Water Recycling Using Membrane Technology

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Institute of Environmental & Water Resource Management (IPASA) in Perspective

- Established in 1994, with ±50 academic staff
- Emphasis on water & environmental science and engineering
- Multidisciplinary R&D group (e.g. membrane tech & river rehabilitation)
- Postgraduate, post-doctoral levels

- Research funding: IRPA, MOSTE, IWK, SIDA (Sweden), DANIDA (Denmark), WOTRO (Netherlands), Vivendi (France), Kubota, EU, Infratech

- Joint R&D with top-ranking universities, companies
- Consultants to Government, private agencies

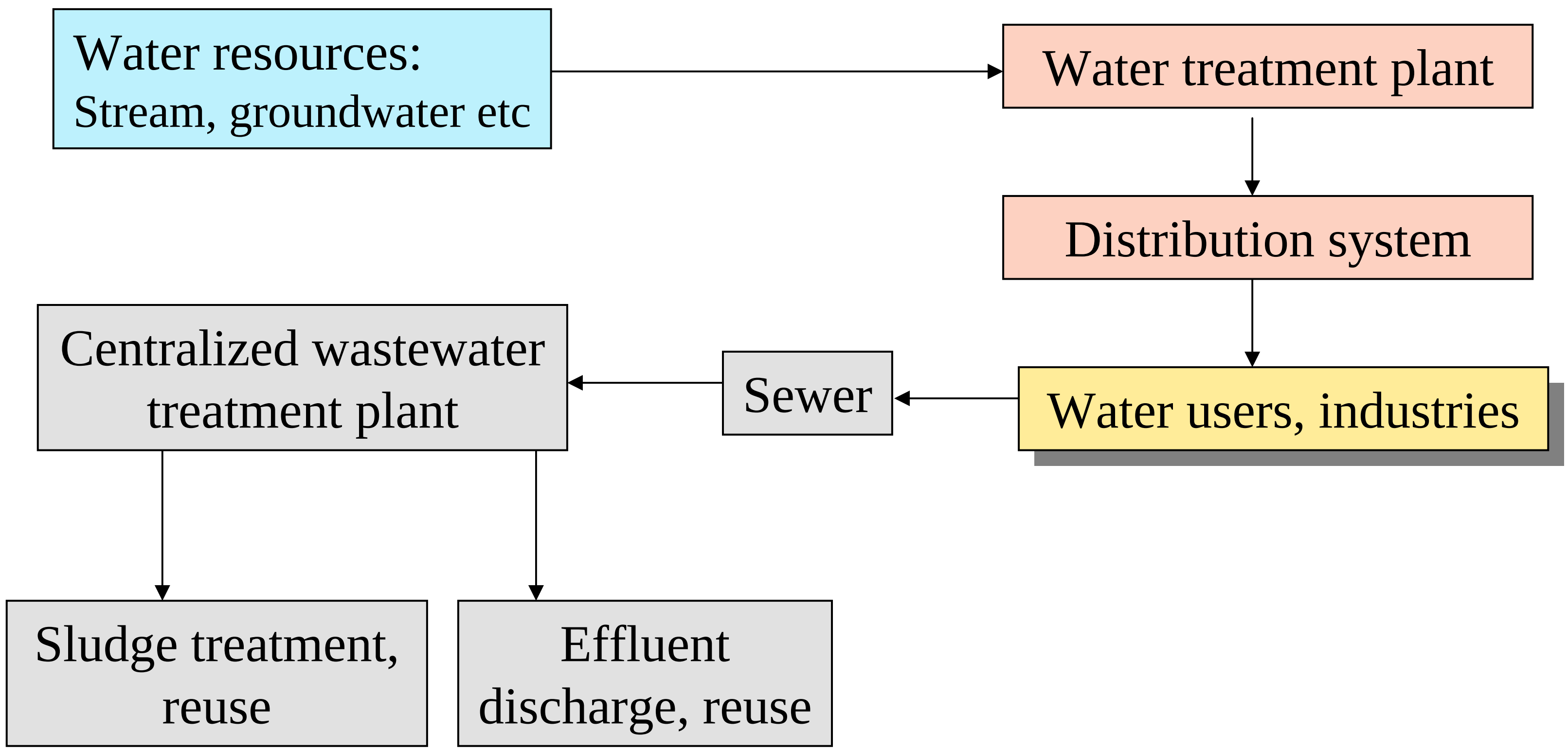
- Internationally known and recognized
- Active in local and international organizations (IWA, WHO, CIWEM)

International reputation, R&D hub

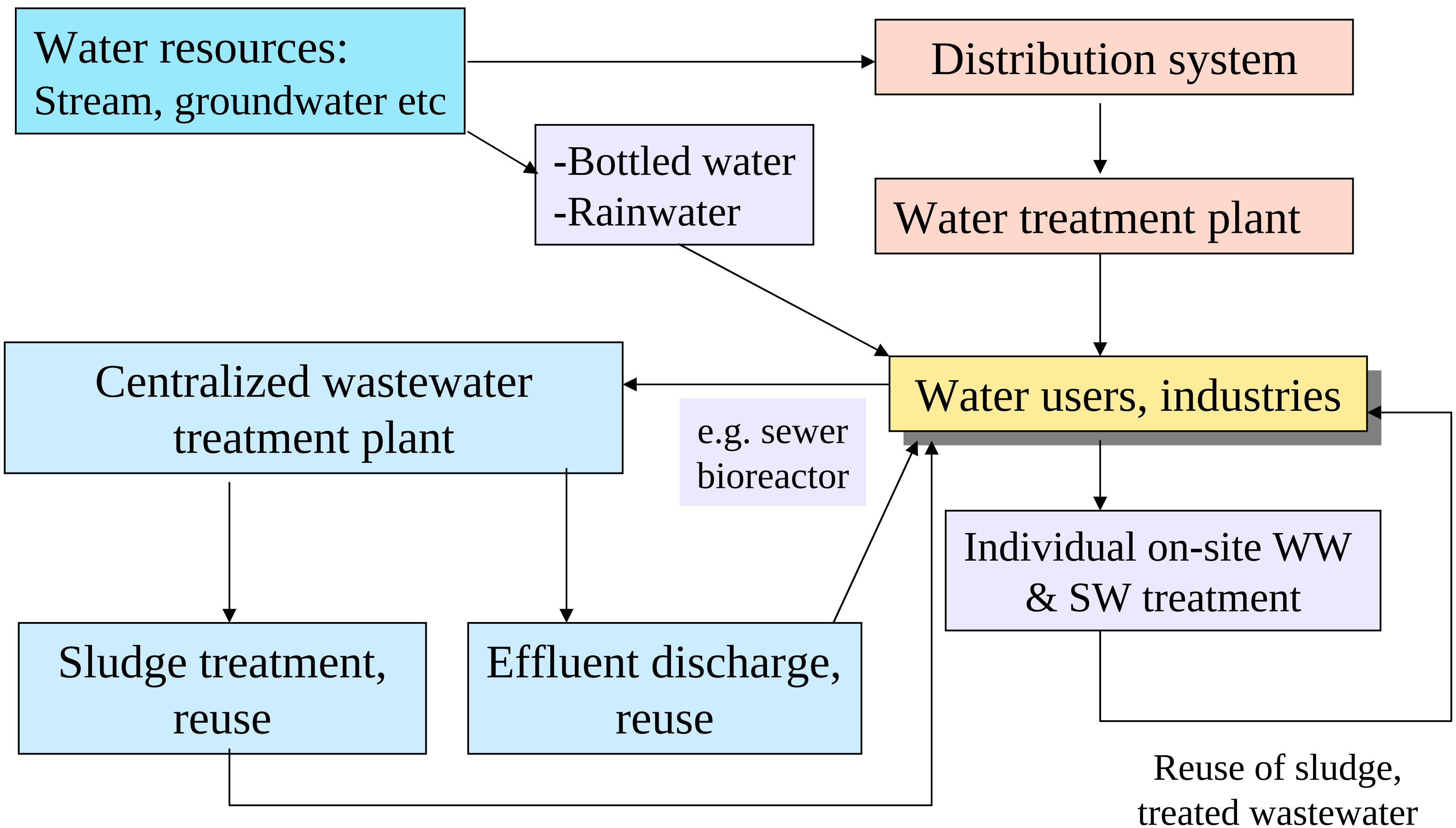
Achievements

- Malaysia Water Award Winner 2004
- Excellent Award for Consultancy Project on Sg Trengganu River Basin Studies 2000
- Local pattern for StormWater Filter™ 2003
- Local pattern for WASDA (Wastewater Treatment Plant Design Advisor) 2003
- R&D Grants from Sweden, Denmark, Holland, Japan and EU

Centralized urban sanitation (CUS)



Decentralized sanitation and reuse (DESAR)

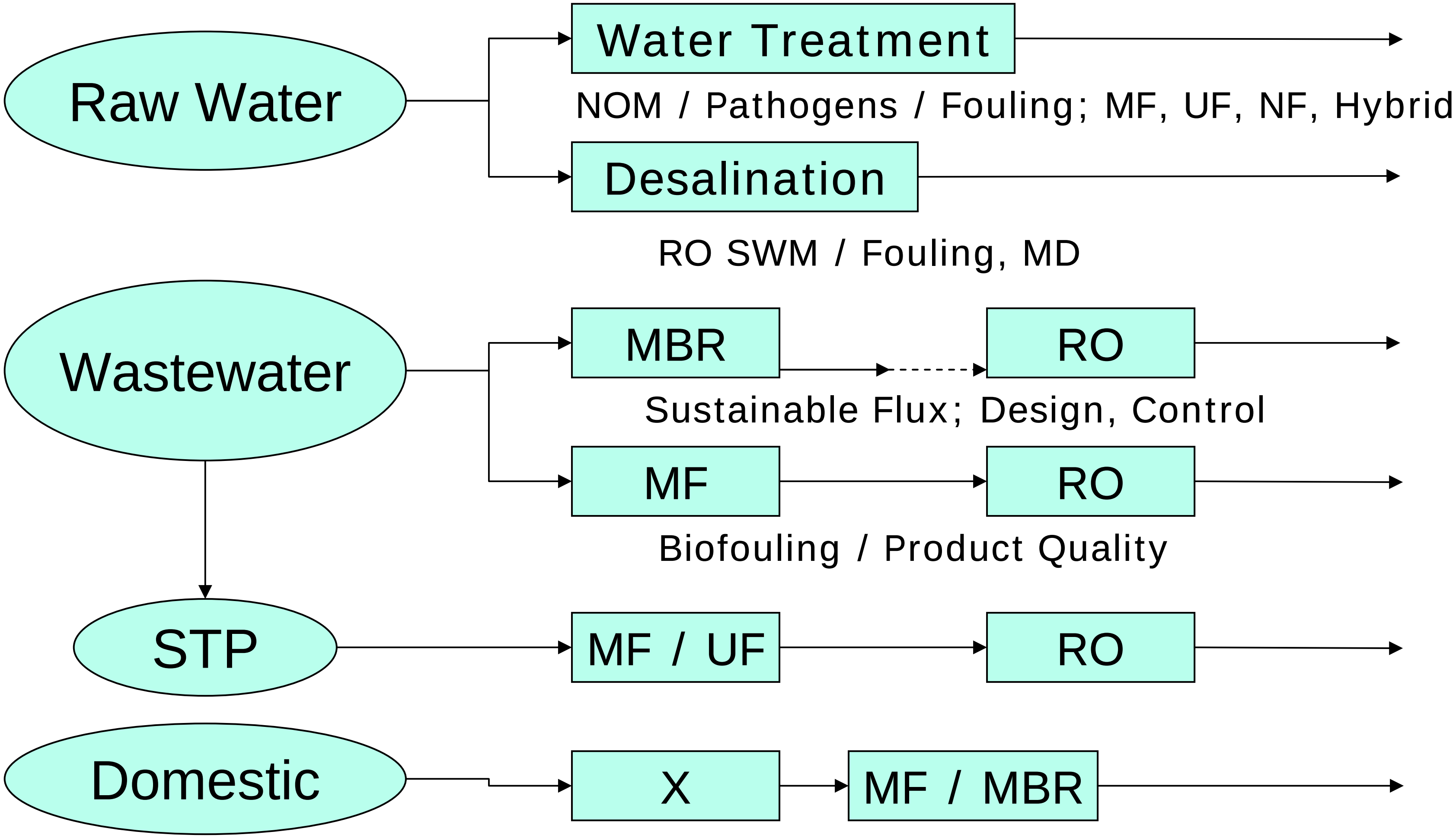


Bellagio Statement

Rockefeller Foundation Residency, Bellagio, Italy, April 2003

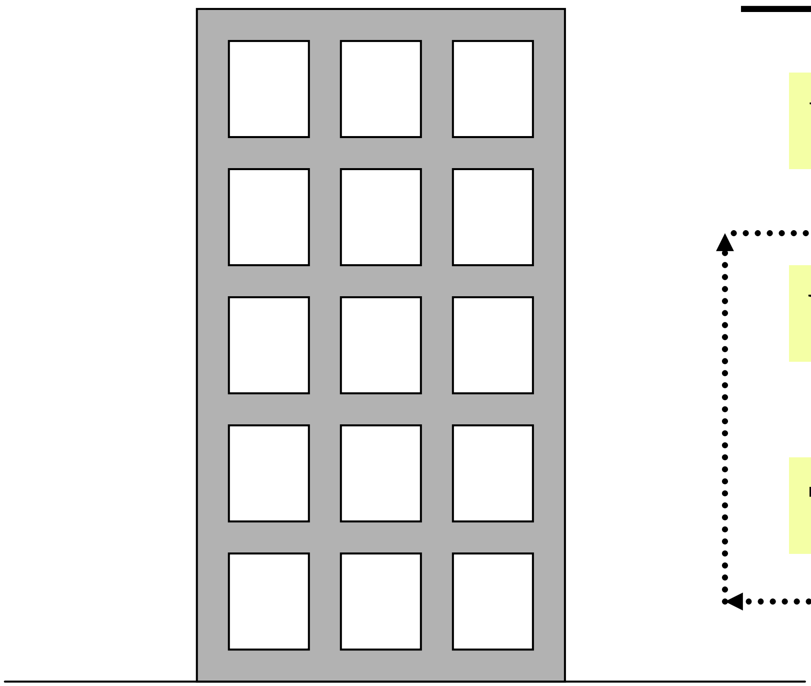
- The importance of small and decentralised water and wastewater systems
- The importance of reuse and recycle to maintain sustainability
- The importance of Membrane Bioreactor to act as technology-bridge for sustainable sanitation program

Membrane technology



Building Scale Wastewater Reclamation

50% reduction in water supply



Drinking Water

Used in Restaurants, Other Taps

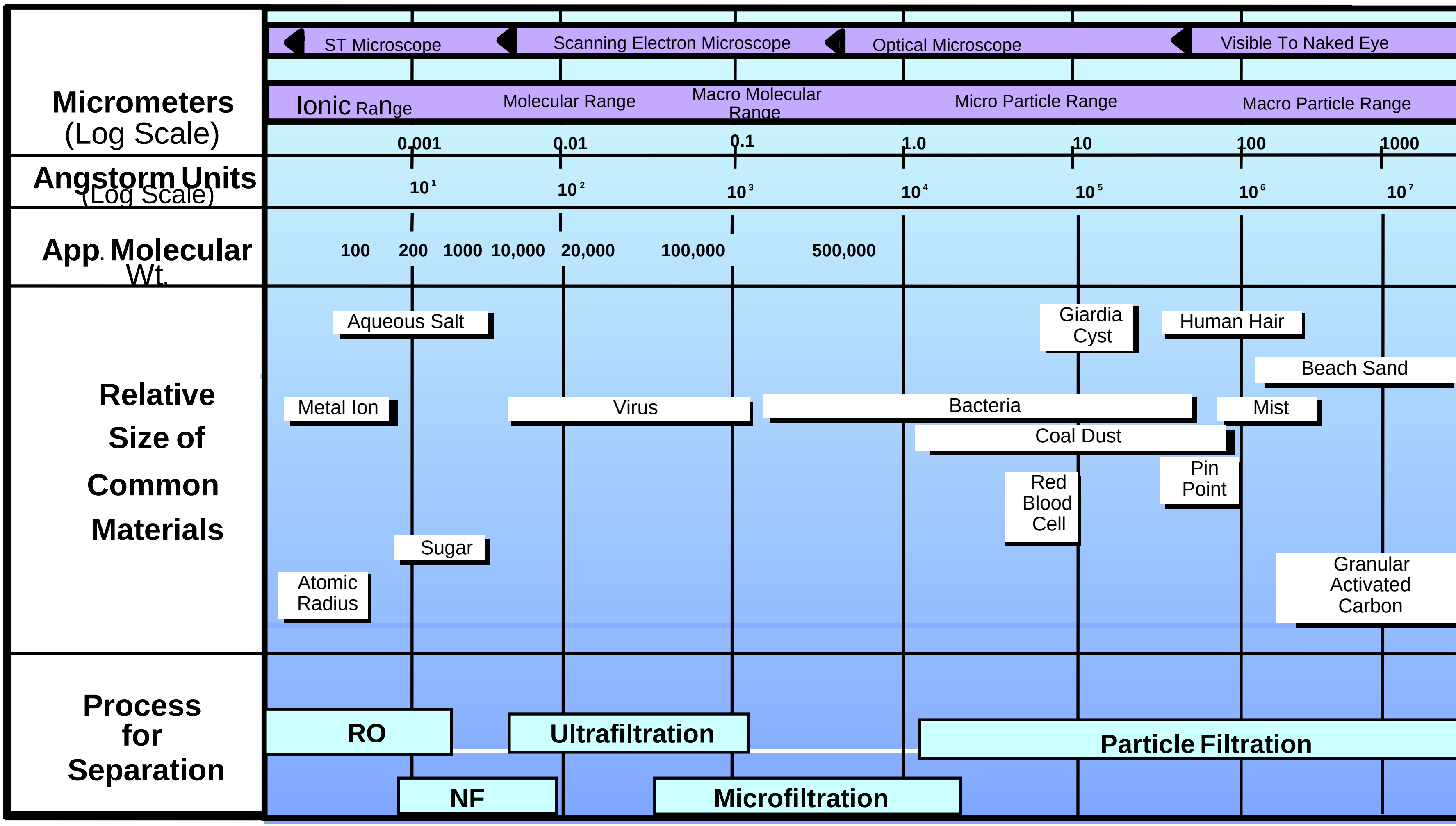
Wastewater reclamation By MBR

Toilet flushing

Discharge to Sewer

Tokyo Metropolitan government and Fukuoka prefectural government set up a regulation that the building constructor should install wastewater reclamation

Filtration spectrum



Membrane as Selective Barrier

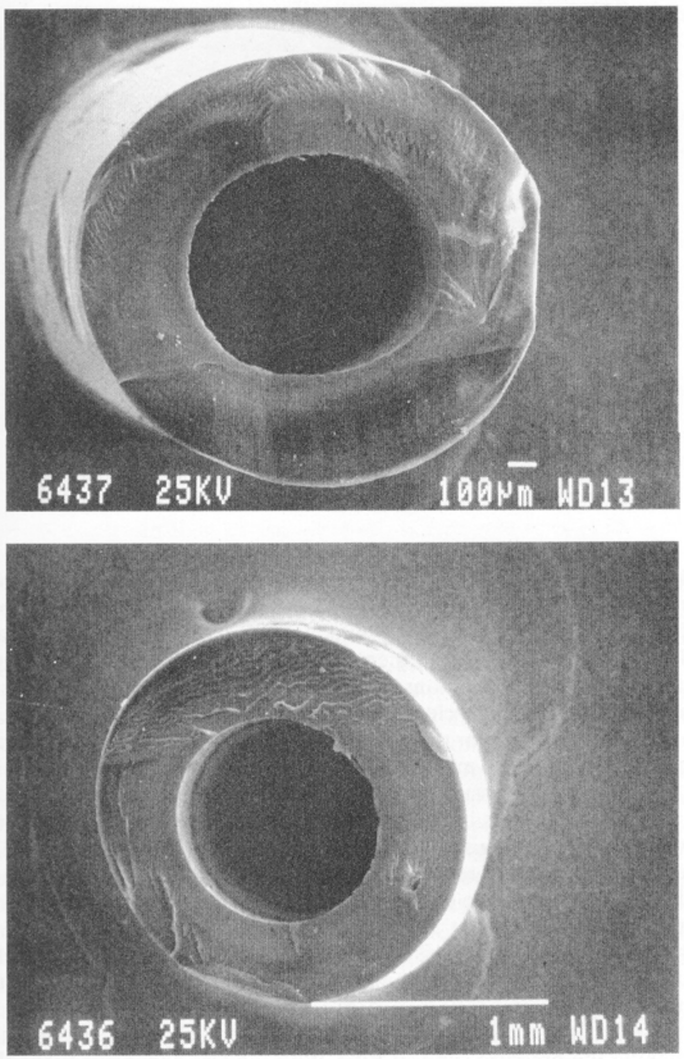


FIGURE 10.8 Micrograph of cross section of double-skinned hollow-fiber Aquasource membrane.

Polio virus on MF membrane

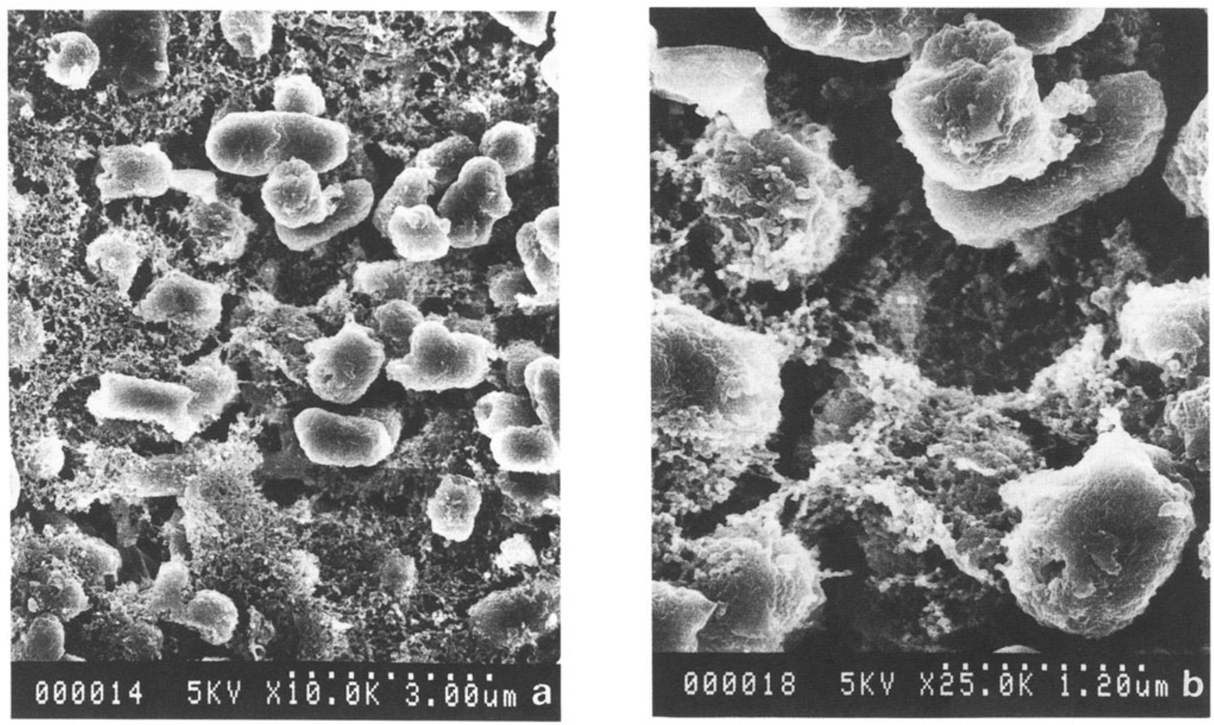
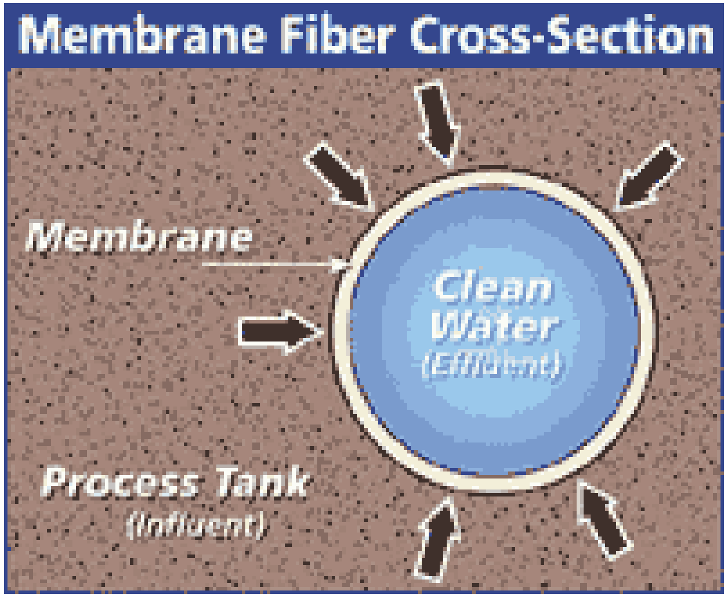


Fig. 5. SEM micrographs of GVHP membrane surface after filtering 3.7 l suspension of mixtures of *E. coli* (initial value 10^6/ml) and *poliovirus* (initial value 10^4/ml) (25 kPa, 400 rpm) (a) 10 K magnification (b) 25 K magnification.

Immersed UF Membrane Principles

- Water is extracted through the membrane fibers in an "outside-in" flow path under a slight vacuum
- Membranes are installed in the tank of water to be filtered
- Membranes replace clarifier and granular media filters of conventional system
- Aeration and mixing create turbulence in the reactor
- Lower driving pressure compared to side-stream membranes



Immersed UF membrane system

Manufacturer:

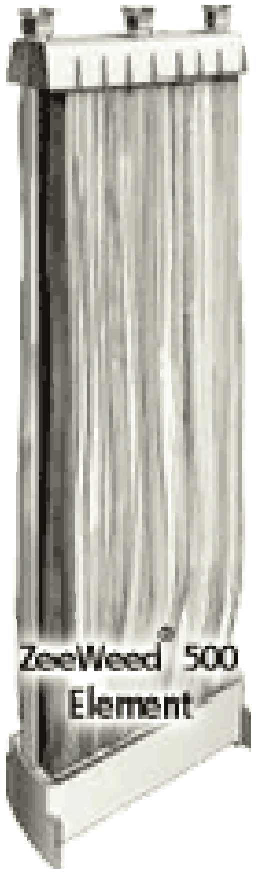
Zenon (Canada)

Products:

- ZeeWeed® 1000
- ZeeWeed ® 500

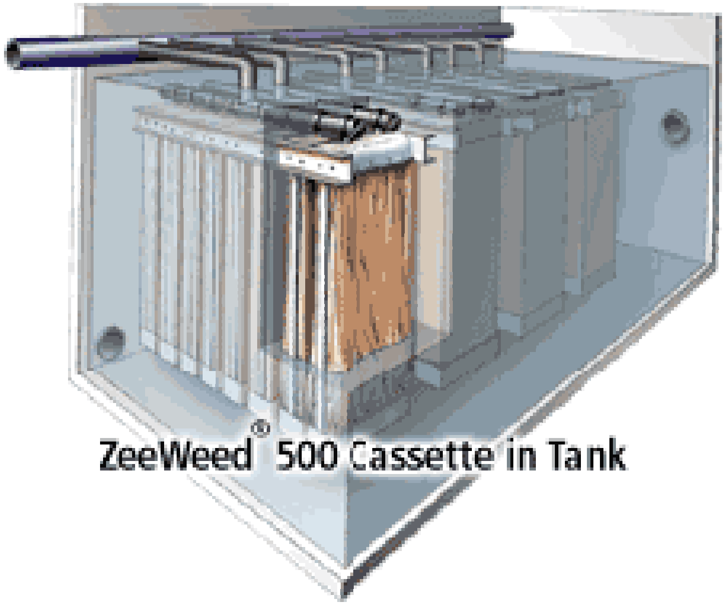
ZeeWeed® 500

- Direct filtration (medium-high solids)
- Ultrafiltration membrane, reinforced fiber with nominal pore size of 0.04 μm
- Hollow fibre
- Can combine with
  - *Coagulation (organic and arsenic removal)*
  - *Chemical oxidation (iron and manganese removal)*
  - *Powdered activated carbon (taste, odor removal)*
  - *Reverse osmosis (to reduce SDI)*



ZeeWeed® 500 System Design

- Two or more parallel trains (process pump, automatic valves, instrumentation)
- Components
  - *Tank*
  - *Metering pumps*
  - *Membrane blowers*
  - *Reject or sludge pump*
  - *Cleaning-in-place instruments*
  - *Vacuum pump for entrained air removal*
  - *Backpulse or wash tank*
  - *Control system*
  - *Strainers*
  - *Feed pumps*
  - *Mixers*
  - *Sludge recirculation pumps*

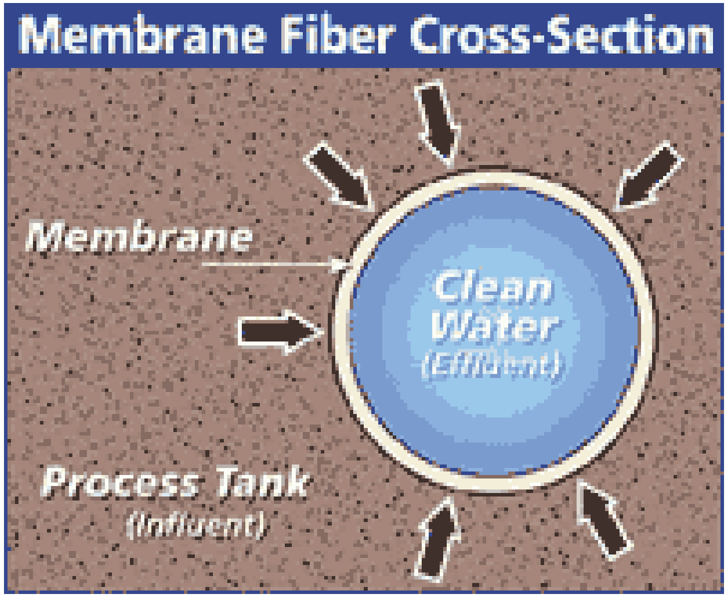


ZeeWeed® 1000

- Direct filtration (low-medium solids)
- UF membrane, reinforced fiber with nominal pore size of 0.04 µm
- Hollow fibre
- Ideal to upgrade the existing plant
- Driving pressure: 3 m water column (4 psi or 30 kPa)
- Can combine with
  - *Coagulation (organic and arsenic removal)*
  - *Chemical oxidation (iron and manganese removal)*
  - *Powdered activated carbon (taste, odor removal)*
  - *Reverse osmosis (to reduce SDI)*

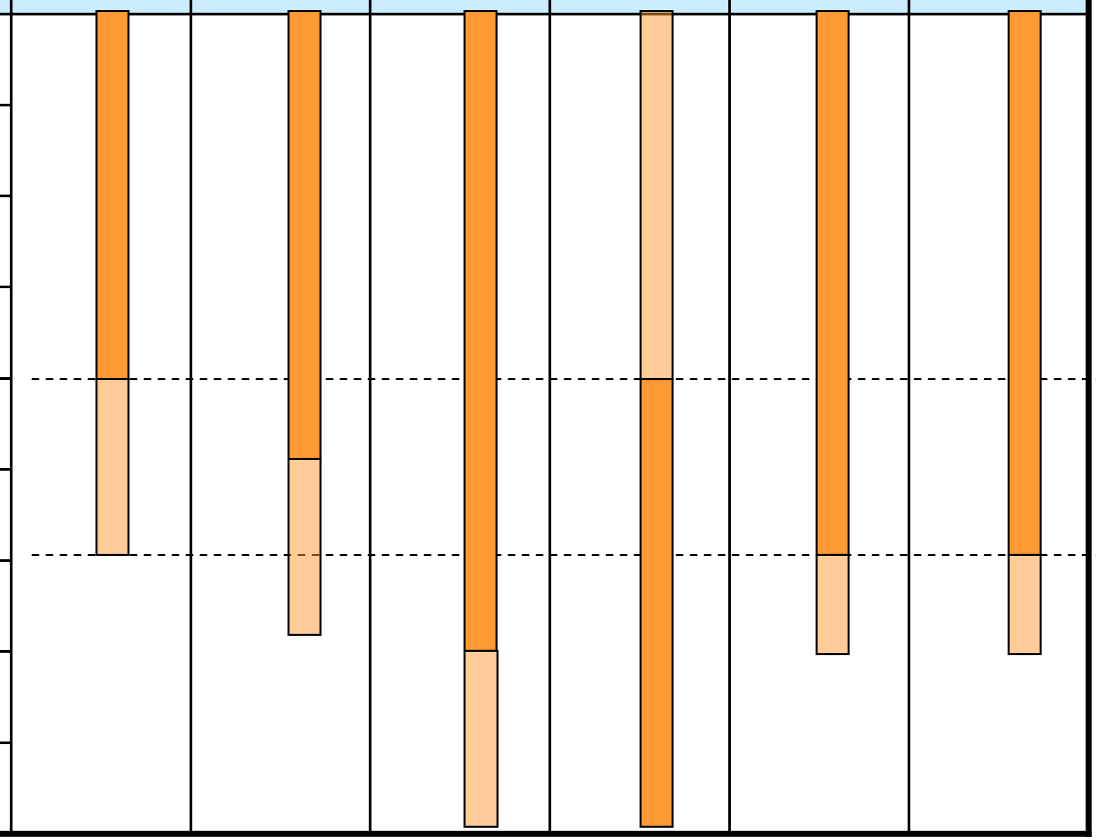
Side Stream UF Membrane Principles

- Water is extracted through the membrane fibers in an "outside-in" or "in-side out" flow path
- Membranes are installed in the tank of water to be filtered
- Membranes replace clarifier and granular media filters of conventional system
- Widely used, e.g. NewWater Plants



Membrane Applications

Species	Size (µm, kD)	MF	UF	NF	RO	H1	H2
Protozoa	> 10						
Coliform	> 1						
Turbidity	1 ~ 0.1						
Cyst/oocyst	~ 0.1						
Virus	0.01~0.1						
THMP	< 10 kD						
Colour	< 10 kD						
Al Species	< 1 kD						
Ions	< 0.1 kD						



■ Near complete removal ■ Partial removal

H1 = Chem. + MF/UF H2 = PAC + MF/UF

Hybrid Membrane Processes

Membrane Bioreactor

- Bioreactor with MF or UF
- Separation of biomass
- Biodegradable organics from waste water

Chemically Assisted Membranes

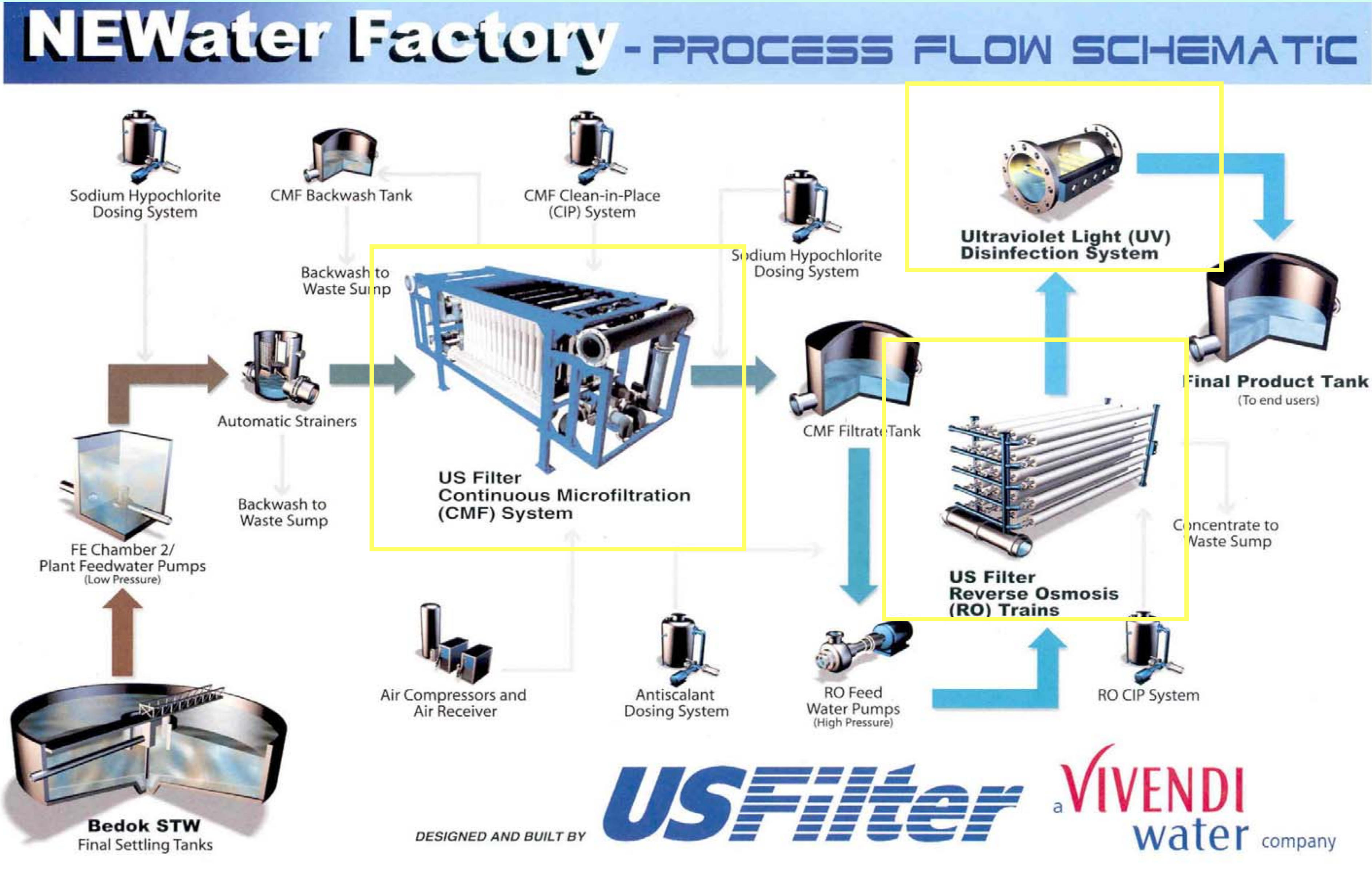
- Chemical floc formed and recovered by membrane
- Heavy metal recovery
- Natural organic matter from raw water

Sorbents + Membranes

- Powdered adsorbents in MF/UF circuit
- Powdered ion exchange resin in MF/UF circuit
- Trace organics (pesticide) from water
- Ionic species (Nitrate) from ground water

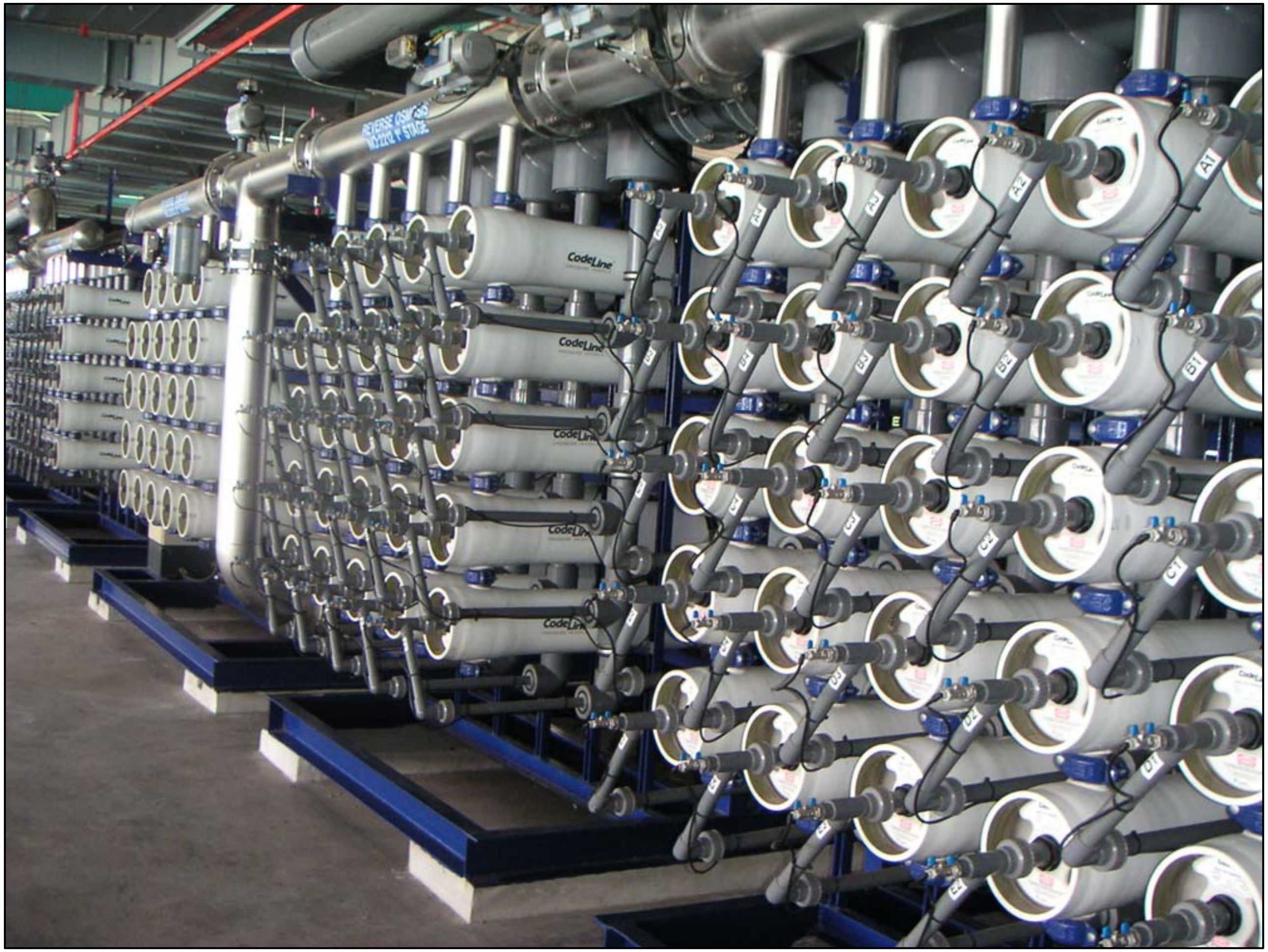
BEDOK NEWATER FACTORY

Water Reclamation Demonstration Plant



Kranji High Grade Water Reclamation Plant, Singapore

Kranji High Grade Water Reclamation Plant, Singapore



Wastewater reclamation costs

Veolia Water Systems

Projects	Production capacity	CAPEX	Status
Bedok NEWater	32,000 m3/d	S$15.53 m	completed
Kranji NEWater	40,000 m3/d	S$21.05 m	Completed
Seletar NEWater	24,000 m3/d	S$25.9 m	

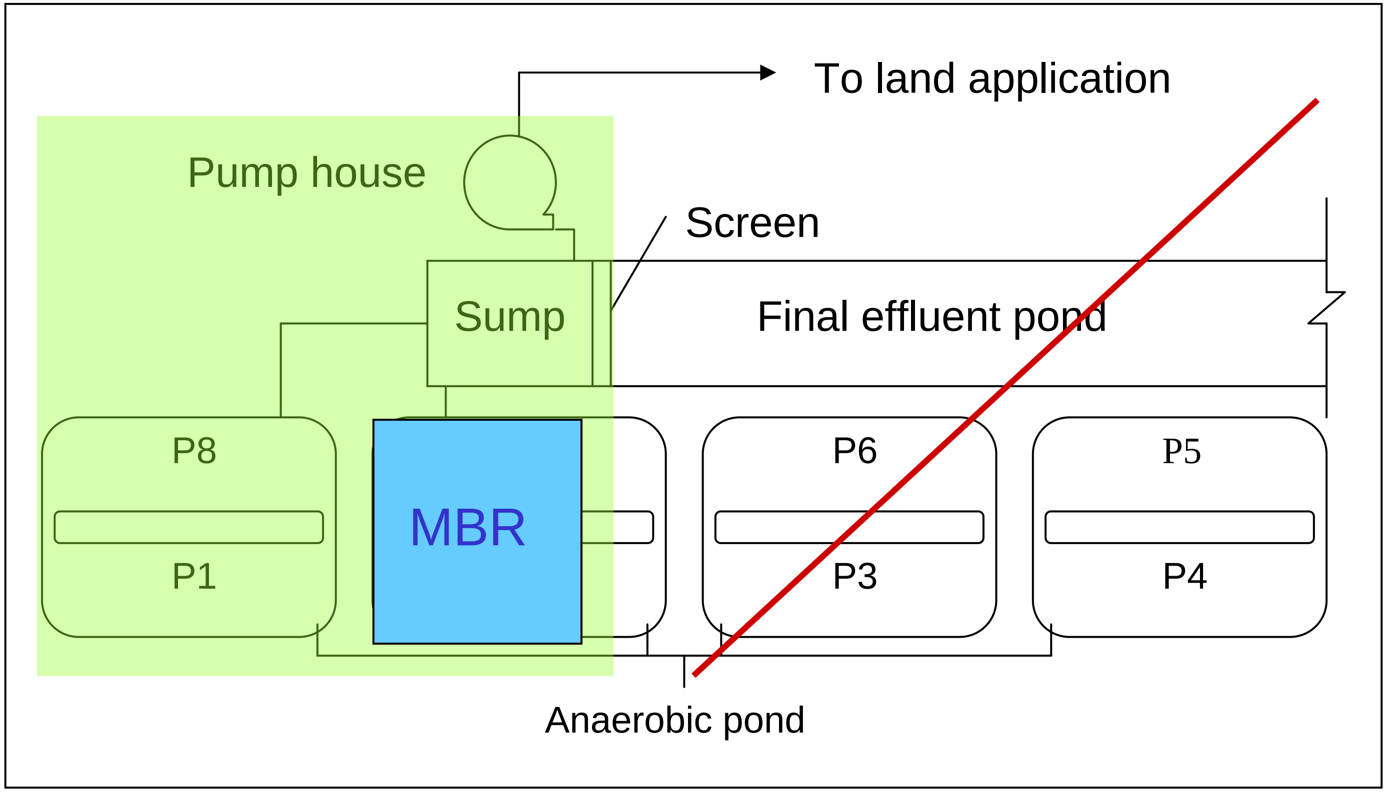
The pilot plant

UTM-Veolia-MWA-DSS-IWK Project

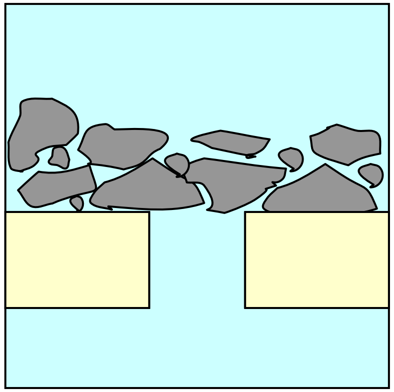
The results

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

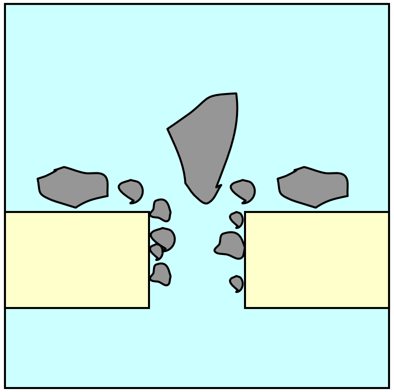
Anaerobic Pond at a Palm Oil Mill



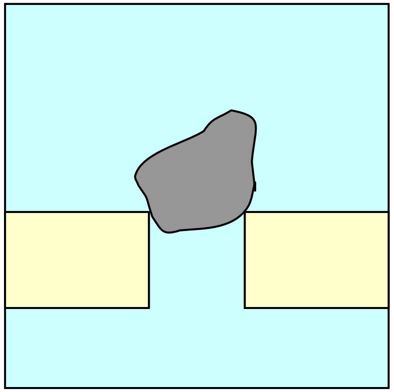
Fouling in MBR



Cake Formation



Pore narrowing



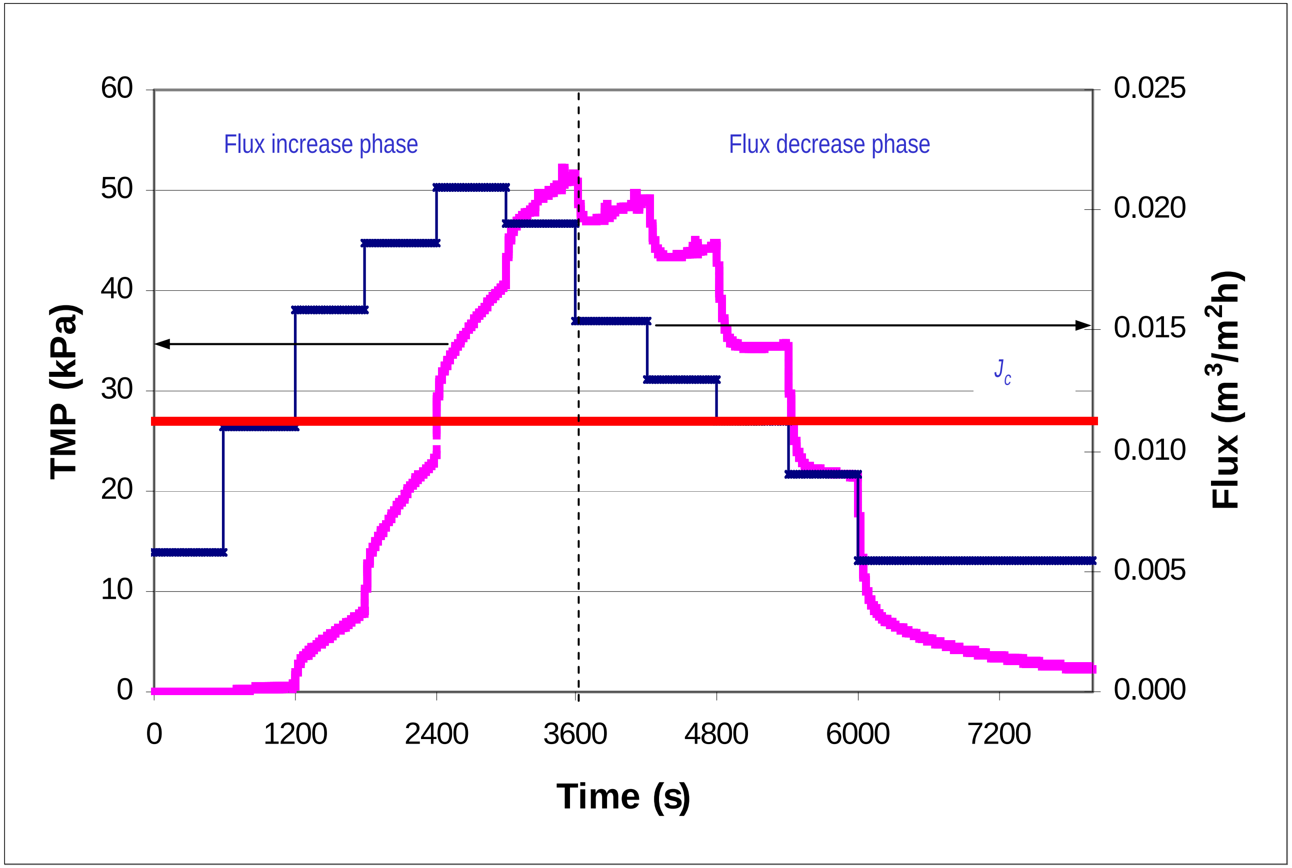
Pore blocking

- Critical flux plays a role in the degree of fouling
- Chemical cleaning can also be applied

Critical Flux Concept

- Critical flux is the flux at which colloidal deposition takes place
- Below the critical flux value, the flux is directly proportional to trans-membrane pressure

Critical Flux for Palm Oil Mill Effluent

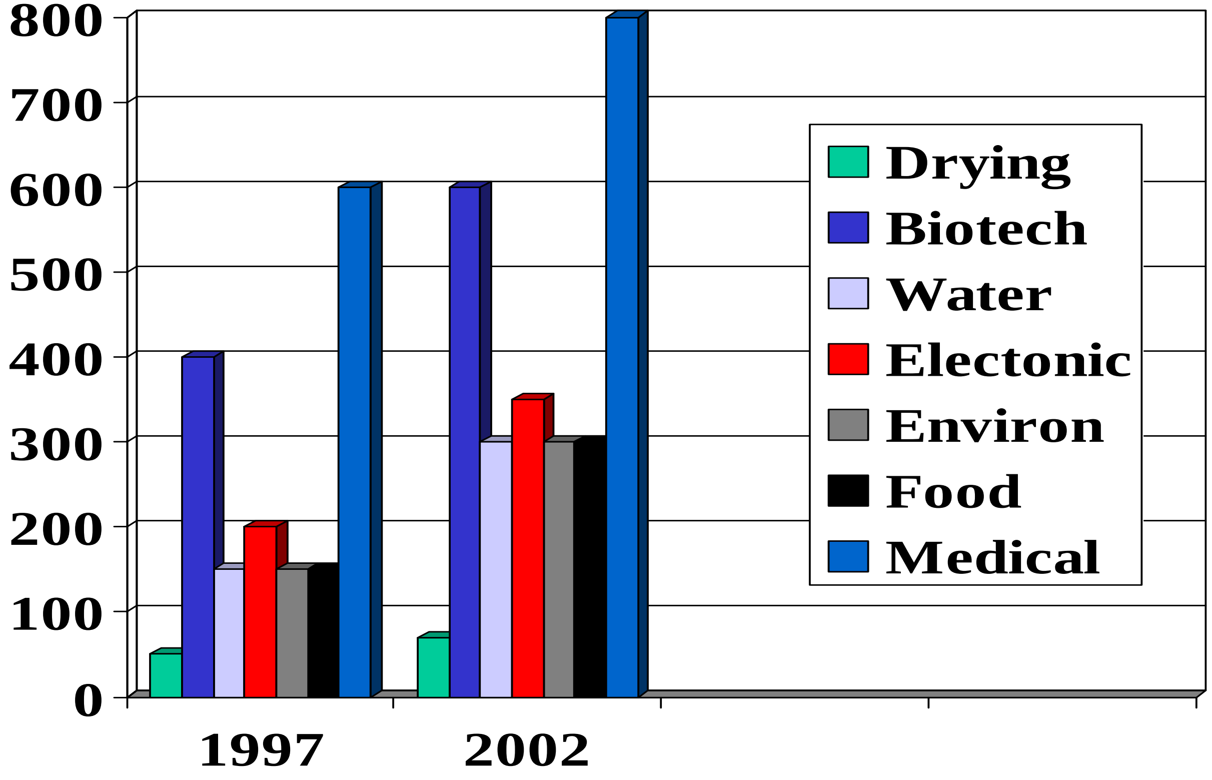


Validation for membrane design

- Membrane selection
  - use membrane cell tests
- Process configuration
  - use pilot plant
- Pretreatment(fouling issues, chemistry)
  - use demonstration plants

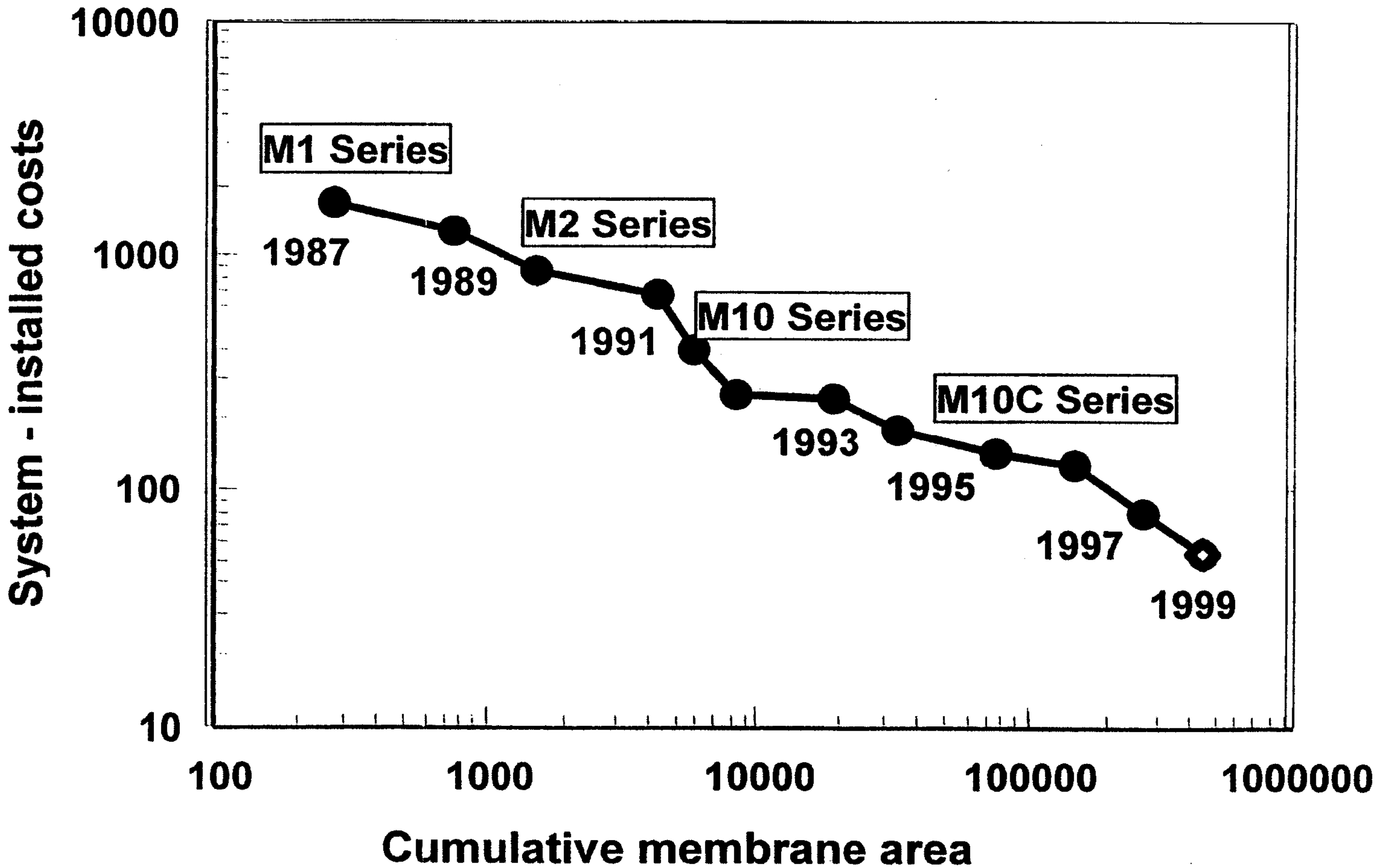
Sectoral distribution of membrane market

Values in USD



Membrane costs

Hollow fiber MF (USF – Memcor data)



Membrane costs

Approximate processing costs (2002) (Fane, 2002)

Seawater RO	A$1.0~1.5 / m^3
NF/LPRO	A$0.5~1.0 / m^3
Ultrafiltration	A$0.25~0.5 / m^3
Microfiltration	A$0.15~0.3 / m^3

Recommendations

- All systems should be tested on-site
- Expenses should include pilot studies to include hands-on O&M by operators
- Often, membrane failure is due to “quick-fix syndrome” in terms of membrane system
- Capital cost should include 5 years guarantee
- Develop local expertise by taking part in system development process
- Membrane is not the critical item (it could be cheaply bought in a competitive market) compared to system development