS

Conventional System

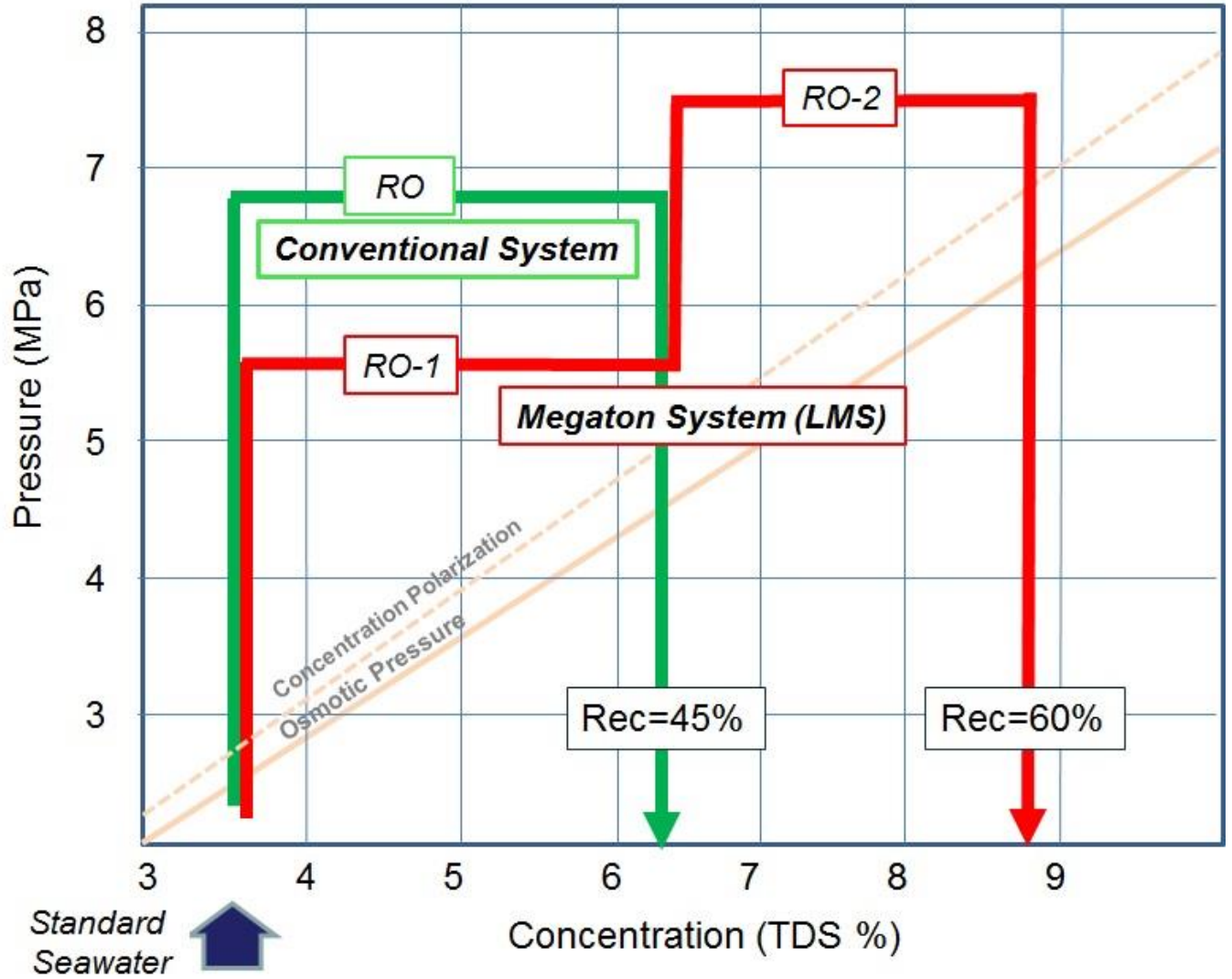


Megaton System (LMS)



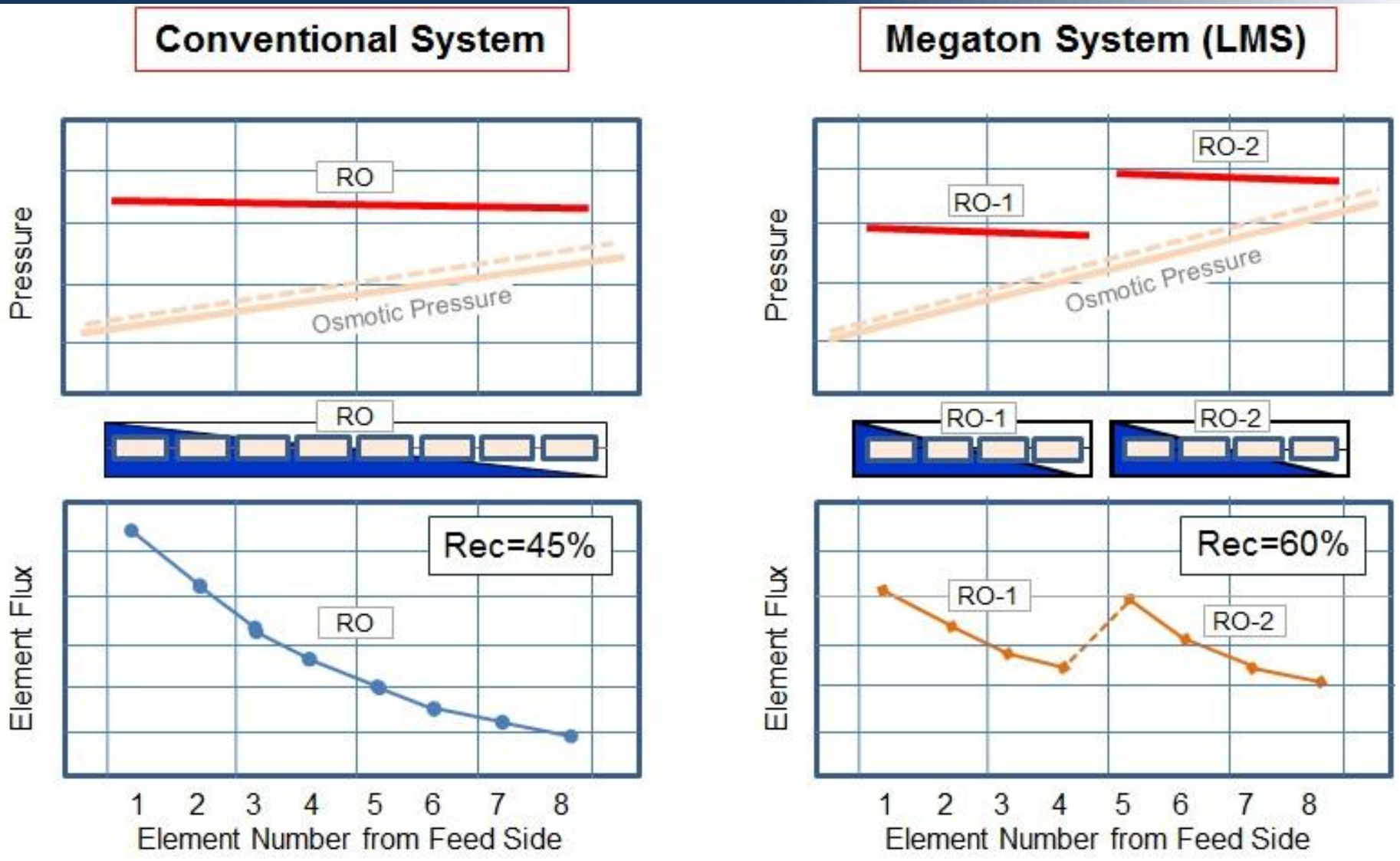
LMS could reach high recovery ratio
and low pressure operation comparing to conventional system.

Relationship between Feed Pressure and Feed water Concentration for Conventional System and LMS



Even though higher recovery ratio, LMS could reduce 1st stage pressure than conventional low recovery ratio system.

Comparison of Pressure and Element Flux between Conventional System and Megaton System (LMS)



LMS could reduce the flux difference of each elements.

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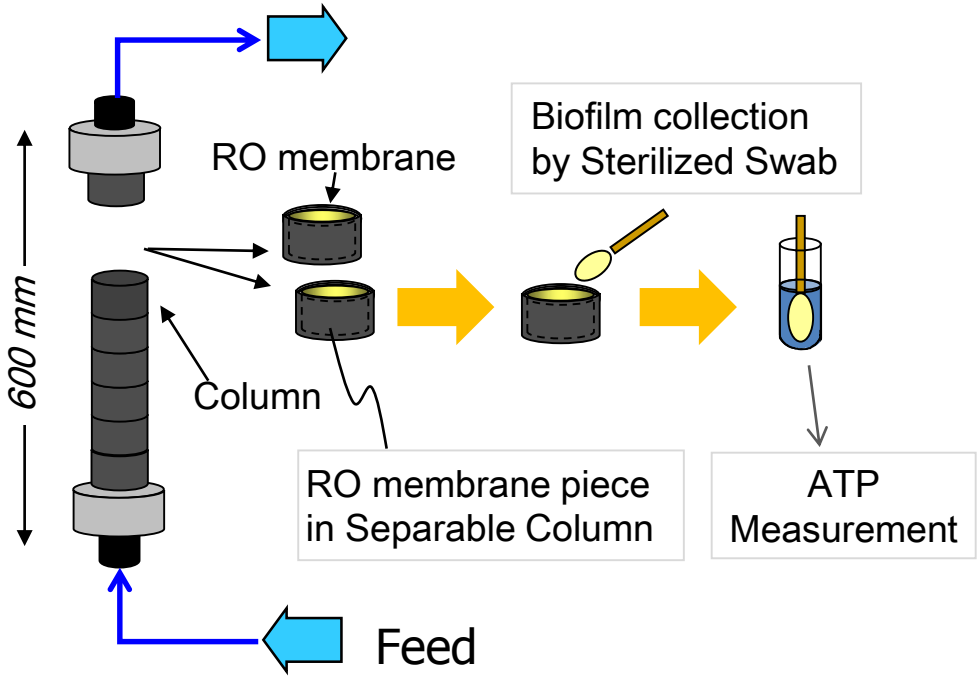
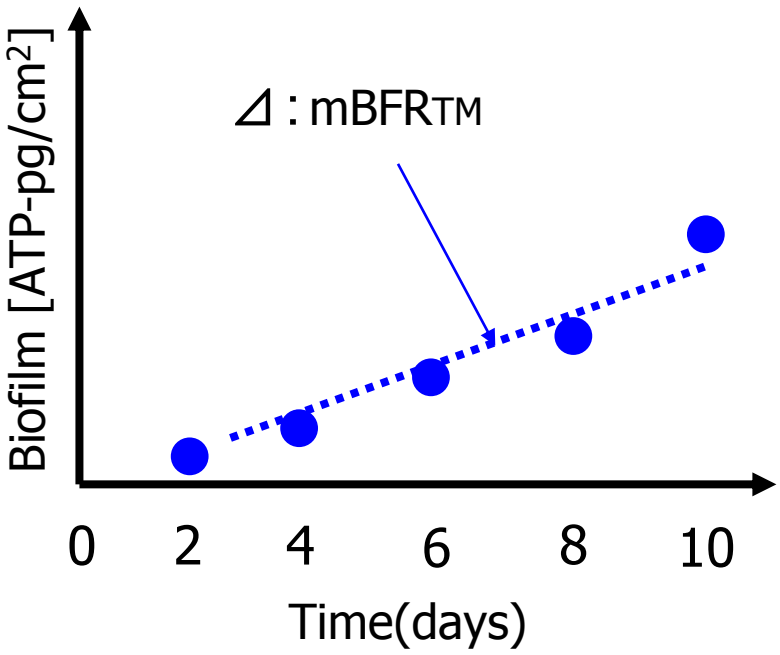
Measuring Procedure of mBFR™

Outline of measurement



Result example

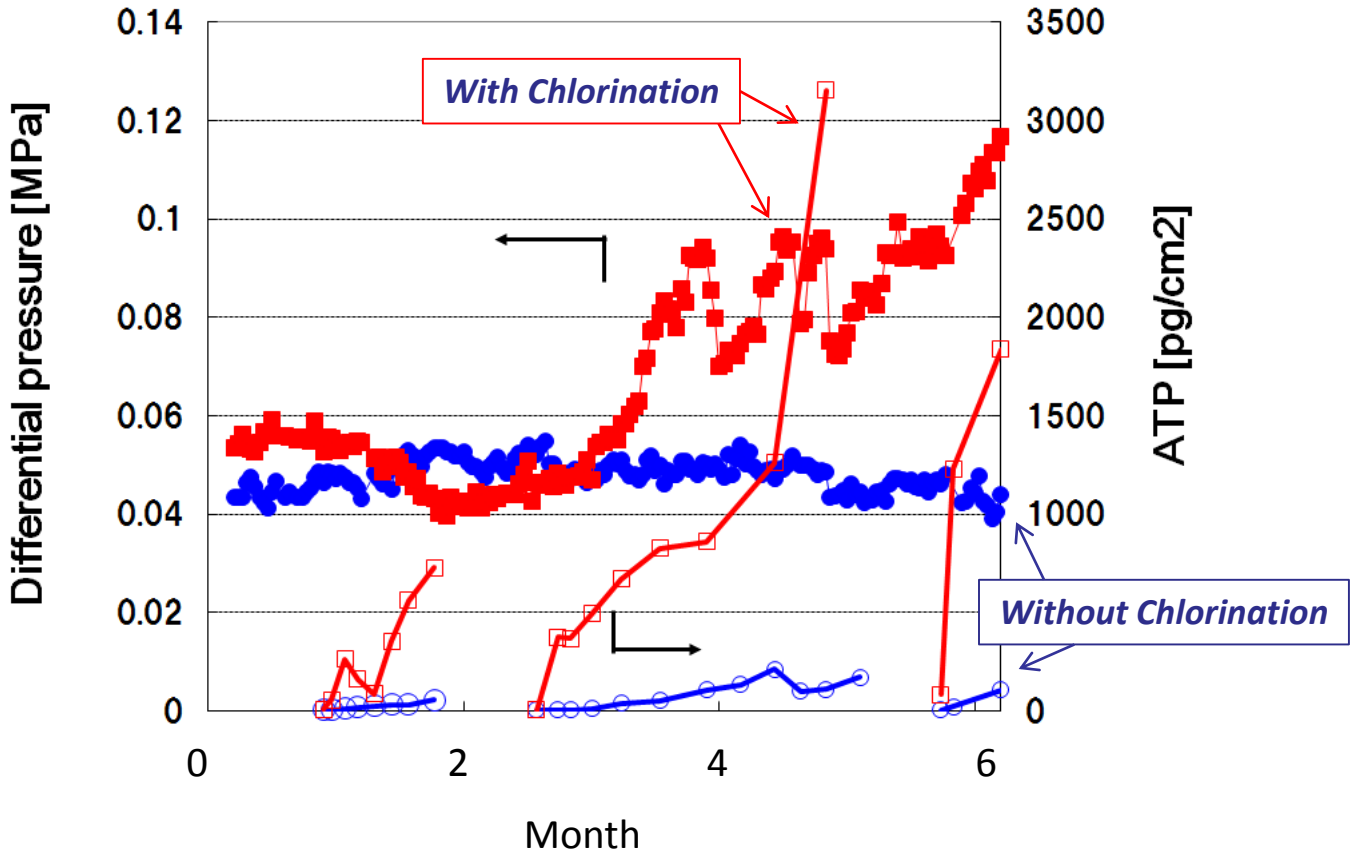


Biofilm is quantified by measuring ATP amount on the carrier

→ Definition: mBFR™ : ⊿ATP(pg/cm2)/ Time (day)

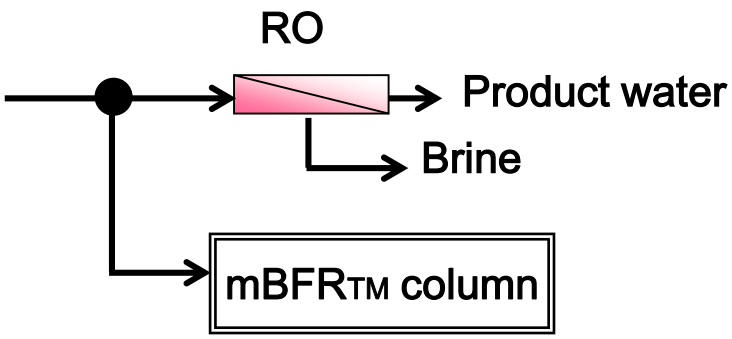
(ATP : Adenosine Triphosphate)

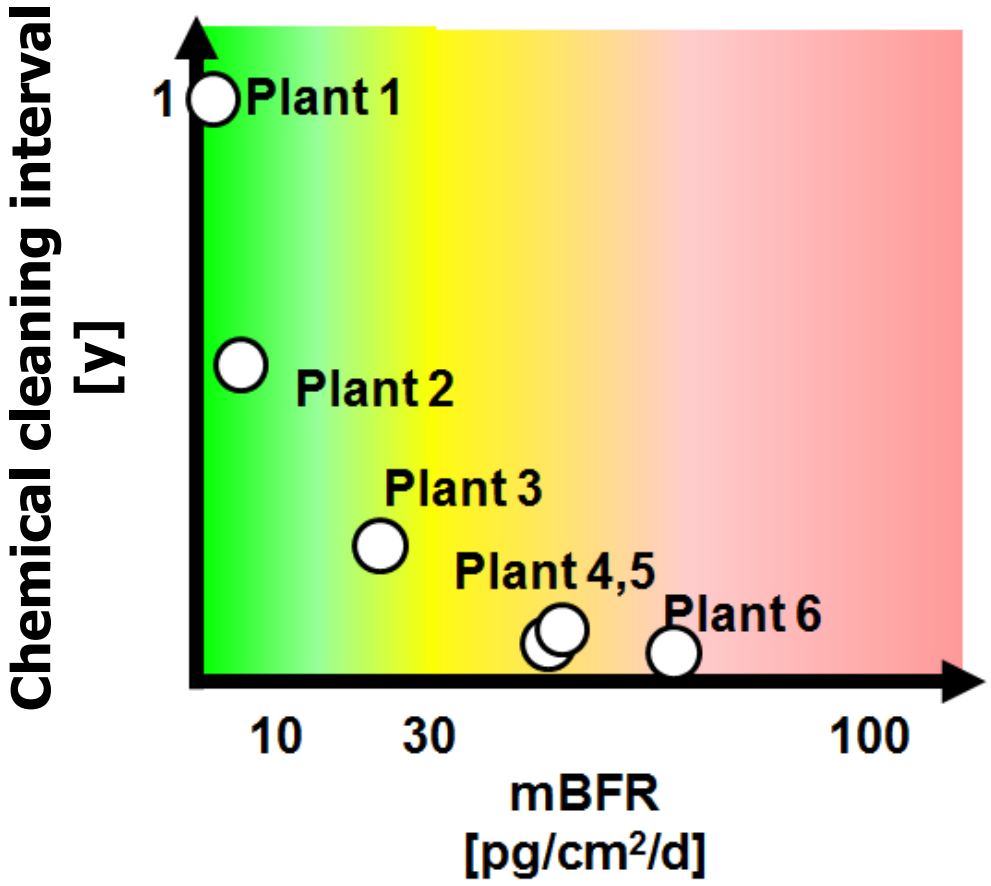
RO Feed-Brine DP and Biofilm Formation Trend on mBFR Monitor



When the mBFR of feed water was small, Differential pressure of element is keeping small value.

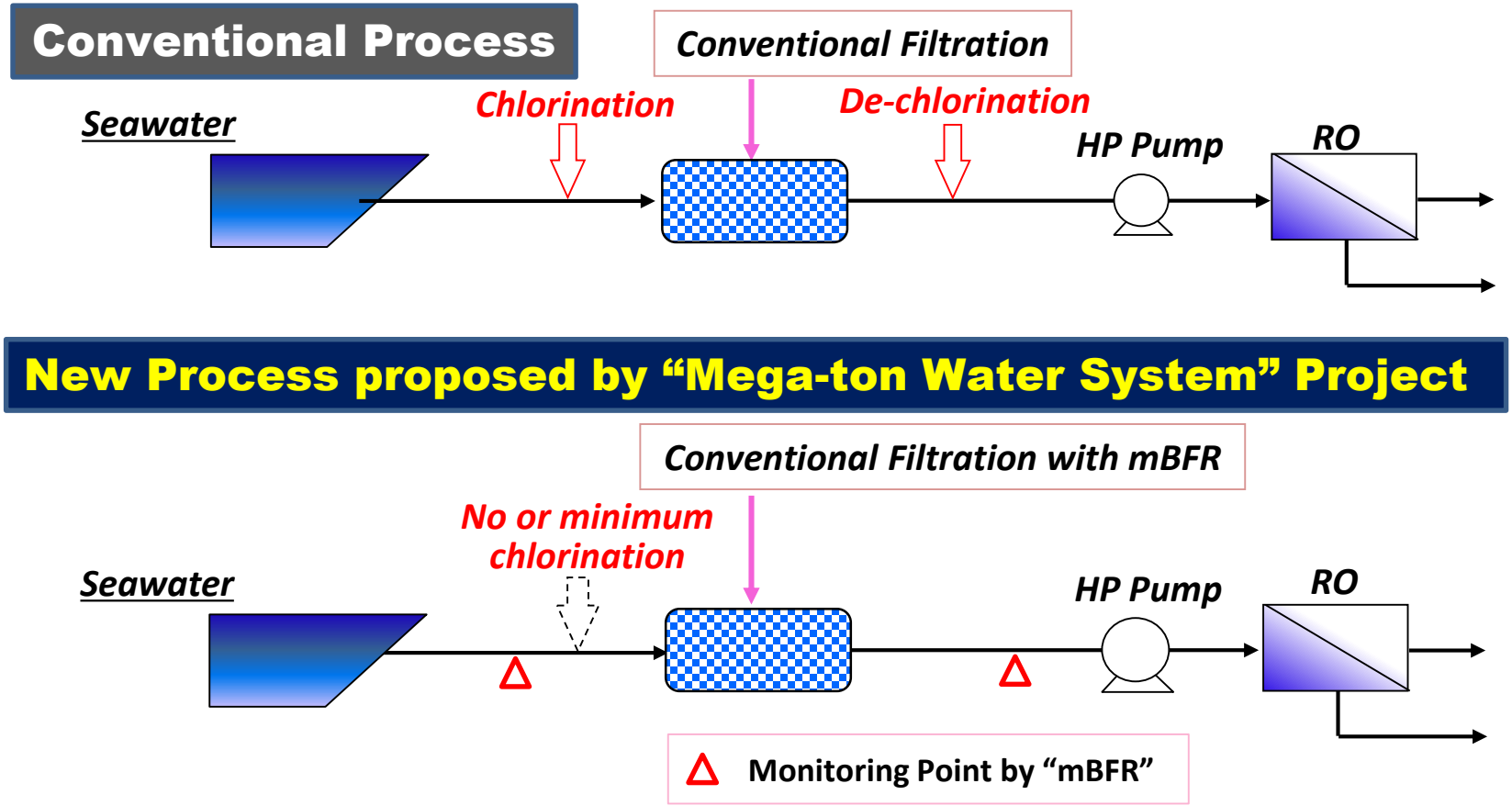
Guideline of Biofouling Risk with mBFR





Quantitative RO chemical cleaning interval is predictable based on RO feed water mBFRTM value.

Comparison of Conventional Process and New Process proposed by “Mega-ton Water System” Project



Operation with reducing chemical and mBFR™ monitoring will contribute to stable operation of SWRO plant.

Energy Reduction by Megaton water Technology for 1,000,000m3/d plant

System <Seawater Conc. = 3.5%>	Membrane	ERD	Pump Efficiency	SEC Rate (%)
Conventional (R=45%)	Conventional	Turbo	70-85%	100
Megaton (R=60%)	Low-Pressure SWRO Membrane	New ERD	90%	80

* Benchmark is Conventional Technologies in 2010.

Conclusion

- Innovative low pressure seawater RO membrane was designed and developed with new micromorphology analysis technology, and production technology of the RO membrane.

- The brine conversion low pressure multistage high recovery system (LMS) was developed and this system reached high recovery ratio (60%) at Japan sea area.

- Feed water monitoring system (mBFR™) was proposed and tested. The mBFR method will contribute to reliable operation.

- Using these Low pressure membrane, LMS and other technology, “Mega-ton Water System” will realize energy reduction (20%), water production cost reduction and low environmental impact.

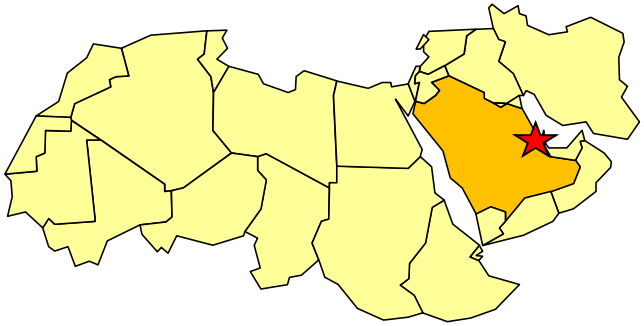
Production of Water Treatment Membrane in Saudi Arabia

Signing of Shareholders' Agreement on February 19, 2014 in Tokyo
in the presence of
King Salman bin Abdulaziz Al Saud, Deputy Crown Prince Mohammed bin Salman bin Abdulaziz Al Saud,
and
Japanese Prime Minister Shinzo Abe

- **Toray Membrane Middle East LLC (TMME)** was established in 2014 as a strategic joint venture between **Abunayyan Holding (AHC)**, a leading water and power company group based in the Kingdom
- TMME is aiming at **manufacturing of RO membrane elements in Saudi Arabia**, and **provide with membrane technology solutions to the MENA region**.

About TMME

Name: Toray Membrane Middle East LLC
Shareholder: Toray Membrane Europe AG : 50%
Abunayyan Holding Co. (AHC) : 50%
Business: RO, NF, UF and MBR Membranes
Location: Dammam 3rd Industrial Zone
Capital: 45 million SAR
Territory: Middle East and North Africa
Function: Production, Sales, Marketing, Technical Service



Evaluation Machine

Factory

Automated Production

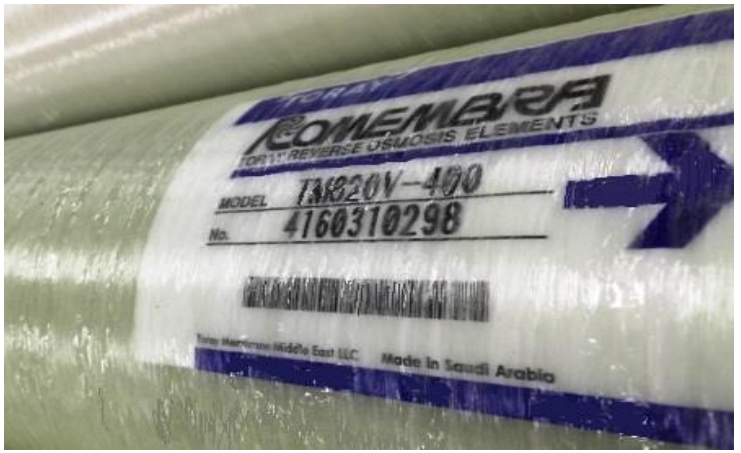
The Global Largest Scale Production in Dammam started its manufacturing in year 2015

Toray's Activities toward Saudi Vision 2030

1. Local Production

Toray Membrane Middle East LLC (TMME) in Dammam, started production of RO Membrane Elements in June 2015

2. Exporting of High Quality Products



Exporting High Quality RO Membrane Elements to MENA Region

3. Saudization

RO Membrane Elements made in Saudi Arabia, made by Saudi Arabian

4. Supplying Water in Saudi Arabia

Many of desalination plants in Saudi Arabia started water production by using TMME RO Membrane Elements.

Thank You for your Attention