Lecture 1

Membrane Technology:

Introduction, Applications, Business

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Presentation Menu

Part 1: Why Membrane Technology?

Part 2: Market forces

Part 3: Water scarcity

Part 4: End-of-Pipe vs Zero Discharge

Part 5: For Developing Countries?

Part 6: Conclusion & Future Directions

Membrane?

Selective barrier that allows entities to pass through, while restricting the passage of others.

Our body separation system is a membrane in nature!!

- Kidney
- Intestinal
- Respiration system, etc.

Selective Barrier

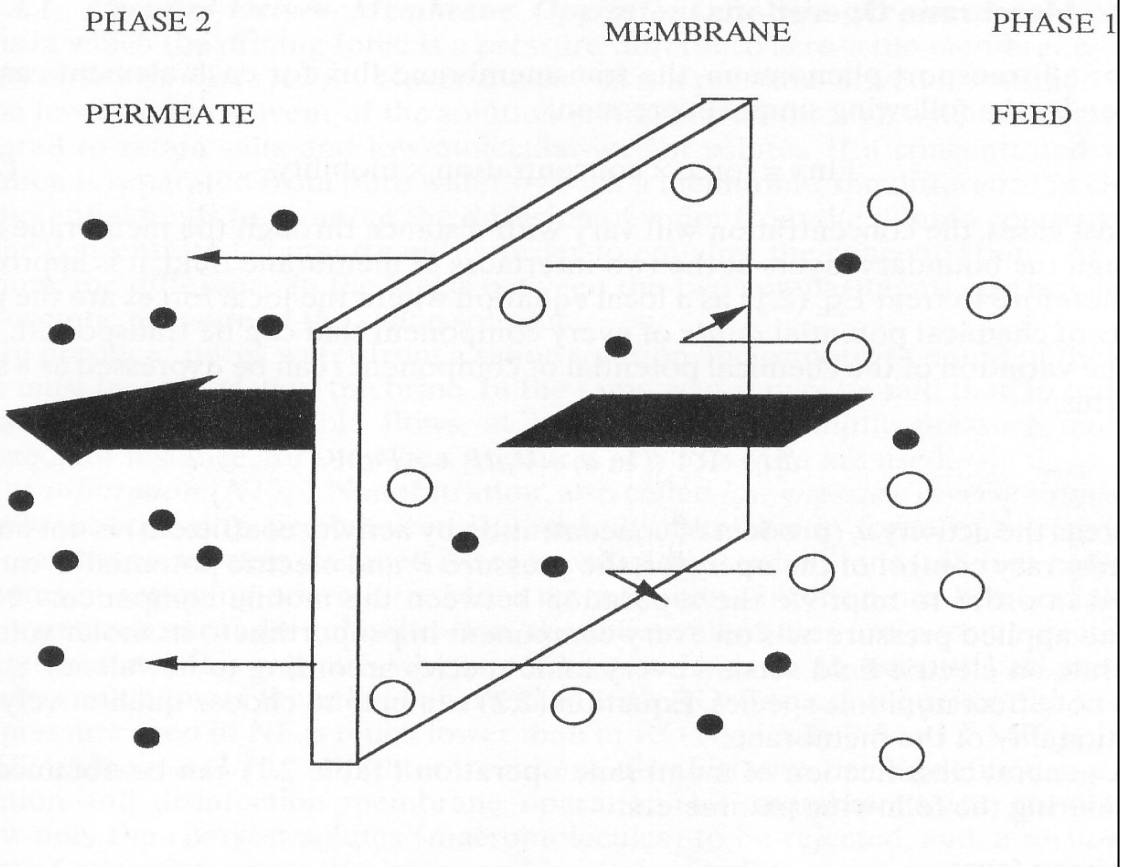


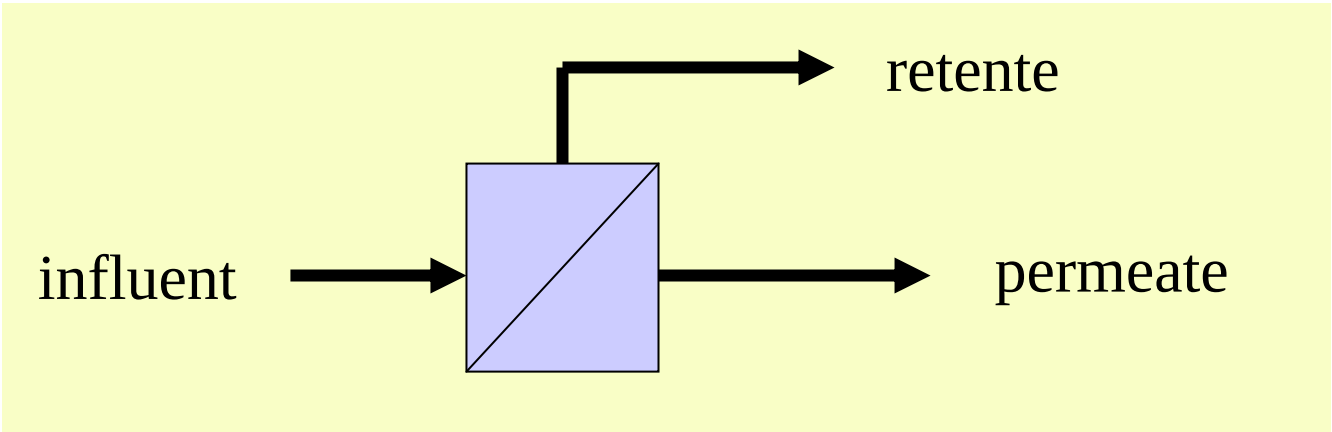
FIGURE 2.1 Definition of a permselective membrane.

Definitions

- Membrane: Thin film separating two phases and acting as a selective barrier to the transport matter
- Membrane Operation: Operation where a feed stream is divided into 2 streams:

  (a) permeate (product/filterate) and

  (b) retente (brine/concentrate/etc)



Membrane plant for water treatment, Ogose Town, Japan

Part 1:

Why Membrane?

Part 1:

Why Membrane?

Technical Answers

- Modular design, compact
- Small foot-print
- Continuous process, simple automation
- Good solid-liquid, liquid-liquid separation
- No phase and temperature change
- Easy for reuse, recycle

Part 1:

Why Membrane?

Management and Regulatory Answers

- Meeting the regulatory standards
- Public health
- Environmental protection
- Market forces

From Options to Necessity

Scenario 1: 1970

- Do we really need tab water?
- Do we require a wastewater treatment plant?
- Do we need landfill for solid and hazardous waste disposal?
- Do you prefer water from well, or river?

From Options to Necessity

Scenario 2: 2004

- Do we really need bottled water?
- How best we can achieve nutrient removal in wastewater treatment plant?
- How best we can operate sanitary landfill for solid and hazardous waste disposal?
- Do you prefer mineral or reverse osmosis water?

Main Environmental Concerns

Scenario 1
Year 1970

- Clean drinking water
- Do we need a toilet?
- Where to dispose?
- Monsoon flood
- Pollution control

Scenario 2
Year 2000

- THM in tab water
- Organic & nutrient removal
- How to dispose
- Flood of WW
- Pollution prevention

Target water pollutants, and technology options

Era	Pollutants	Solutions
1800s	Pathogenic bacteria	Sewer system
1900s	BOD, COD	Biological wastewater plants
1950s	Heavy metals, biodegradable substances	Treatment at source
1970s	Eutrophication	N and P control
1980s	Trace substances, carcinogens, flavor, taste	Activated carbon, membrane technology
1990s	CO_2, NH_4, N_2O, CFCs, NO_x, SO_x	Energy saving, photosyntetic bacteria, biotechnology, MBR
2000s	Endocrine disrupting chemicals (EDCs), eco-hazard	Membrane technology

Part 2:
Market Forces

Part 2:

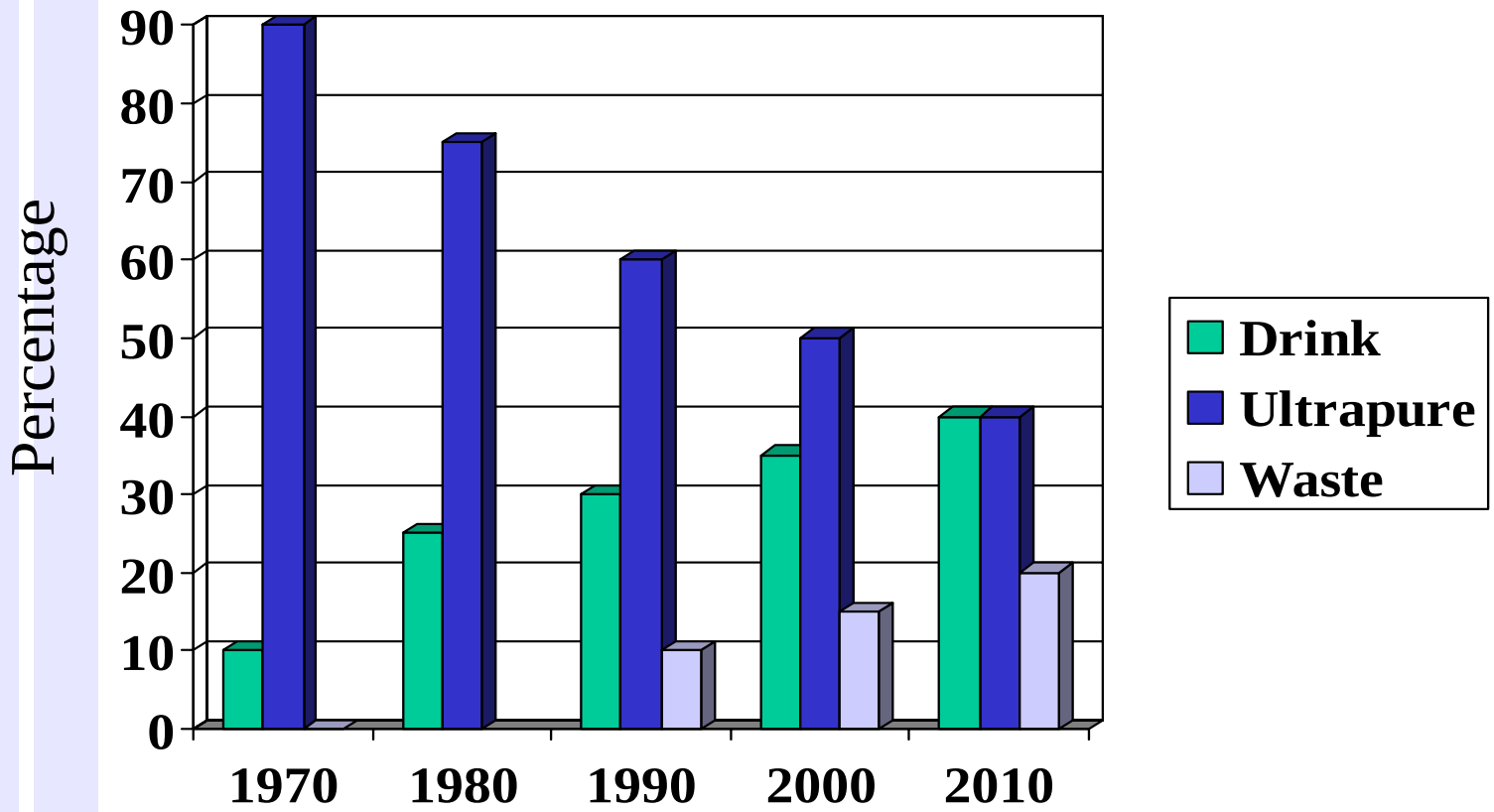
Market Forces – Demand Sector

- High quality drinking water
- High quality process water (ultrapure)
- High quality laboratory water (ultrapure)
- Cleaner production – 3R
- Relatively cheaper
- Relatively easier maintenance

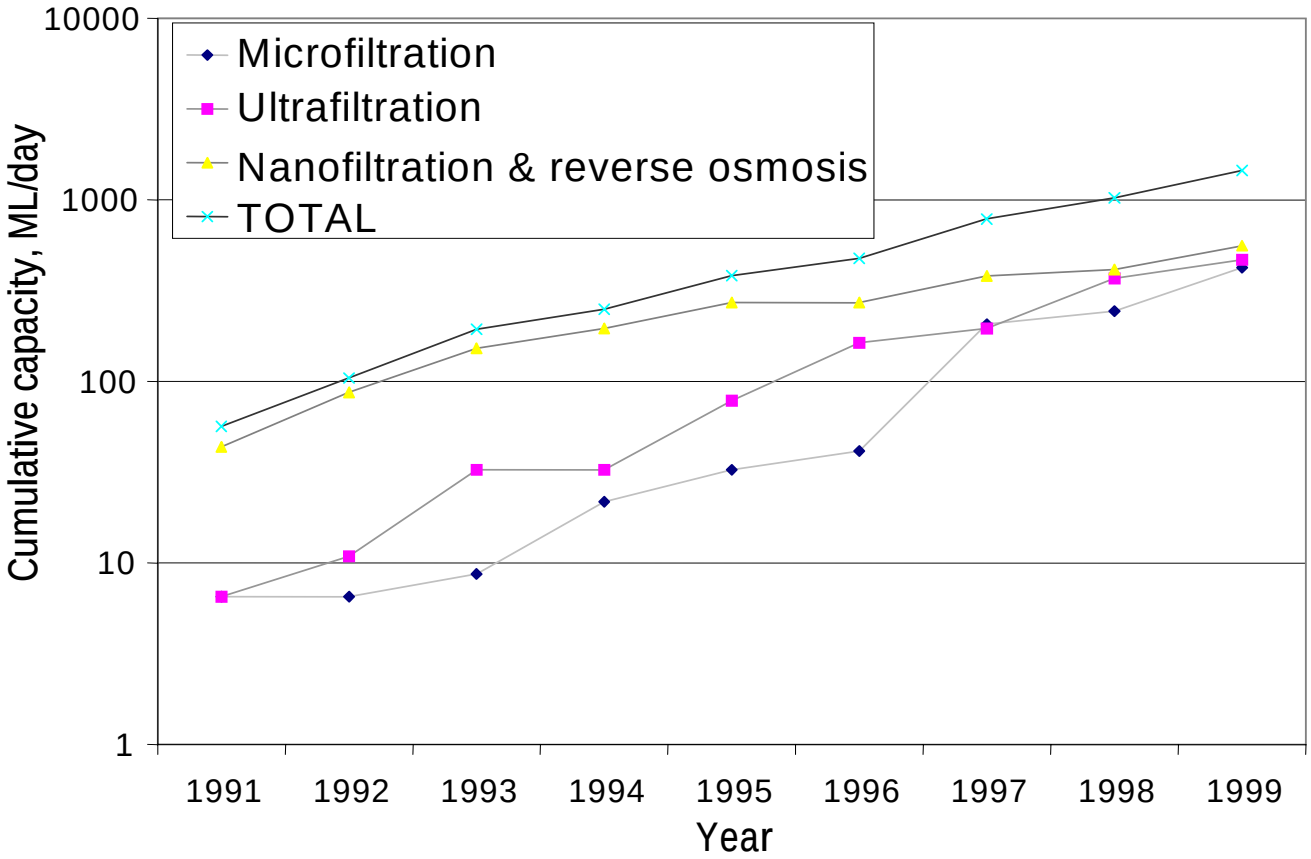
Worldwide Market Segments

- Drinking/potable water production
  - *Desalination*
  - *Treatment of polluted water resources*
  - *Treatment for higher quality requirements*
- Ultrapure water production
- Wastewater management

Worldwide Market Segments

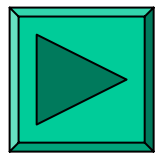


Worldwide Membrane Market

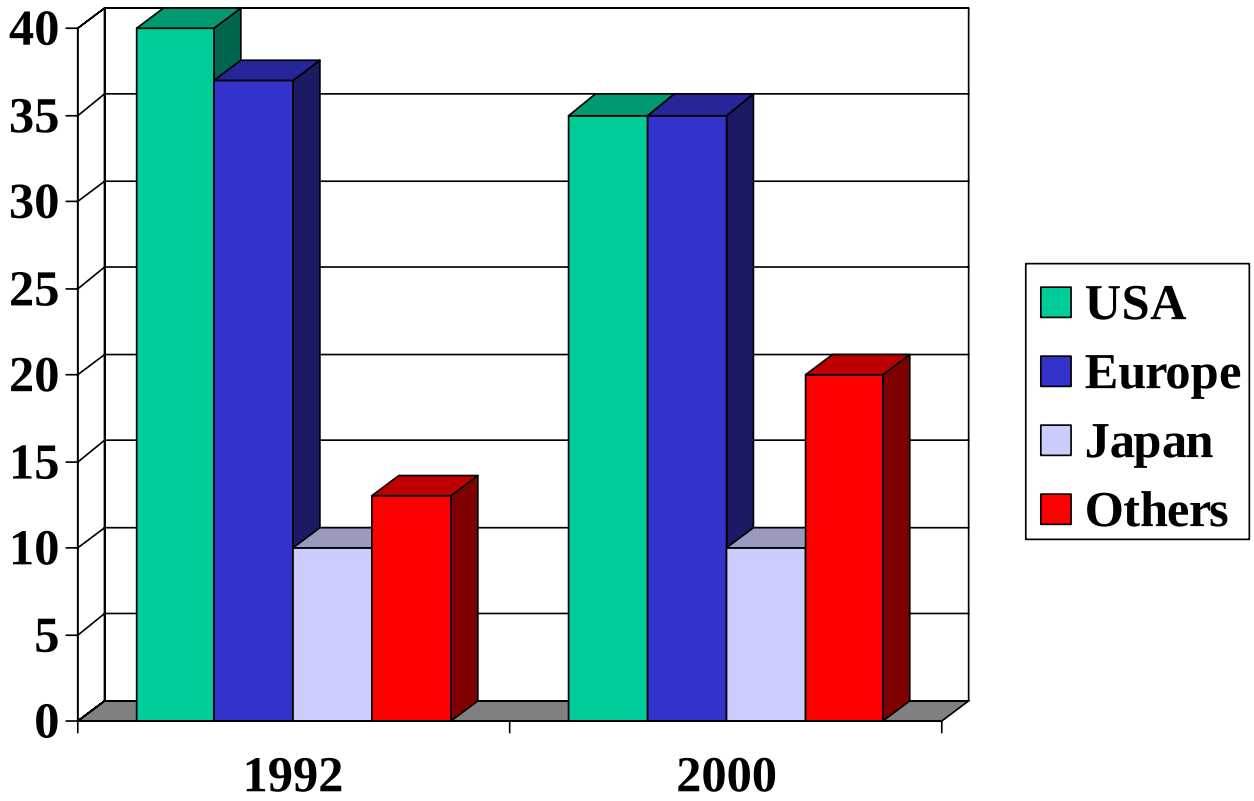


Worldwide Membrane Market

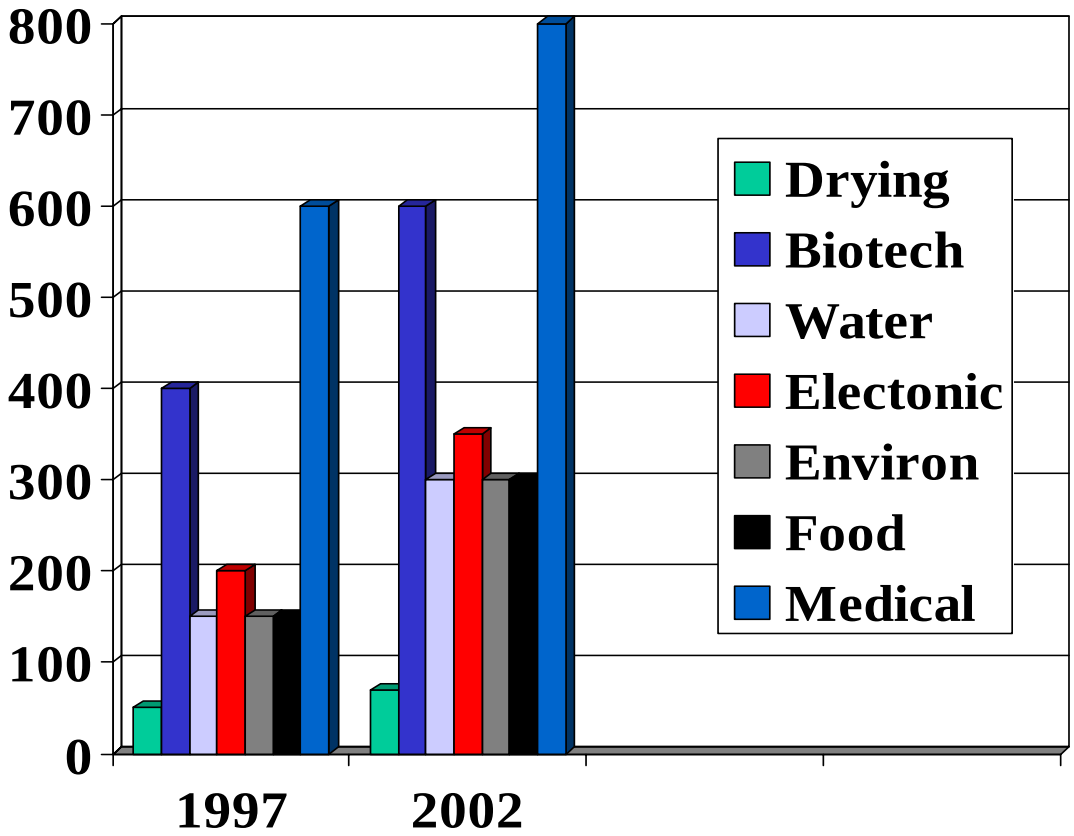
- Membrane for potable water production
- Membrane for municipal wastewater treatment



Regional Distribution of Membrane Market



Sectoral Distribution of Membrane Market



Values in USD

Part3:

Water Stress & Water Scarcity

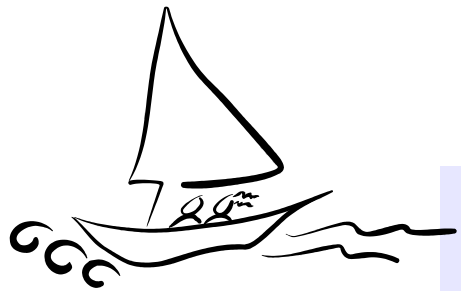
Part 3:

Water Stress & Scarcity

- Acceptable raw water for drinking water processes?
- Polluted water resources
- Insufficient quantity of resources, e.g. KL, Jakarta, Manila
- High cost for inter basin water transfer
- Long piping system – cost, maintenance
- Business opportunities to export to other countries

Worldwide Water Resources

- 97% in sea (35,000 mg/l salt concentration)
- 0.1% in rivers and lakes
- 0.6% in reservoirs
- 5 x 10^{15} m^3 of freshwater in rivers, lakes and shallow aquifers



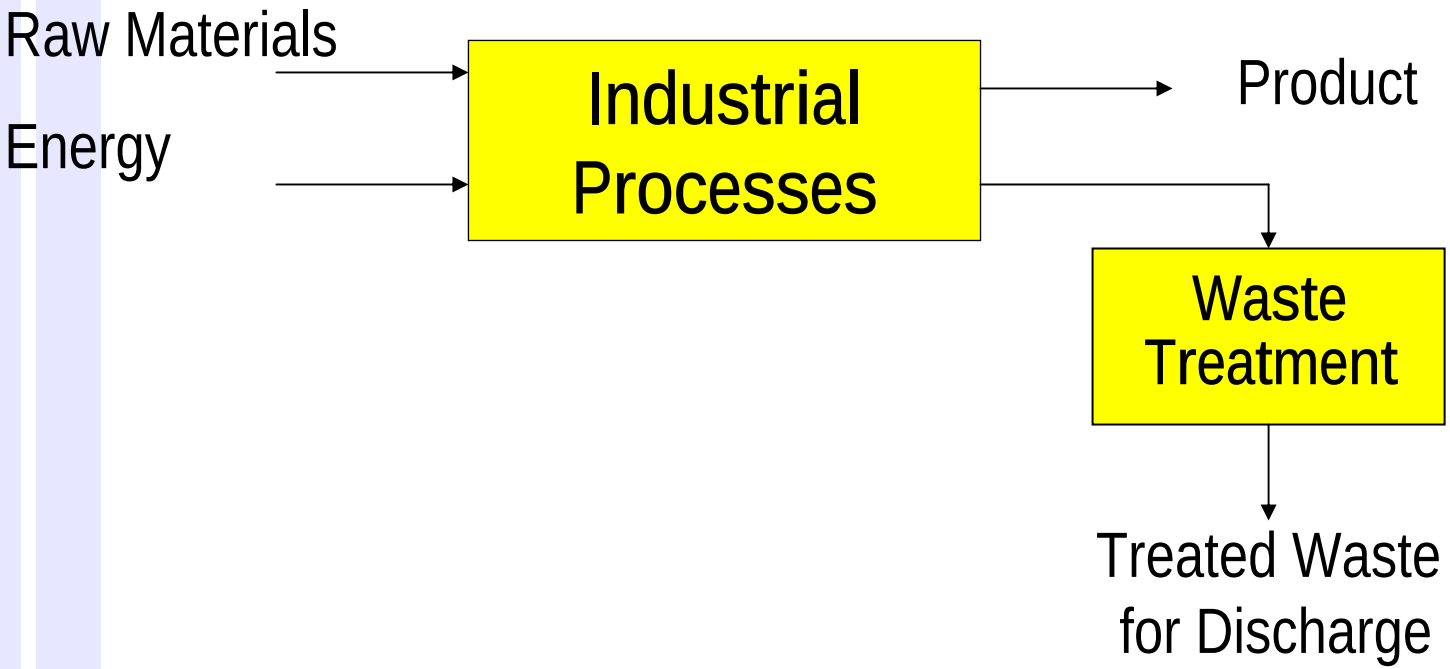
Water Consumption in Malaysia

- 225 l/d.capita

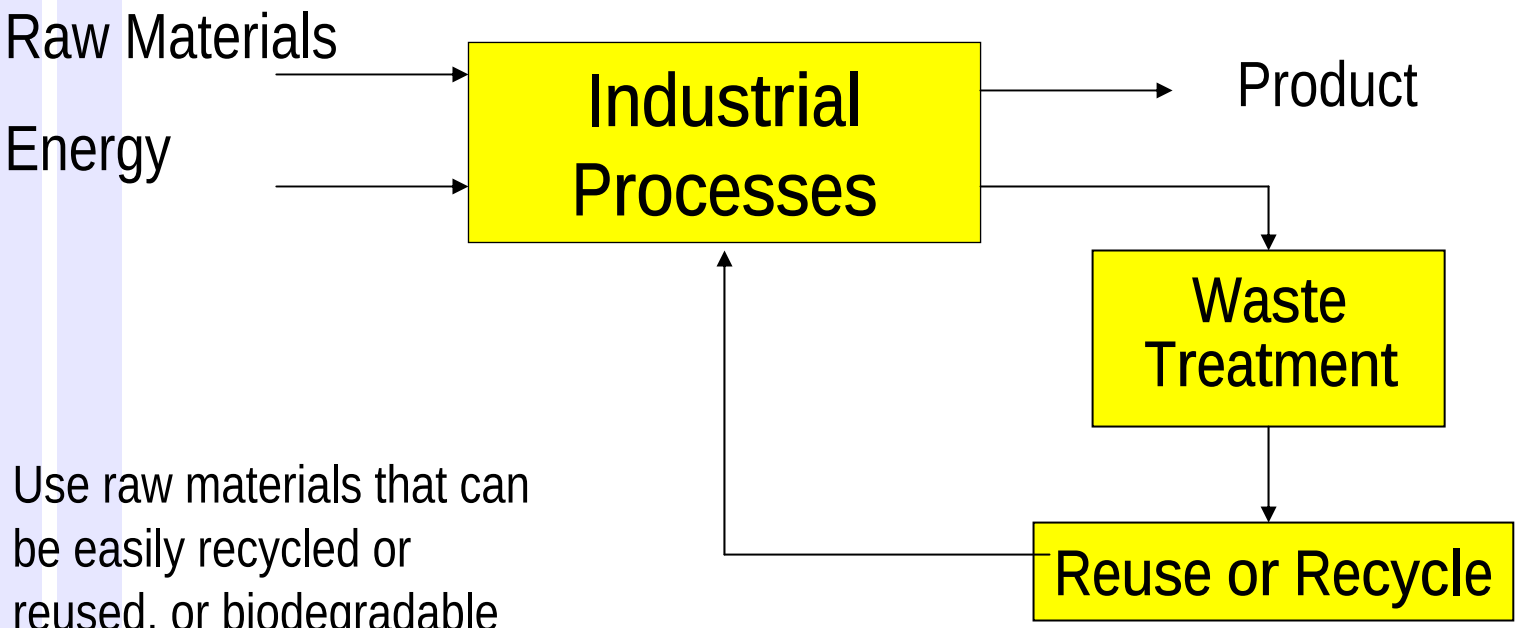
Bottled Water Industry

Part 4:
End-of-pipe vs Zero discharge

End-of-Pipe Engineering



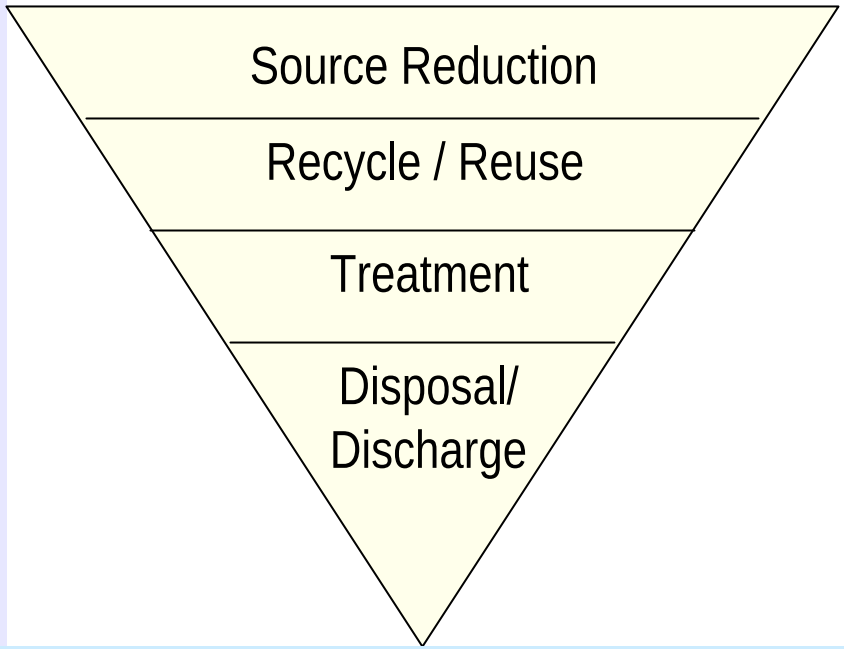
Zero Discharge Engineering



Principles and Priority in Waste Management Within Zero Emission Concept

Pollution should be prevented or reduced whenever possible

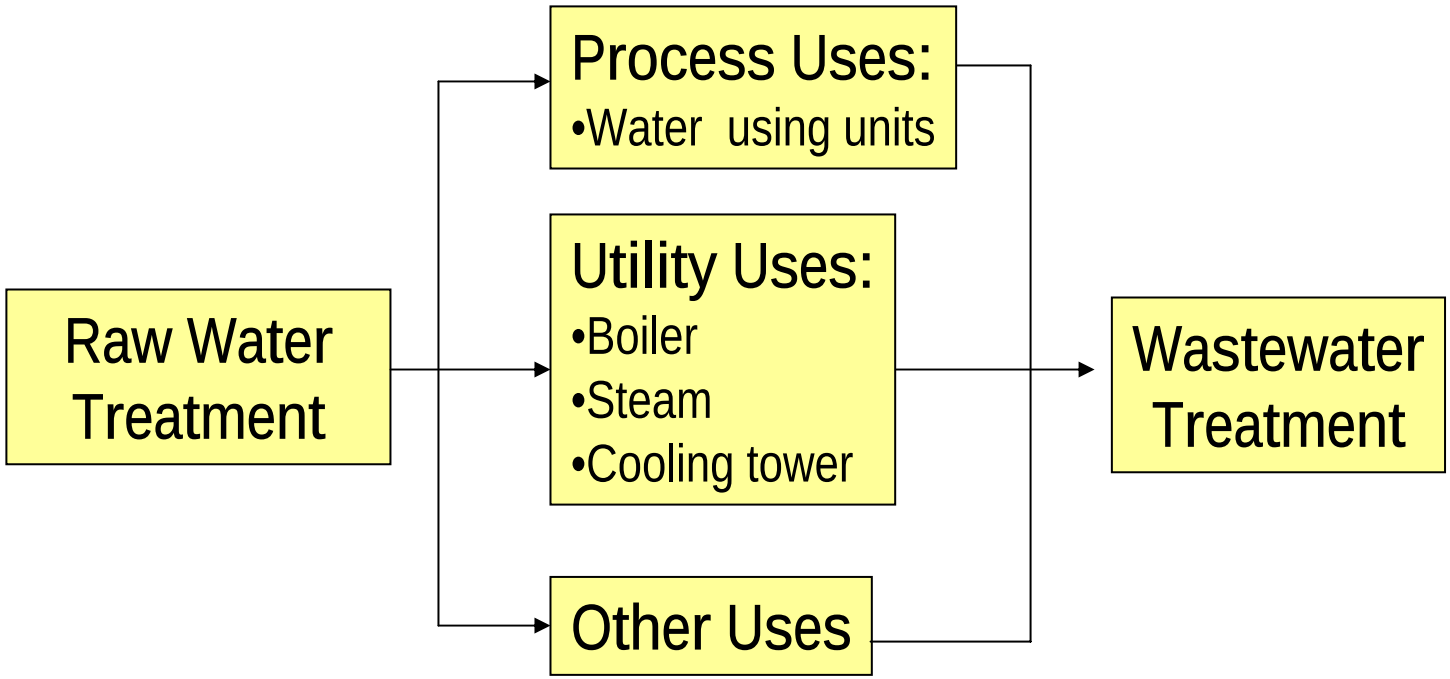
PRINCIPLE 1



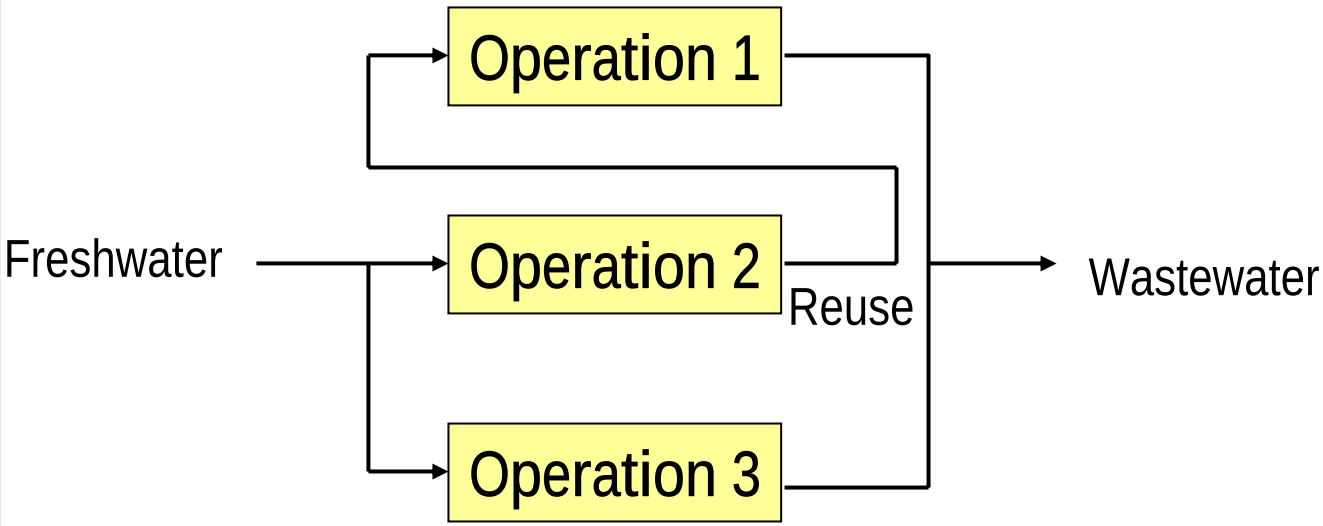
Disposal or discharge to the environment should be employed only as a last resort

PRINCIPLE 2

Typical water uses in a chemical process industries

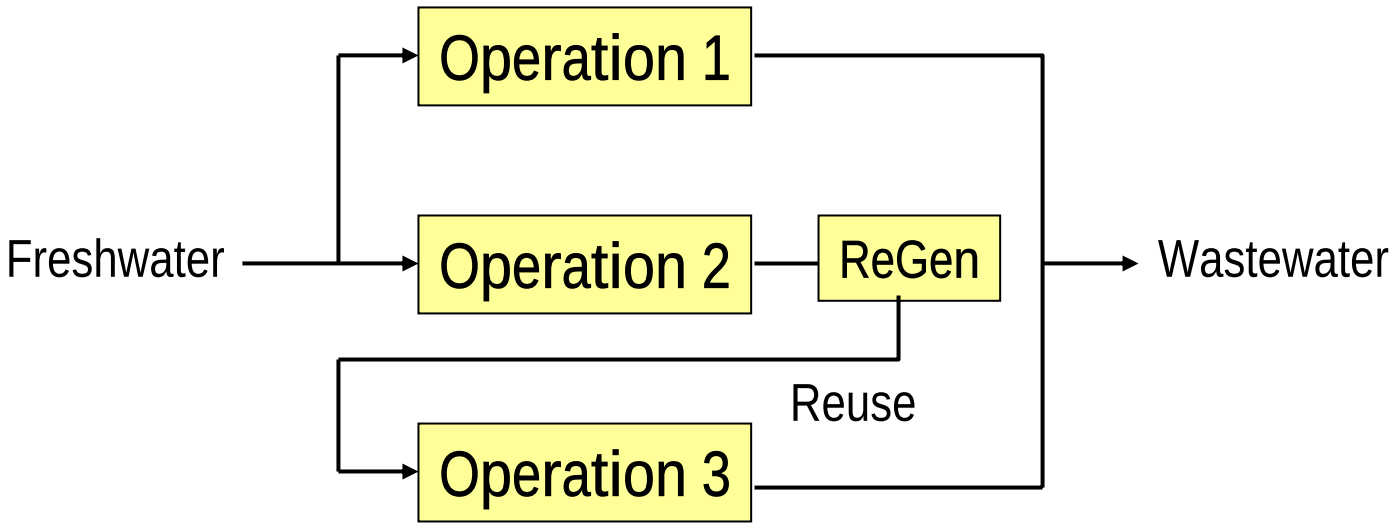


Regeneration, Flowrate Changes & Multiple Contaminants



Wastewater minimization through reuse

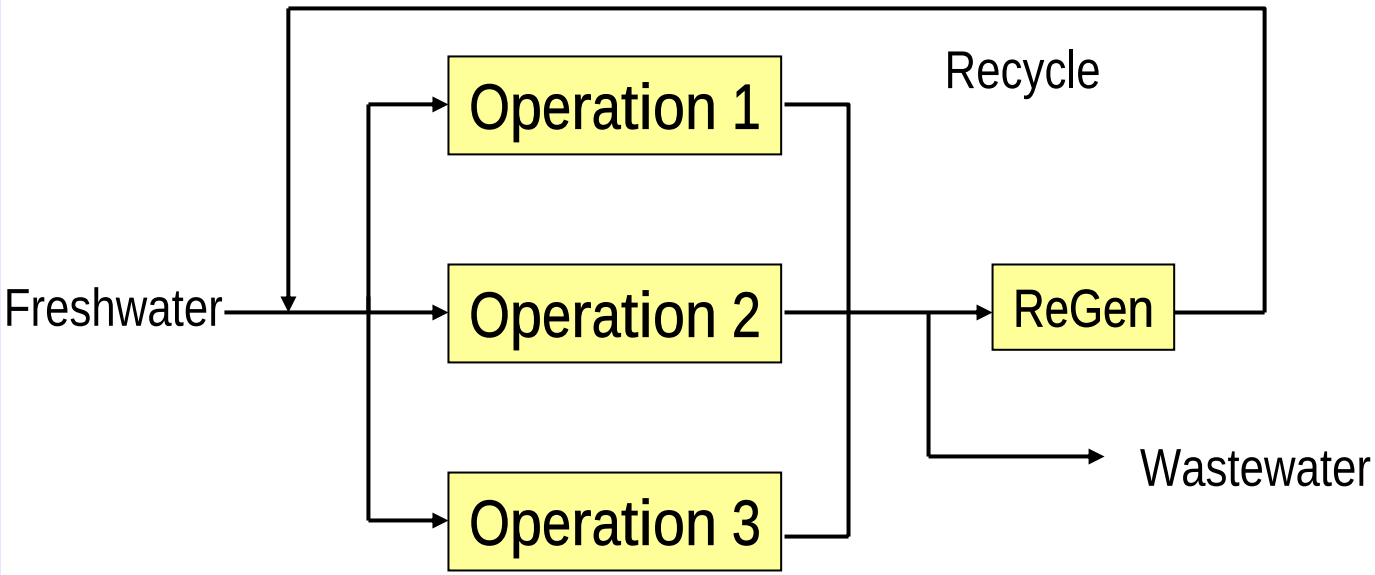
Regeneration, Flowrate Changes & Multiple Contaminants



Wastewater minimization through regeneration & reuse

Note: ReGen=Regeneration

Regeneration, Flowrate Changes & Multiple Contaminants

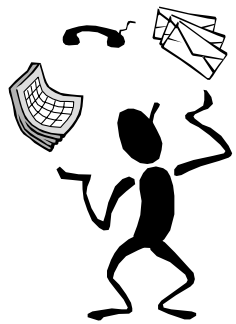


Wastewater minimization through regeneration & reuse

Note: ReGen=Regeneration

Strategies for Industrial Water Reuse & Wastewater Minimization

- Reduce freshwater consumption
- Minimize effluent discharges by reducing wastewater flowrates
- Zero liquid discharges



Part 5:

For Developing Countries?

Principles in Environmental Economics

- Environmental protection measures are much cheaper than curative measures post-pollution
- You get back what you discharge
- Environmental protection is much cheaper than the economic lost in **pollution remediation**, **health damage**, **natural resources** and **eco-tourism**.
- Zero discharge can absorb the cost by waste reuse and recycle schemes.

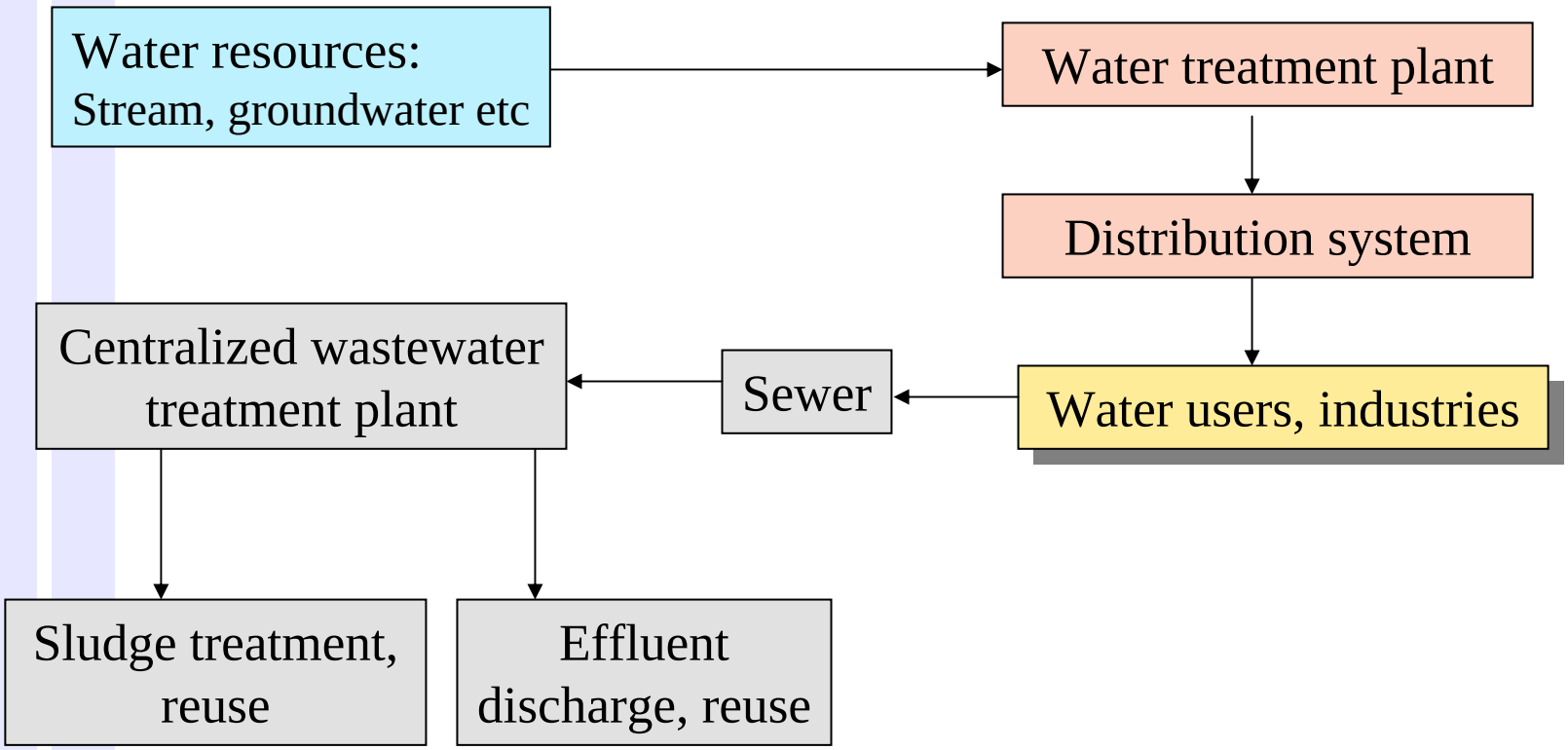
Comparison: Cost of Damage from Minamata Disease around Minamata Bay vs. Cost of Pollution Prevention

Items		Yen/Year
Cost of industrial pollution control		123 million
Total damage		12,631 million
Health damage	7,671 million	
Environmental pollution	4,271 million	
Fishery damage	689 million	

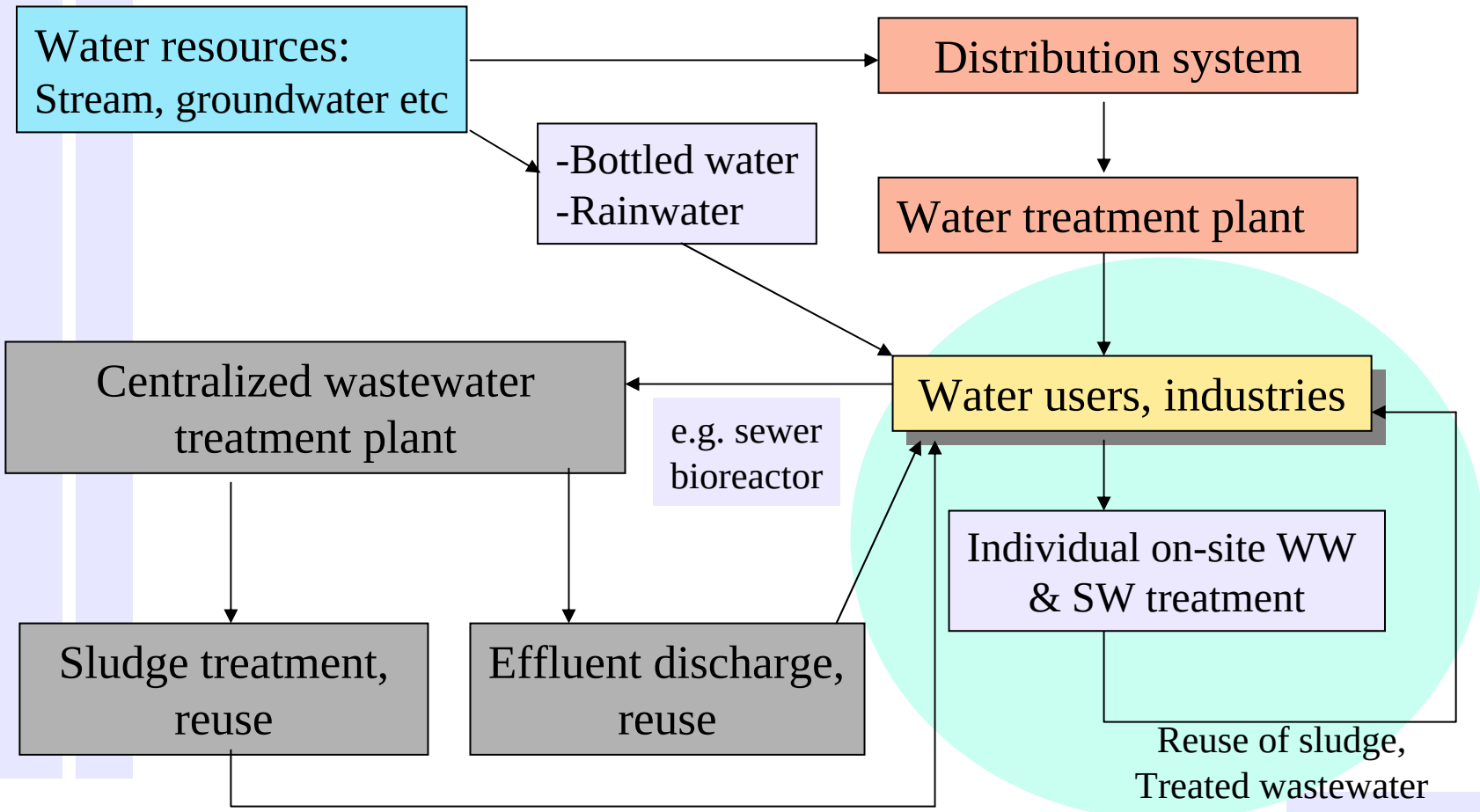
Water Supply in Indonesia

20% of drinking water is supplied in bottles (???)

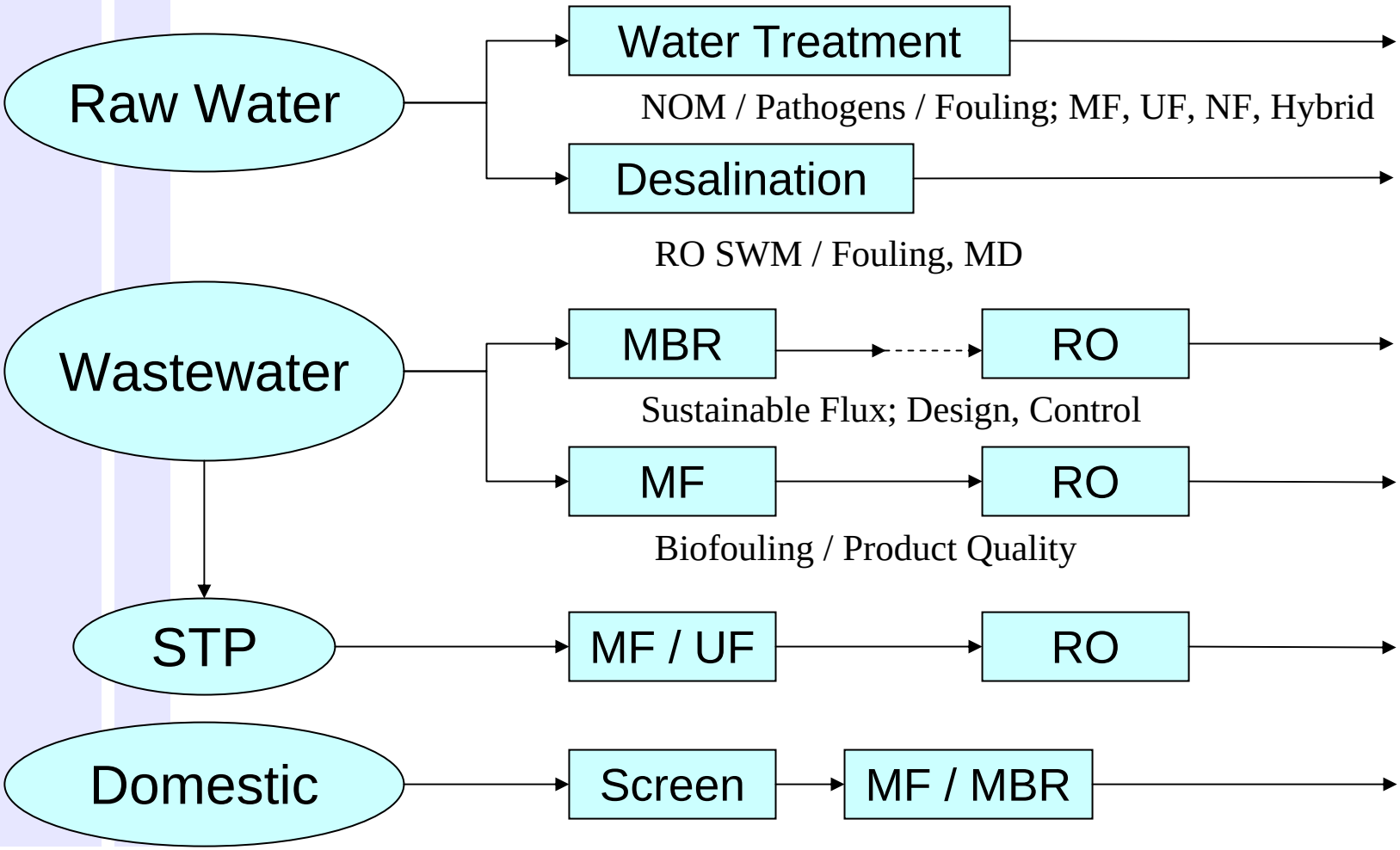
Centralized urban sanitation



Decentralized sanitation & reuse (DESAR)

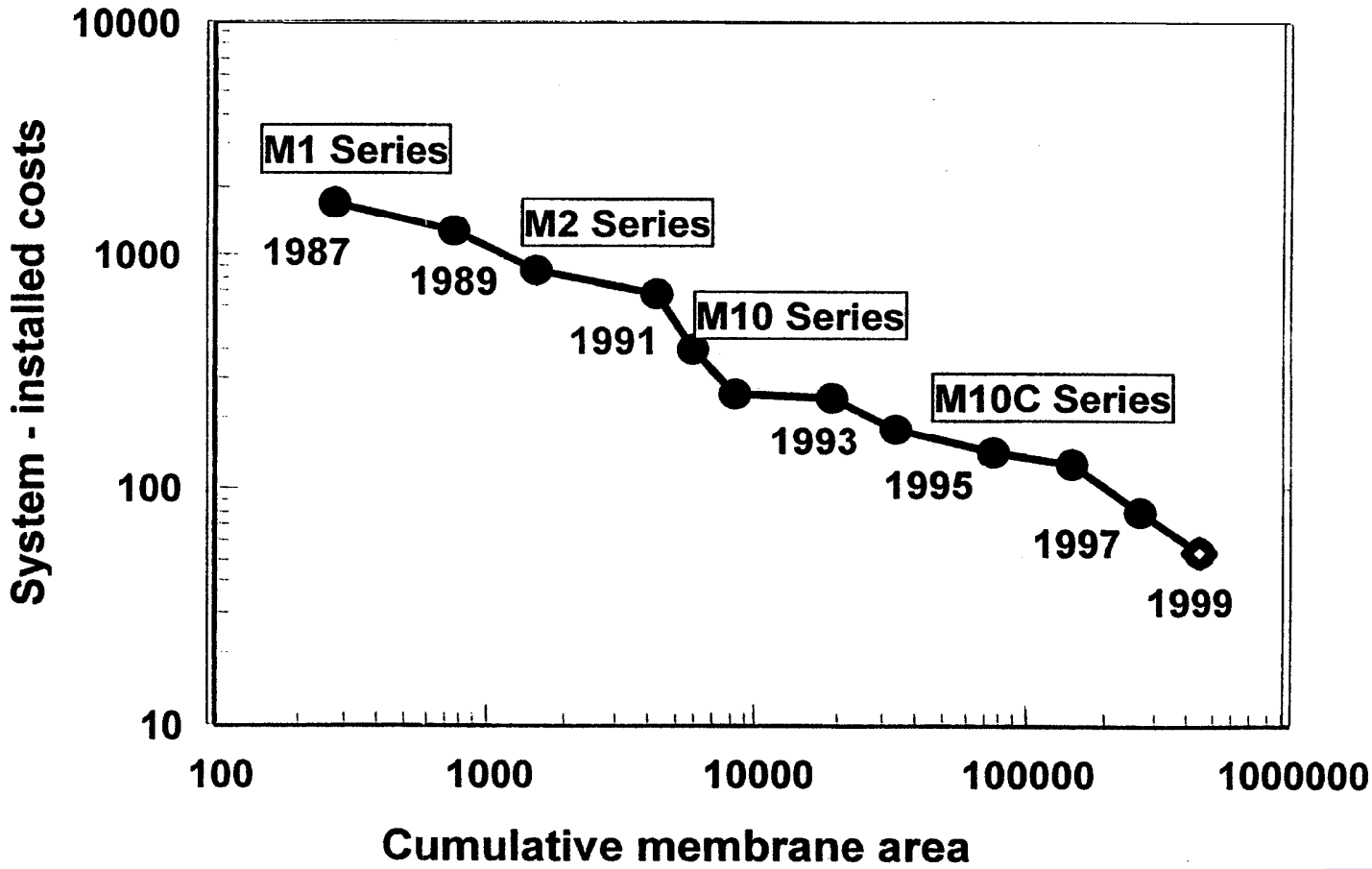


Membrane technology



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/LPROM	A$0.5~1.0 / m^3
Ultrafiltration	A$0.25~0.5 / m^3
Microfiltration	A$0.15~0.3 / m^3

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$25.90 m	Completed

Part 6:
Conclusion & Future Directions

Part 6

Conclusion

- Membrane technology is well accepted in high quality of water production
  - drinking, process, bottled, laboratory
- Membrane tech is growing fast & instrumental for implementation of zero discharge concept
- Zero emissions can absorb the cost by waste reuse and recycling
- Zero emission is much cheaper than allowing pollution to take place

Part 6

Future Directions

- Membrane technology will be central in public water production – EDC, heavy metals etc.
- Membrane is to be household technology in many industries for process water treatment, waste recycling and cleaner production
- Membrane vs Pollution

Latest R&D on Physical Separation

- Membrane materials
- Low pressure membrane operation
- High chlorine resistant membranes
- Membrane transport phenomena
- Membrane fouling
- Module design & Portable membrane
- Integration in Waste Minimization