Lecture 7

Membrane Application

High Purity Water Production

Prof. Ir. Dr. Zaini Ujang.

Ph.D., E.Eng. (M), C.Eng.(UK), C.Sci. (UK), C.W.E.M. (UK), MIEM, MIWA, DNS, PPT

Institute of Environmental & Water Resource Management
UNIVERSITI TEKNOLOGI MALAYSIA
Email: zaini@utm.my Homepage: http://web.utm.my/ipasa

Presentation Menu

Part 1: Introduction

Part 2: Membrane configurations

Part 3: Membrane systems

Part 1:

Introduction

High Purity Water Production

(Also known as ULTRAPURE water)

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

Applications of High Purity Water Production

(Also known as ULTRAPURE water)

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

Boiler feed water

Steam generator water quality guidelines

Drum pressure	Silica (ppm SiO2)	Total alkalinity (ppm CaCO3)	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

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

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

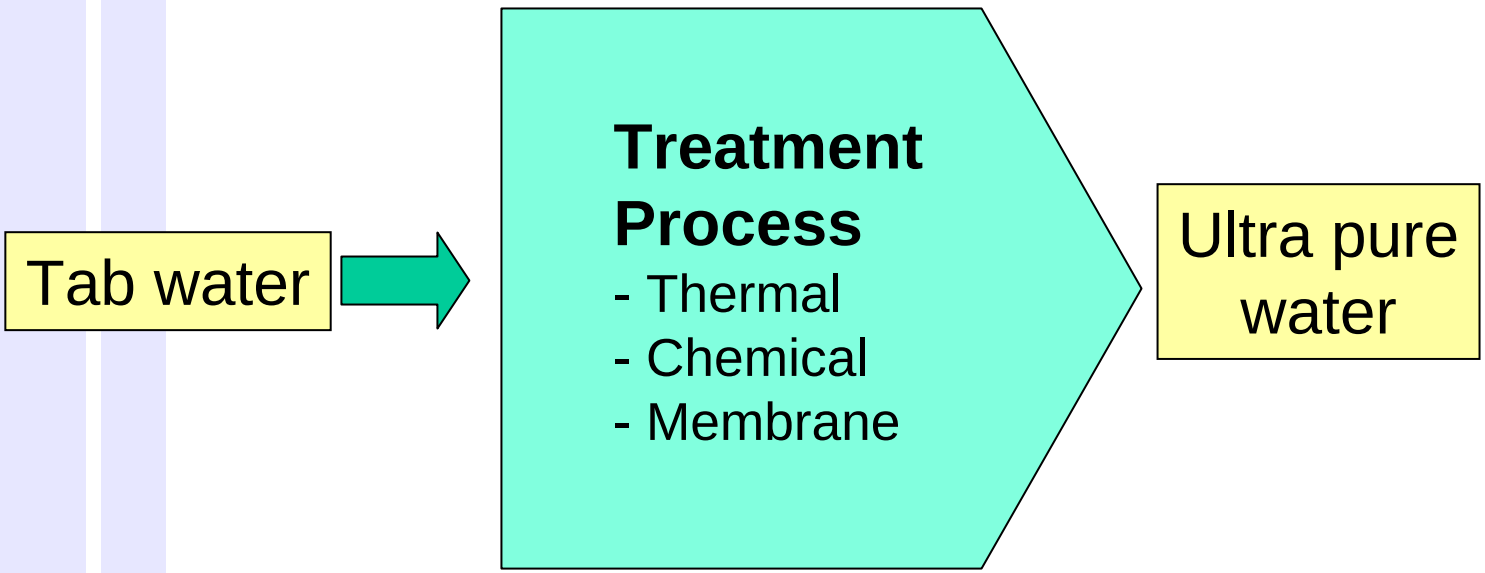
Medical & pharmaceuticals

- **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

Conventional treatment flow scheme for ultra pure water production

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

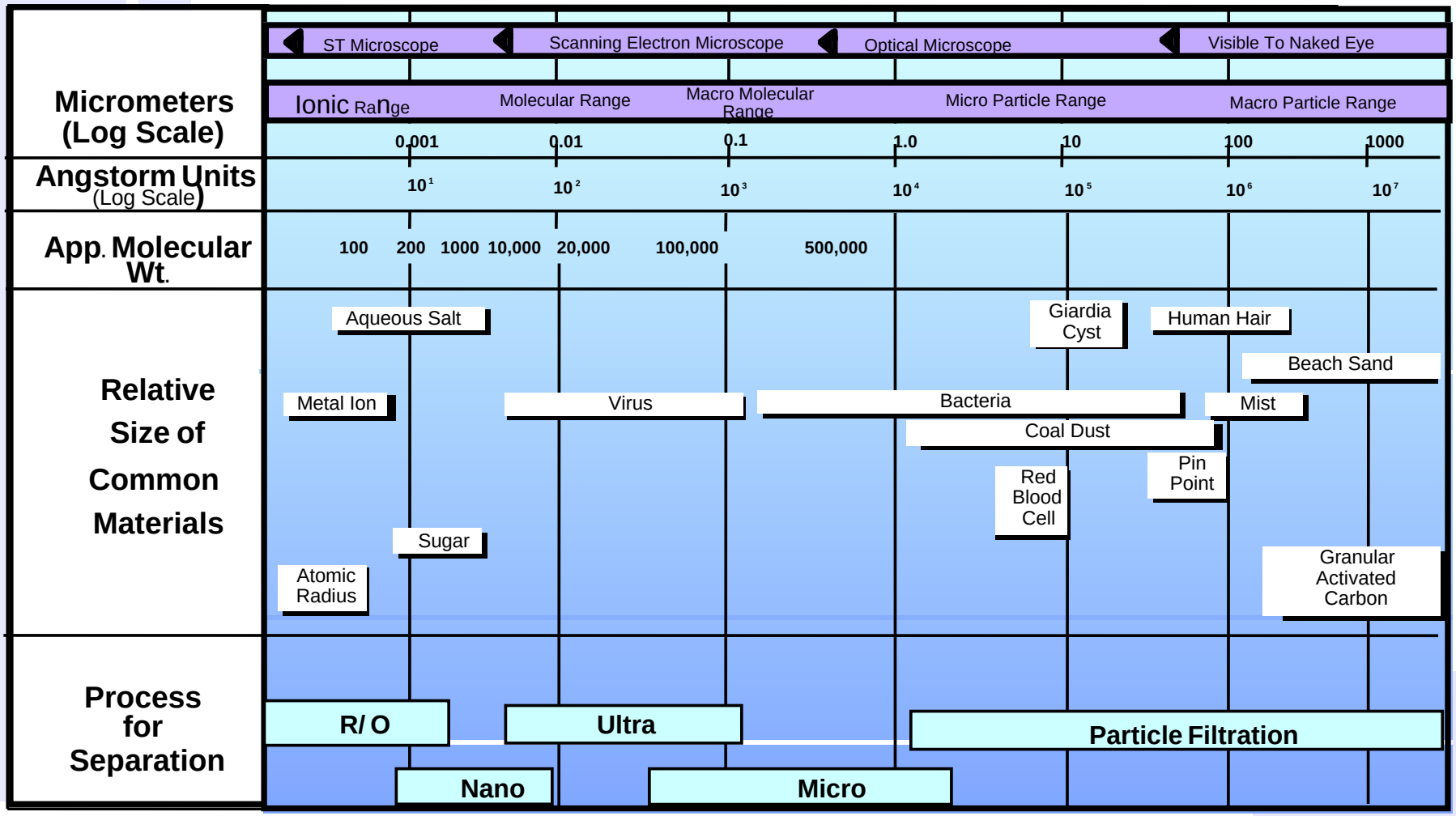
Conventional treatment flow scheme for ultra pure water production



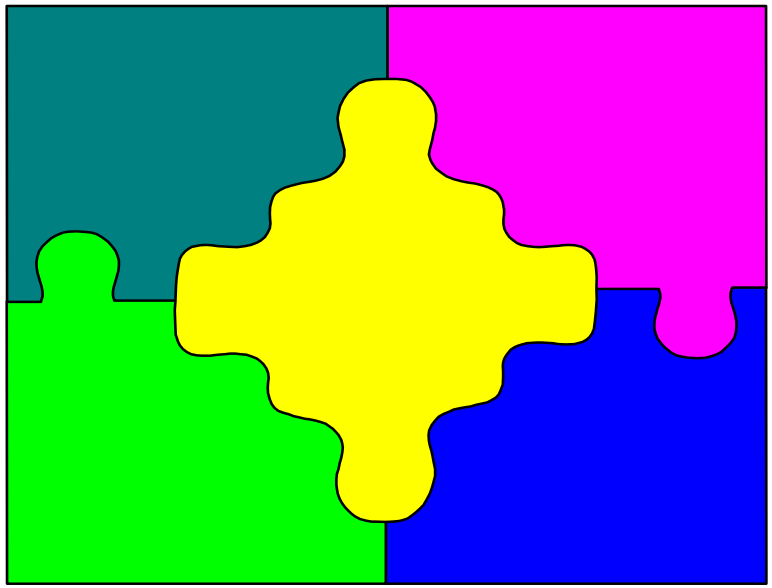
Advanced Water Treatment (4)

Coagulation	Solid/liquid separation
RO	Solid/liquid separation Organic, taste & odor removal NOM removal
Disinfection (UV)	Bacterial removal

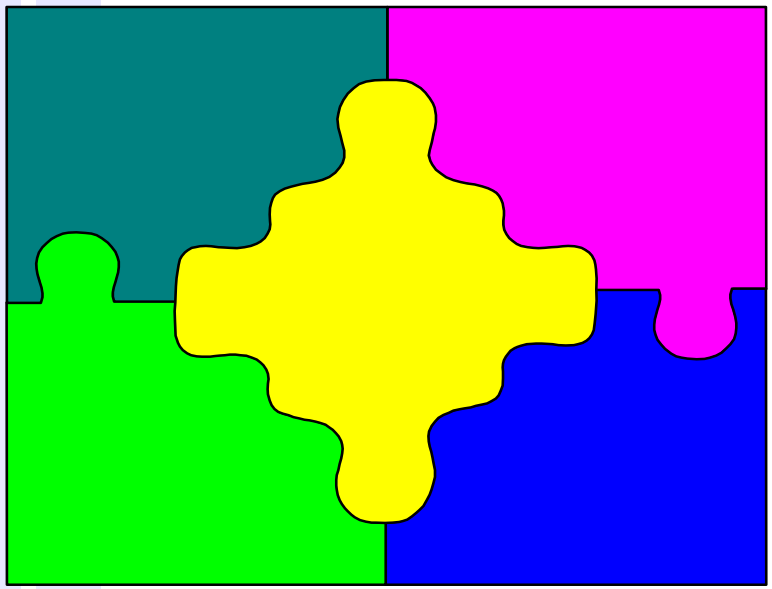
Filtration Spectrum



Part 2:
Membrane configurations, designs, operations



Part 3:
Membrane Systems



Reverse osmosis

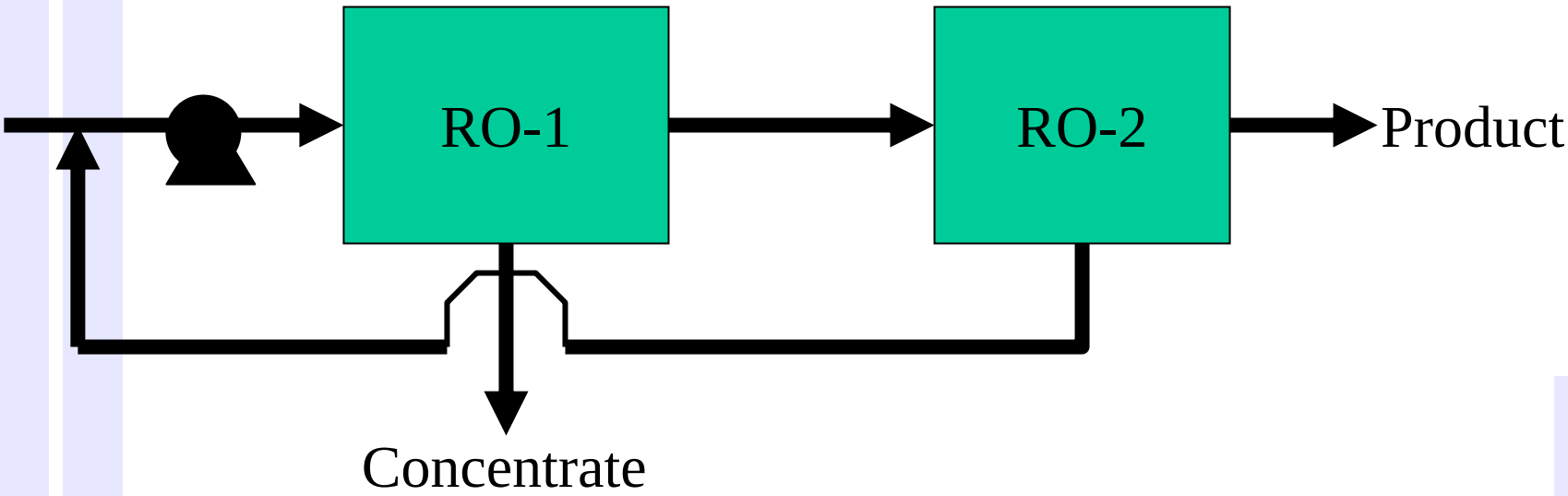
- Normally used for high purity water in many industries at the moment, coupled with UV
- Purposes:
  - Ionic removal
  - Organic removal
  - Silica removal
  - Particles and bacteria

Problems in high purity water systems

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

Double-pass reverse osmosis

Increase rejection level



Pre-treatment and post-treatment

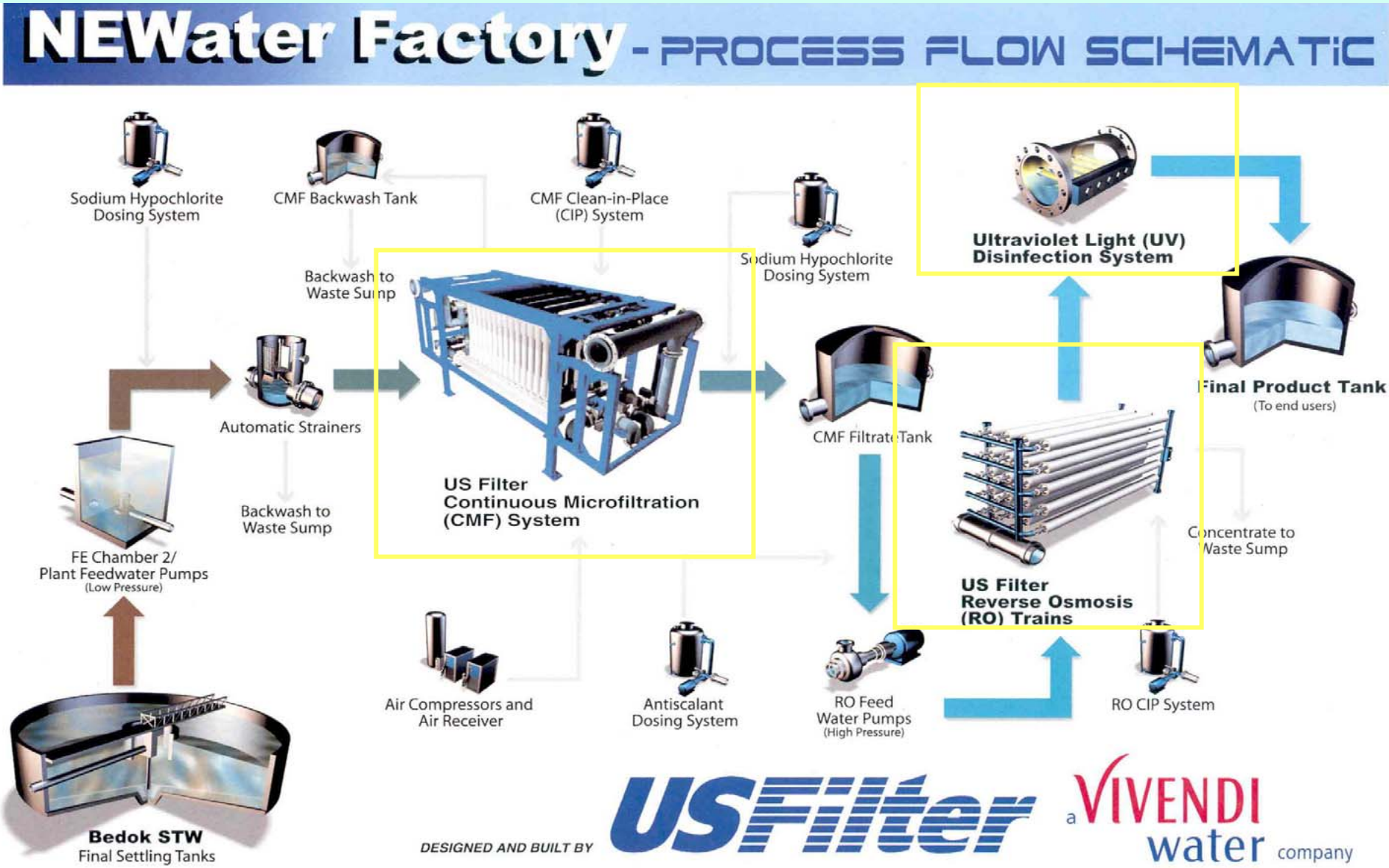
- Particle stabilization
- Ionic stabilization
- Biological control
- Polishing treatment

Market size and projections

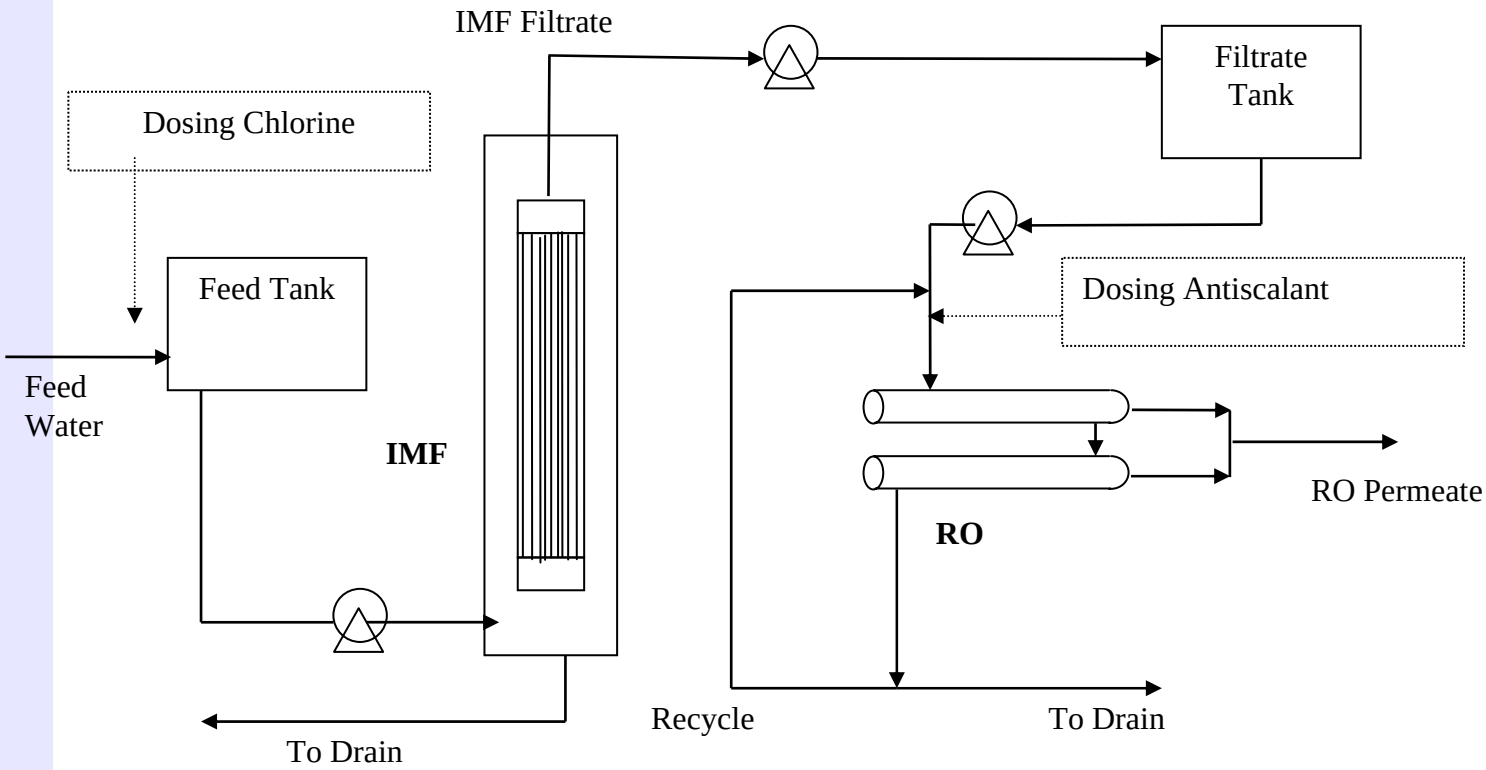
- 2.5% annual growth (global)
- RO is replacing ion exchange
- The more industrial growth in electronic, medical & pharmaceutical industries – the more market for membrane technology

BEDOK NEWATER FACTORY

Water Reclamation Demonstration Plant



The pilot plant



Membrane Specification

Specification 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

Specification for the RO

Manufacturer	-	Hydranautics
Commercial Designation	-	LFC1-4040
Active Membrane Area (outside)	m^2	7.9 per module
Memrane 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

IMF operating conditions

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

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

The pilot plant

The components

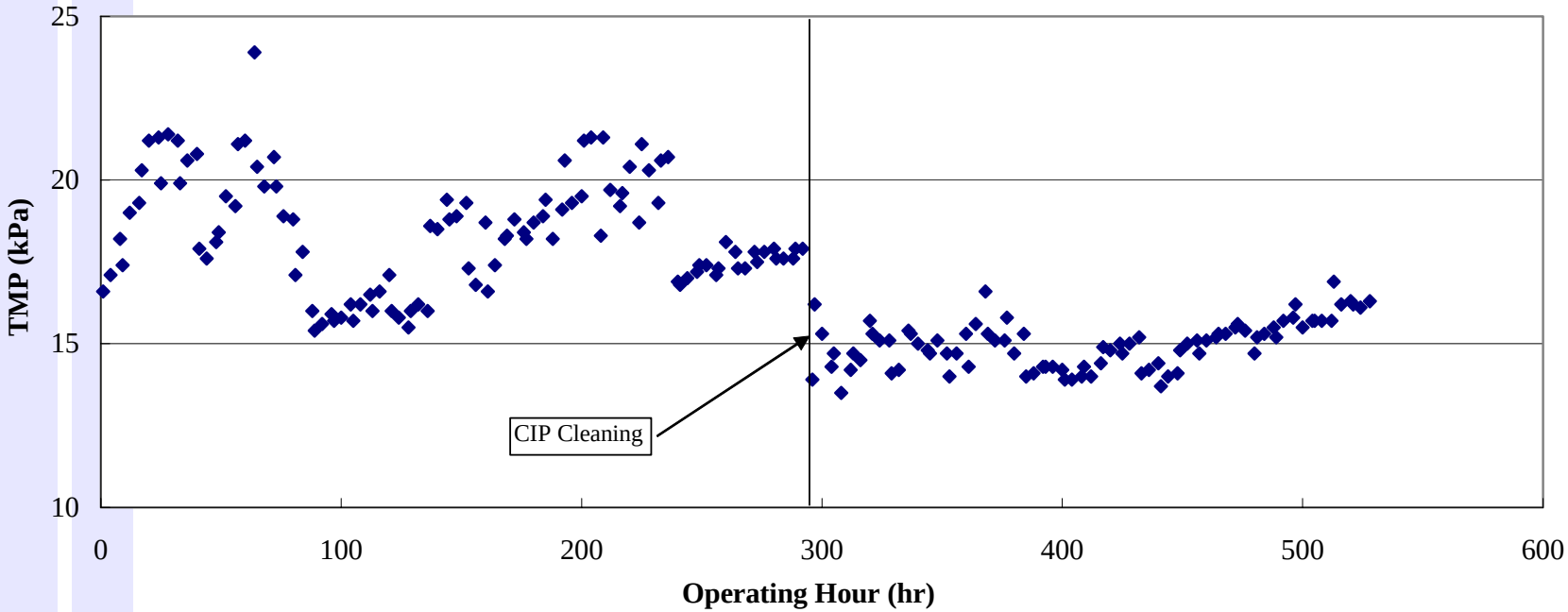
The components

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

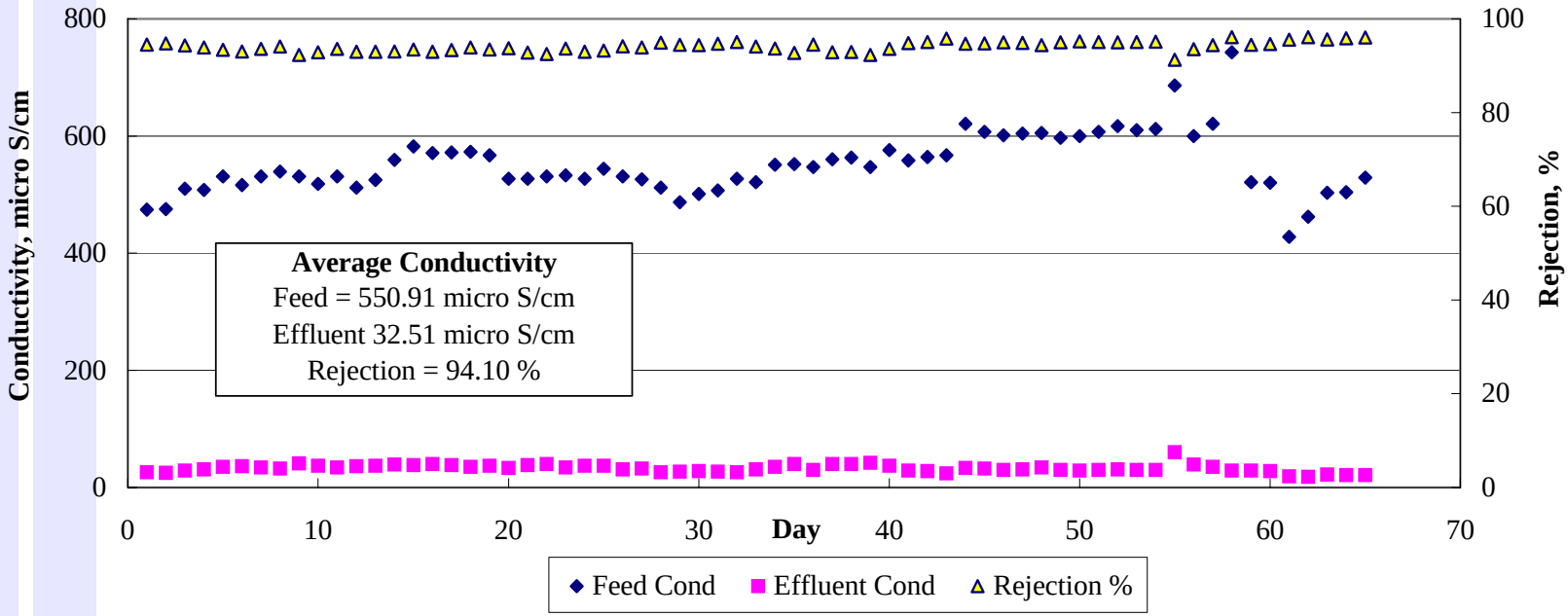
Experimental results on TMP

CMF-s



Experimental results on 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 %)

Discussions

- **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)

The overall results

Meeting the requirement of both effluent Standard A and drinking water

Rockeffeller 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!