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Specialized Short Course on **MEMBRANE TECHNOLOGY** for Water and Wastewater Treatment

27 – 28 June 2009 (4 -5 Rajab 1430 H)

Prince Khalid bin Sultan Chair for Water Research
Civil Engineering Department, Hall 1 A 36
College of Engineering, King Saud University



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Lecture 6

Membrane Applications: High Purity Water Production

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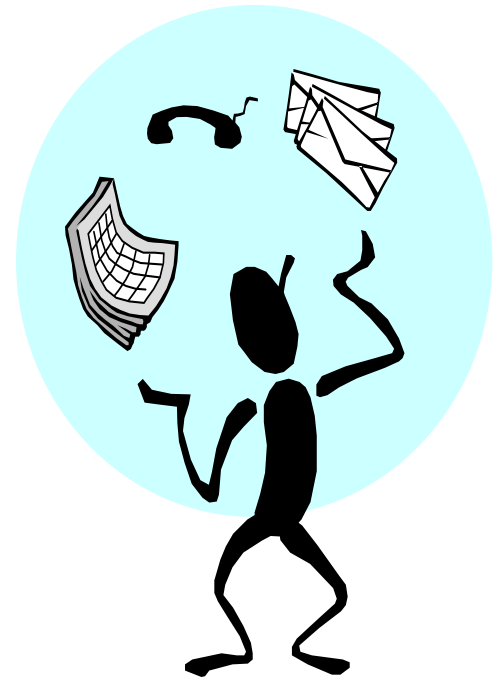
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Presentation Menu

Part 1: Introduction

Part 2: Membrane configurations

Part 3: Membrane systems





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Part 1. Introduction

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High Purity Water Production

Also known as ULTRAPURE water

- Boiler feed water
- Laboratory
- Process water
- Cleaning / rinse water
 - electronic
 - pharmaceuticals



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Applications of High Purity Water Production

- Boiler feed water
- Electronics
- Metal finishing
- Medical and pharmaceuticals
- Packaging
- Cleaning processes
- Painting materials
- Food industry



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Boiler Feed

Steam Generator Water Quality Guidelines

Drum pressure	Silica (ppm SiO ₂)	Total alkalinity (ppm CaCO ₃)	Specific conductance (µmhos/cm)
0-300	150	350	3,500
301-450	90	300	3,000
451-650	40	250	2,500
651-750	30	200	2,000
751-900	20	150	1,500
901-1000	8	100	1,000
1001-1500	2	0	150
1501-2000	1	0	100

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Electronic Industry

Ultrapure water specifications for IM DRAM Manufacture

Parameters	Attainable	Acceptable
TOC (ppb)	<10	<30
Particles/liter by SEM		
0.2-0.3 μm	-	<2,000
0.3-0.5 μm	<200	<200
>0.5 μm	<1	<1
Bacteria/100 ml		
By culture	0	<6
By SEM	<1	<10
By EPI	<5	<50
Silica, dissolved (ppb)	<4	4



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Metal Finishing Industry

- Products: doorknobs, lighting fixture, electrical relay contacts etc.
- Plating materials: gold, copper, cadmium, copper, chrome etc.
- High purity water: 1 – 10 megohm
- For rinsing operation



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Medical & Pharmaceuticals

- **Medicinal preparations**, e.g. lotions & creams
- **Pharmaceutical products**: eye drops, contact lens, laboratory practice etc.
- **Hemodialysis** machines use membrane technology (for producing high purity water and separating the blood cells)
- **Medical uses**: water for procedures, water for cleansing and cleaning



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Ultrapure Water Production

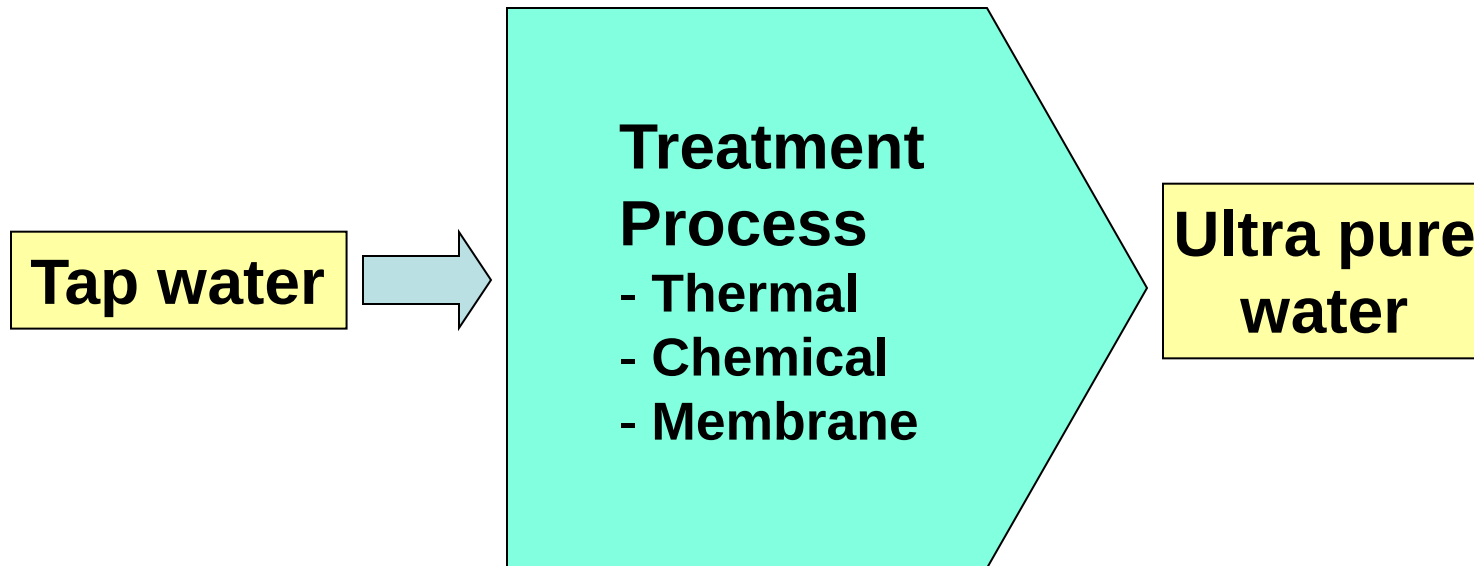
- Feed water: Tap water
- Quality problems:
 - Residual chlorine
 - Total dissolved solids
 - Organic fractions
 - Microorganisms
- Treatment:
 - Thermal process
 - Chemical and ultraviolet process
 - Membrane



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Treatment Flow Scheme of Ultrapure Water Production





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Advanced Water Treatment

Coagulation

Solid/liquid separation

RO

Solid/liquid separation

Organic, taste & odor removal

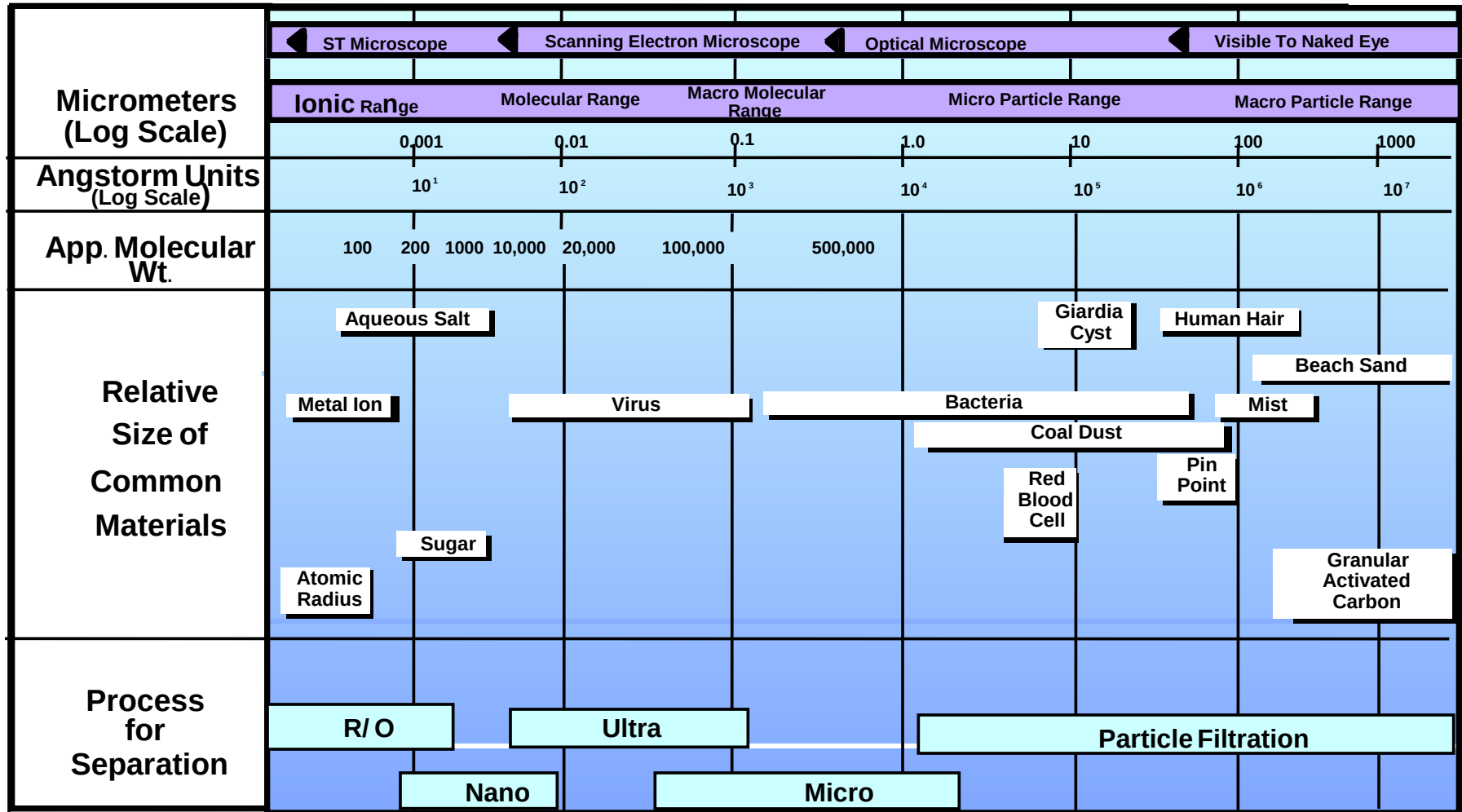
NOM removal

Disinfection (UV)

Bacterial removal



Filtration Spectrum

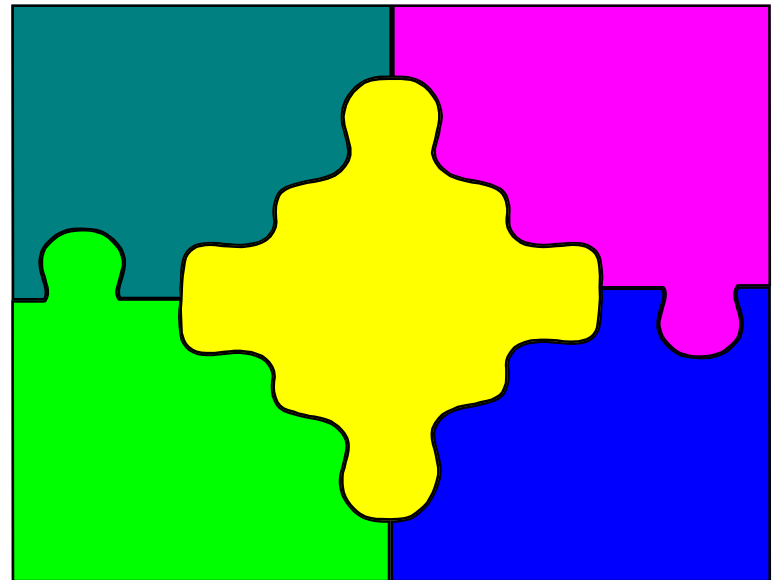




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Part 2. Membrane configurations, designs, operations

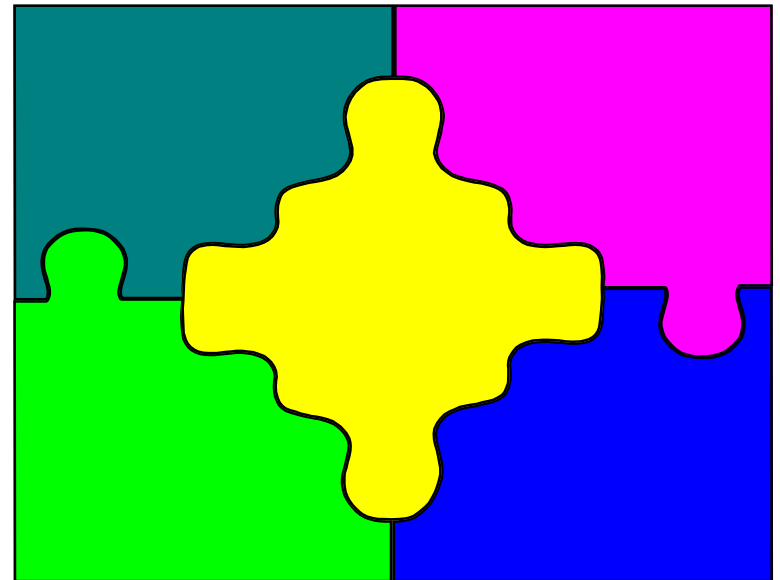




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Part 3. Membrane Systems





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Reverse Osmosis

- Normally used for high purity water in many industries at the moment, coupled with UV
- Purposes:
 - Ionic removal
 - Organic removal
 - Silica removal
 - Particles and bacteria



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Problems in High Purity Water Systems

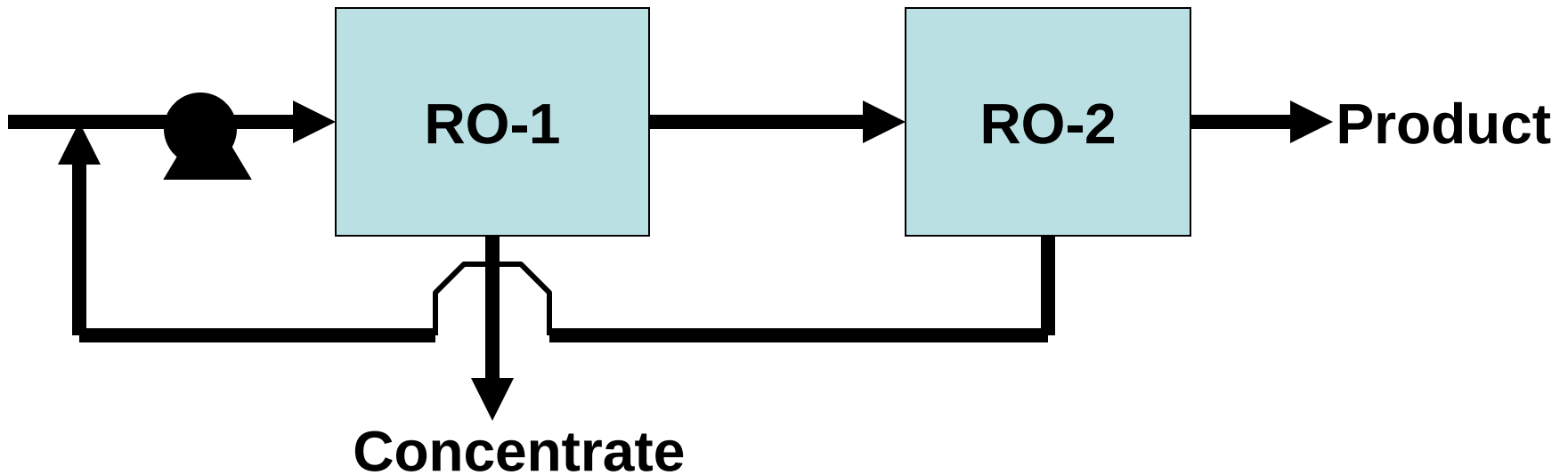
- Post treatment contamination
- Membrane bypass
- Differential passage of silica and carbon dioxide



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Double-pass Reverse Osmosis Increase Rejection Level





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Pre-Treatment and Post-Treatment

- Particle stabilization
- Ionic stabilization
- Biological control
- Polishing treatment



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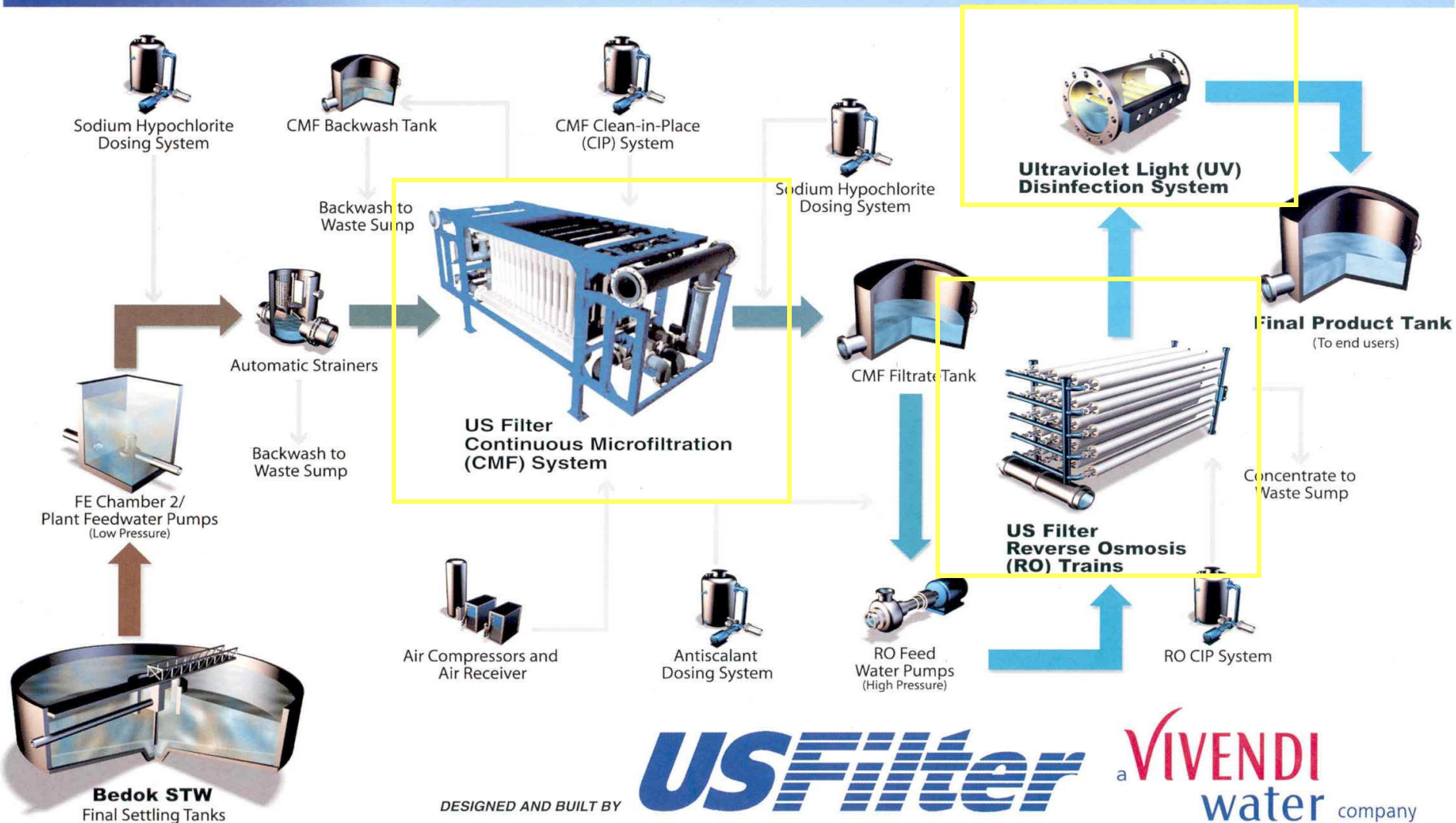
Market Size and Projections

- 2.5% annual growth (global)
- RO is replacing ion exchange
- The more industrial growth in electronic, medical & pharmaceutical industries – the more market for membrane technology

BEDOK NEWATER FACTORY

Water Reclamation Demonstration Plant

NEWater Factory - PROCESS FLOW SCHEMATIC

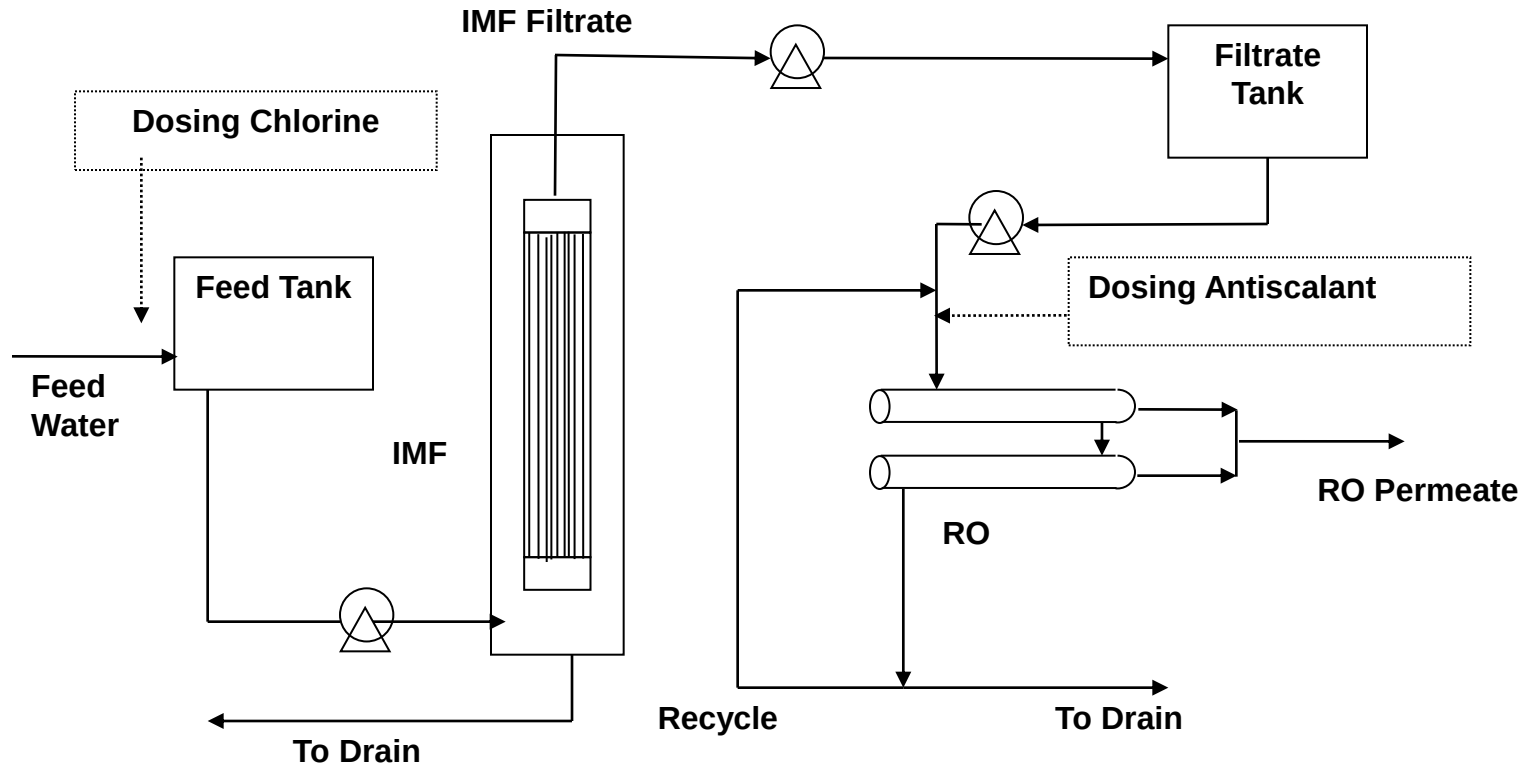




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The Pilot Plant



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Membrane Specifications

Specifications for the IMF

Manufacturer	-	Memcor
Commercial Designation	-	1S10X CMF-s
Active Membrane Area (outside)	m ²	31.3
Flow Direction	-	outside-in
Nominal Membrane Pore size	µm	0.2
Membrane Material/Construction	-	polypropylene, hollow fiber
Membrane Charge	-	slightly negative
Design Flux	L/hr.m ²	31.1

Specifications for the RO

Manufacturer	-	Hydranautics
Commercial Designation	-	LFC1-4040
Active Membrane Area (outside)	m ²	7.9 per module
Membrane Material	-	Polyamide (thin film composite)
Operating pH Range	-	2.0-10.0
Maximum Operating Temperature	deg C	45
Free Chlorine Resistance	mg/L	<0.2



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IMF Operating Conditions

Parameters	Value
IMF Unit	
Filtrate flow rate	0.8 m ³ /hr
Backwash interval setting	18 minutes/2 minutes
Filtrate temperature	30 – 35 °C
Backwash liquid flow	2.20-2.25 m ³ /hr
Feed chlorine level	0.5-1.0 ppm



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RO Operating Conditions

Parameters	Value
RO Units	
Feed flowrate	28 L/min
Permeate flowrate	4.5 L/min
Rejection flowrate	5.0 L/min
Recycle flowrate	15.5 L/min
Feed pressure	8 – 9 bar
Permeate & rejection pressure	1 bar
Silt density index	3.7 – 5.5



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The Pilot Plant



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The Components



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The Experimental Results

Parameters	Feed	Effluent	% Rejection
BOD, mg/l	25	1	95
COD, mg/l	70	14	80
Suspended solids, mg/l	20	1	95
Hardness	998	12	88
TOC	20	1	95
Ammoniacal Nitrogen	33	<3	92
Nitrate, mg/l	0.3	0.1	>66
Total Phosphorus, mg/l	5.18	0.46	>90
Iron	0.47	0.03	93
Manganese, mg/l	0.08	0.02	75
Silica, mg/l	8.29	0.54	94
Total plate count	775×10^3 cfu/100mL	291×10^3 cfu/100mL	>62

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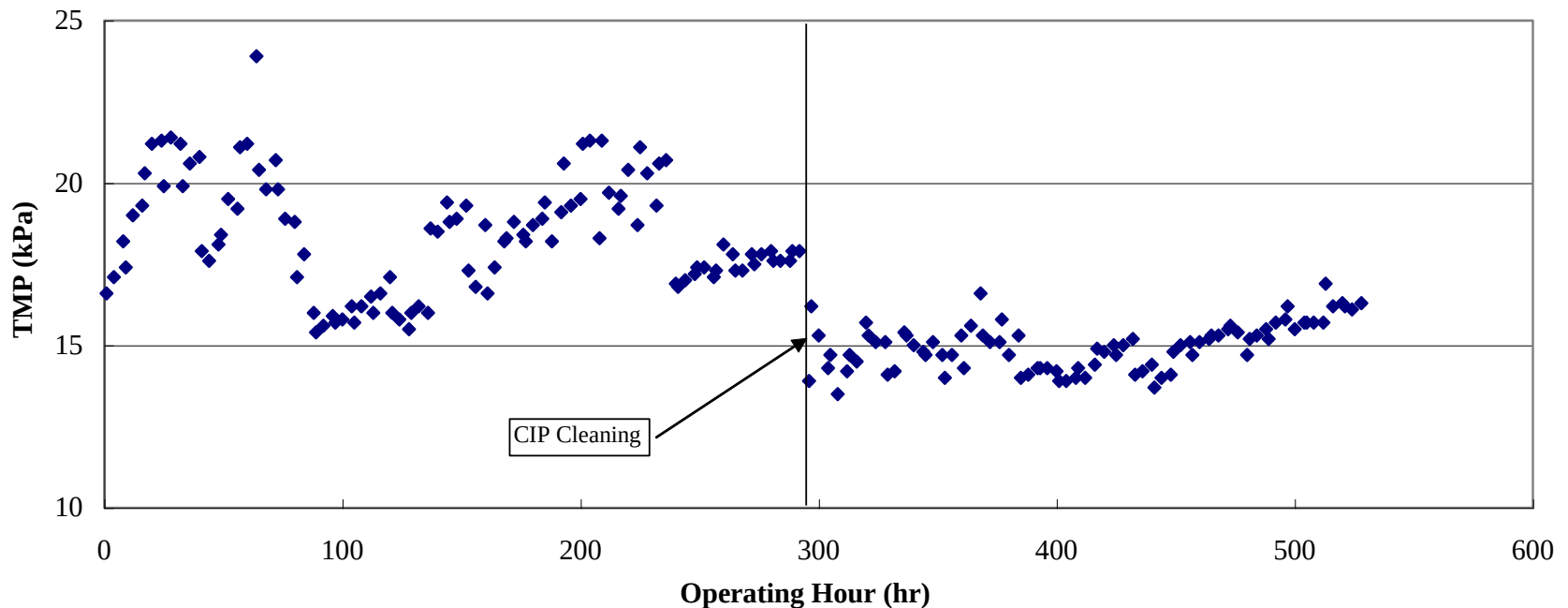


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Experimental Results - TMP

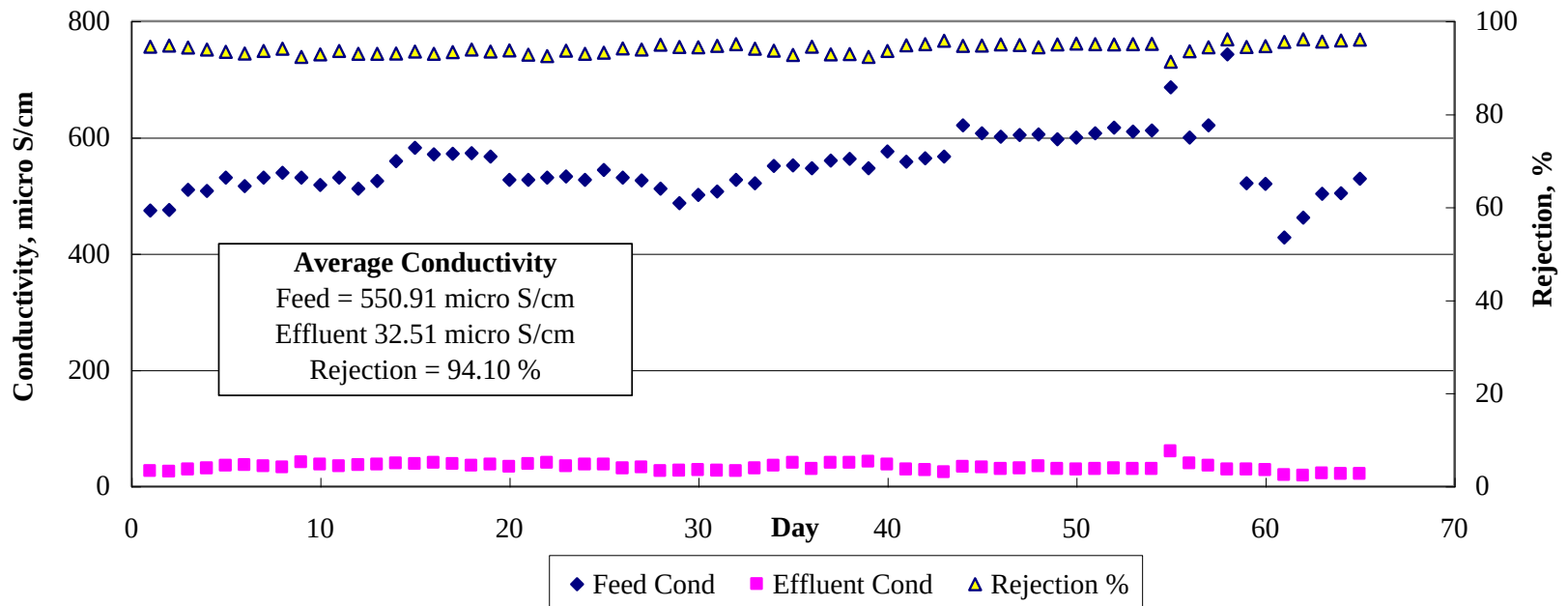
CMF-s





Experimental Results - Conductivity

RO





Discussions

- pH of reclaimed water slightly acidic (pH 6 – 6.5)
- permeate of RO always slightly acidic (drop by ~0.5) vs influent due to:
 - the removal of silica
 - the usage of acid as RO anti-scalant.
- Ammonical nitrogen in reclaimed water averaging 2.5 mg/L (WHO guideline at 1.5 mg/L)
- Unexpected high ammonical nitrogen in the influent (with 32 mg/L).
- STP should produced effluent with ammoniacal nitrogen down to 5 – 10 mg/L.
- Excellent removal rate of ammonical nitrogen with RO have been achieved (average 90 – 93 %)



■ High plate count in reclaimed water

Theoretically, RO would remove all bacteria and virus. However, the pilot plant is running only 8 hr/day and as such substantial bacteria growth in the post RO piping system as the pilot plant is not equipped with disinfection (UV, chlorination)



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The Overall Results



**Meeting the
requirements of
both effluent
Standard A and
drinking water**

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Rockefeller Foundation Team Residency

Exploration of the potential of membrane technology for sustainable sanitation

- Politecnico di Milano,
Milan, Italy
- April 23-26, 2003
- Only 14 participants
representing various
global fractions!



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