
Focus on Membrane Technology for Water Treatment
Toray Industries, Inc.
Dr. Masaru Kurihara
September 2003

CONTENT

Introduction of Doctor M. Kurihara

Title:

Toray Industries, Inc. Senior Director
In charge of Water Treatment Division, Technology Center (Water Treatment Technology Center), and Research & Development Division
Director of International Desalination Association (IDA)
Vice President of Japan Desalination Association (JDA)
Director of Japan Membrane Society, Part-time lecturer at Kyoto University

Personal History:

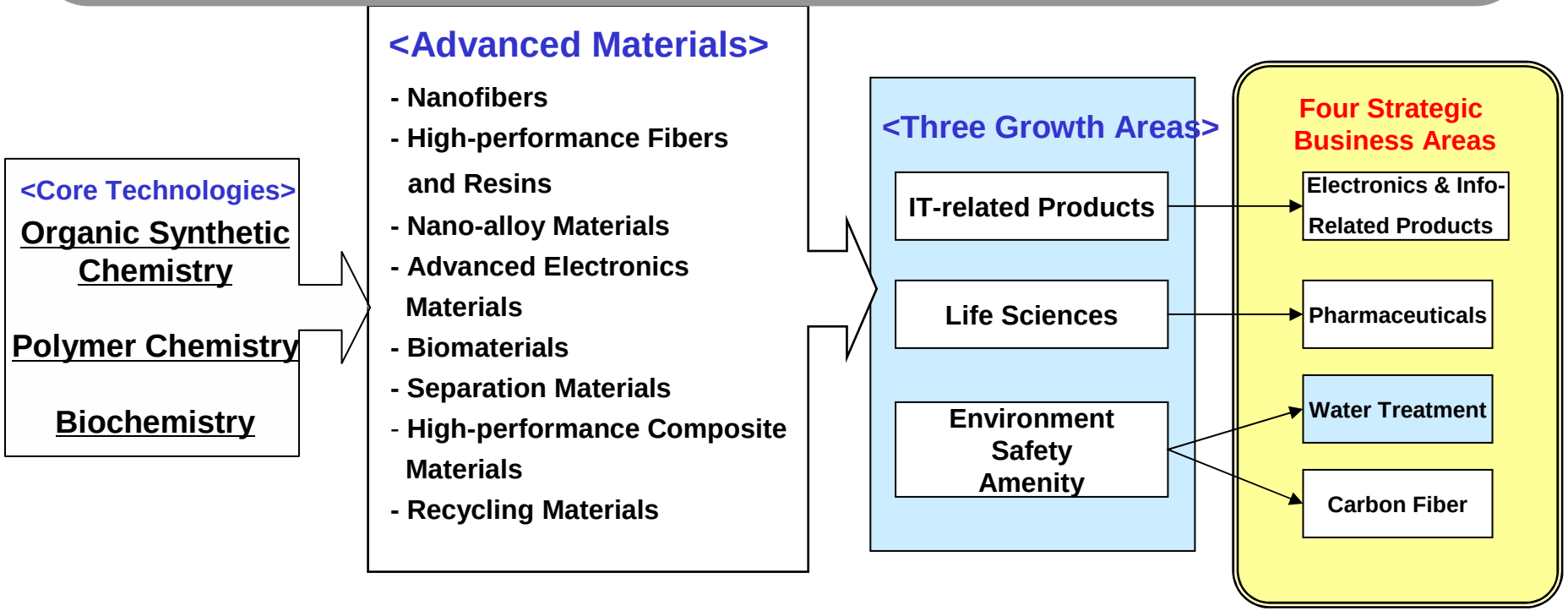
1963 Joined Toray Ind., Inc.
1970 Doctoral Dissertation at the University of Tokyo
Membrane Research with Prof. J.K. Stille at the University of Iowa as Post-Doctoral Fellow
1991 General Manager, Polymers Research Labs

Awards:

1992 Chemical Society of Japan Technical Award
2002 International Desalination Association Presidential Award
2003 Okochi Memorial Production Prize

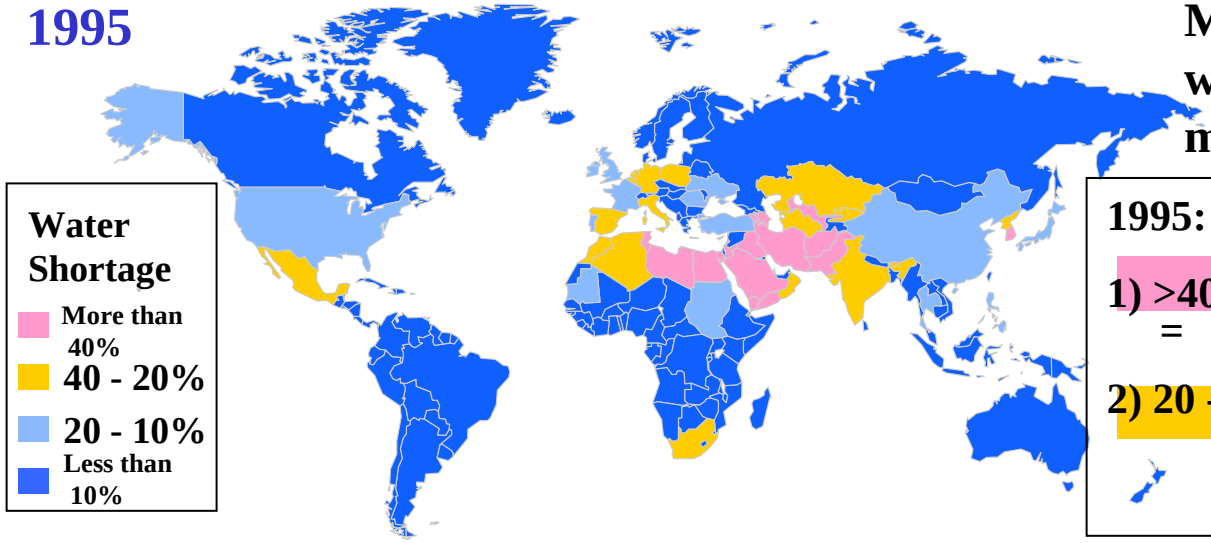
Toray – The Leader in "Advanced Materials"

Achieving High Growth by Constantly Supplying "Advanced Materials" – Developed with our Core Technologies – into our Three Growth Areas (an expansion of our four strategic business areas)



World Water Shortage - Now and Future (WMO and others, 1996)

1995



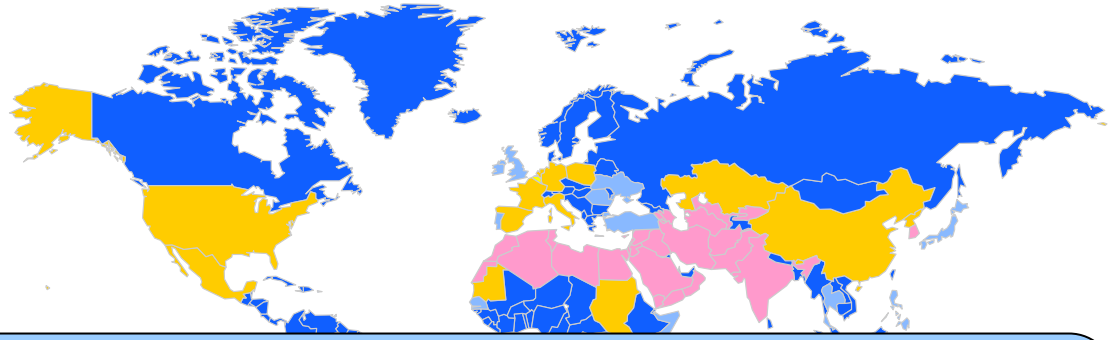
Main regions which have high water shortage percentages of more than 20%

1995:

1) >40% = : Middle East, Singapore, Korea, Pakistan

2) 20 - 40%: India, Mexico, Europe (excluding UK and France), Taiwan, South Africa

2025



2025:

1) >40% : Middle East, Korea, Pakistan, India, Algeria, South Africa, etc.

2) 20 - 40%: Mexico, China, USA, Europe (excluding UK)

Water shortage presumed to continue worldwide especially in Europe, the U.S.A., and China by 2025

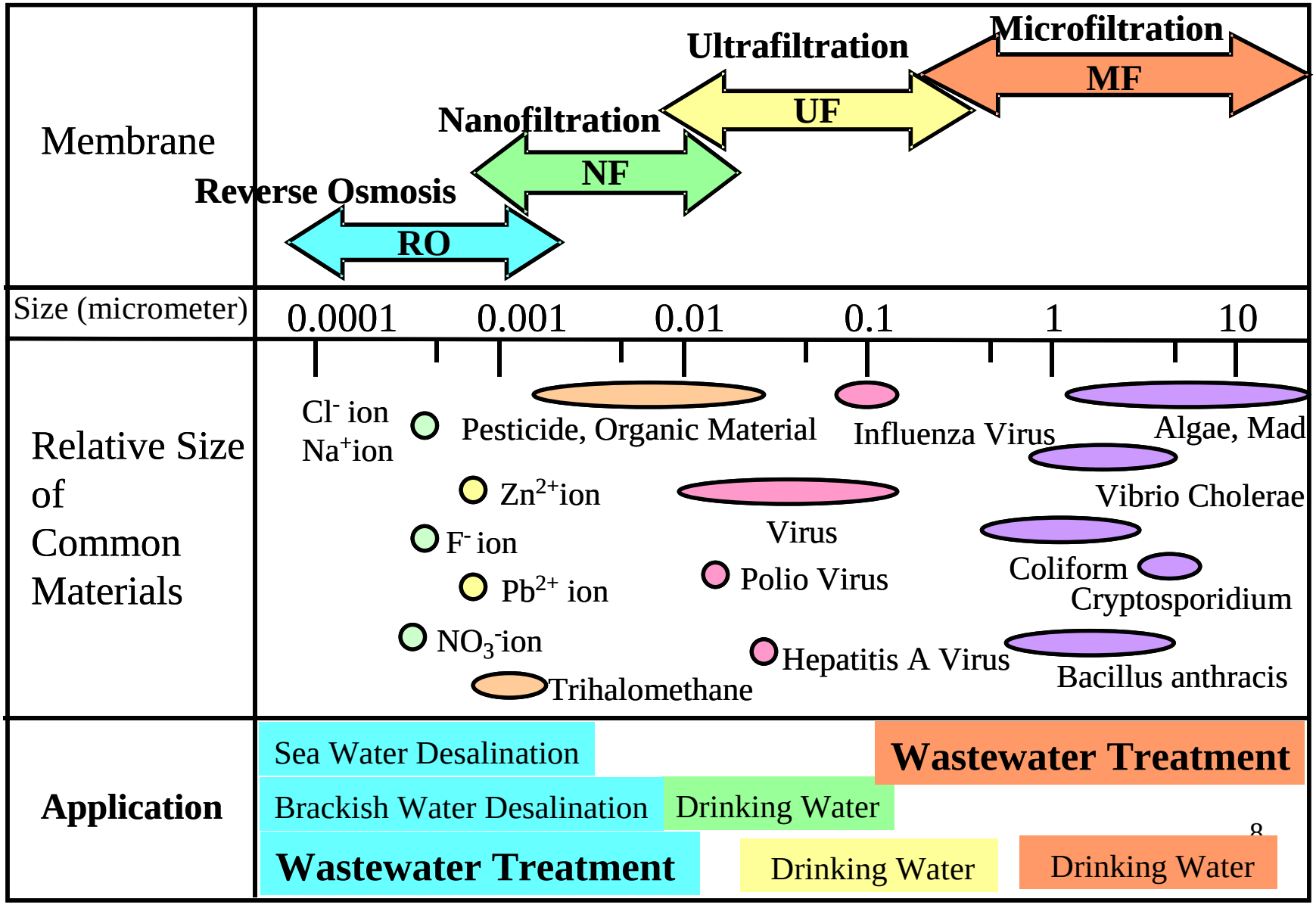
Water Problem and Membrane Technology

Region, Country	Water Problem		Membrane Technology for Water Treatment		
	Water Resource Shortage	Water Pollution	Fresh Water Treatment	Desalination	**Wastewater Reuse & Reclamation**
United States	Problem	Problem	In operation	In operation	**Construction**
Benelux		Problem	Being applied		**In operation**
UK, France		Problem	In operation		Being applied
Spain	Problem	Problem	Being applied	In operation	Being applied
Saudi Arabia	**Severe**			In operation	Planning
Kuwait	**Severe**			In operation	**Construction**
China	Problem	**Severe**	Being applied	Being applied	Planning
Singapore	**Severe**		In operation	In operation	**In operation**
Japan		Problem	In operation	In operation	

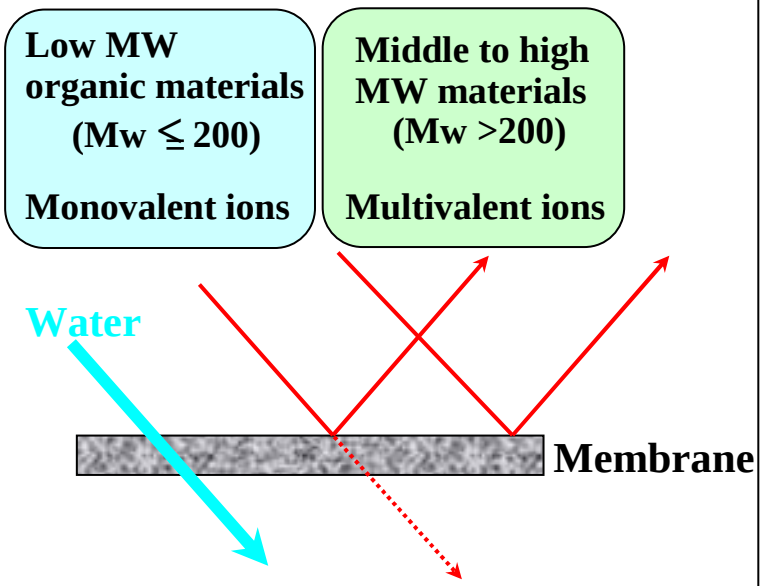
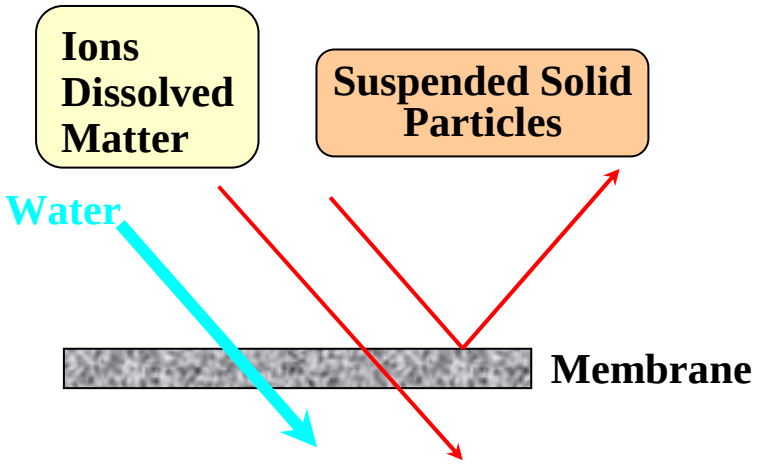
Water resources are extending from fresh water to sea water and wastewater.

Water Treatment Membranes

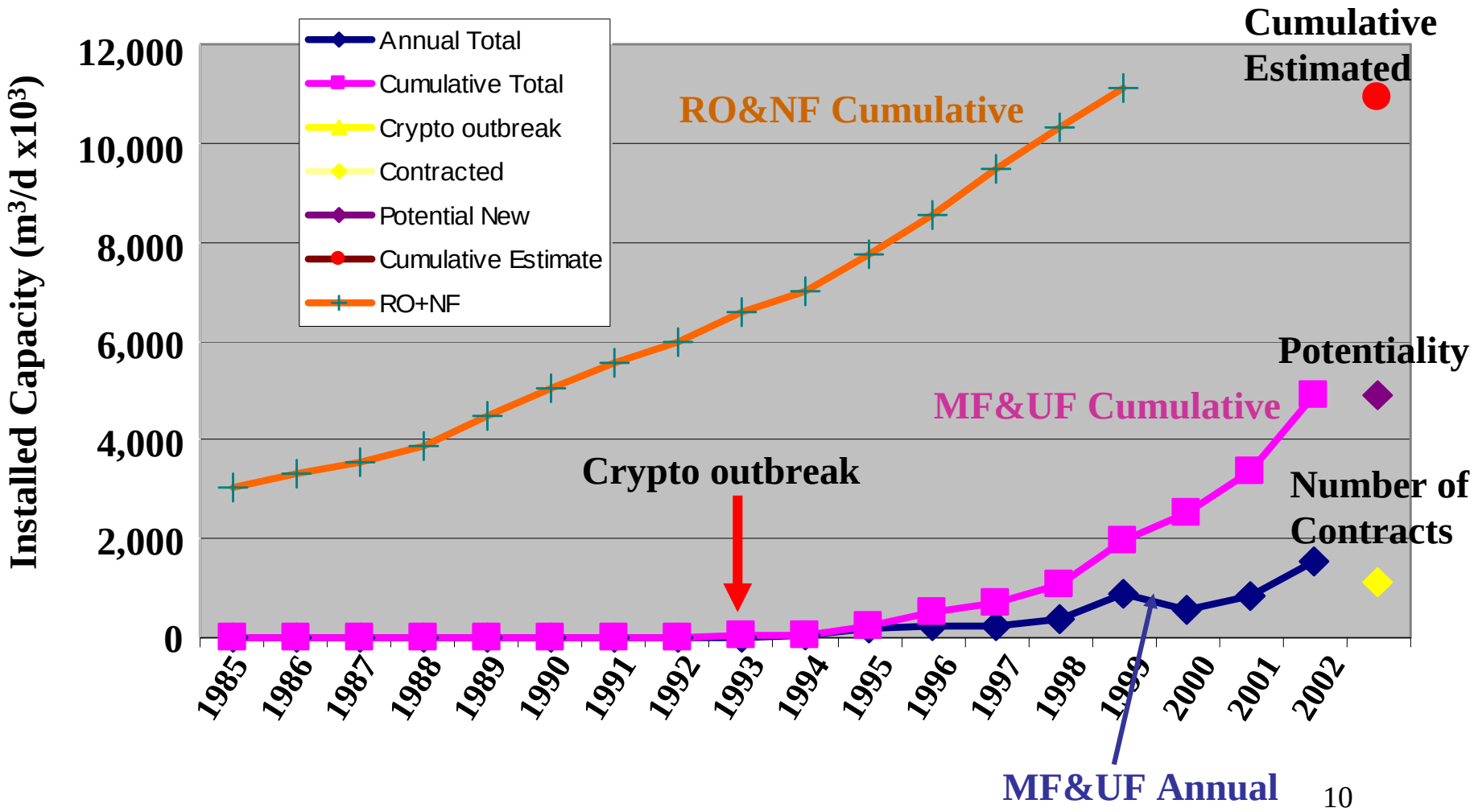
Membranes and Relative Size of Common Materials



Separation Characteristics of Various Membranes

	RO/NF Membranes	UF/MF Membranes
Permeation and Rejection		
Separation Mechanism	RO: Molecular interaction Solution diffusion Electric repulsion NF: Size exclusion	MF: Dynamic separation Size exclusion UF: Electric repulsion
Pore Size	RO: <1 nm NF: 1~10 nm	UF: 10~100 nm MF: >100 nm

Global Capacity of Membrane Filtration Plants



Membrane Applications - Conventional & New Technologies

: New membrane products ( ) : in R & D

Water treatment processes				Technical target	Toray's products
Desalination	Conventional	Sea-water	Multi Stage Flush (MSF)	Low cost (=High recovery)	RO membrane with high boron removal
			Single Stage SWRO		
	New		NF → Multi stage flush (MSF)	High quality (Low boron conc.)	NF membrane for scaling inhibition
			NF → Brine conversion Two-stage SWRO		RO membrane for brine conversion system
Drinking water production	Conv.	River Lake Ground	Coagulation & Sedimentation → Sand Filter	Security conservation Removal of cryptosporidium	PAN hollow fiber UF membrane
	New		Coagulation & Sedimentation → MF/UF membrane		PVDF hollow fiber MF(UF) membrane
Wastewater treatment	Conv.	Sewage & Ind.	Activated Sludge → Sedimentation	High quality for reuse and reclamation	PVDF MF/UF flat sheet membrane for MBR
	New		MF/UF Membrane Bio-Reactor (MBR) → Low-fouling RO		Low-fouling RO membrane

Toray's Membranes & Applications

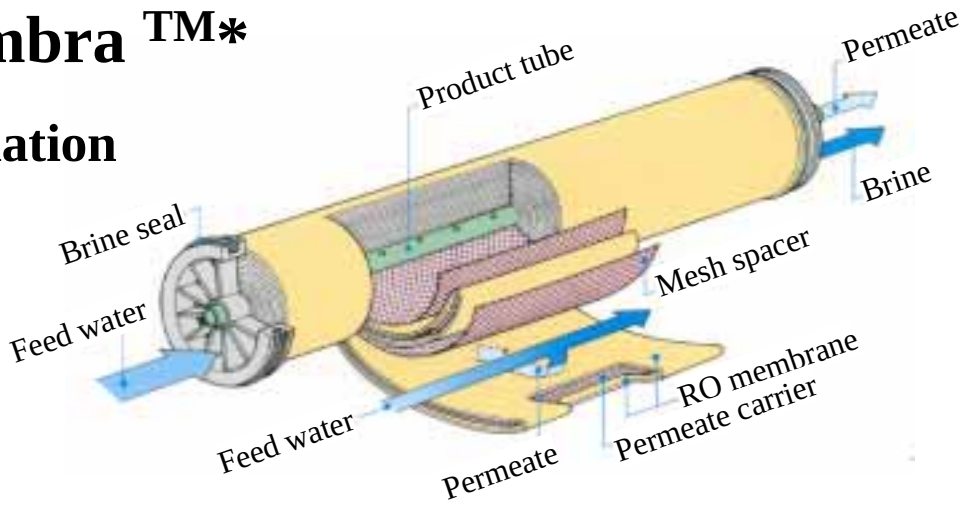
1. RO & NF Membrane Romembra ™*

1) Seawater & brackish water desalination

2) Ultra pure water production

3) Harmful material removal

4) Wastewater reuse

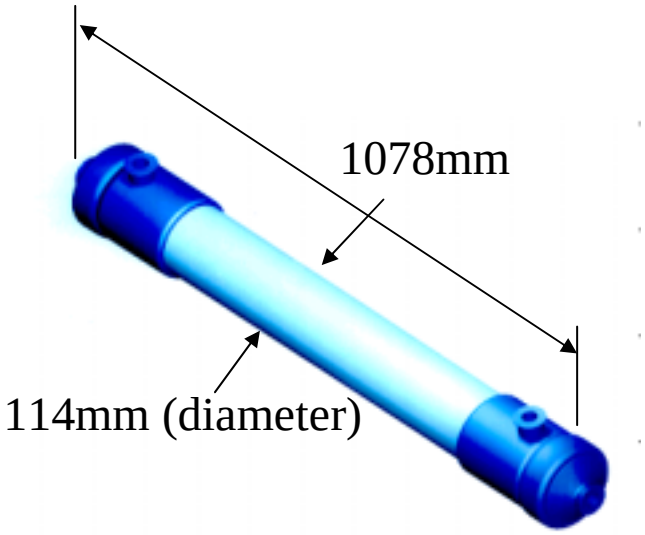


2. PAN Hollow Fiber UF Membrane Torayfil ™*

1) Industrial process water production

2) Drinking water production

3) Wastewater reuse



Toray's Membranes & Applications

3. PVDF Hollow Fiber MF Membrane
Torayfil-F TM*

1) Drinking water production

2) Industrial process water production

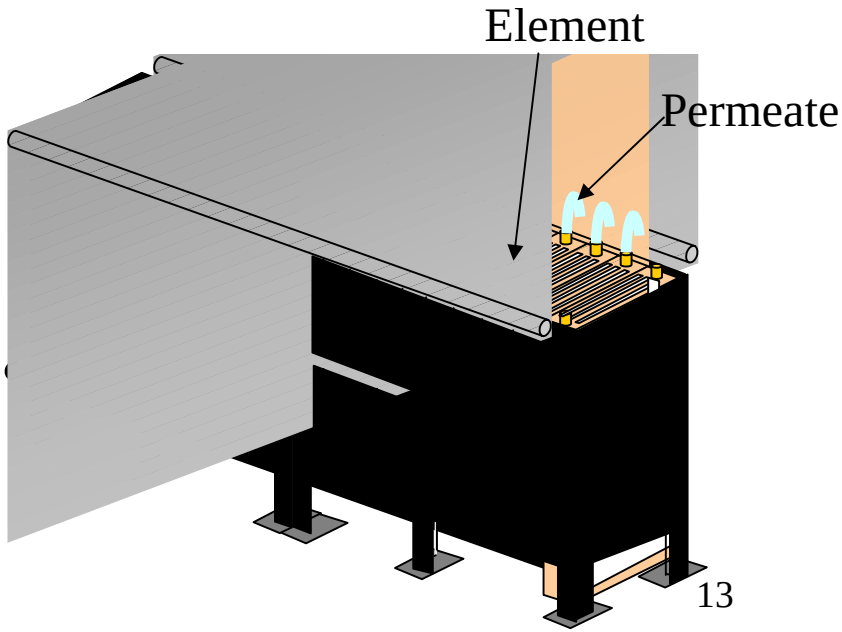
3) Pre-treatment for seawater desalination

4) Wastewater reuse

4. PVDF Flat Sheet MF Membrane for MBR

1) Municipal and industrial wastewater treatment

2) Municipal and industrial wastewater reuse



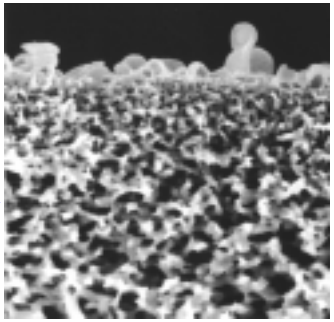
RO Membranes & NF Membranes

Structure of RO Membrane Element

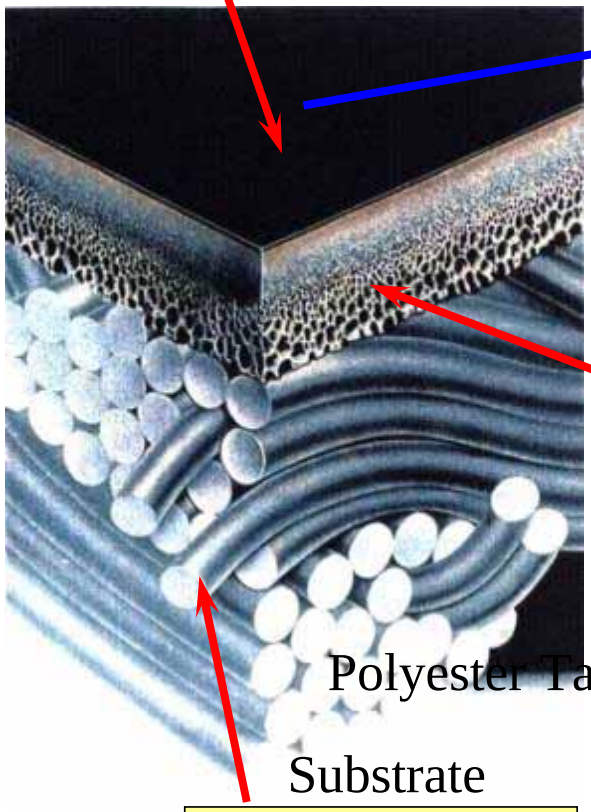
Separation Membrane

Feed

Crosslinked Aromatic Polyamide
0.2 micrometer



Structure of RO Membrane



Support Membrane

Polysulfone
45 micrometer

Polyester Taffta

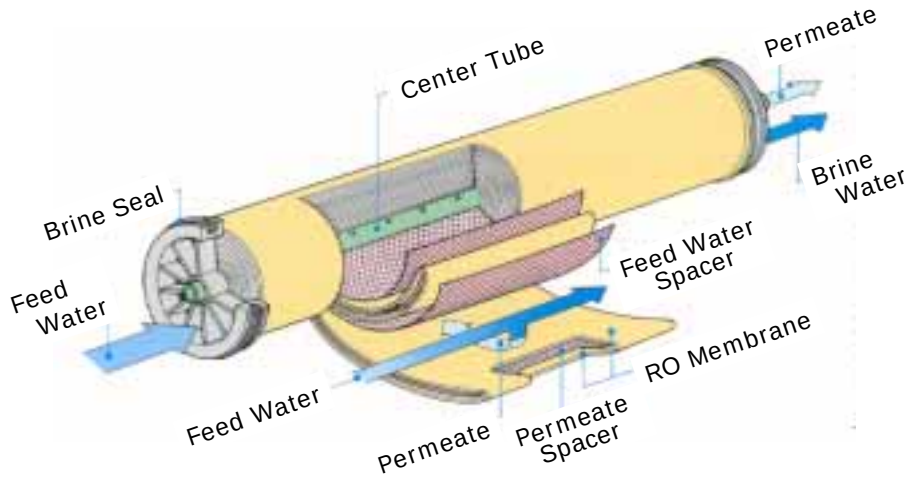
Substrate

Polyester Taffta
150 micrometer

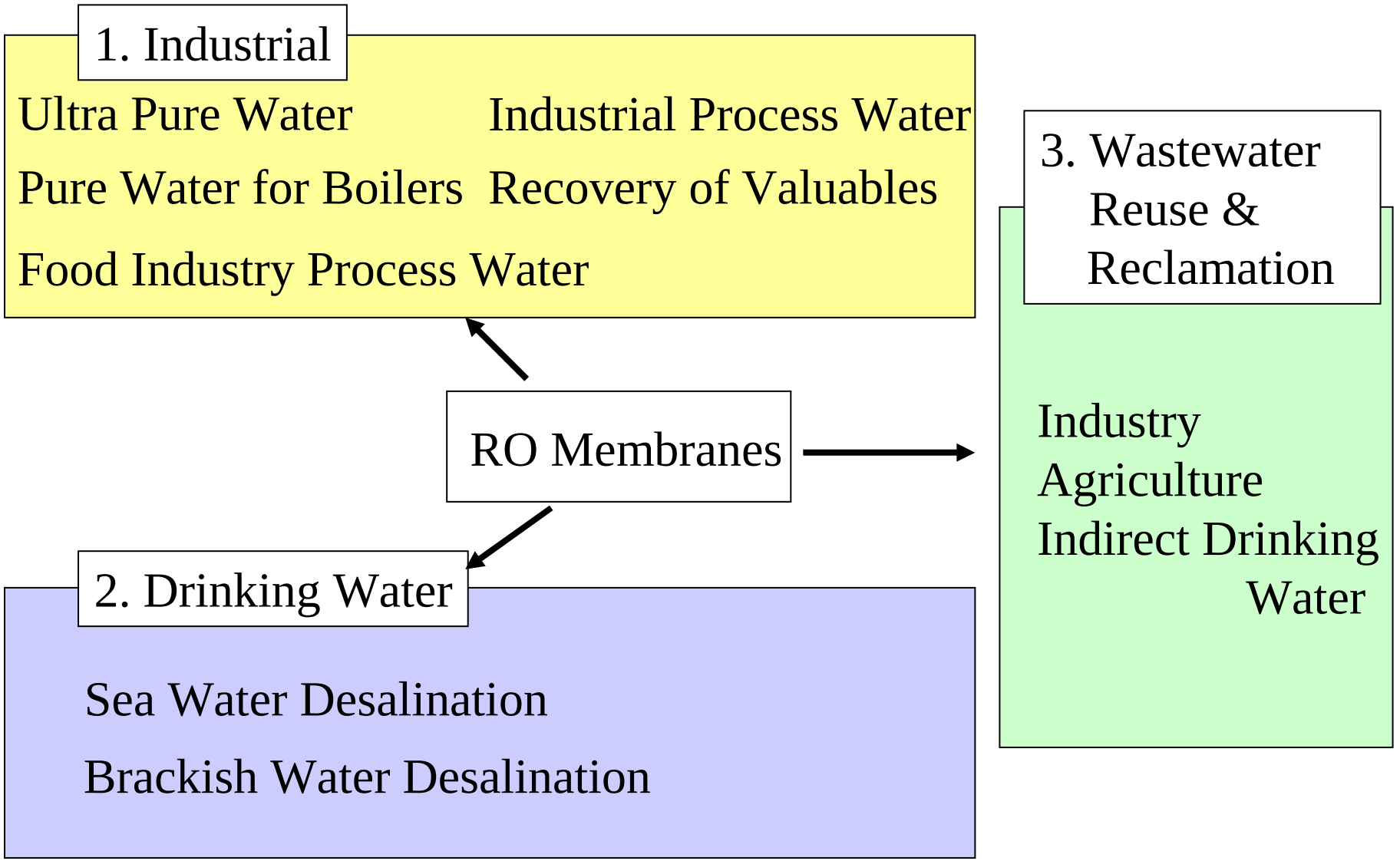
Filtrate

Structure of Composite Membrane

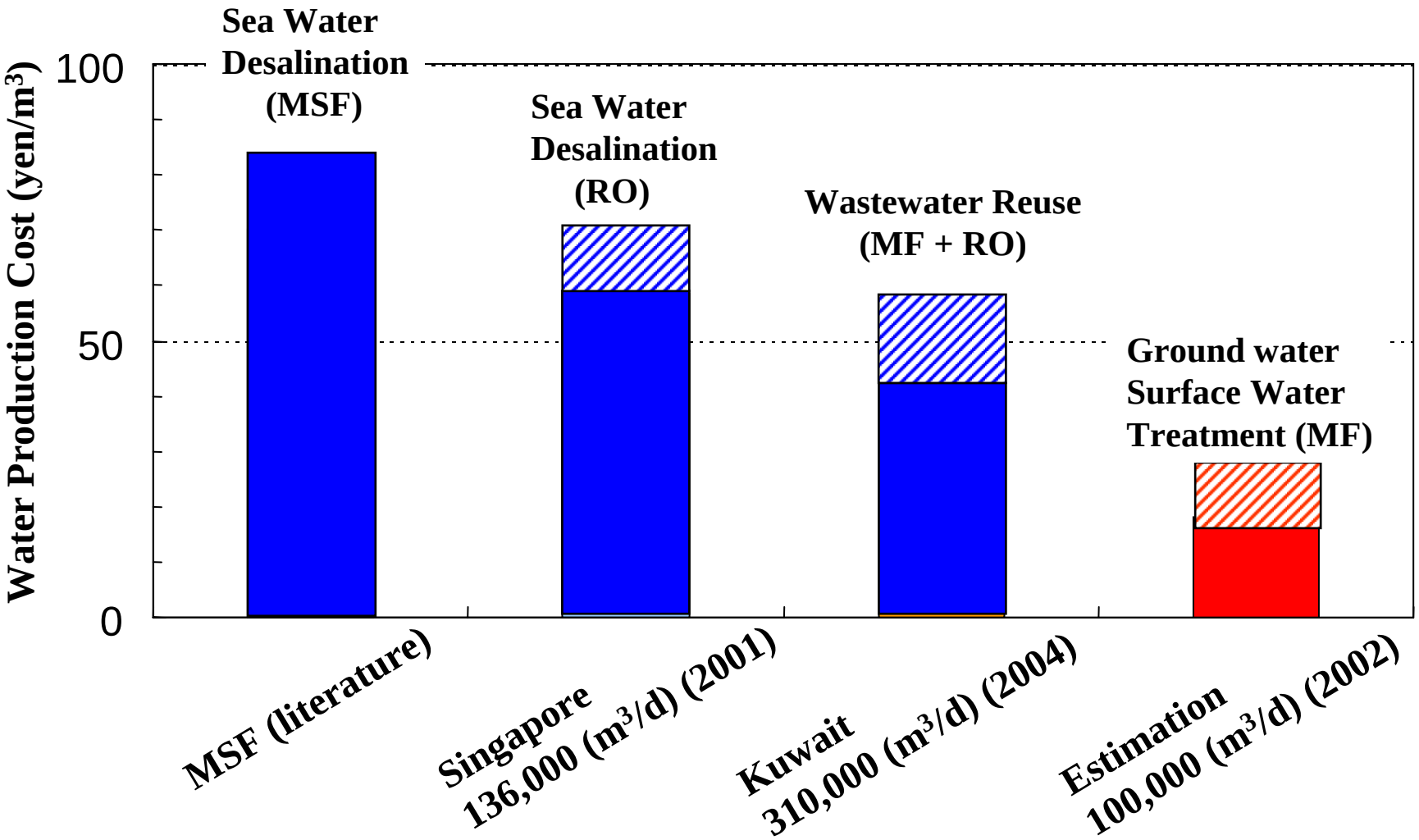
Structure of RO Element



Application of RO Membranes



Water Production Cost



Water resource can be chosen by country.

Progress of RO Seawater Desalination Plants

		1980‘s	1990‘s	2000‘s
Recovery	%	25	40 - 50	55 - 65
Operational Pressure	psig (MPa)	1,000 (6.9)	1,200 (8.25)	1,400 (9.7)
Product Water Quality (TDS)	mg/l	500	300	<200
Energy Consumption	kWh/kgal (kWh/m^3)	45 (12)	21 (5.5)	17.4 (4.6)

I. Moch, Pre-prints of ADA Conference in Lake Tahoe (2000)

Progress of membrane technology realized good quality and energy saving.

'TORAY'

Sea Water Desalination RO Membranes in Global Market

Module Type	Supplier	Product	Material	Morphology
Spiral	Toray	SU-800	Crosslinked Aromatic Polyamide	Composite Membrane
	Dow/ Filmtech	SW-30		
	Koch/ Fluidosystems	TFCL-HP		
	Nitto Denko/ Hydranautics	NTR-SWC		
Hollow Fiber	Toyobo	HOLLOSEP	Cellulose Triacetate	Asymmetric Membrane

Crosslinked aromatic polyamide/spiral module is global standard.

Toyobo is the only hollow fiber module supplier.

DuPont withdrew from the hollow fiber RO module business in March 2001.

Technological Trends of RO/NF Membranes

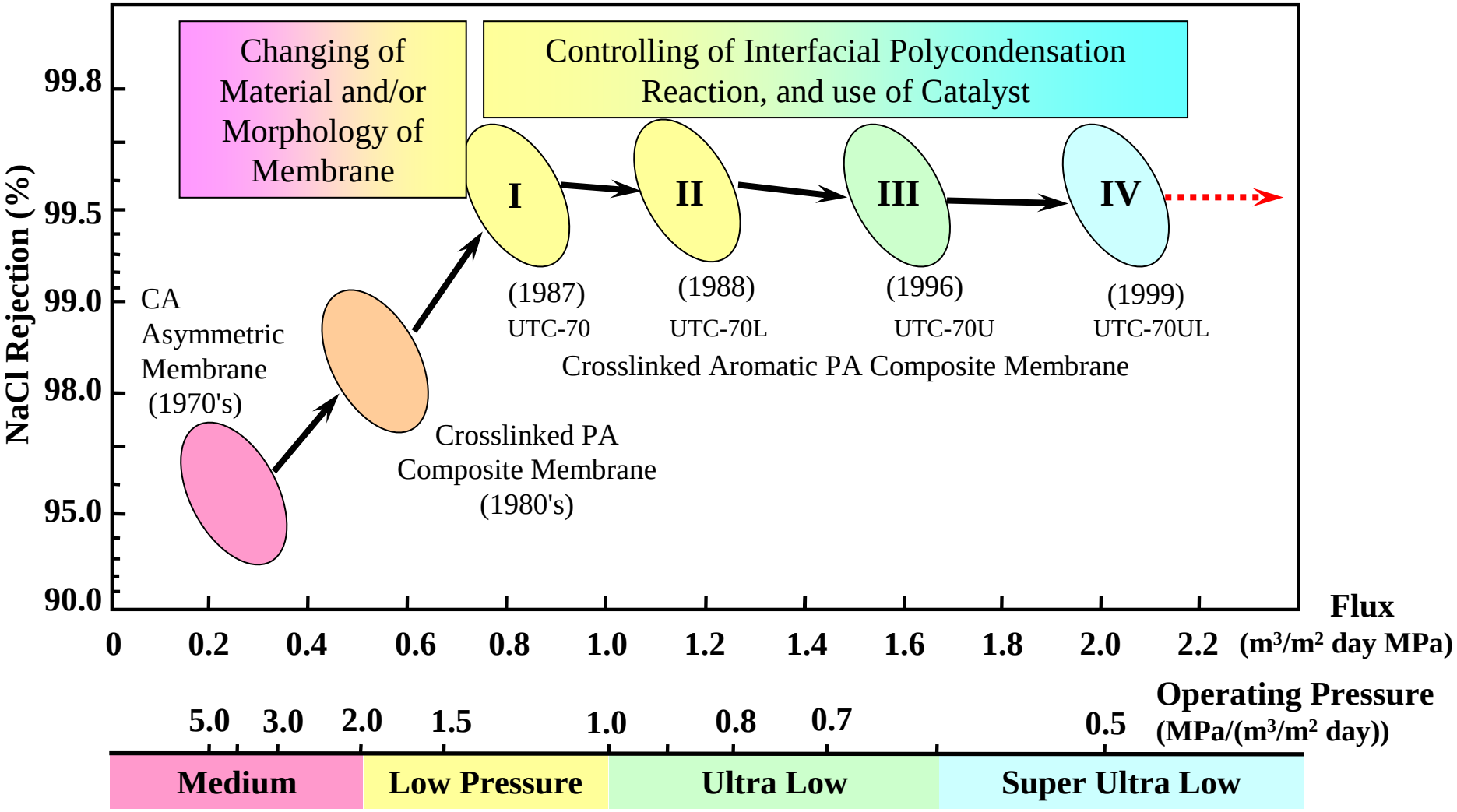
'TORAY'

Operating Pressure [MPa]			Super low	Ultra low	Low	High	Ultra high	Notes
			0.3	0.5	1.0	2.0	5.5 10.0	
Reverse osmosis	SWRO	2nd stg.				Recovery = 60%		High TDS removal Pressure durability High boron removal
		1st stg.				Recovery = 40% N Co., D Co.		High TDS removal High boron removal
	BW RO			Lower pressure N Co., H Co.				Cost reduction Low-fouling
	Ultra pure water			N Co.				High TOC removal High quality Cost reduction
	Waste water reuse				D Co., N Co., H Co.			Low-fouling Cost reduction
Nanofiltration	Drinking water Product.		D Co., N Co.					Toxic mat. removal Cost reduction
	Pre-Ttreat. of SWRO							Scale removal

in R & D by Toray

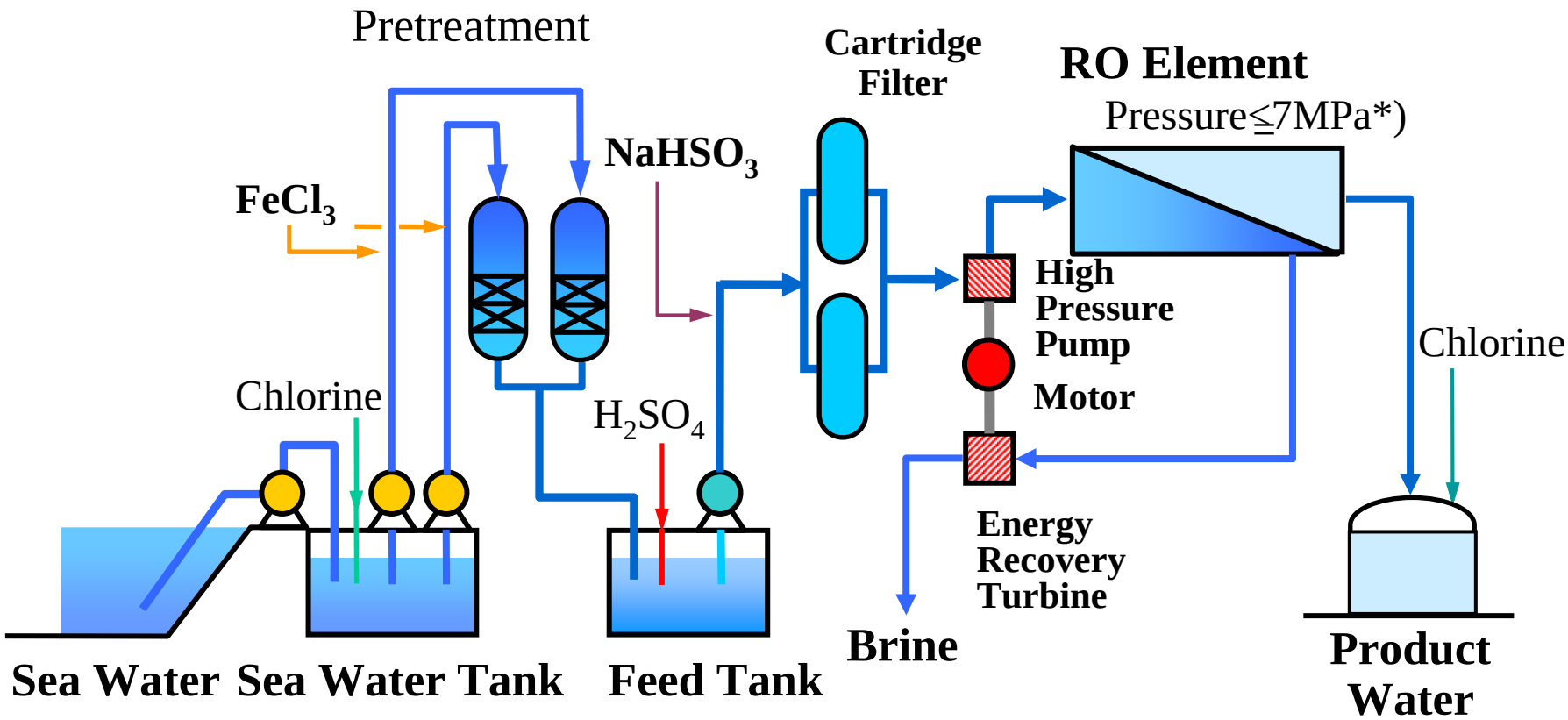
D Co. : Dow N Co. : Nitto Denko H Co.: Hydranautics

Progress of RO Membrane Performance



World's No. 1 Membrane Performance

Conventional One-Stage RO Sea Water Desalination System



*) Spiral element

Okinawa Sea Water Desalination Plant

(Capacity: 40,000 m³/d, 1996)

40,000m³/d: Tap water for 160,000 people

RO Module Installation
(each unit produces 5,000m³/d)

Toray module is used in Japan's largest plant.

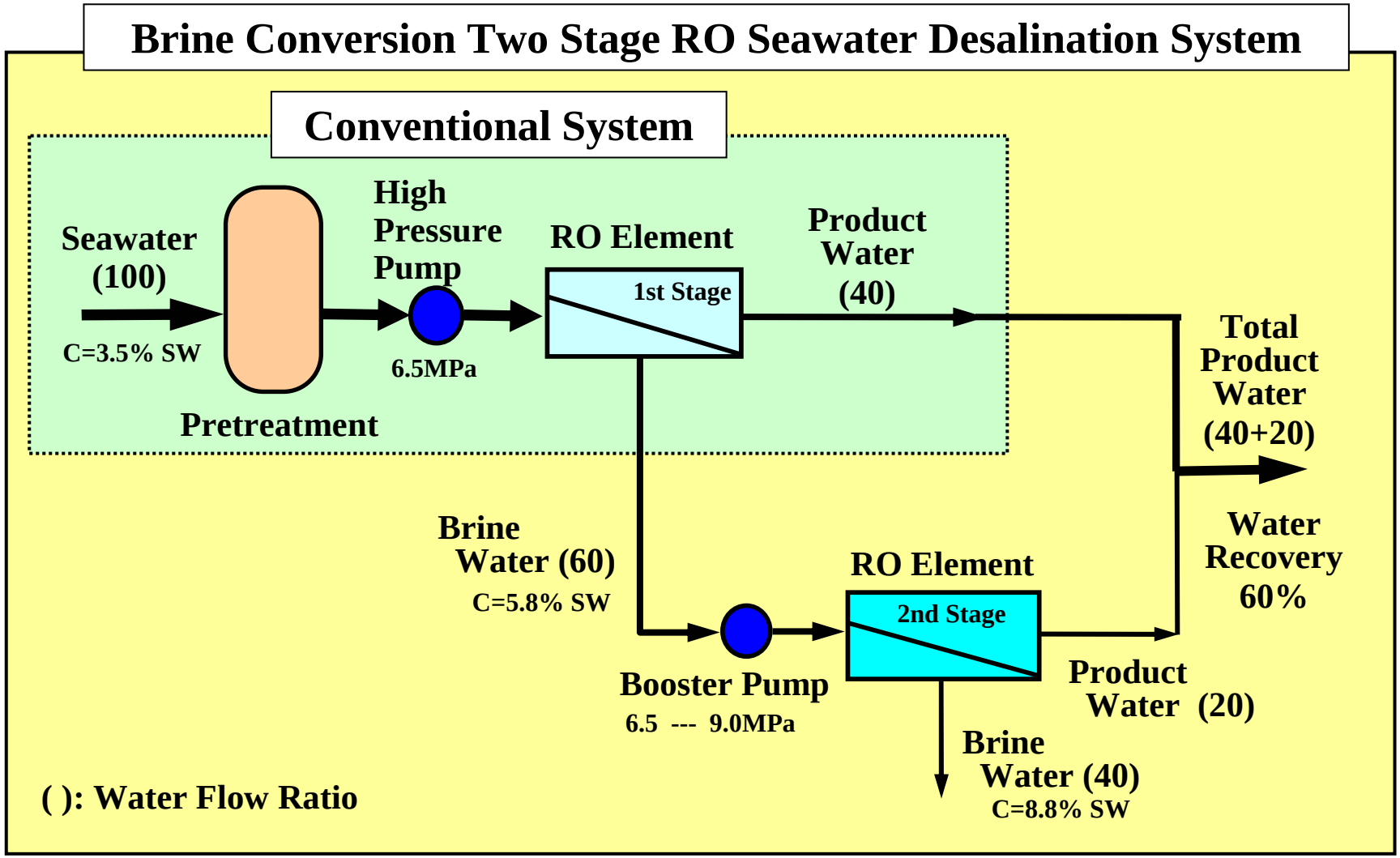
Largest Sea Water Desalination Plants in the World

No.	Country	Plant Site	Capacity (m^3/d)	Number of Units	Contract (year)	Operation (year)	Plant Manufacturer	Membrane Manufacturer
1	Trinidad	Trinidad	136,000	8	99	2002	Ionics	Toray
2	Saudi Arabia	Yanbu RO2	128,000	15	92	98	MHI	Toyobo
3	Saudi Arabia	Al Jubail III	91,000	15	93	2000	Preussag	DuPont, Toray
4	Saudi Arabia	Jeddah RO1	56,800	10	86	89	MHI	Toyobo
4	Saudi Arabia	Jeddah RO2	56,800	10	91	94	MHI	Toyobo
6	Spain	Marbella	56,400	10	97	99	Inima	DuPont
7	Malta	Penbroke	54,000	10	-	94	Polymetric	DuPont
8	Bahrain	Al Dur	45,000	8	84	89	Weirwest garthge	DuPont
9	Spain	Bl Mallorca	42,000	6	96	98	Degremont	DuPont, Toray
10	Japan	Okinawa	40,000	8	94 - 95	96 - 97	Kurita, etc.	Toray, Nitto

* DuPont withdrew from RO business in 2001

RO sea water desalination seems very difficult in the Arabian Gulf, because troubles occurred at all of DuPont's RO plants. Al Jubail III is the first successful plant.

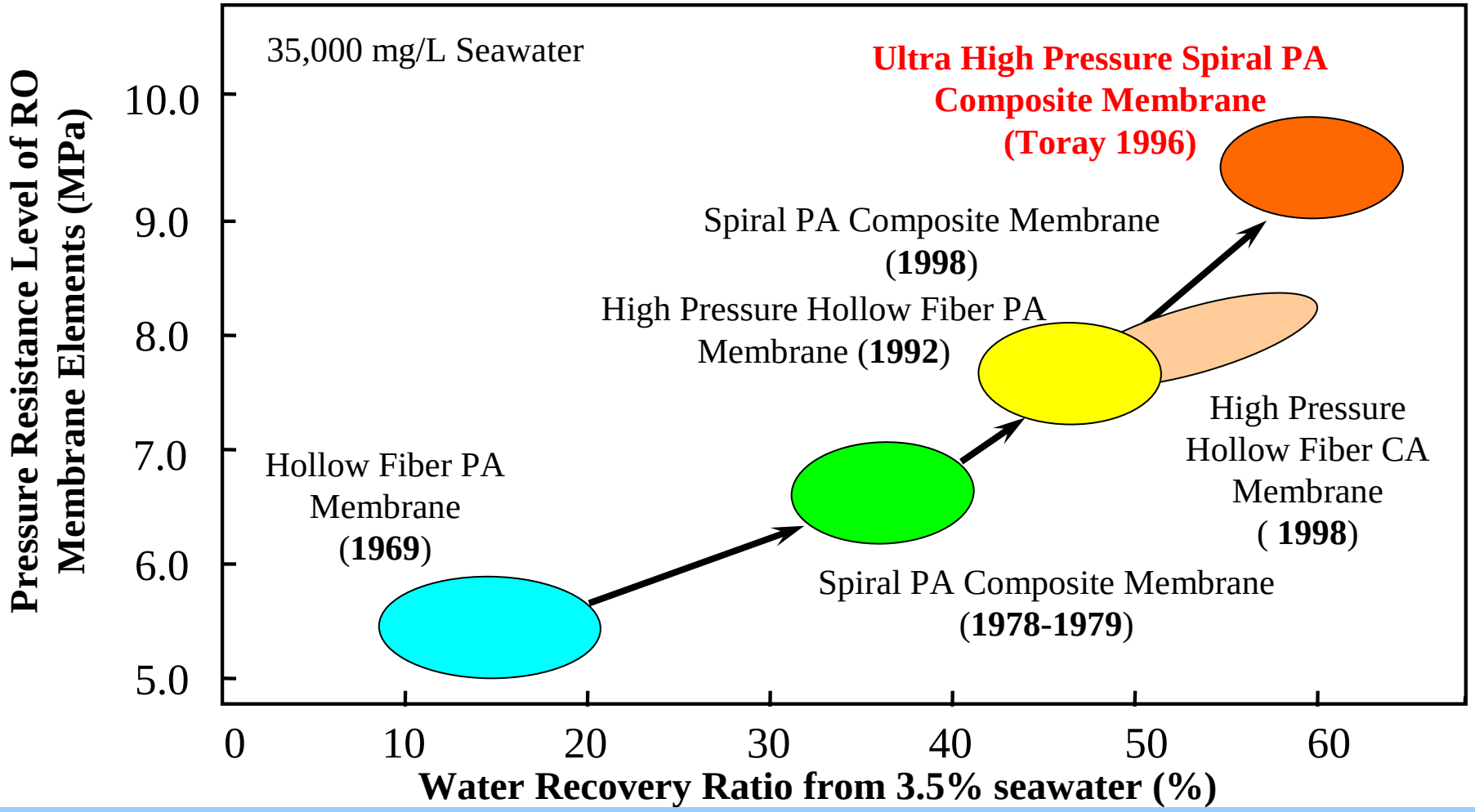
Typical Flow Diagram of Brine Conversion Two Stage RO Seawater Desalination System



Toray's Patent:

Japanese Patent Application 1994-245184(1994), US: 6187200(2001), CA: 216033(2001), RC: 302294(1997), AU: 691649(1998), EU(granted 2002), KR: 204608(1999), Pending - JP, CH

Performance Trends of RO Membranes for Seawater Desalination



Toray's membrane performance for sea water desalination is world's No.1.

Global Installations of Toray Sea Water Desalination Ros

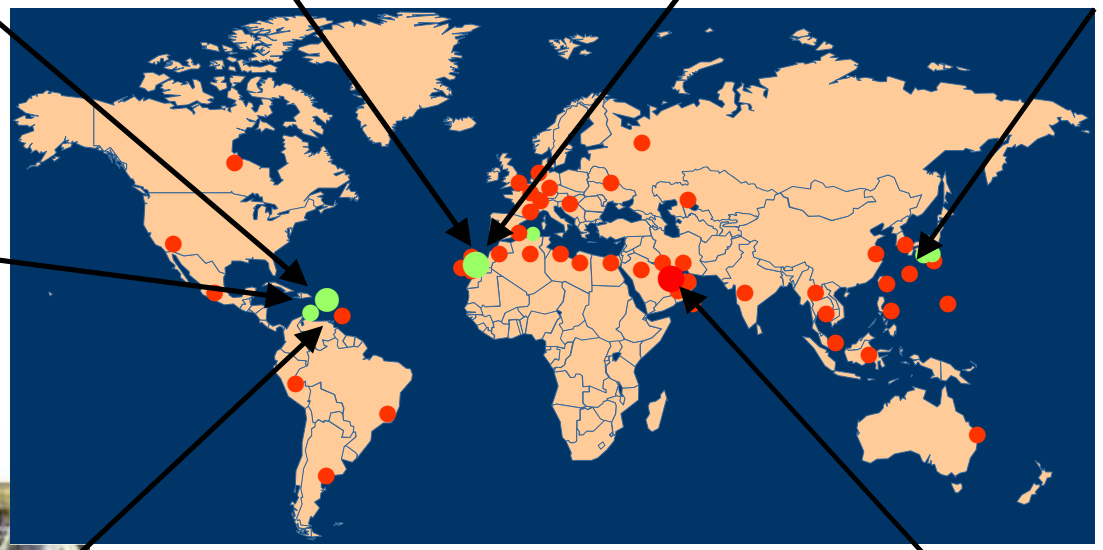
KAE Curacao
(Netherlands, Antilles)
11,400 (m3/d)

Mas Palomas
(Spain, Canary Island)
No. 1 Plant 4,500 (m3/d)

Mas Palomas
(Spain, Canary Islands)
No. 2, 3 Plant 9,000 (m3/d)

Okinawa
(Japan)
40,000 (m3/d)

Tortola
(British, Virgin Islands)
690 (m3/d)

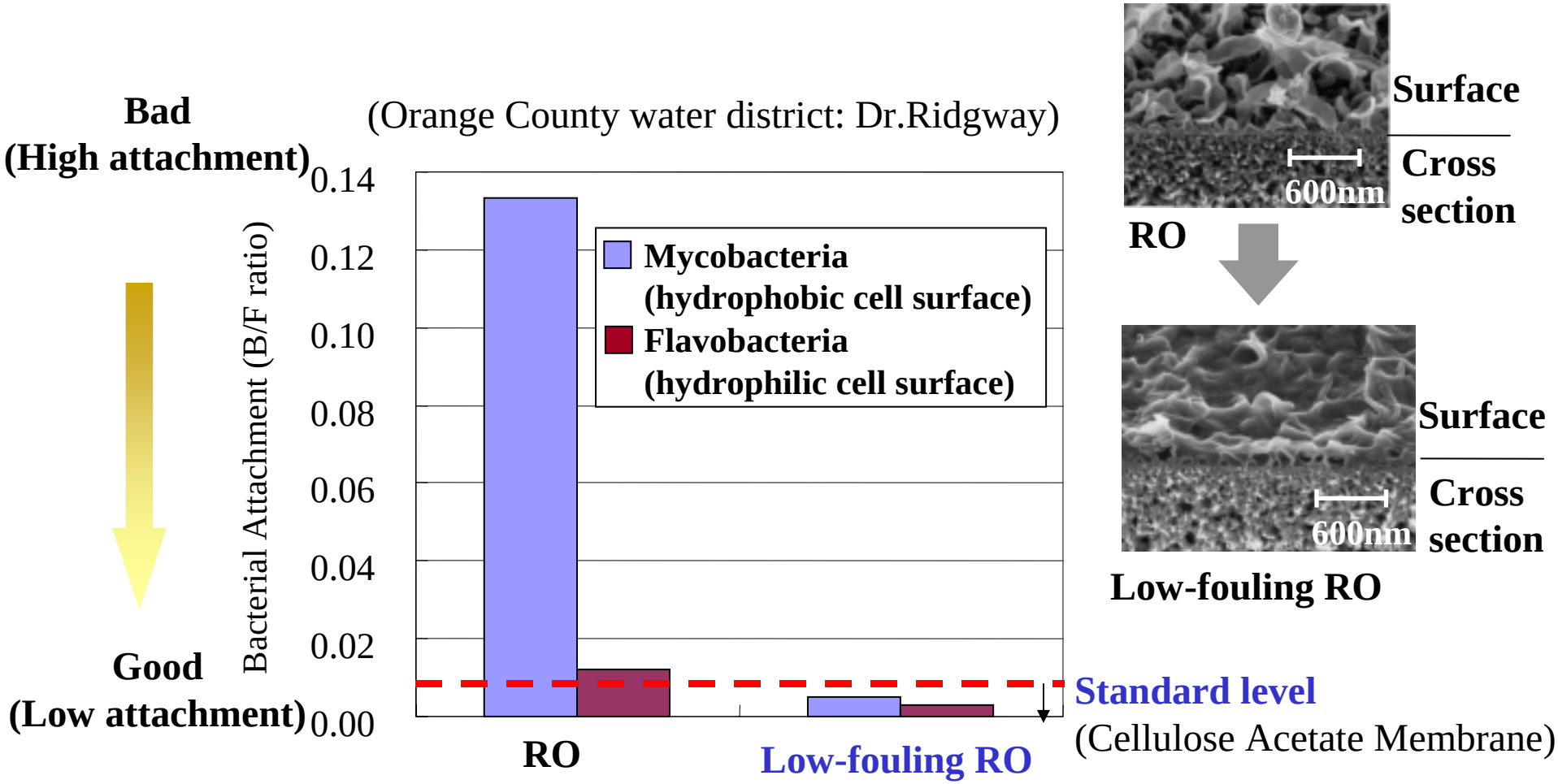


:Toray's 2-Stage RO Systems
:Conventional RO Systems

Trinidad and Tobago
136,000 (m3/d)

Al Jubail
(Saudi Arabia)
91,000 (m3/d)

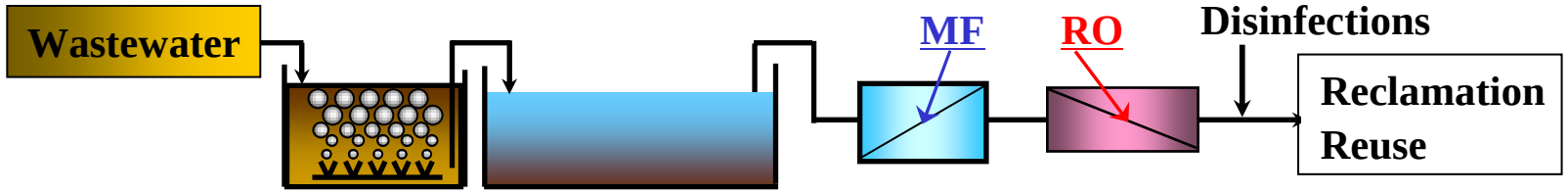
Results of Membrane Biofouling (MBP) Assay



Fouling : Deterioration of membrane performance caused by stains

Toray less-fouling RO membrane has extremely low bacteria attachment.

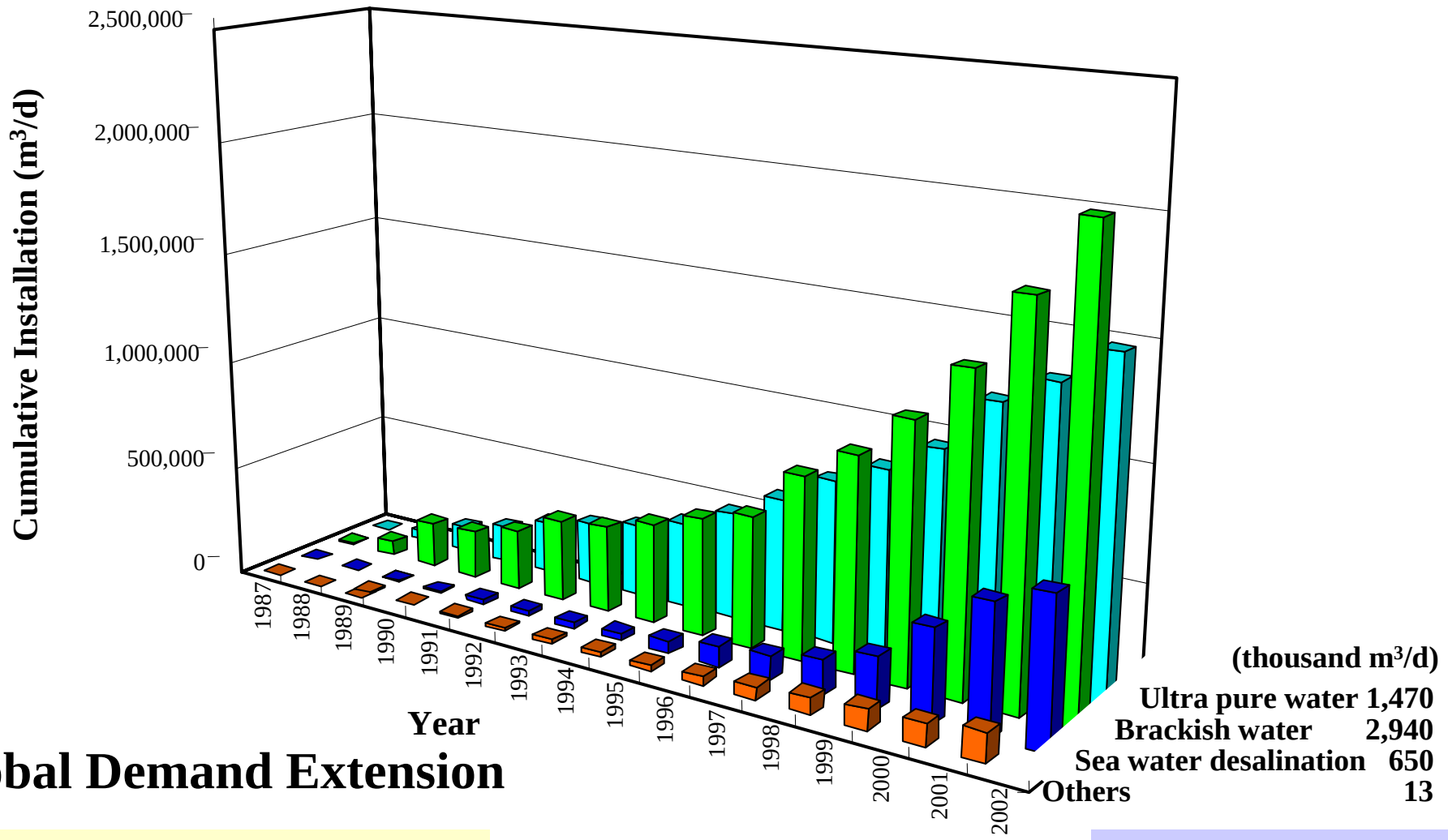
Wastewater Reclamation & Reuse Plants



Plant (Country)	Capacity (m^3/d)	Installation	MF/UF Supplier	RO Supplier
Jewel (Singapore)	30,000	2000		Dow
Luggage Point (Australia)	14,000	2000	Pall	Dow
Bedok (Singapore)	10,000	2000	US Filter	Hydranautics
Bedok (Singapore)	32,000	2003	Zenon	Hydranautics
Kranji (Singapore)	40,000	2003	US Filter	Hydranautics
Seleta (Singapore)	**24,000**	**2003**	Hyflux	**Toray**
Sulaibiya (Kuwait)	**310,000**	**2004**	Norit	**Toray**
Orange County (USA)	220,000	2004	US Filter	**Piloting**
Ulpandan (Singapore)	140,000	2004	**Piloting**	**Piloting**

Toray less-fouling RO was selected at the world's largest RO plant.

Cumulative Installations of Toray ROs by Application



Global Demand Extension

Ultra pure water production
Brackish water desalination

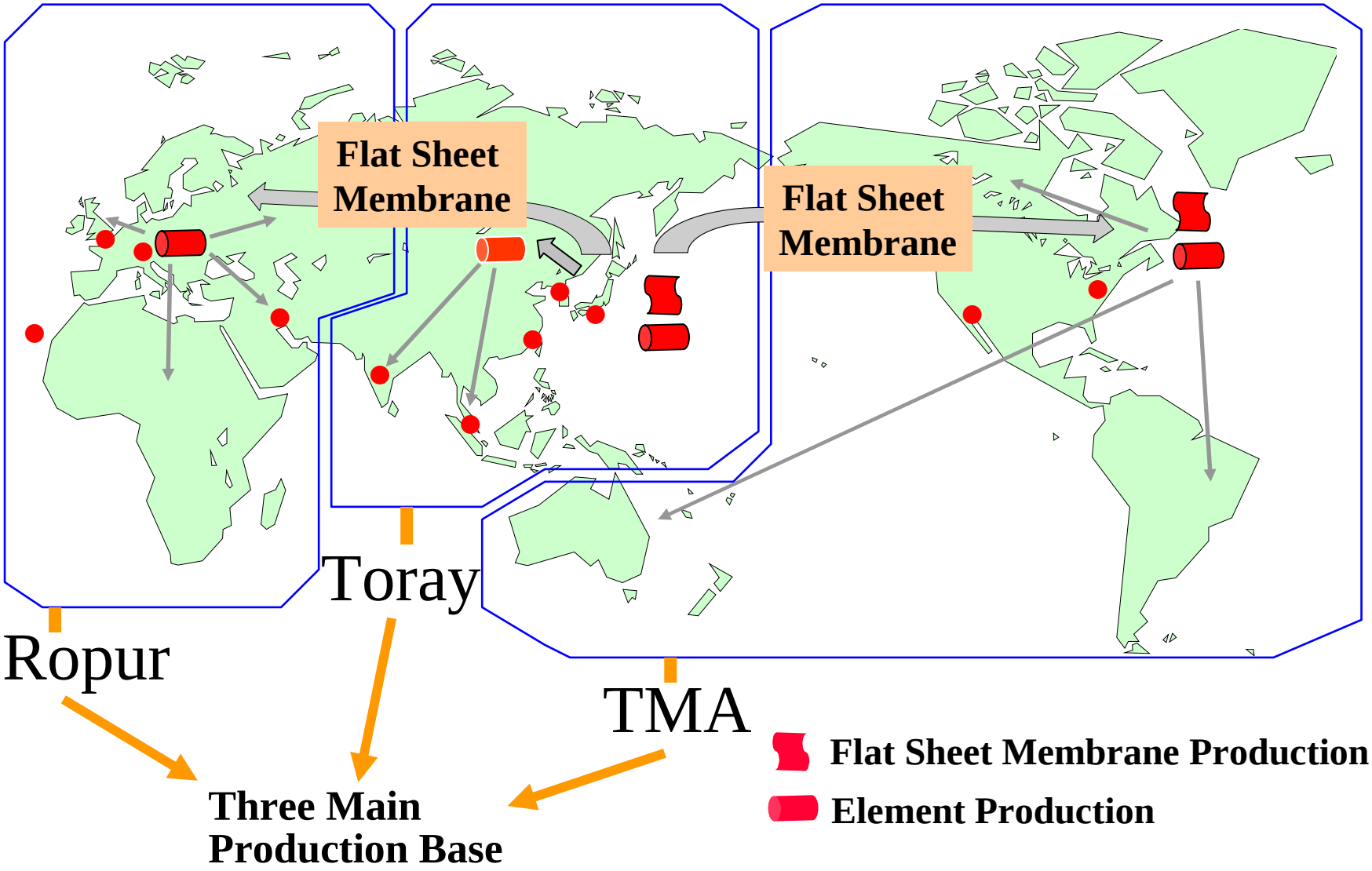
➡

Sea water desalination

➡

Wastewater reuse & reclamation

Toray Group's Business Bases and Global Operations



Conclusion – RO•NF Membranes

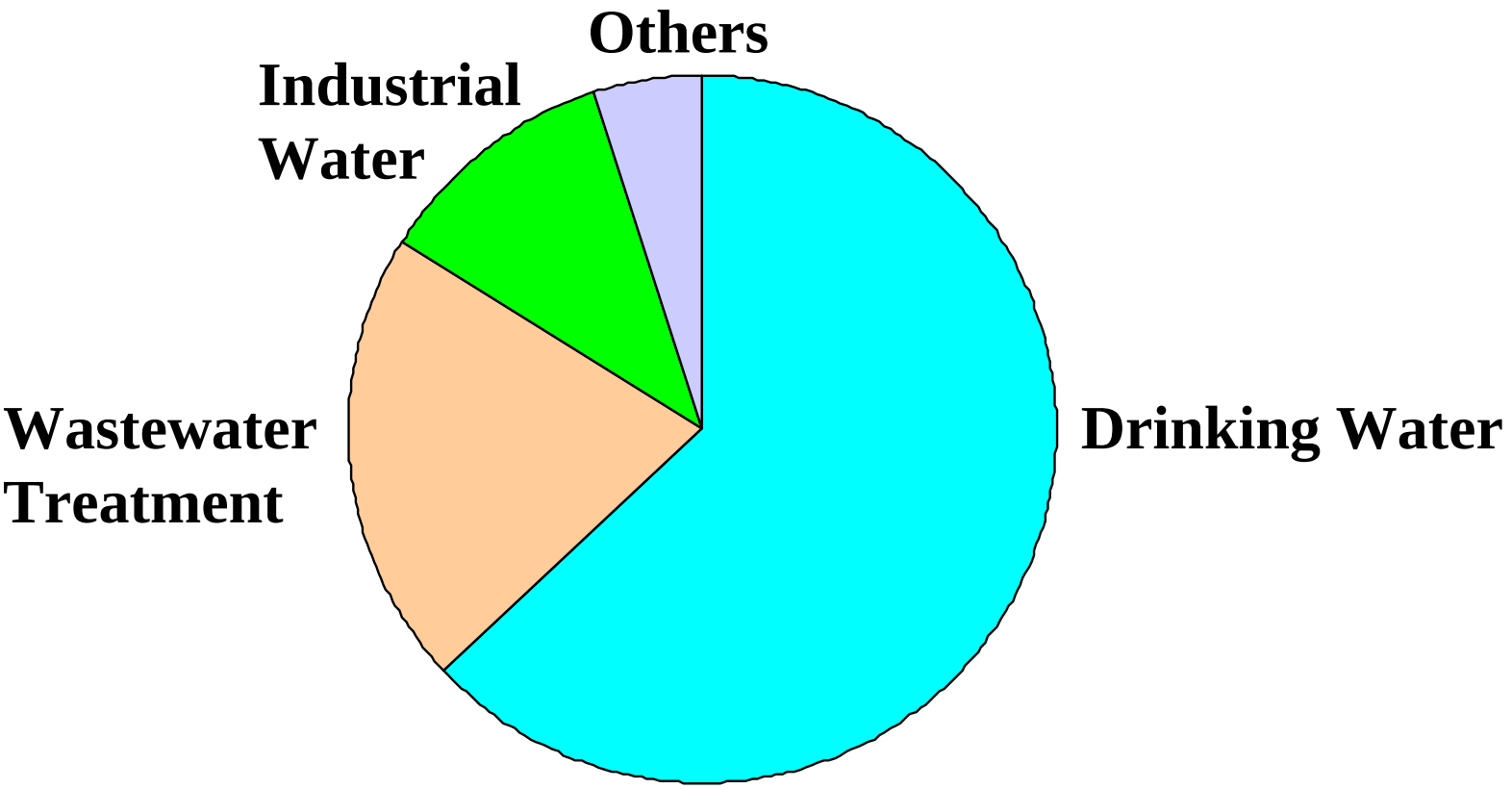
1. **The RO seawater desalination system has entered a stable growth stage and the business is expanding steadily.**

2. **Wastewater reuse and reclamation is expected to be a new RO application.**

3. **Expansion of the NF membrane businesses is expected in the pretreatment of seawater desalination, and in highly efficient water purification systems.**

UF Membranes & MF Membranes
- Drinking Water Production -

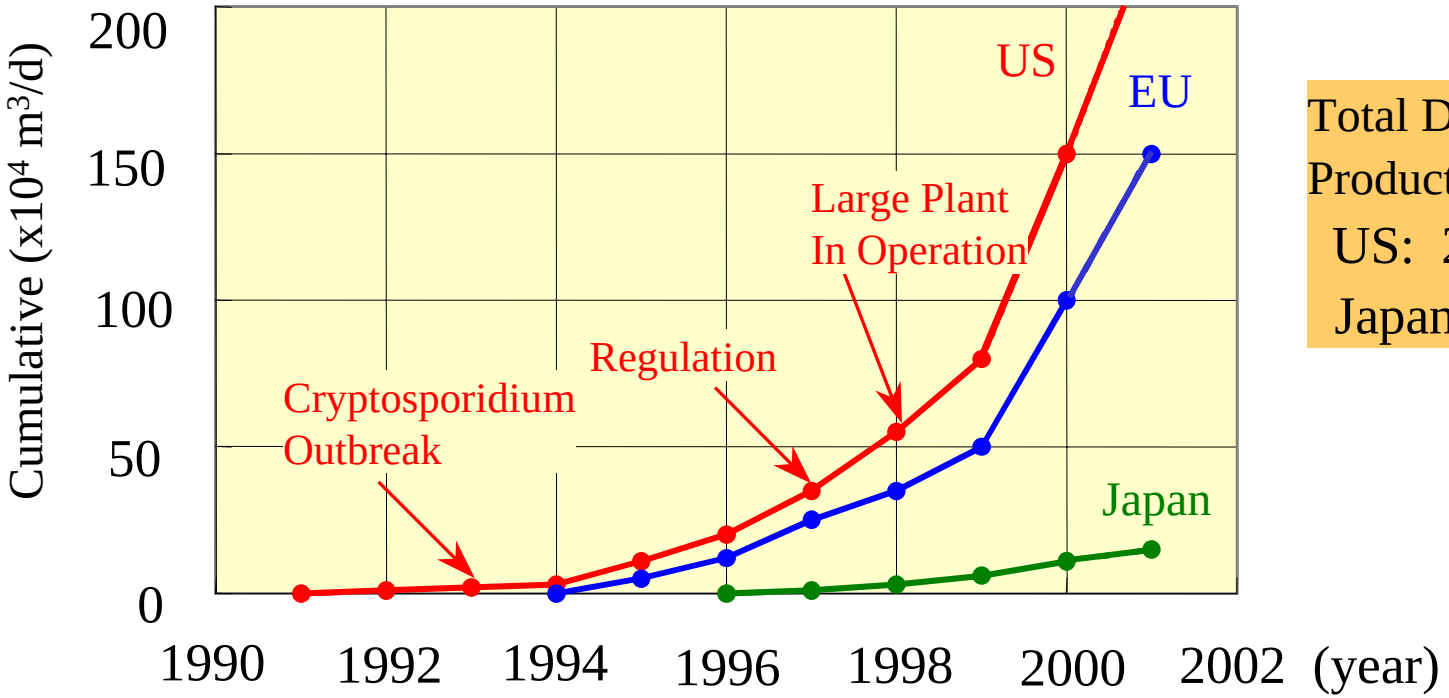
UF & MF Membranes – Breakdown of World Applications -



Ref: David H. Furukawa,
WATERMARK, October 17, 2002

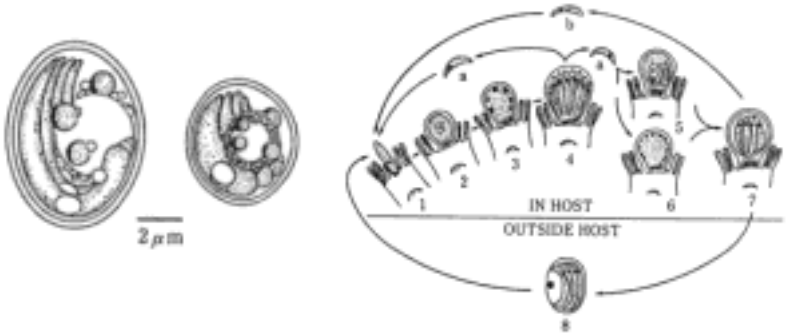
Total Water Production: 4.9 million m^3/d

Market for Hollow-fiber Membranes for Drinking Water Production



Total Drinking Water Production (x10⁴ m³/d)
US: 2900
Japan: 6900

Cryptosporidium parvum (4 ~ 8micrometer)



1993 400,000 people experienced intestinal illness in Milwaukee. At least 50 died of the disease.

1996 8,000 people infected in Ogose, Saitama, Japan

1998 Enhanced regulations of surface water treatment

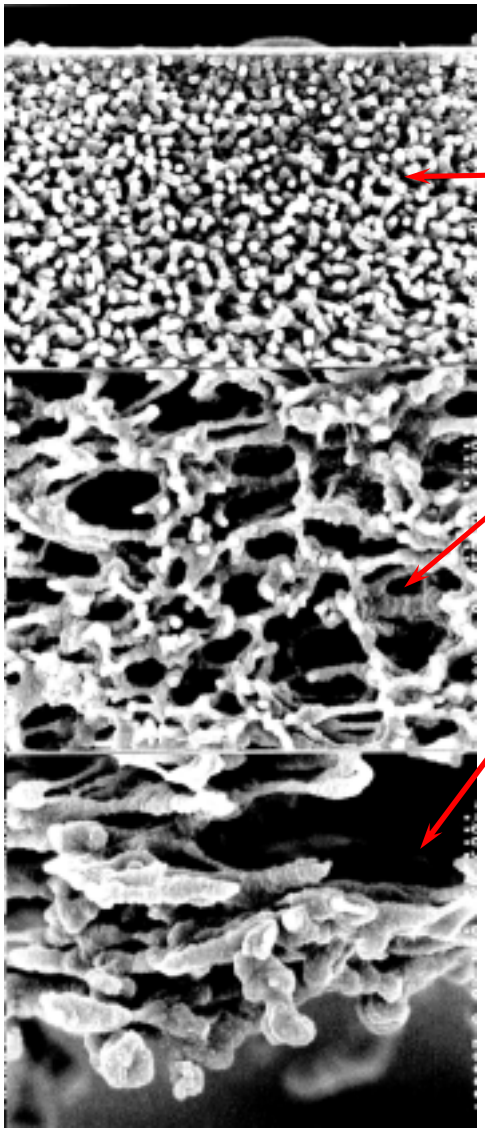
Enhancement of Pathogen Regulations caused market expansion.

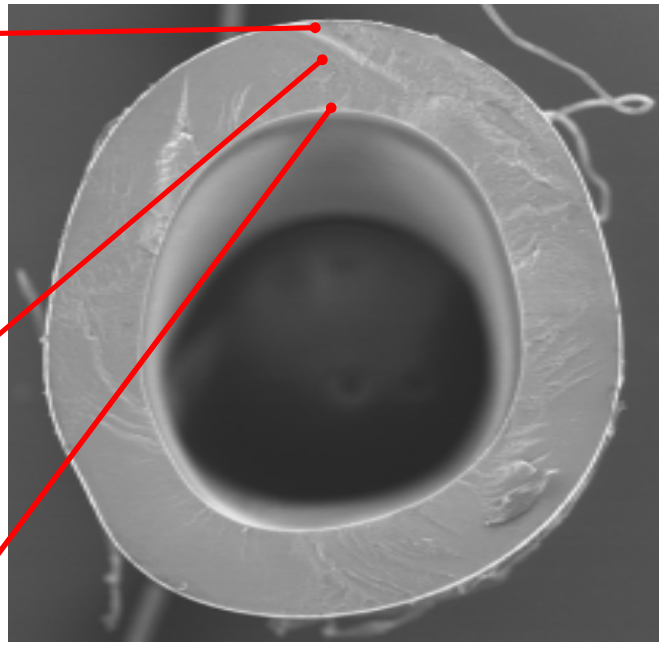
Membrane Filtration Plants for Drinking Water in Japan

Capacity (m^3/d)	Location	Engineering	Membrane Supplier	Installation (Year)
4,000	Saitama, Ogose	Kurita	Kuraray (UF)	1998
6,200	Hokkaido, Nishisorachi	Orugano	Daiseru (UF)	1999
2,400	Ooita, Notsu	Hitachi	Toray (UF)	1999
10,000	Tochigi, Imaichi	Orugano	Daiseru (UF)	2000
1,900	Fukui, Miyazaki	Suido Kiko	Asahi Kasei (UF)	2000
1,600	Fukushima, Aizuwakamatsu	Orugano	Daiseru (UF)	2000
6,000	Miyagi, Onagawa	NKK	Memcore (MF)	2001
5,000	Mie, Kiho	Ebara	Mitsubishi (MF)	2001
1,900	Fukui, Eiheiji	Maezawa	Toray (UF)	2001
4,500	Gifu, Ena	Suido Kiko	Asahi Kasei (UF)	2001
1,900	Gunma, Showa	Suido Kiko	Asahi Kasei (UF)	2001
5,000		Suido Kiko	Toray (MF)	2002
8,000		Suido Kiko	Toray (MF)	2003

Application of UF/MF membranes is expanding in Japan. Cumulative installations are 200,000 (m^3/d) as of June 2003.

PAN-based Hollow Fiber UF Membrane



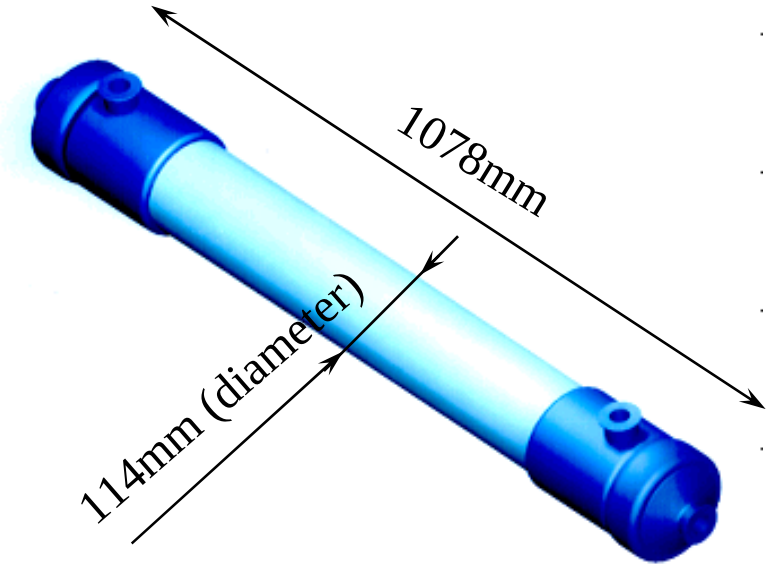


Cross section

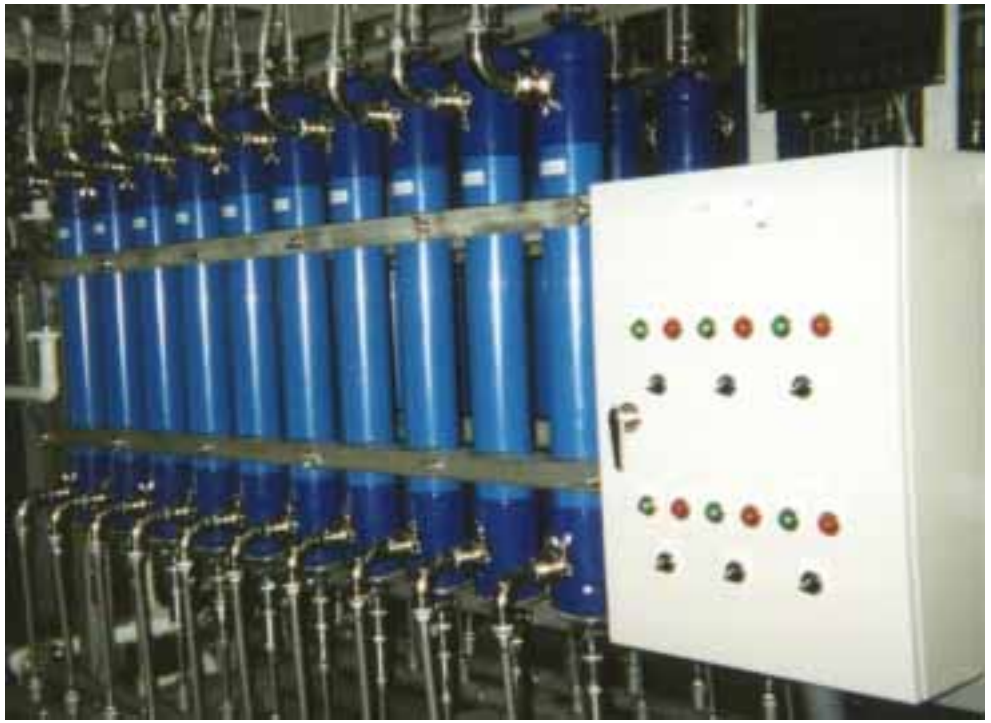
Pore size: 0.01 micrometer

Outer surface

Casing Type Module

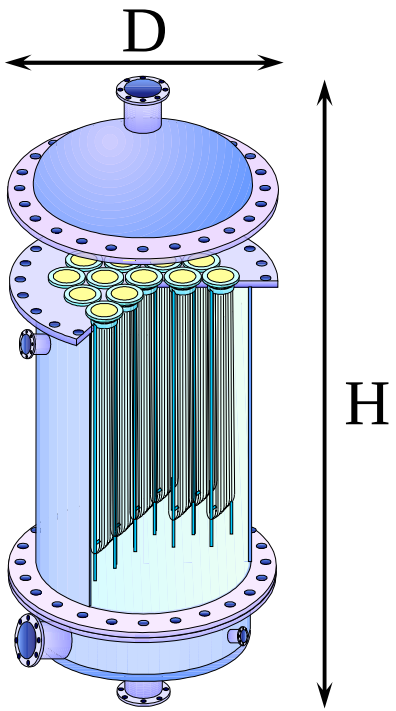


Membrane area: 12 m^2
Water production: 10 m^3/d



Drinking water production plant

Tank Type Module



Merit

- Low Initial Cost
- Small Footprint
- Easy Maintenance

Flux (m^3/d)	70	200	500	800
Membrane area (m^2)	84	228	576	960
Diameter (D) (cm)	45	75	120	150
Height (H) (cm)	200	230	250	250

Design Concept of PVDF Hollow Fiber MF Membrane

Operation

1. High Water Flux
2. Low Operational Pressure
3. Frequent Physical Washing
4. Frequent Chemical Rinse

Functional Requirement

1. High Water Permeability
2. Precise Pore Size
3. High Physical Stability
4. Good Chemical Resistance

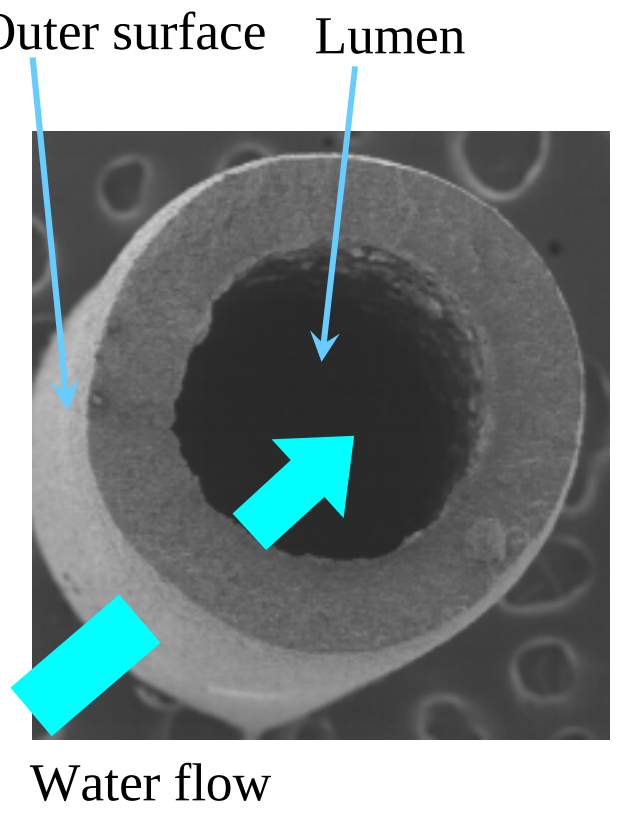
PVDF(Poly Vinylidene Fluoride) polymer is suitable

Performance of hollow fiber membrane depends highly on spinning process → Proprietary spinning process

High Permeability & High Physical Strength

Toray PVDF Hollow Fiber Membrane

	Spinning Method	Feature
Melt Spinning	**Extraction** Melt spinning with pore formation agent and extraction	High Strength High Cost
	Drawing Melt spinning and drawing	High Strength Low Cost
Solution Spinning	**Non-solvent Induced Phase Separation** Polymer solution is coagulated by non-solvent	UF/MF Applicable Low Cost Permeability and High-strength inconsistent
	Thermally Induced Phase Separation Polymer solution is cooled down to phase separation temperature	High Strength High Flux Low Cost



Comparison of Hollow Fiber Membrane with Other Companies

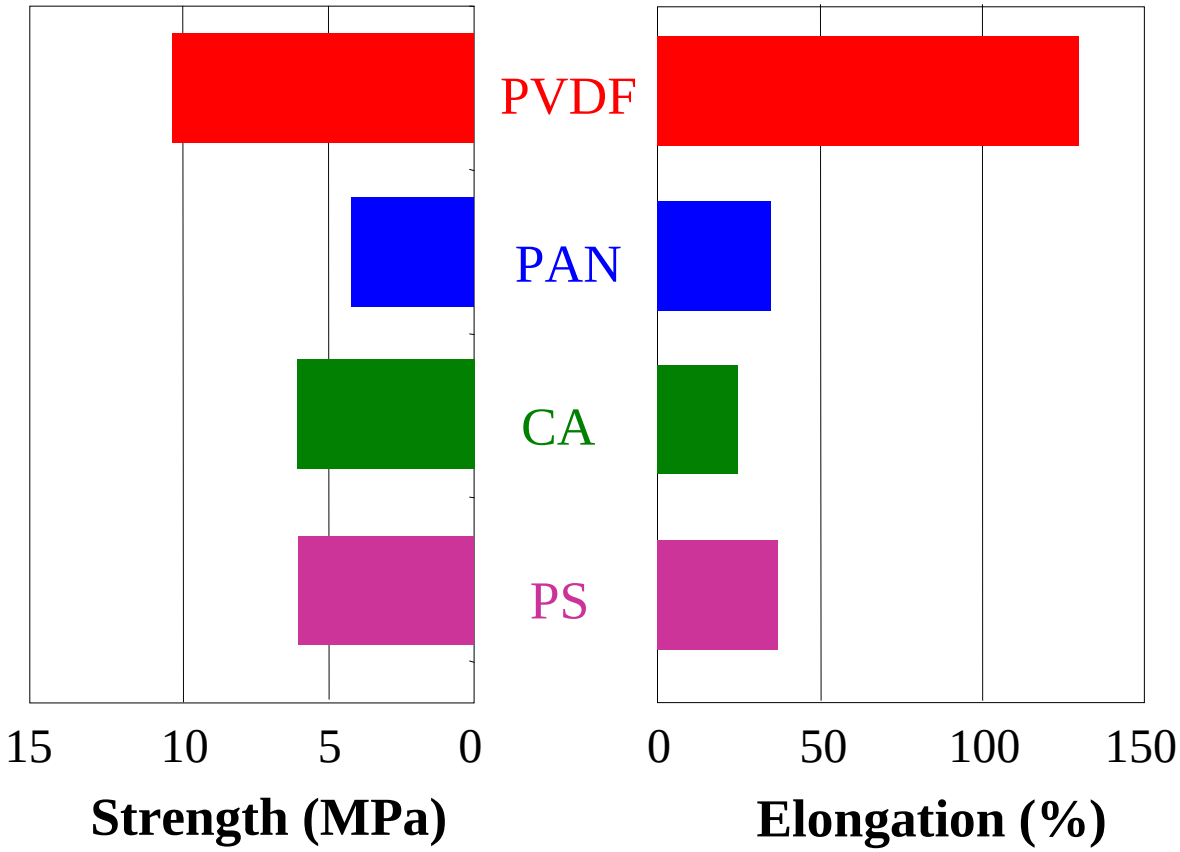
* Pure Water, at 50 kPa

Supplier	U Company		Z Company	N Company	A Company	Toray
Material	PP	PVDF	PVDF	PES	PVDF	PVDF
Permeability* (m^3 / m^2-d)	4.8	-	1.5	3.0	5.3	6.7
Membrane Area (m^2)	30	-	56	35	50	72
Module						

PP: Polypropylene, PVDF: Poly (Vinylidene Fluoride), PES: Poly (Ether Sulfone)

Toray's hollow fiber membranes are World's No.1 in permeability and the largest module.

Comparison of Strength & Elongation - Membrane Material -



Physical property depends highly on material & spinning method.

Comparison of Chemical Stability of PVDF Hollow Fiber
-Accelerated Oxidation-

Purpose: Confirmation of stability against strong oxidation agent

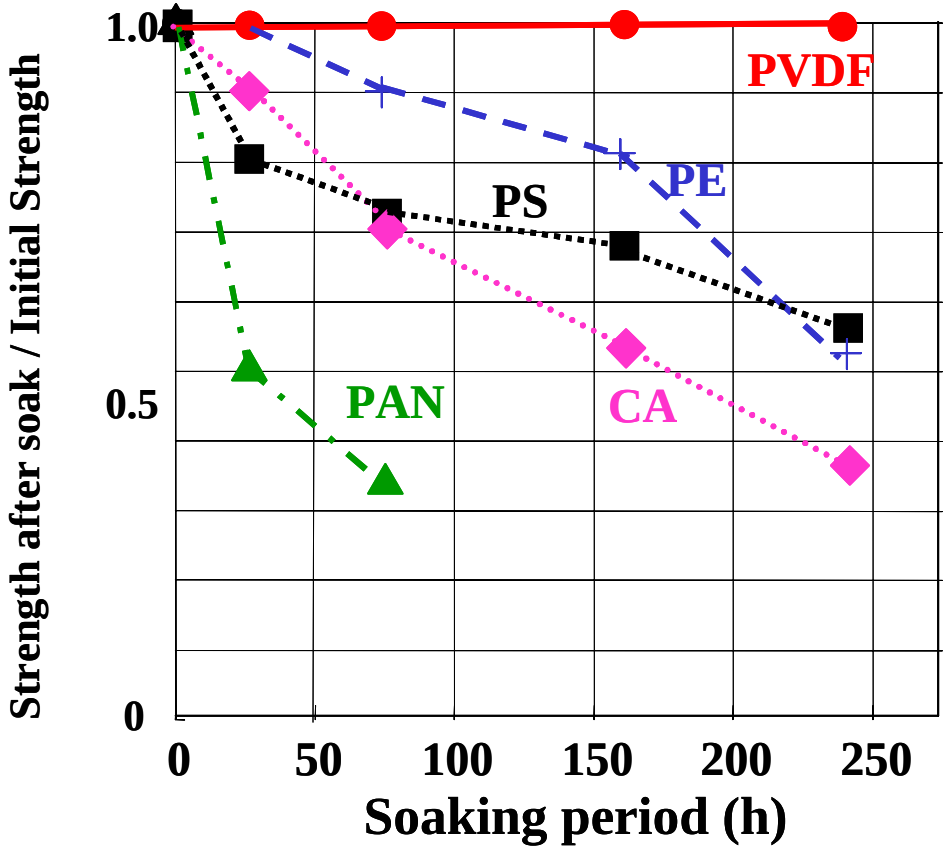
Accelerated oxidation

1. Evaluation of membrane configuration
2. Evaluation under cleaning condition

(5,000 ppm as H_2O_2 with $FeSO_4$)

Results

1. PVDF-MF membrane is very stable under strong oxidation conditions.
2. PVDF-MF membrane can be cleaned with a concentrated oxidation agent.



Comparison of Oxidation Resistance

Comparison of Chlorine Resistance of PVDF Hollow Fiber

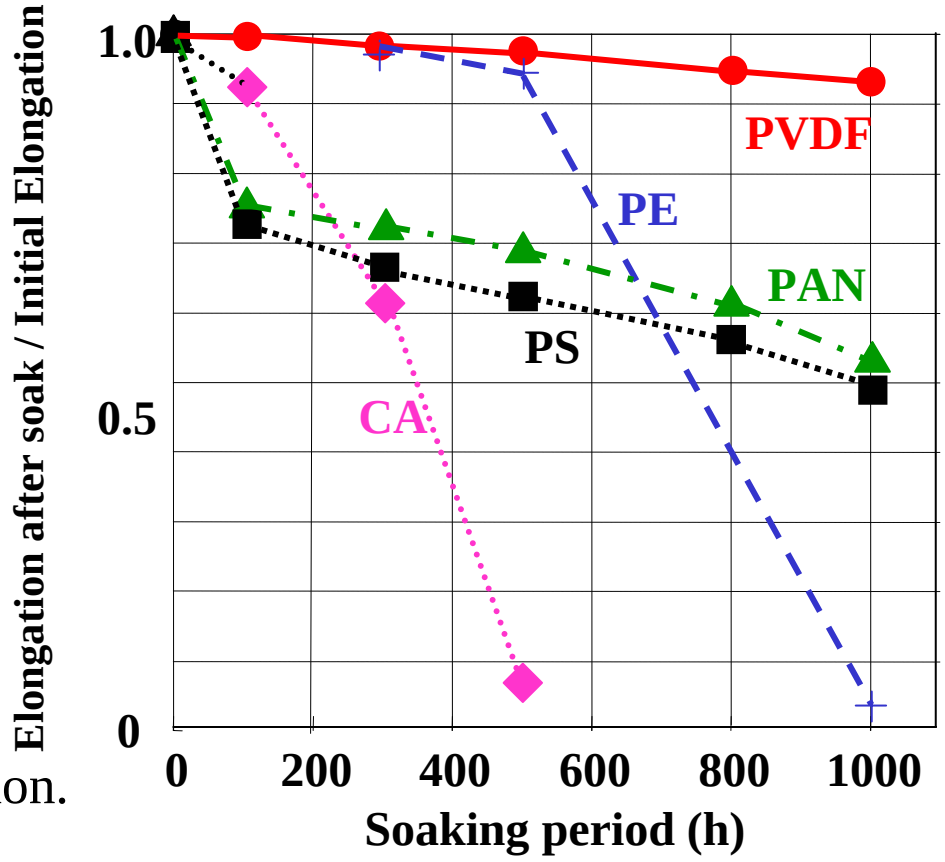
Purpose: Confirmation of stability against chlorine

Evaluation condition

1. Evaluation of membrane configuration
2. Evaluation **under cleaning condition**
   (1,000 ppm as Chlorine, **pH=10**)

Results

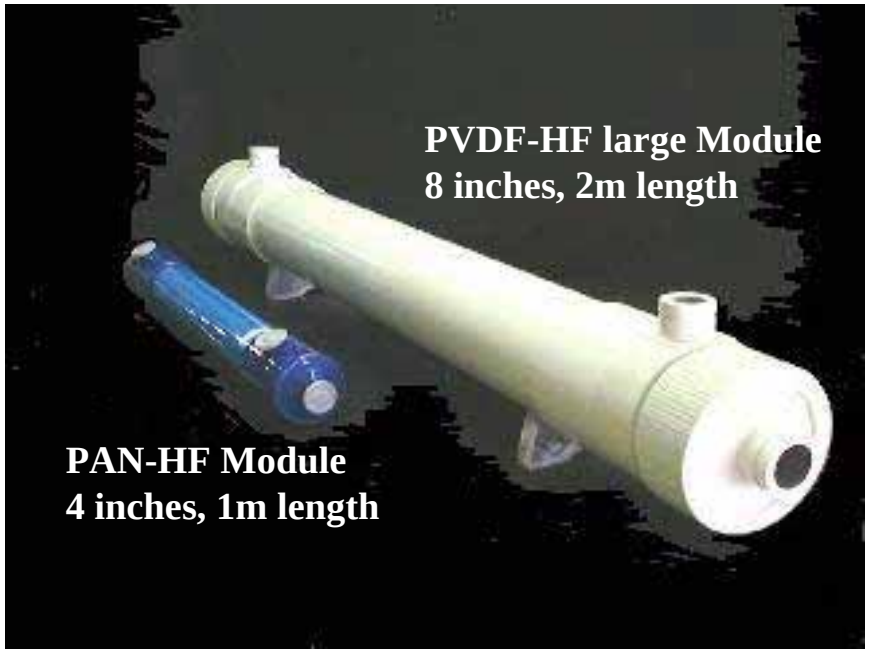
1. PVDF MF membrane is very stable in a concentrated chlorine solution.
2. PVDF-MF membrane can be cleaned with a concentrated chlorine solution.



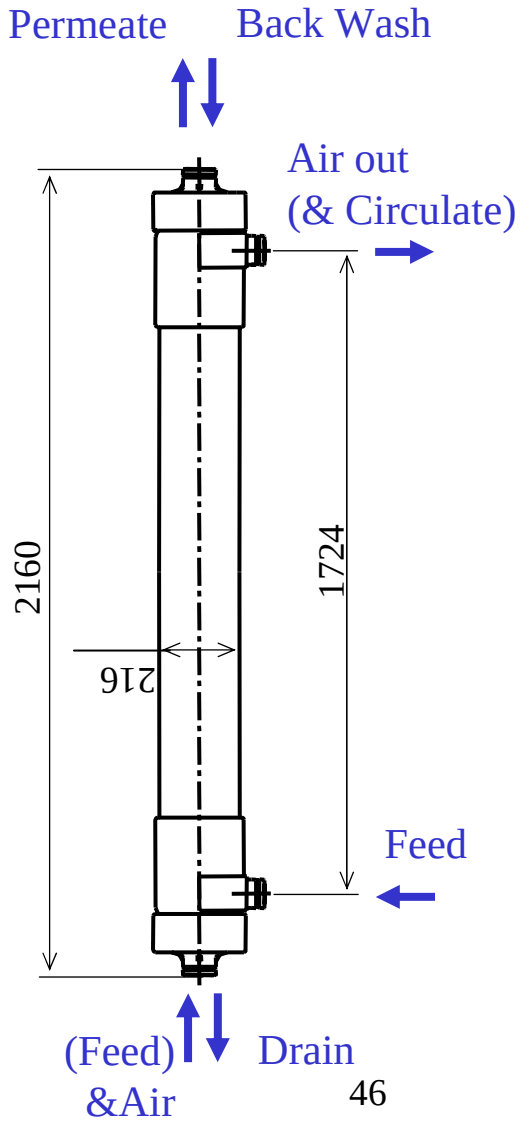
Comparison of Chlorine Resistance

PVDF MF Membrane 8” Module

Specifications



Items		Toray 8B Module
Module Size	[mm]	216 (8B) dia. x 2,160L
Membrane Area	[m2]	72
Flux (pure water) [m3/h/50kPa]		20
Temperature	[deg.]	0 – 40

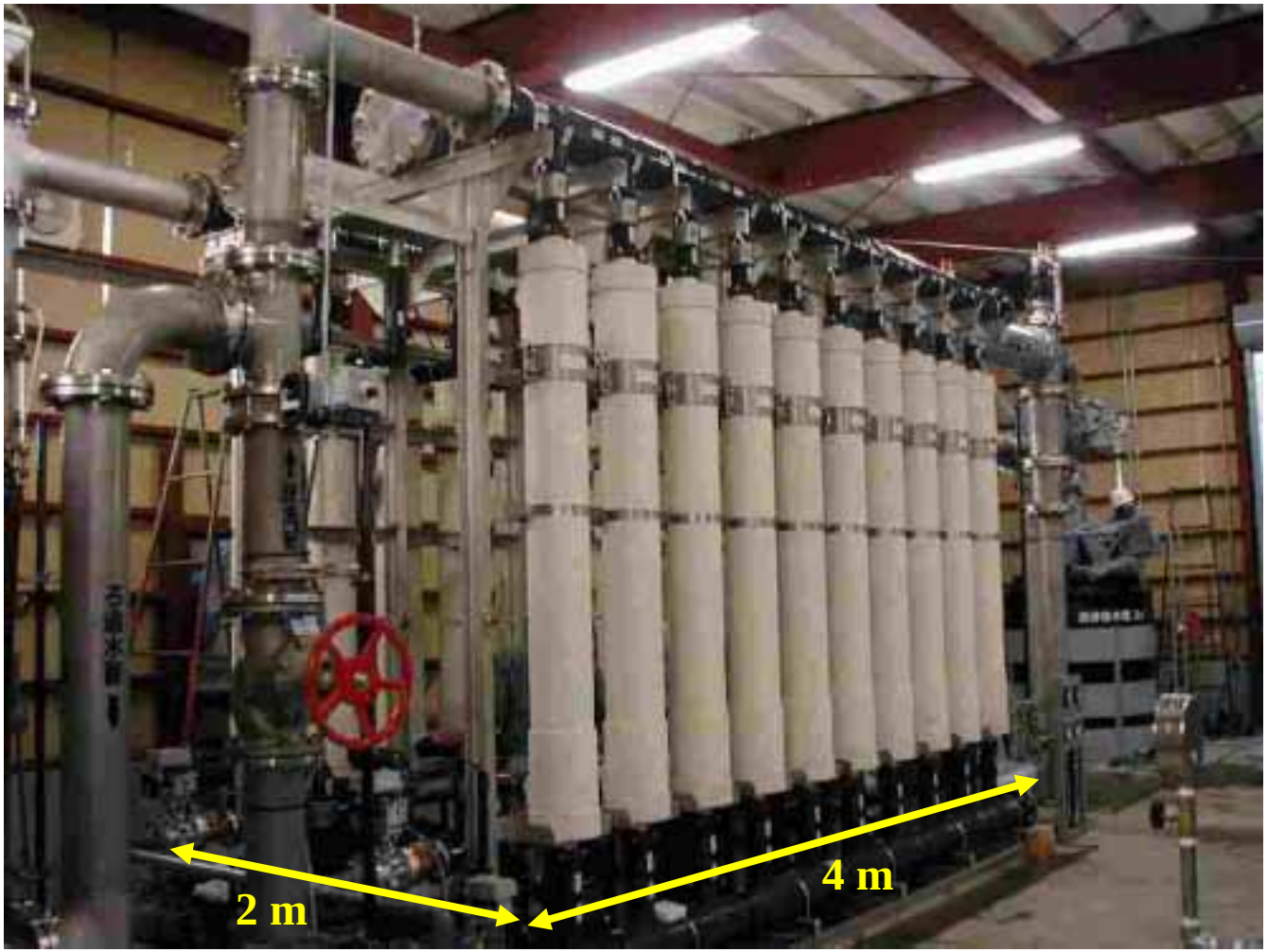


HFM-2020 Standard Operational Conditions

Feed Water Type	Pretreated Water Clean Ground Water	River & Lake Surface Water
Filtration Flux ($m^3/m^2/d$)	2 – 5	1 - 2
Backwash Condition	Flux: 1 - 2 times of filtration flux Chlorine dosing: 1 - 10 ppm Time: 30 – 60 sec. Frequency: every 0.3 – 2 h	
Scrubbing Condition	Air flow: 4 – 10 Nm^3/h/Module Time: 30 – 120 sec. Frequency: every 0.3 – 2 h	
Operation Temp. (degrees C)	≦ 40	
Operation pH	1 – 10	
Chemical Cleaning	(1) CIP (Clean In Place): every 3 - 6 months (2) Trans-Membrane pressure (3 - 5 times of initial, or 150 kPa) (3) Chemicals: 1N-HCl + 3,000 ppm NaClO	

Large Scale Ground Water Filtration Plant

(5,000 m^3/d, for 20,000 people)



Compact and High Productivity

Outline of Suido Kiko Kaisha, Ltd.

Profile

Established : 1936

Net Sales : 200 million dollars

Function : One of the largest water system and equipment companies in Japan

Alliance with Toray : Toray owns 20% of shares

- Joint water business venture
- Development of new systems and membrane products
- Sharing and exchange of technical and business information

Domestic position

Positioned in 15th place as a water treatment company, second, behind Ebara, in the drinking water production business, and first in membrane filtration systems (Orugano second, Ebara third)

Toray Collaboration with Suido Kiko

Suido Kiko's Advantages

- Pioneer and first-ranking manufacturer in the drinking water systems business
- Experience in Government and Public Businesses

Toray's Advantages

- Capable of meeting diverse demand with a wide range of products from MF to RD membranes
- Operating businesses in Japan, the U.S., and Europe

Development into an Overall Water Treatment System Business

Japan : Supplies Membranes to Suido Kiko

Korea/China : Jointly Launched Business -

Toray Supplies Membrane Technology,

Suido Kiko Offers Engineering Technology

Water Treatment Related National Projects

Year	Title	Toray's R&D Theme
1992 1993	Project Membrane Aqua Century 21 (**MAC21**)	
1994 1995 1996	New Membrane Aqua Century 21 (**MAC21**)	- Highly efficient water purification system utilizing NF membranes (Toray Engineering Co.)
1997 1998 1999 2000 2001	Advanced Aqua Clean Technology for the 21st Century (**ACT21**)	[Search for New Technology Application of Membrane Filtration] - Development of efficient coagulation and sedimentation technology to be applied in the UF pretreatment -Development of operational stability during the NF advanced water purification process [Development of Advanced Water Purification System of River Water] - Technological examination of combination of conventional water purification systems and membrane filtration
2002 2003 2004	Environmental, Ecological, Energy Saving and Economical Water Purification System (**e-Water**)	Group 1: Development of large-capacity membrane filtration technology (Kawai,Yokohama/Shinishikawa,Okinawa) Group 2: Total water purification system (Ayase,Yokohama/Otogane,Fukuoka) Group 3: Observation technology at the drinking water supply source

Participation in National Project (e-water)

Water Drinking Production Plant Order Award Requirements:

1. Qualification of the Facility
2. Approval of Construction Work
3. Acquisition of National Licenses
4. Actual Experience in Plant Delivery

Water Purification Plant	Feed Water	Subject	Participants/ Toray's Expected Role
Kawai, Yokohama June/03 - Mar/05	Fresh Water	- Comparative Experiments of 6 Groups, including Ebara - Case Trial - 200,000 m^3/d	- Toray/Suido Kiko Joint Team - Toray; Experiment Supervisor, Basic Design, Manufacture of Experimental Facility, Follow-up of Operations
Ayase, Yokohama Aug/03 - Mar/05	Fresh Water	- Examination of Appropriate Operating Conditions	- Co-R&D of 38 Companies - Toray; Basic Design, Supply of PVDF Modules
Otogane, Fukuoka Sept/03 - Mar/05	Fresh Water	- Comparative Experiments of 5 Groups including Maezawa and Shinko Pantec - Case Trial - 110,000 m^3/d	- Suido Kiko as the Supervisor - Toray; Supplies PVDF Modules, Supports System Examination
Ishikawa, Okinawa Oct/03 - Mar/05	Fresh Water	- MF Pretreatment+NF Membrane (to confront Ozone + Activated Carbon Method) - Only Successful Group to actually demonstrate use of membranes - Case Trial - 50,000 m^3/d	- Nishihara; Supervisor, Joint Team of Suido Kiko, Ebara, Kubota, and Toray - Toray; Basic Design and Supply of PVDF and NF Modules

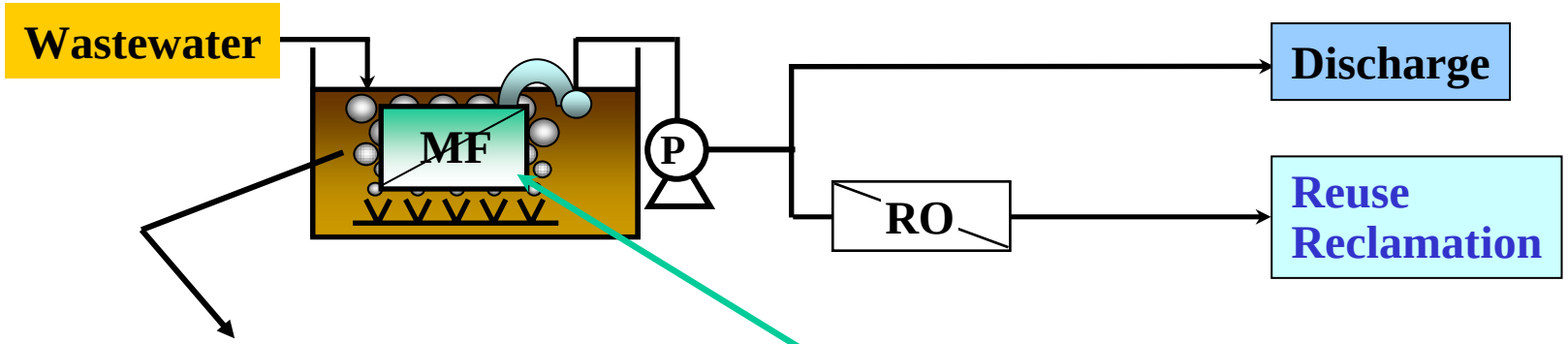
Conclusion - UF/MF Membranes for Drinking Water

1. **The Drinking Water Production Market is expanding rapidly, centering on the U.S. and Europe.**
2. **Toray has developed highly water-permeable and highly stable PVDF hollow fiber large modules suitable for drinking water production.**
3. **Although still in the experimental stage, Toray's technology is highly appraised, and we are aiming to enter the market as soon as possible.**

Immersed Membrane Modules for Wastewater Treatment

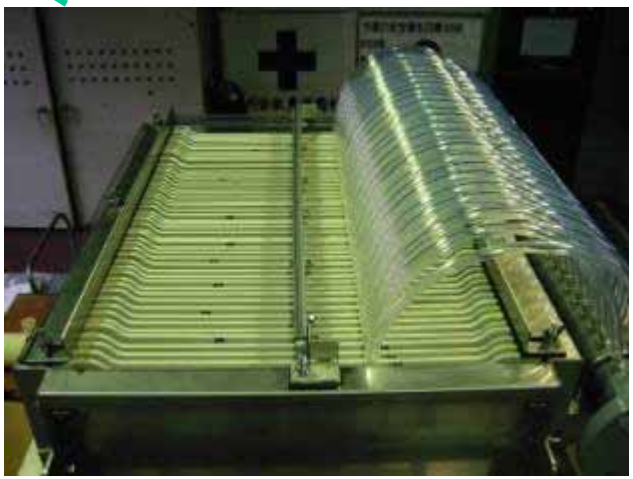
Immersed Membrane Module System

MBR (Membrane Bioreactor)



Activated Sludge in MBR

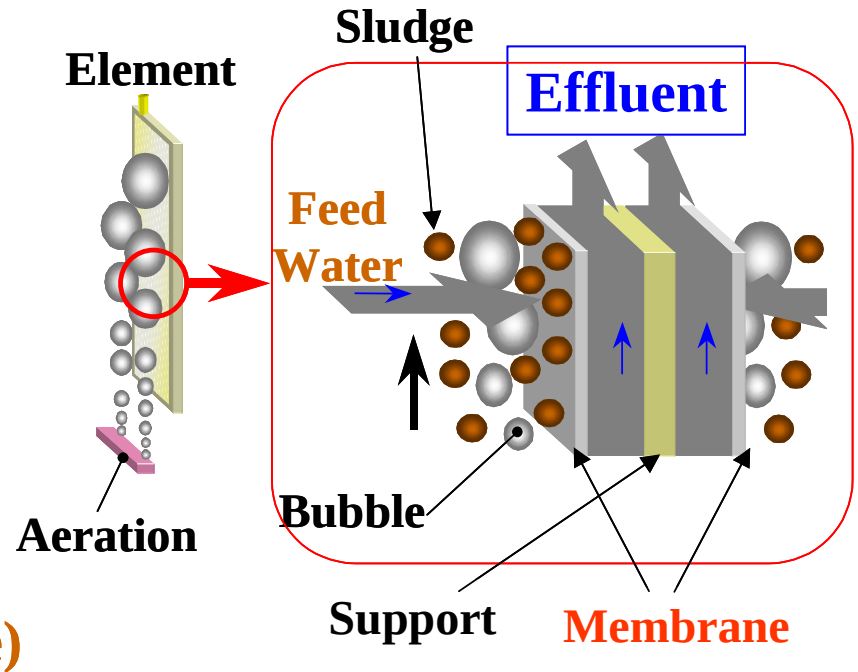
Immersed Membrane Module



Features good water quality, small footprint, reduced excess sludge, and the market is yet undeveloped.

Filtration Mechanism and Required Characteristics

Feed Water
(Activated Sludge)



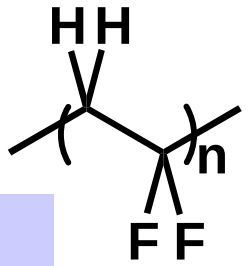
Effluent

Requirement		
Stability	Physical Stability	Impact of bubble and sludge. Vibration.
	Chemical Stability	Chlorine, acid, oxidation agent, alkaline
Permeability	Initial Permeability	High permeability
	Durability	Prevention for clogging

Design Concept of Immersed Membrane

1. Membrane Material

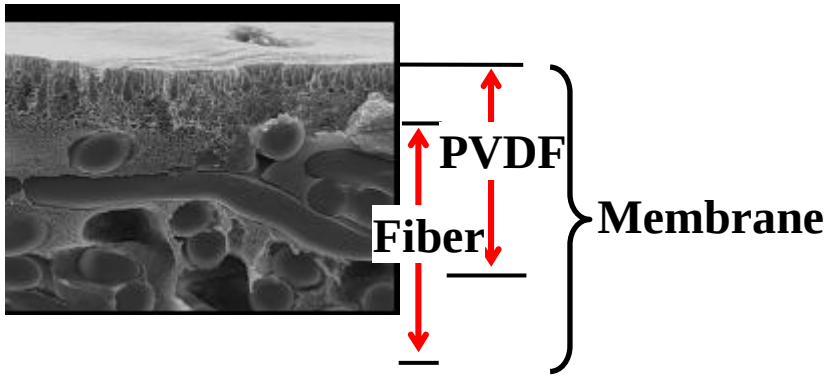
Poly (Vinylidene Fluoride): PVDF



High stability for chemicals : fluorine polymer
High physical strength : high molecular weight
(MW=300,000－400,000)

2. Membrane Form

Fiber reinforced (non-woven)
flat sheet membrane



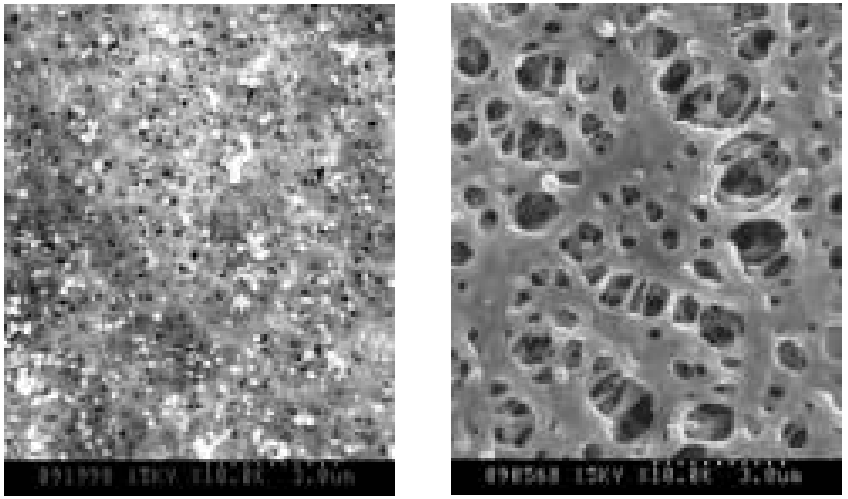
3. Surface Pore Diameter

1) **Small pore diameter**
2) **Narrow pore diameter distribution**
3) **Numerous pores**

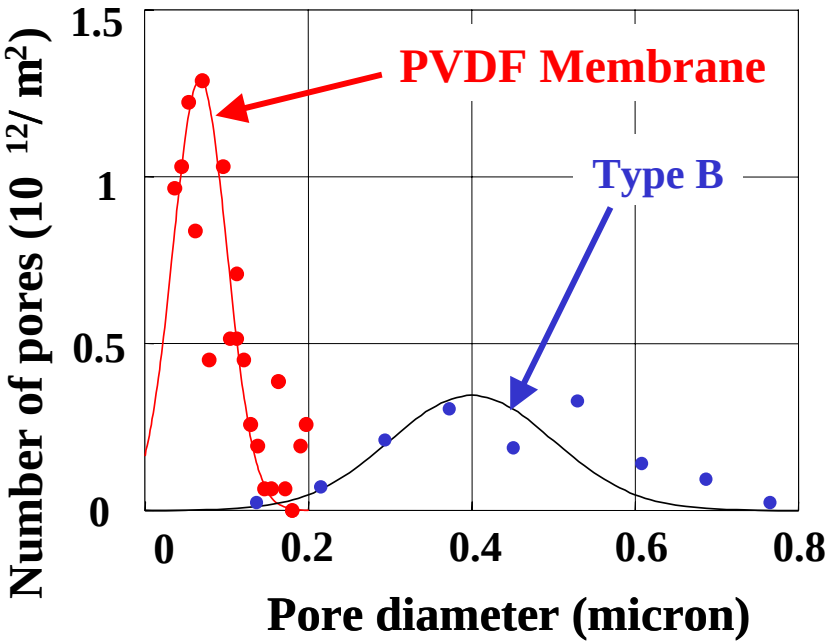
⇨ **Good permeate quality**
Prevention of clogging

⇨ **High flux**

Basic Characteristics of Immersed Membranes



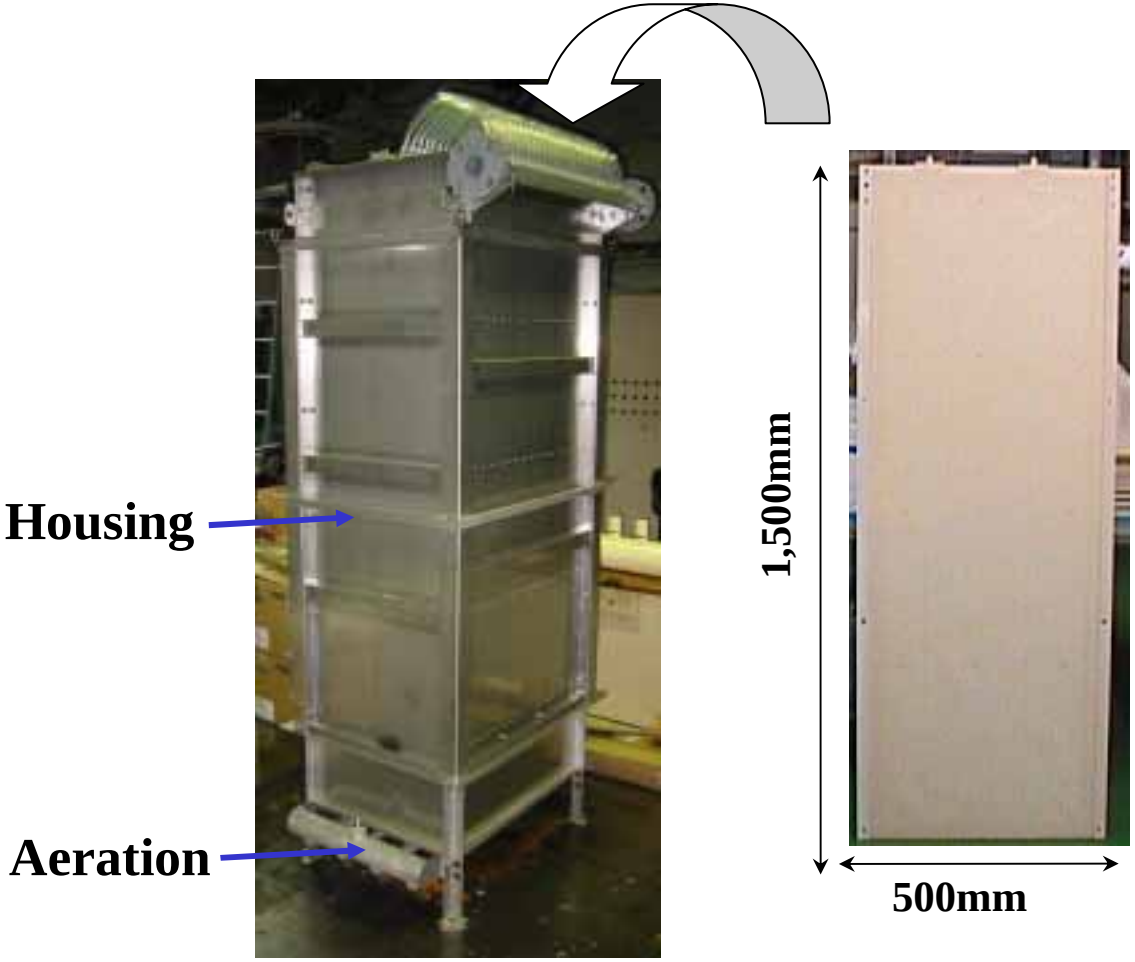
FE-SEM photographs of
Flat sheet membrane surface



Pore diameter distribution of surface
(Estimated from SEM photos)

Ideal membrane micro structure is achieved.

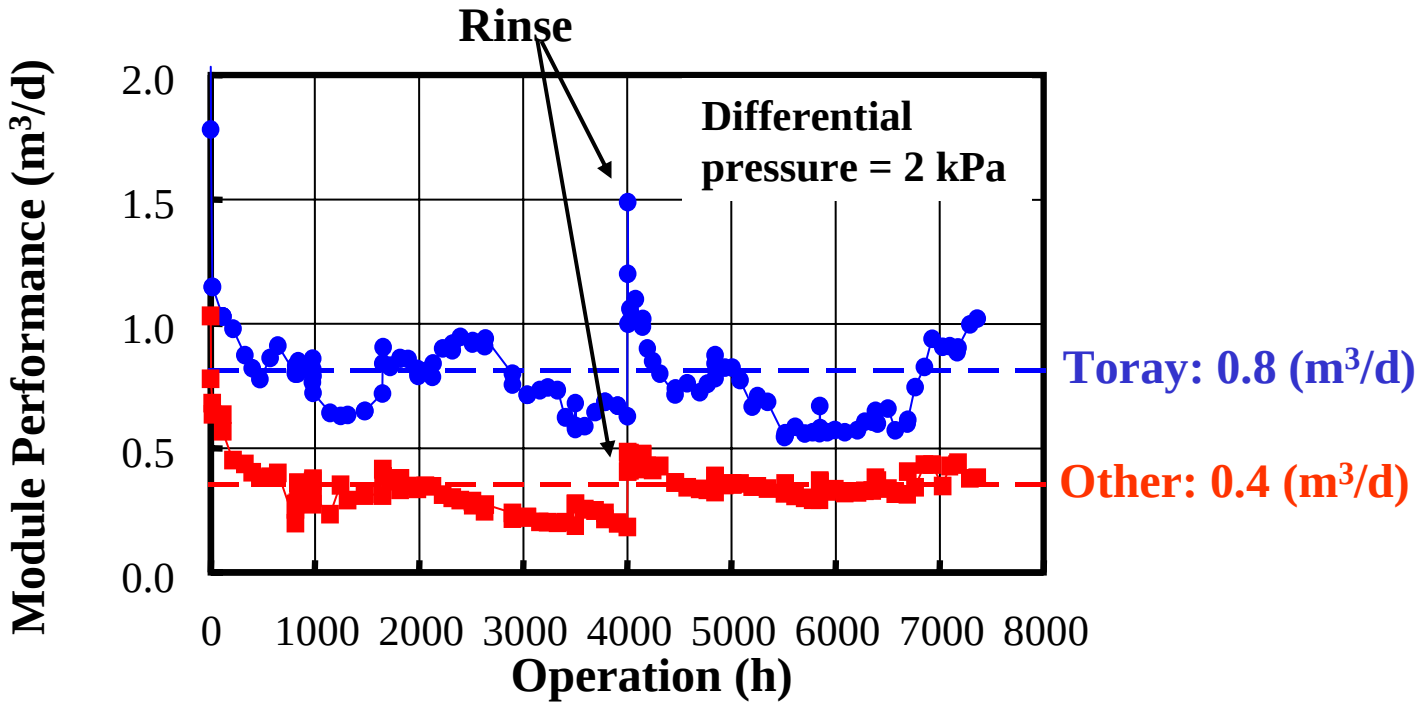
Immersed Membrane Element & Module



Toray's modules features high performance per footprint.

Comparison of Module Performance

Module Performance (m^3/footprint)	=	Membrane Performance (m^3/m^2)	X	Membrane Area (m^2)	=	2
(Compared to other modules)		(1.4)		(1.5)		



Toray module performance is twice as competent as others.

Operational Technology

1. Roll of Operational Technology

1) To maintain efficiency and stability of the performance of modules and module elements
2) To achieve module performance targets at low cost
3) Required as software in case of selling modules and module elements

2. Alliance with SKG*

1) Joint pilot tests in Europe and Singapore

2) Joint businesses in Europe, Singapore, and China

*** SKG (Seghers Keppel Technology Group):**
More than 200 Activated Sludge System installations Worldwide

Pilot Test at Beverwijk WWTP (the Netherlands)

Consulting company DHV conducts tests of MBR suppliers and immersed membranes

The Absolute Group in Europe's Wastewater Treatment Business

Pilot test is showing good performance.

Conclusion
- Immersed Membranes for Wastewater Treatment

1. **Performances such as good water quality, small footprint, and reduced surplus sludge are expected in MBR technology, and the market is still globally new.**
2. **Toray has developed highly stable, highly permeable and reduced clog types of PVDF flat sheet membrane modules.**
3. **Toray making progress in pilot tests in Europe, Singapore, and China, and aiming at entering the market at an early stage.**

Conclusion
- Toray's Membrane Separation Technology for Water Treatment

1. **Toray is a synthetic membrane manufacturer whose products cover all types - RO, NF, UF, and MF.**

2. **Placing top priority on seawater desalination, drinking water production, and wastewater treatment, Toray intends to expand its membrane technology business throughout the world.**

3. **High water quality and an Integrated Membrane System (IMS), a combination of several membranes, is required in the future market. Toray, possessing all types of membranes, is in an advantageous position in expanding business utilizing the IMS.**

Toray can contribute to ensuring sustainable water resources with membrane technology.

River, Lake, Ground Water

Sea Water

Wastewater