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Specialized Short Course on
MEMBRANE TECHNOLOGY for Water and Wastewater Treatment

27 – 28 June 2009 (4 -5 Rajab 1430 H)

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Lecture 7
Membrane Applications: Wastewater Treatment and Recycling
(A Paradigm Shift from End-of-Pipe-Engineering to Zero Emissions)

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Presentation Menu

Part 1: Membrane for WW Management

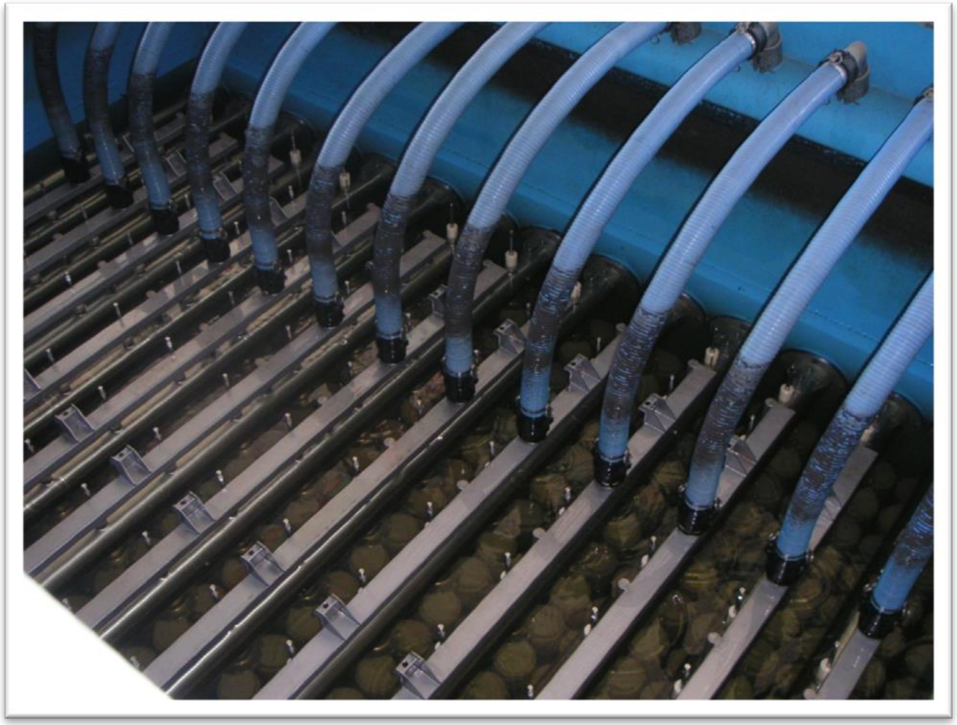
Part 2: Low-Pressure Membrane

Part 3: Immersed Membrane

Part 4: Membrane Bioreactor

Part 5: End-of-Pipe vs Zero Discharge

Part 1.
Membrane for Wastewater Management



Chronology of Membrane Applications

- Treatment of industrial wastewater
- Biomass retention in treatment of municipal wastewater
- Treatment and recycling – Bellagio 2003
- Zero emissions / cleaner production

Chronology of Membrane Applications in Industrial WWT

- Since 1970s
- Electronics, pharmaceutical, nuclear, weapons
- Using organic membranes – e.g. acetate-based
- Problems: Fouling and membrane life span
- Solution:
  - Progress in membrane materials
  - Low pressure systems

Chronology of Membrane Applications in Municipal WWT

- Since 1980s
- For activated sludge system
- Using organic membranes
- Problems: Fouling and membrane life span
- Solution:
  - Progress in membrane materials
  - Low pressure systems

Bellagio Team Residency, Rockefeller Foundation 2003

Meeting Sustainability Criteria for Wastewater Systems by MBR Technology

Criteria	Indicators	Improvement Needed	Good Now
Economic	Cost & Affordability	X	
Environmental	Effluent Water Quality		
	Microbes		X
	Suspended Solid		X
	Biodegradable Organics		X
	Nutrient Removal		X
	Chemical Usage	X	
	Energy	X	
	Land Usage		X
Technical	Reliability		X
	Ease of Use	X	
	Flexible & adaptable		X
	Small – scale systems		X
Social-Cultural	Instituitional Requirements	X	
	Acceptance	X	
	Expertise	X	
OVERALL SUSTAINABILITY		**GOOD**	

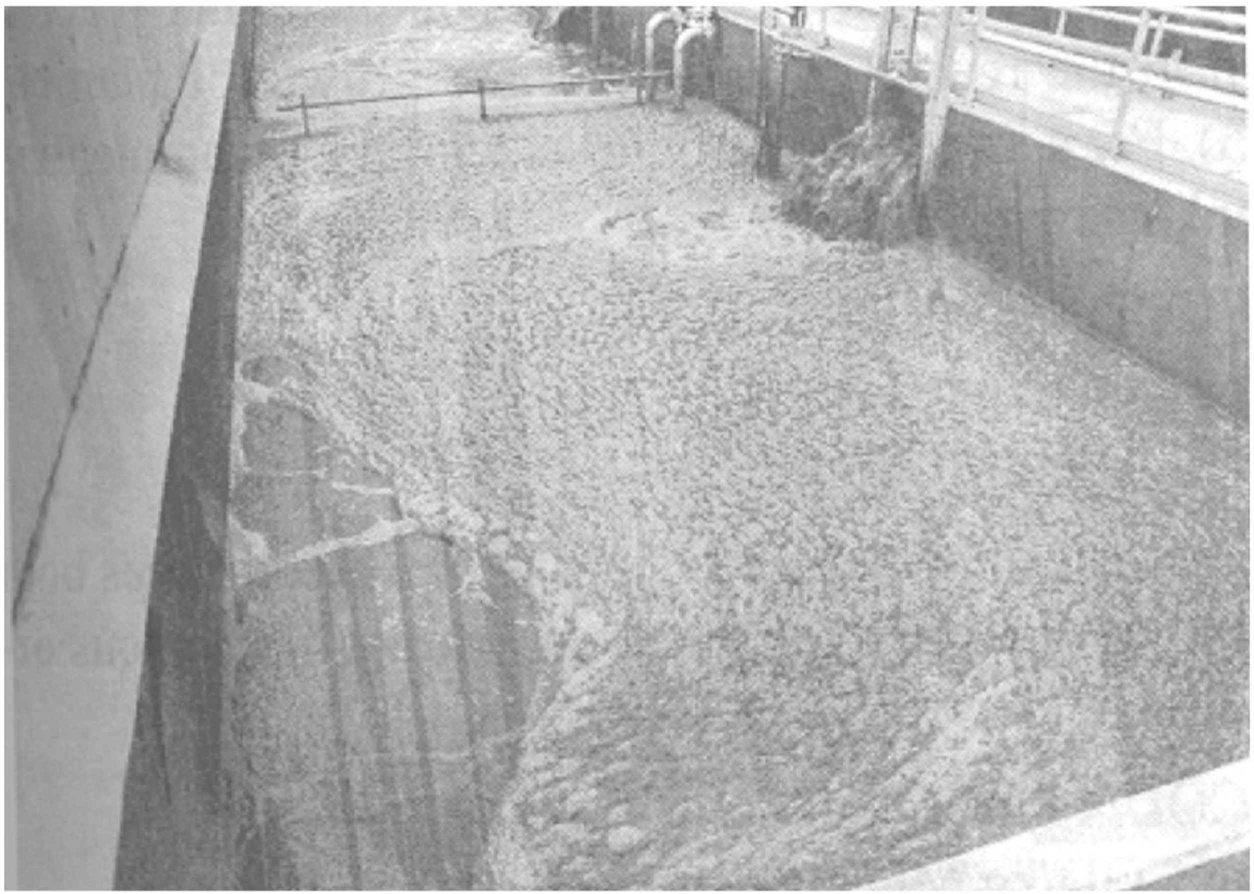
Why MBR is Becoming More Acceptable

- Improvements in membrane materials
- Innovation in application methods
- Increased competition between vendors is resulting in dramatic reductions in membrane costs
- Cost effective in much wider range of applications
- Sludge production, and process control

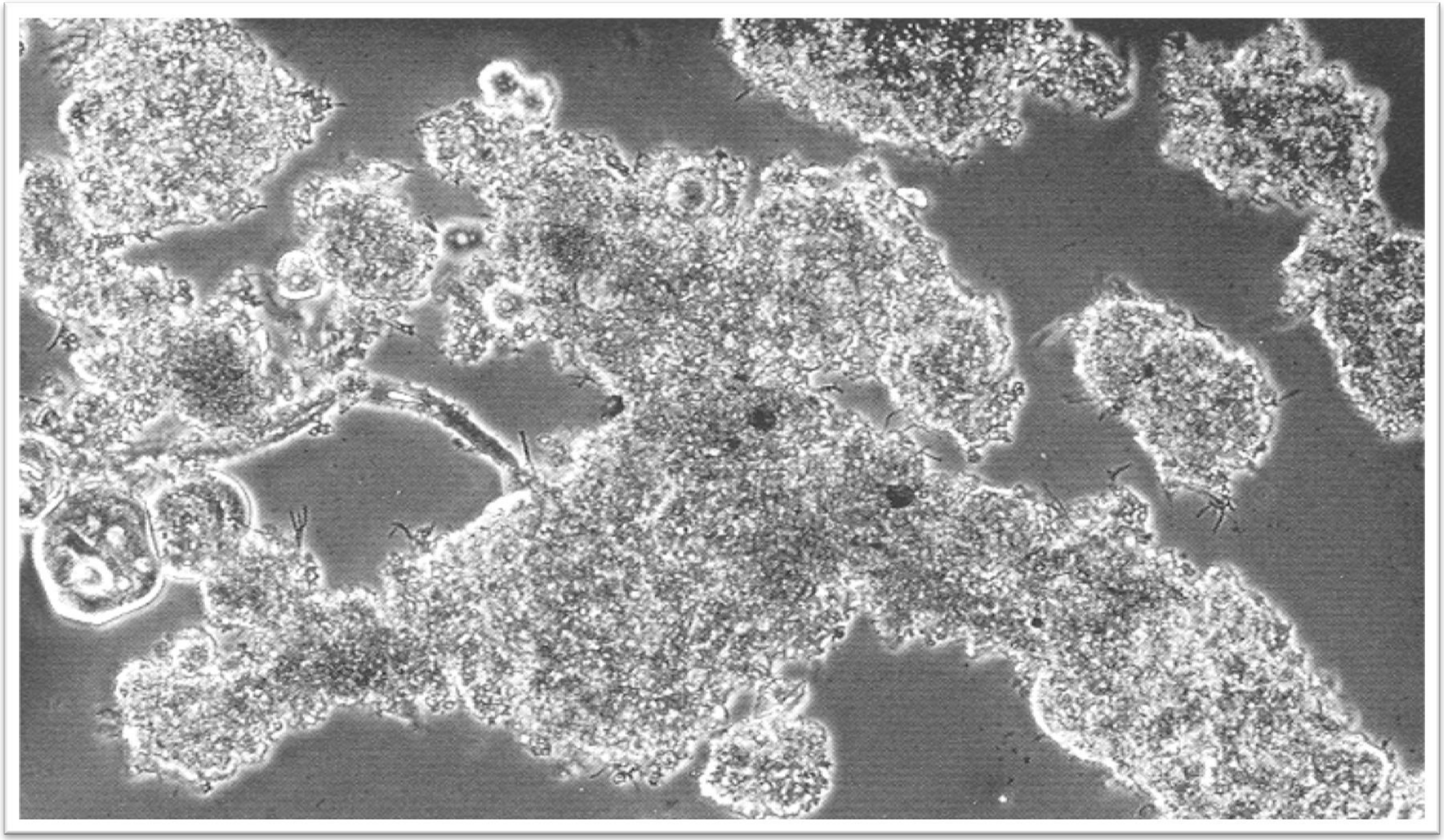
Operational Problems Associated with Activated Sludge System

- **Maintaining young sludge / biomass**
- **Separation between sludge-supernatant**
- **Foaming**
- **Bulking**
- **Large foot print for clarifiers**

Foaming Phenomena in Activated Sludge Secondary Clarifier



Microorganisms in Activated Sludge Flocs – Adsorption and enmeshment



Microorganisms and their Activities

Adsorption and enmeshment

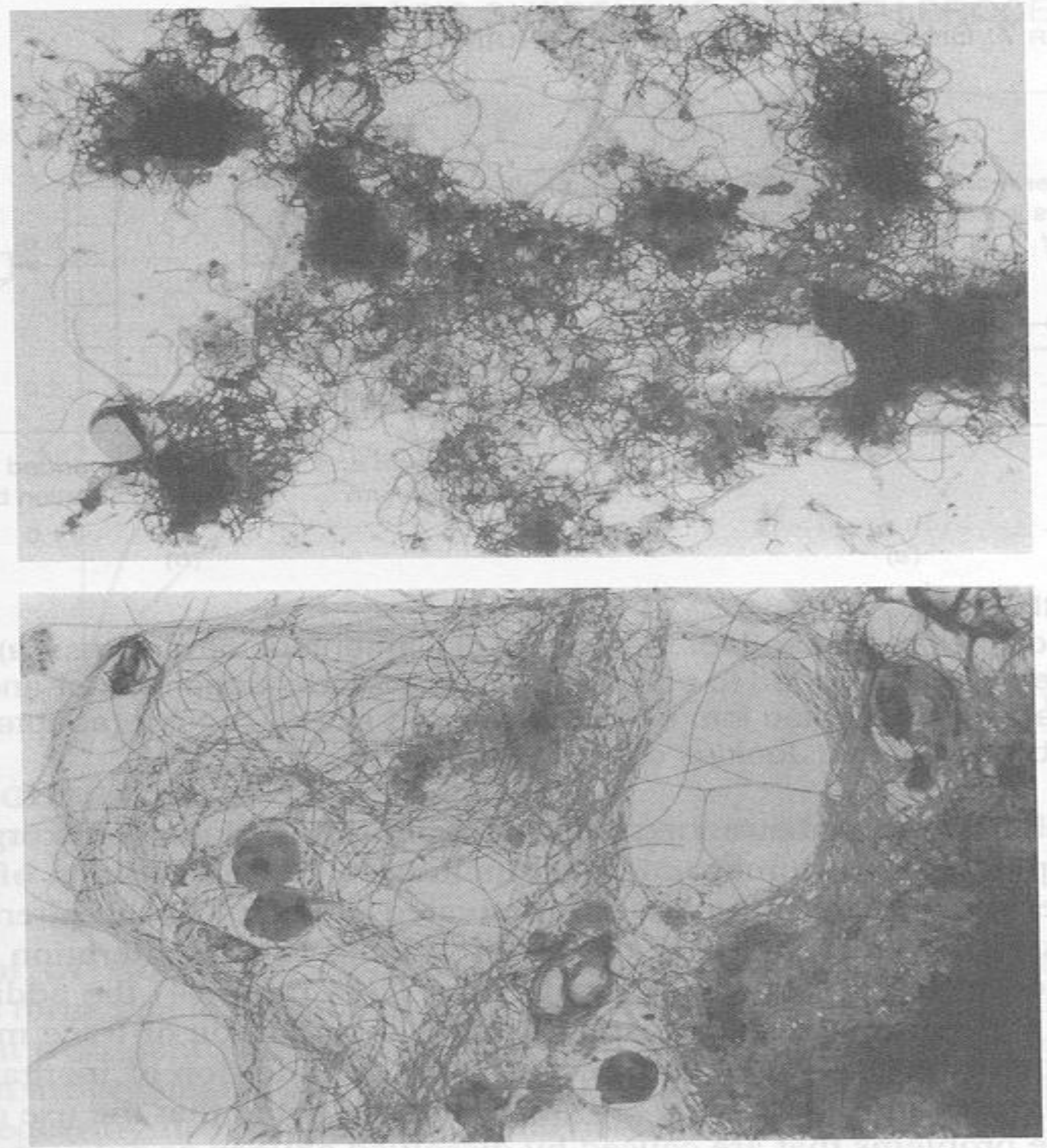


FIGURE 7-28
Typical examples of filamentous organisms that can develop in the activated-sludge process and affect the settleability of the MLSS.

Advantages of MBR over Conventional Activated Sludge

- Retain essentially all particulate matter and associated pollutants
- Remove bacteria without chemical disinfection
- Retain slow growing organisms
- Operate at high MLSS concentrations (5 to 15 g/L)
- Reduce plant footprint
- Increased automation and simpler operation
- Increased opportunities for reliable decentralized treatment

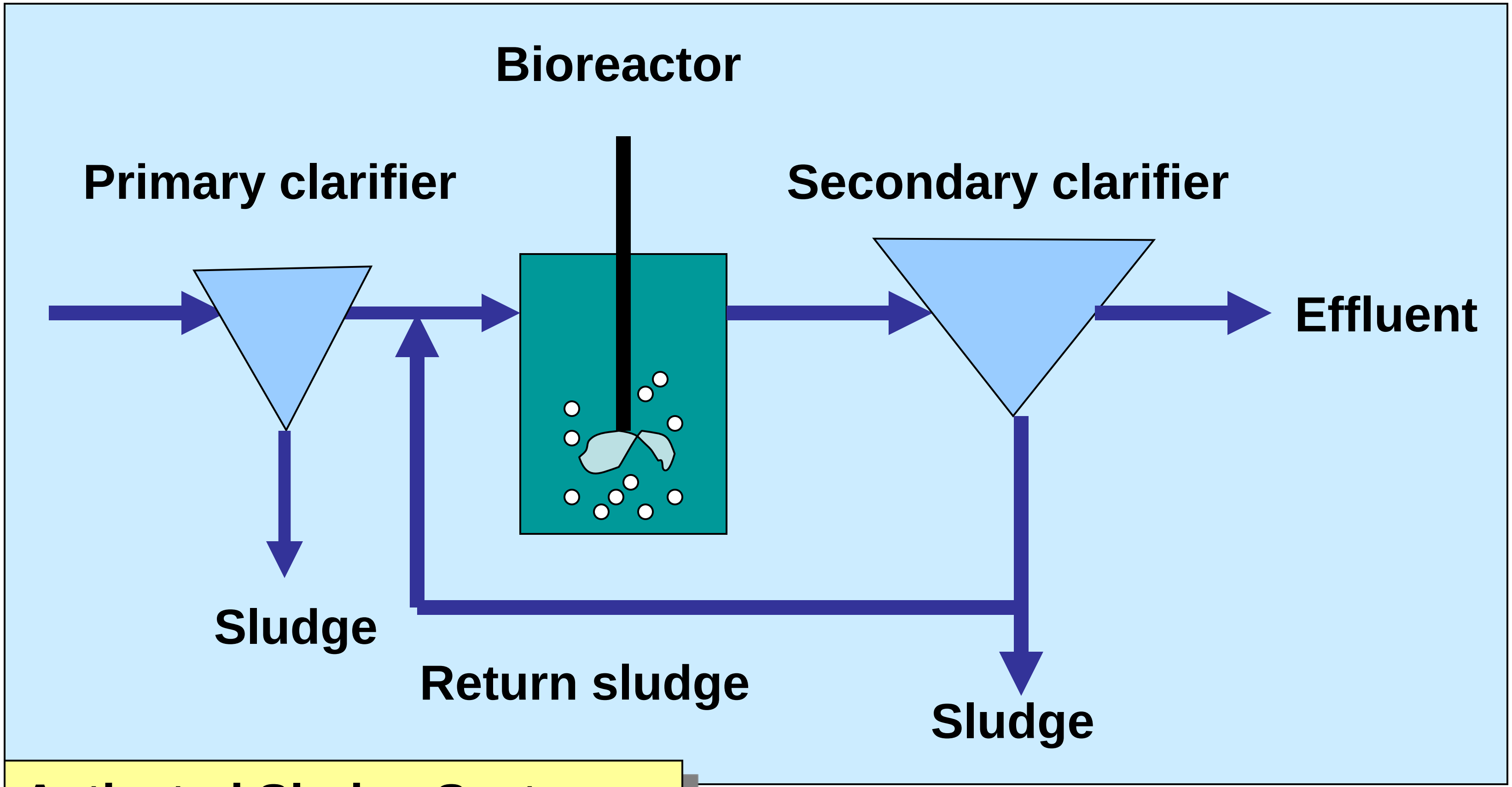
Water Sustainability

- To deliver in a sustainable way the basic human rights of safe water supply and sanitation
- A key to holistic water management is more effective use of water resources
- The sustainability of wastewater treatment systems can be assessed in terms of economic, environmental, technical and socio-cultural indicators

Sustainability of Membrane Technology

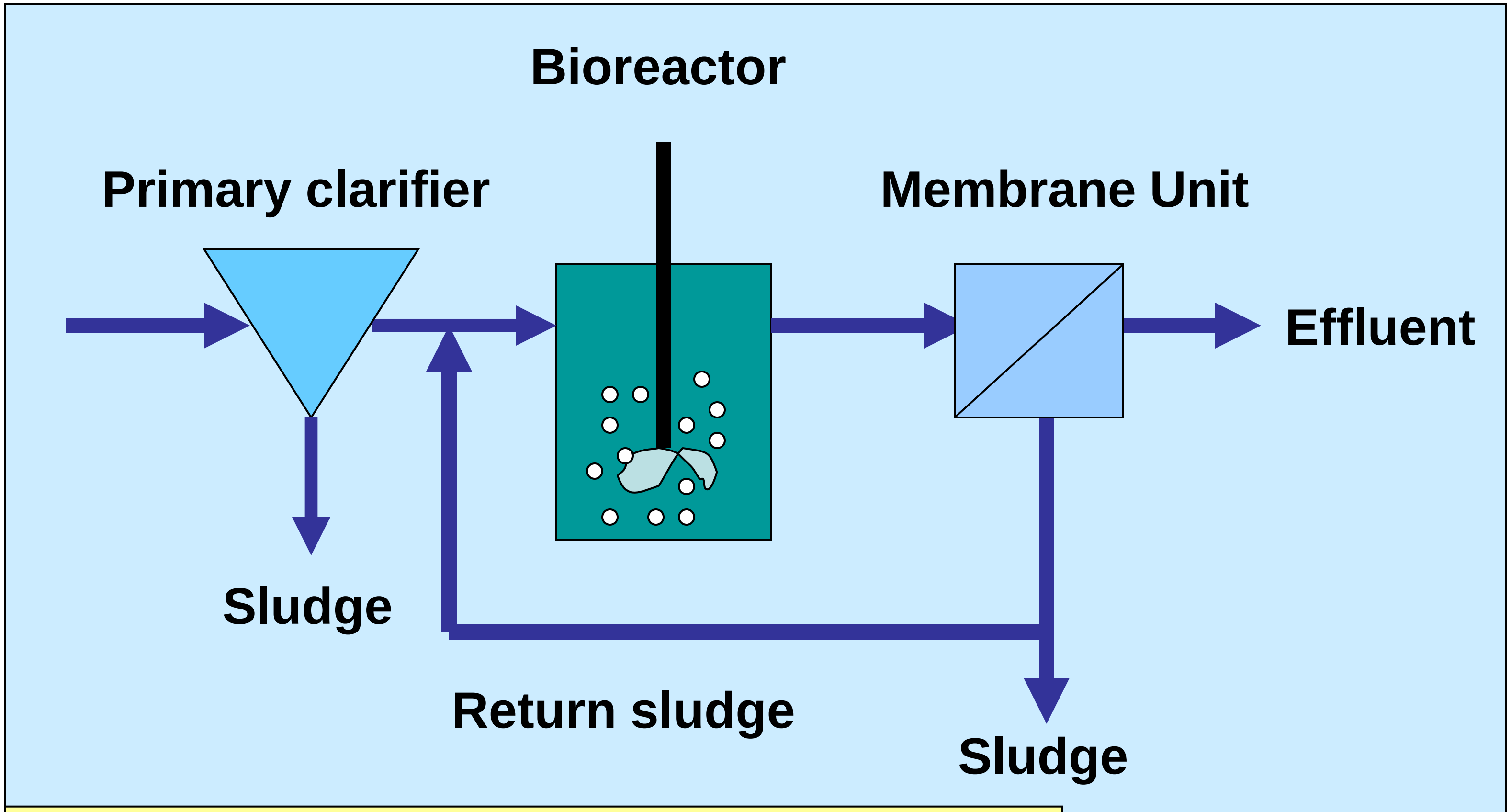
- Scaleable
- Excellent purification ability
- Automatic and less operating problems
- Good competition industry
- Compactness, simplicity (Newater requires only 2 operators – control room, security)

Why MBR for Wastewater Treatment



Activated Sludge System

Biomass Retention using Membrane for WWT

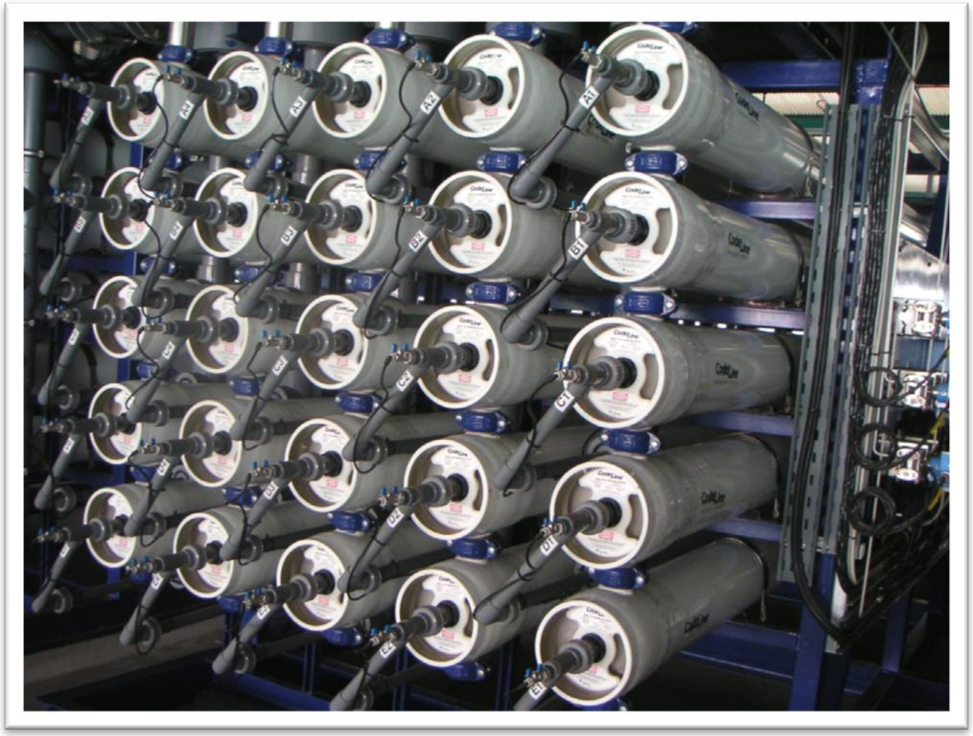


Activated Sludge Membrane System

Chronology of Membrane Applications

Treatment and Recycling

- Since 1990s
- Electronics, pharmaceutical, nuclear, weapons, MWW
- Using organic and inorganic membranes
- Problems: TDS build-up,
- Solution:
  - Progress in membrane materials
  - Low pressure systems

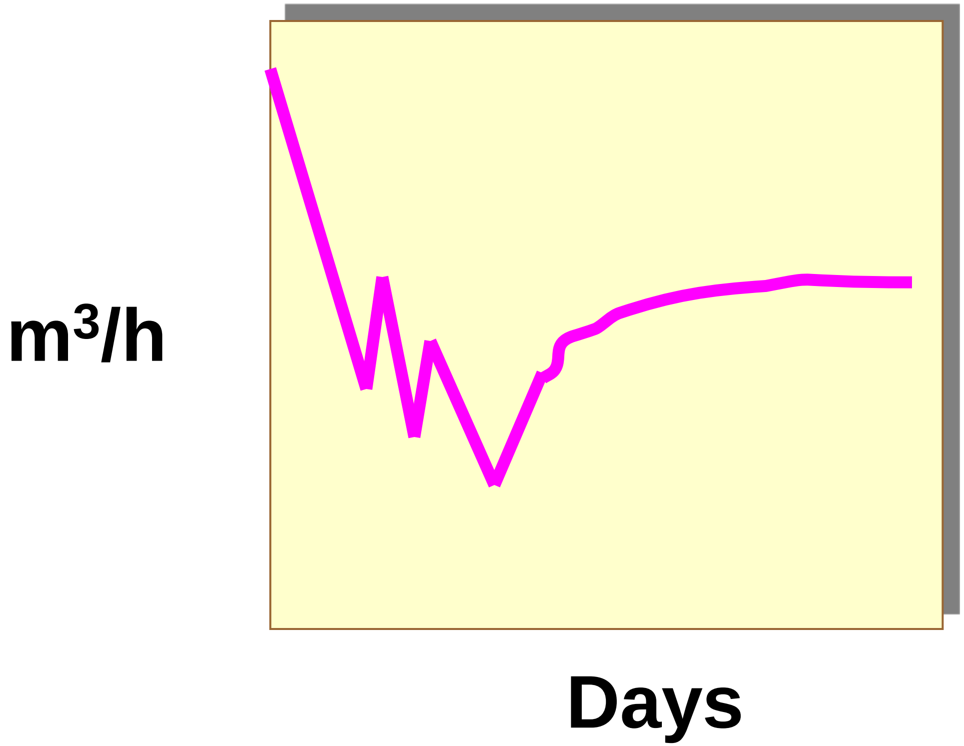


Part 2. Low-Pressure Membrane

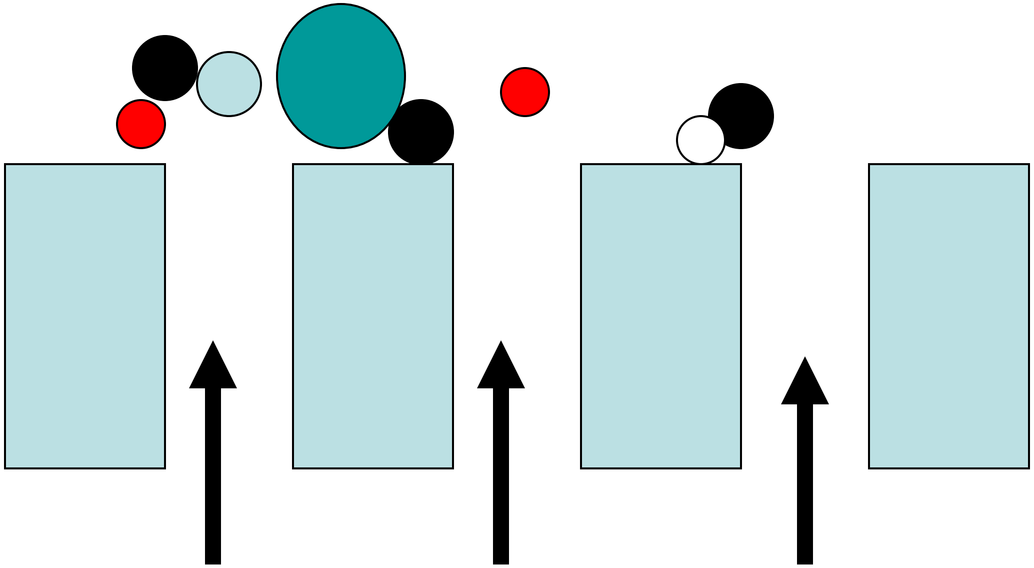
Why Low-Pressure?

- Low fouling problems
- Low compaction on membrane surface
- Less energy consumption
- Relatively easier cleaning procedure
- Relatively cheaper
- Relatively easier maintenance
- Overall: Low OPEX

Typical Permeate Flow Decline in Membrane Operation

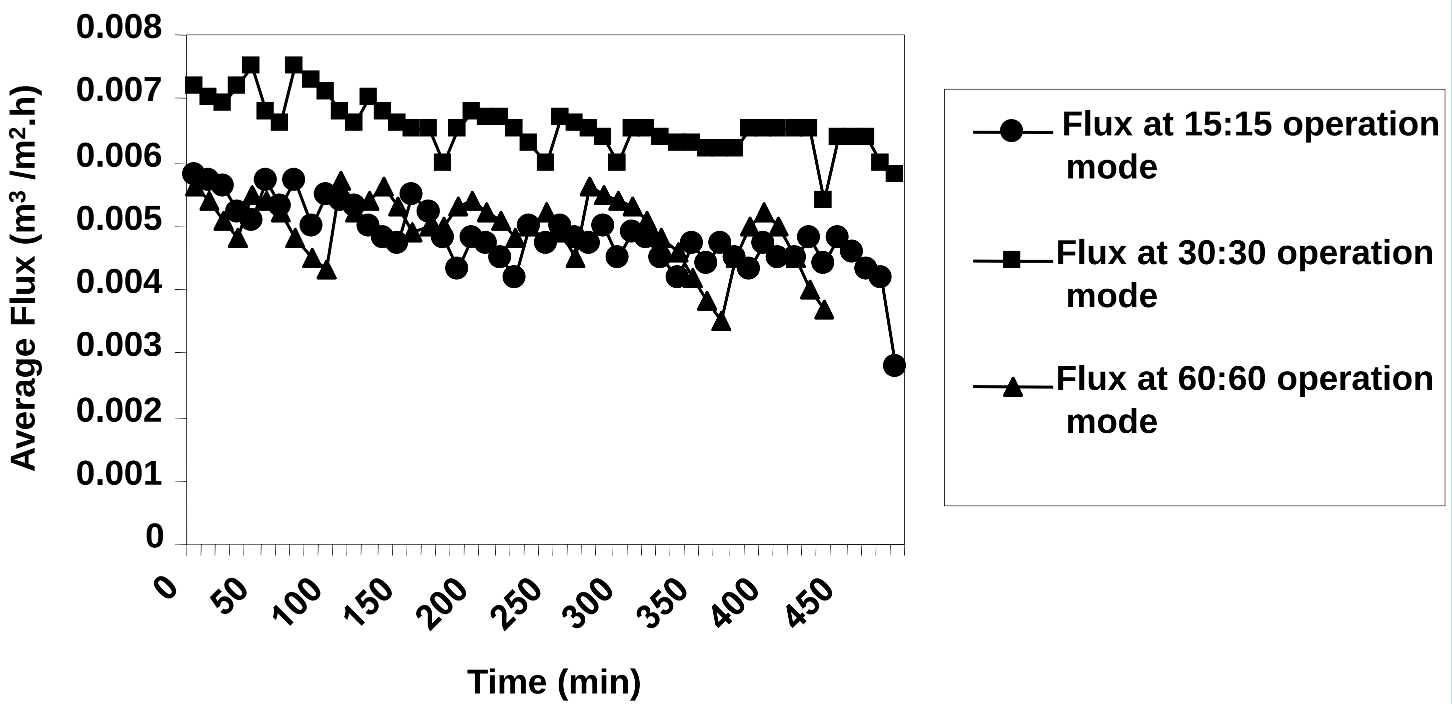


Backwash on Low-Pressure Membrane



Backwash (Plus Chemicals)

MBR for Leachate Treatment (Fitrah & Ujang, 2004)

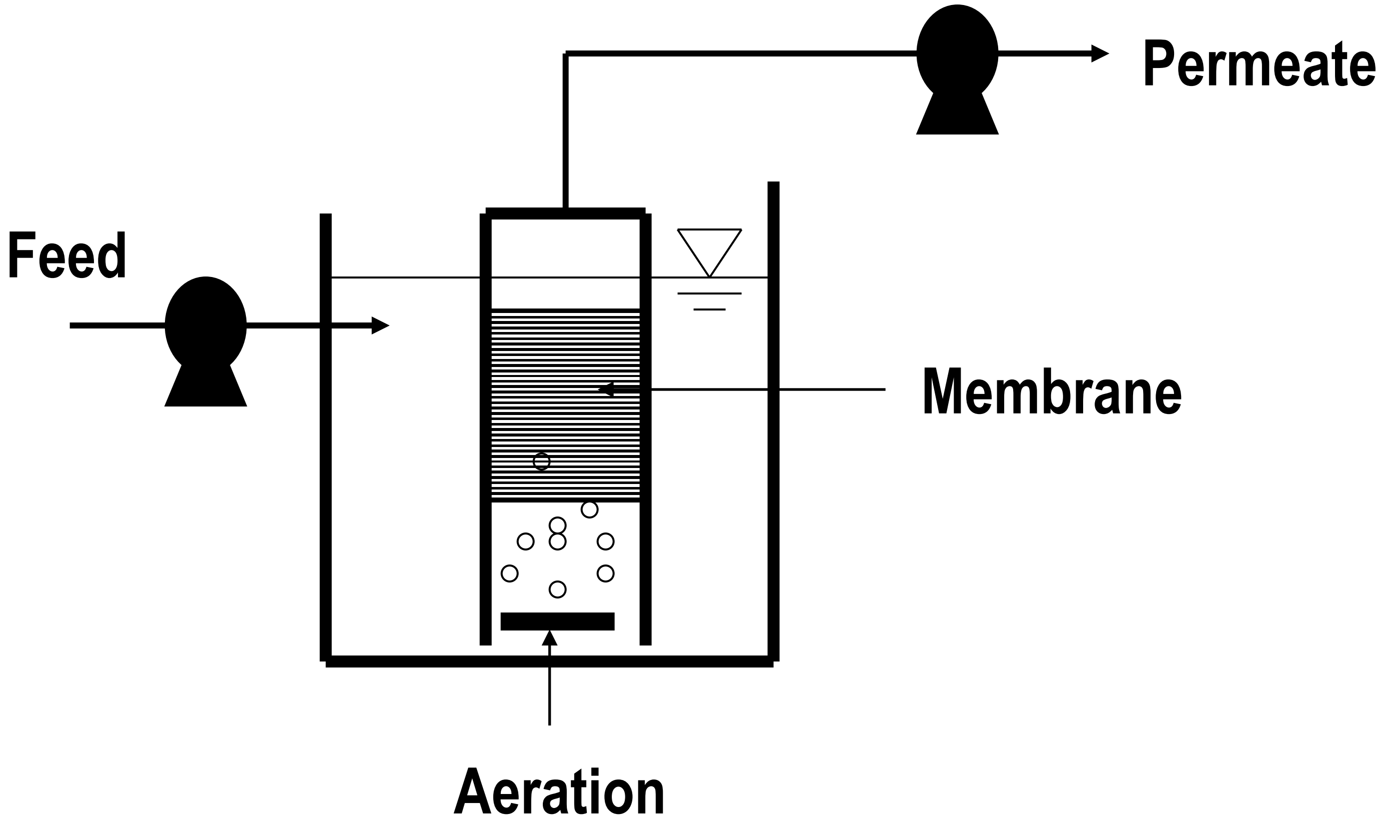


Part 3.
Immersed Membrane

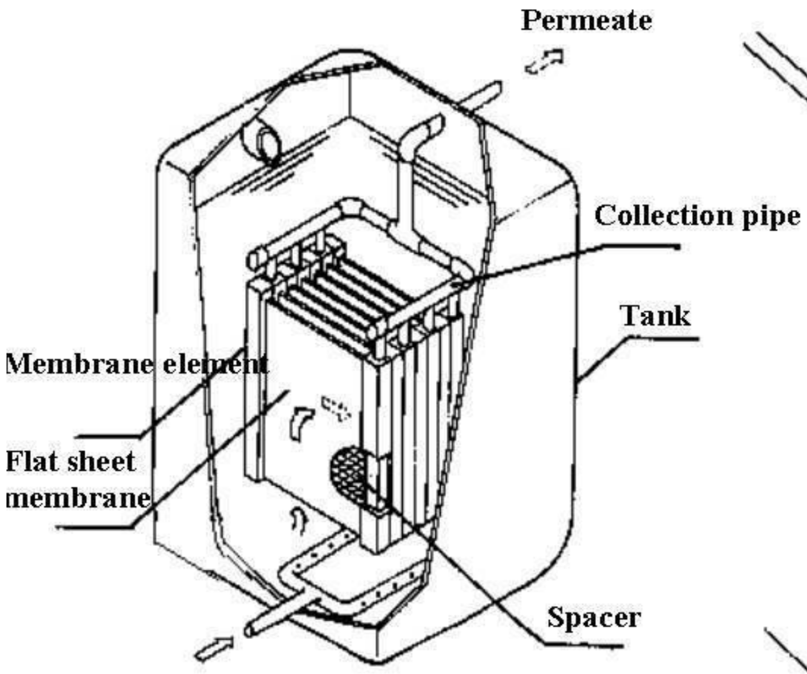
Why Immersed System?

- Low pressure system
- Hybrid with biochemical processes
- Hybrid with chemical processes
- Less fouling problems
- Relatively easier cleaning procedure
- Less sludge or by-products production

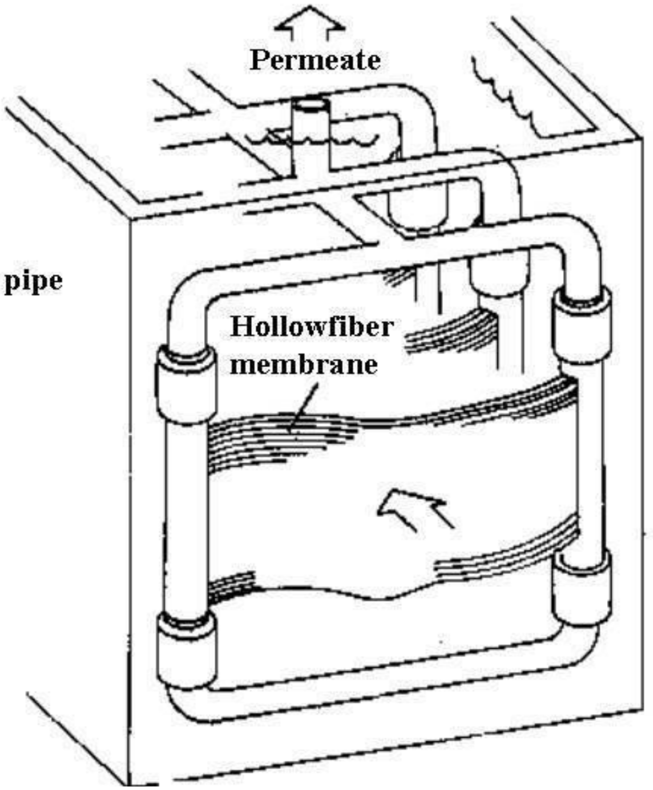
Immersed Membrane



Immersed Membrane

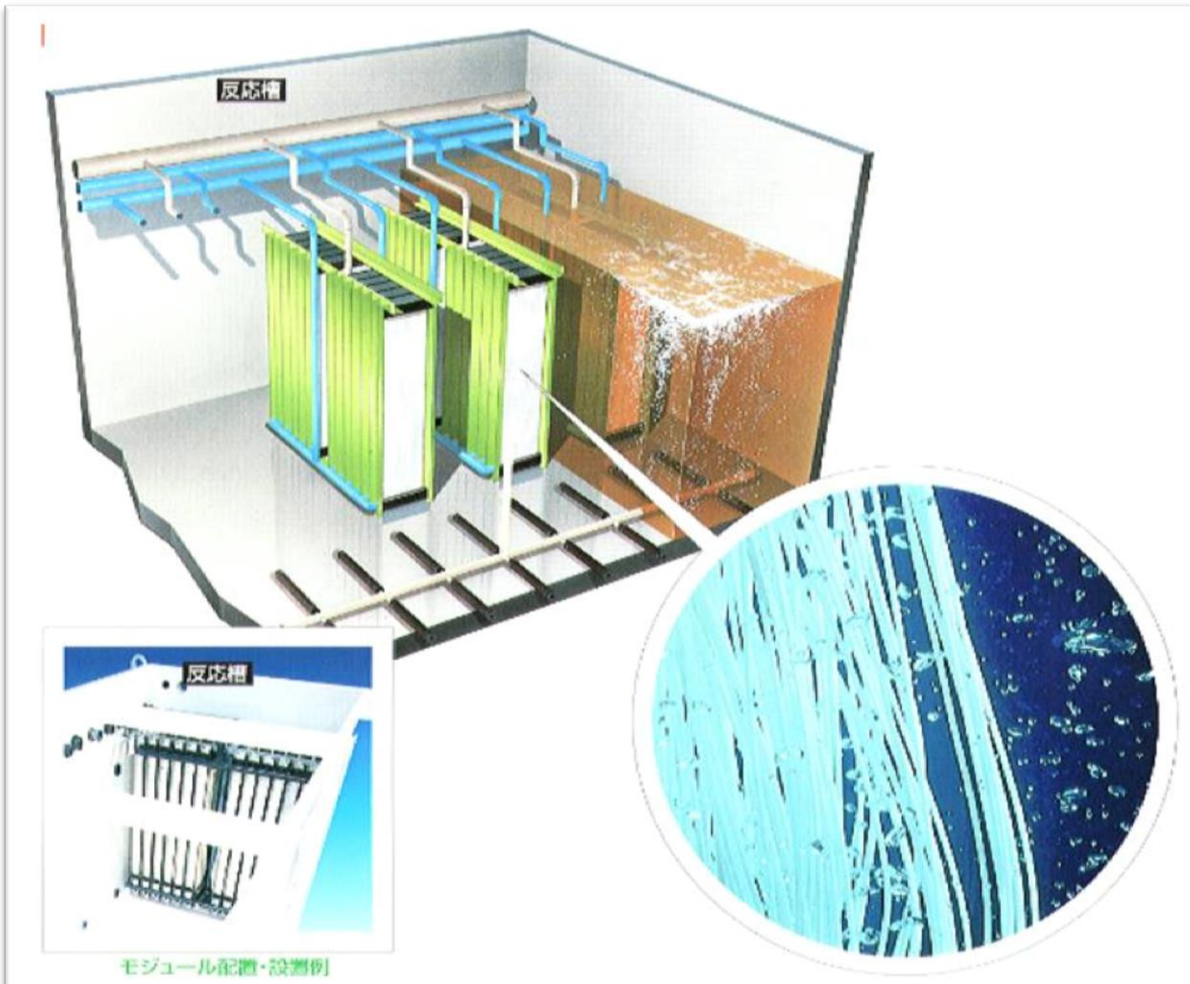


(a) Flat Sheet Membrane

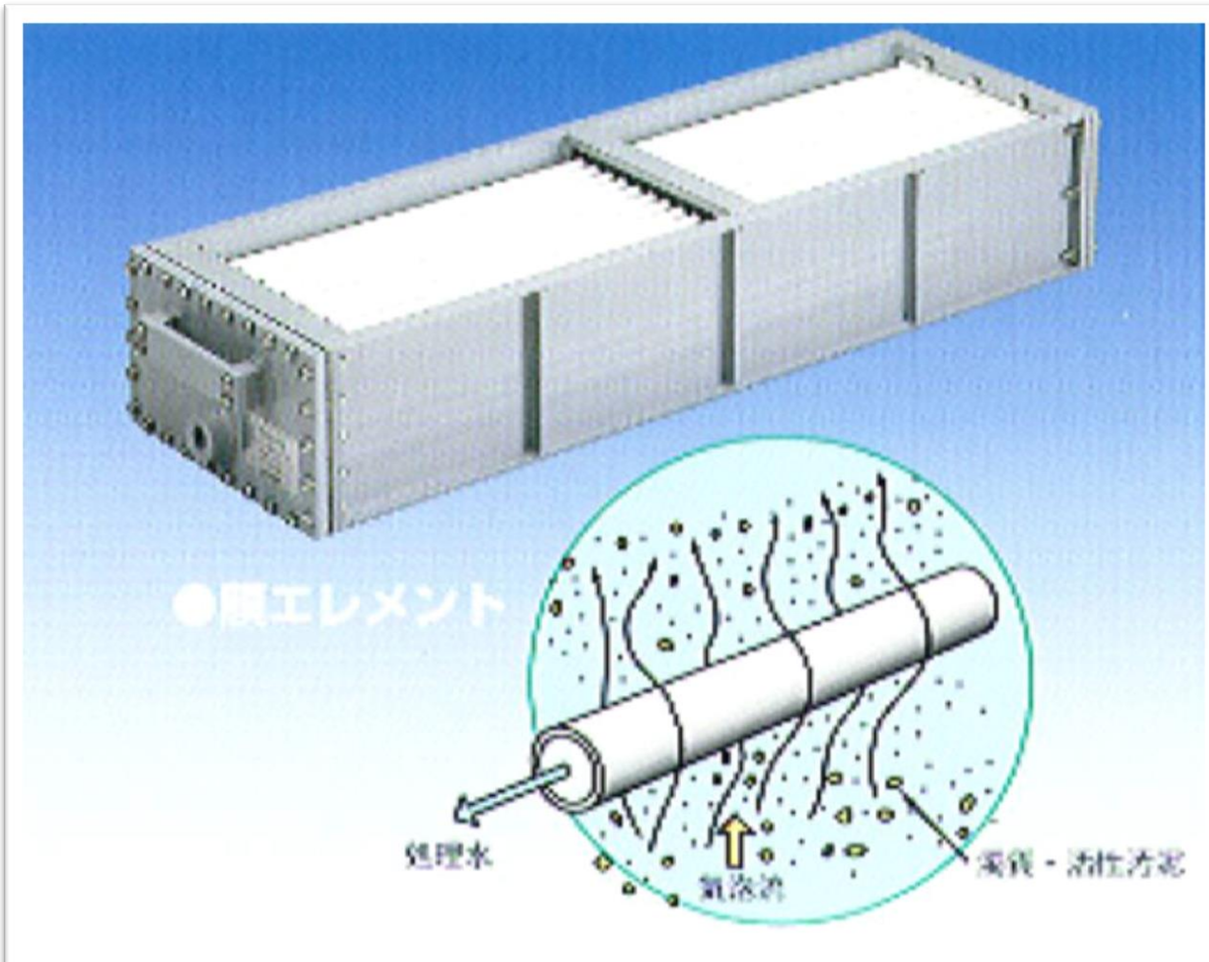


(b) Hollow Fibre Membrane

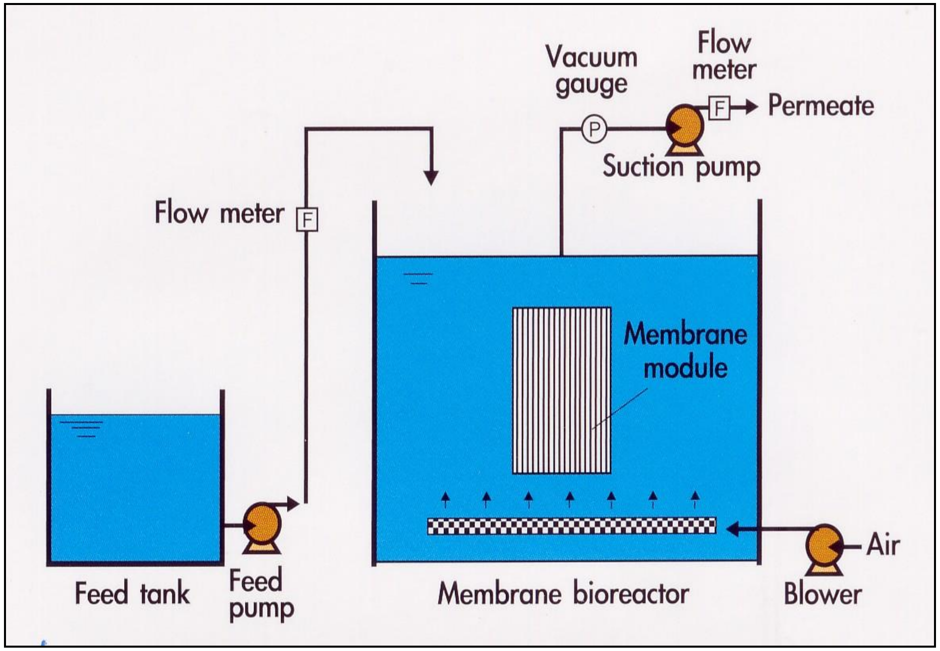
Zenon's MF Hollow-Fibre Module



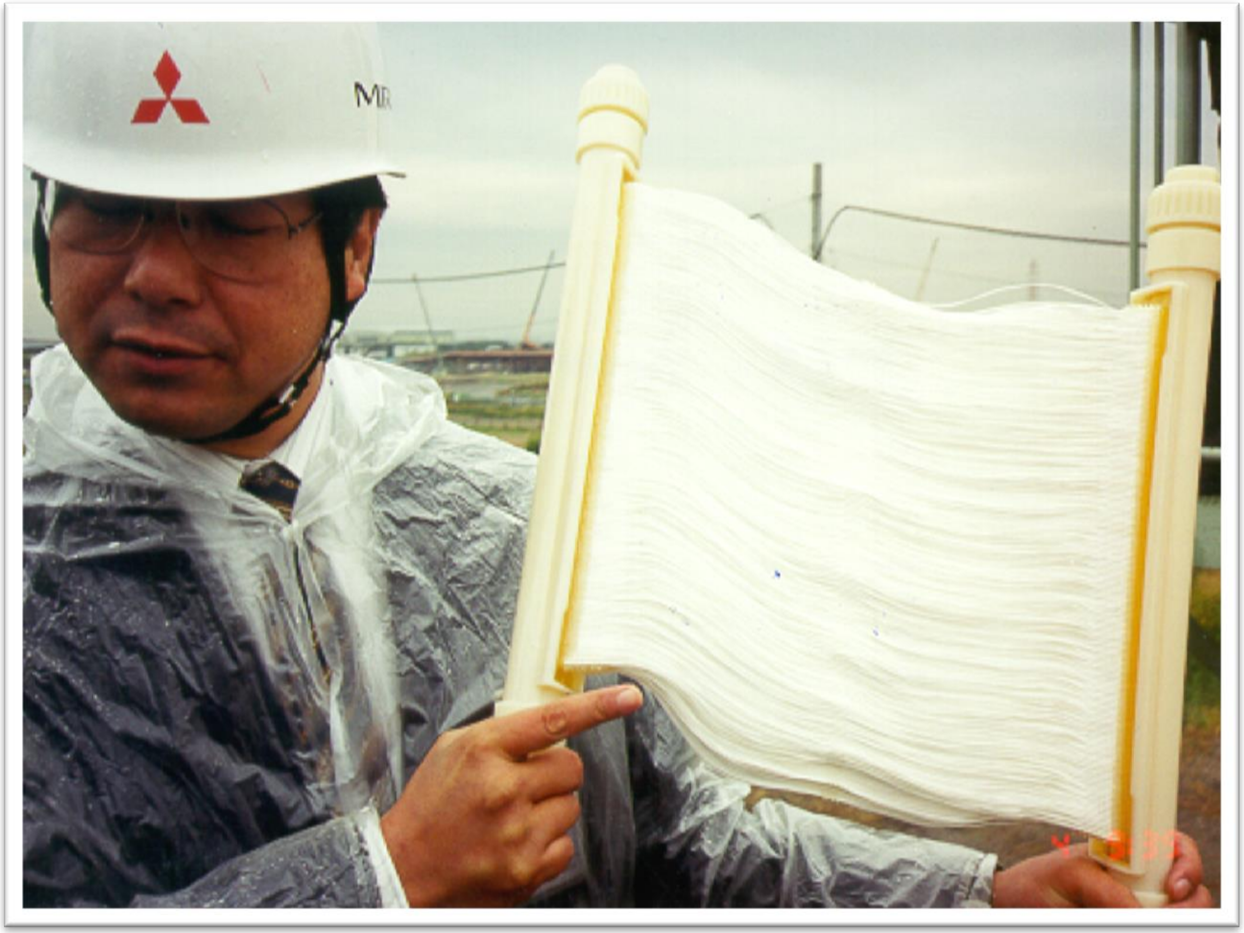
Kubota's MF Tubular (Ceramic)



Part 4.
Membrane Bioreactor



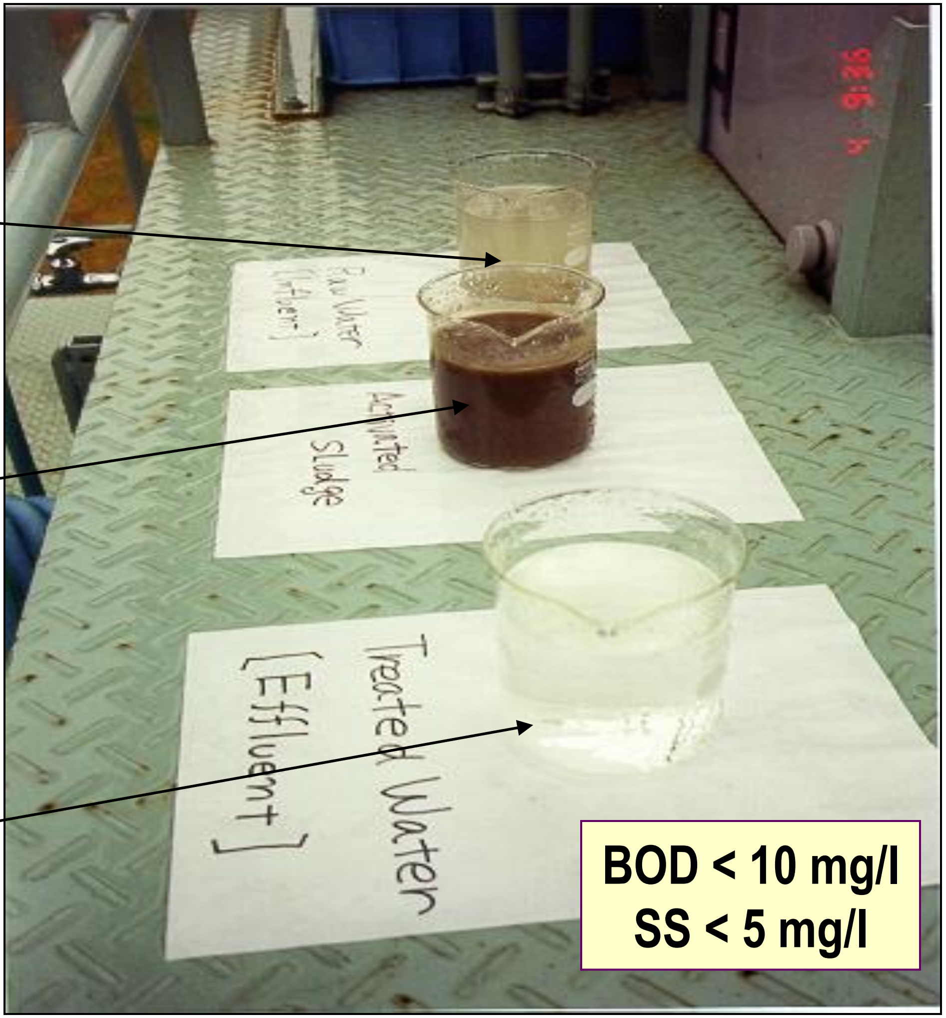
MBR by Mitsubishi Rayon Engineering



MBR by Mitsubishi Rayon Engineering

Items	Plant Conditions
Treatment Capacity (m^3/d)	32-48
Type of filtration	Continuous flow
Flux ($m^3/m^2.d$)	Operating flux 0.5-0.7
	Daily average 0.4-0.6
Intermittent operation (min)	Operating: 8-12; Stop: 2
MLSS (g/L)	10
Air diffusion ($m^3/m^2.s$)	0.06
Retention time (h)	5.5 - 8.0
Recirculation ratio	3

Effluent of MBR from Mitsubishi Pilot Plant



Feed

Activated sludge

Treated effluent

BOD < 10 mg/l
SS < 5 mg/l

Costing

MBR vs Conventional Activates Sludge

Items	MBR	CAS
Sludge (m^3/day)	0.069	0.963
Operating cost* ($/day)	8.37	11.25
Sludge treatment* ($/day)	34.65	48.3
Running cost	72%	100%
Space	30%	100%

* Price for electricity at US$0.075

Source: MRC, 1997 (inVisvanathan*et al*., 2000)

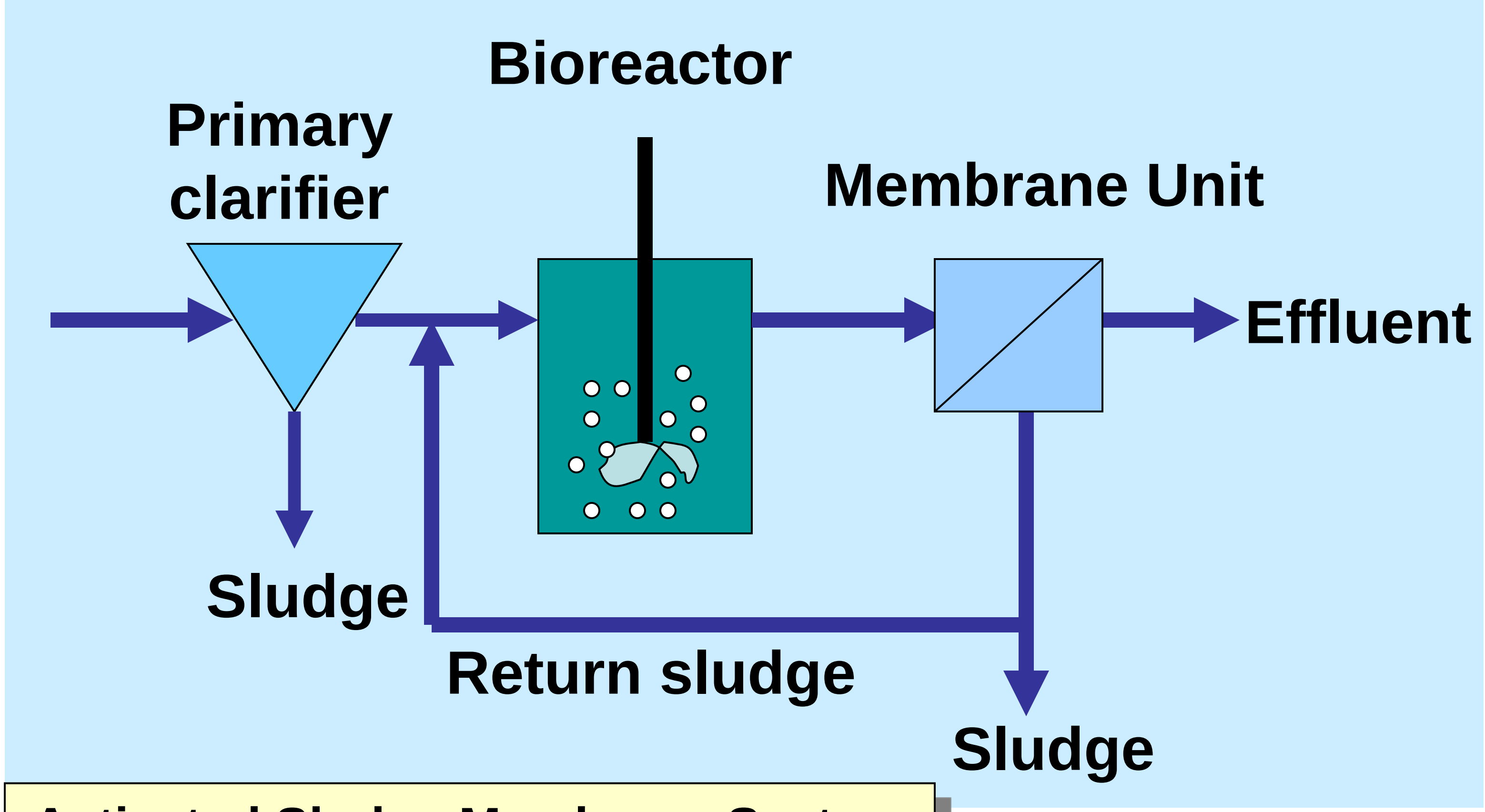
Terminology MBR Confusion

- Activated sludge membrane reactor (Yamamoto et al.)
- Membrane process for biomass retention (Anderson et al., 1984)
- Membrane separation bioreactor (Yamamoto et al.)
- Integrated type membrane separation activated sludge (Takeuchi et al., 1990)
- Membrane bioreactors (most authors since 2000)

Why MBR for Industrial WWT

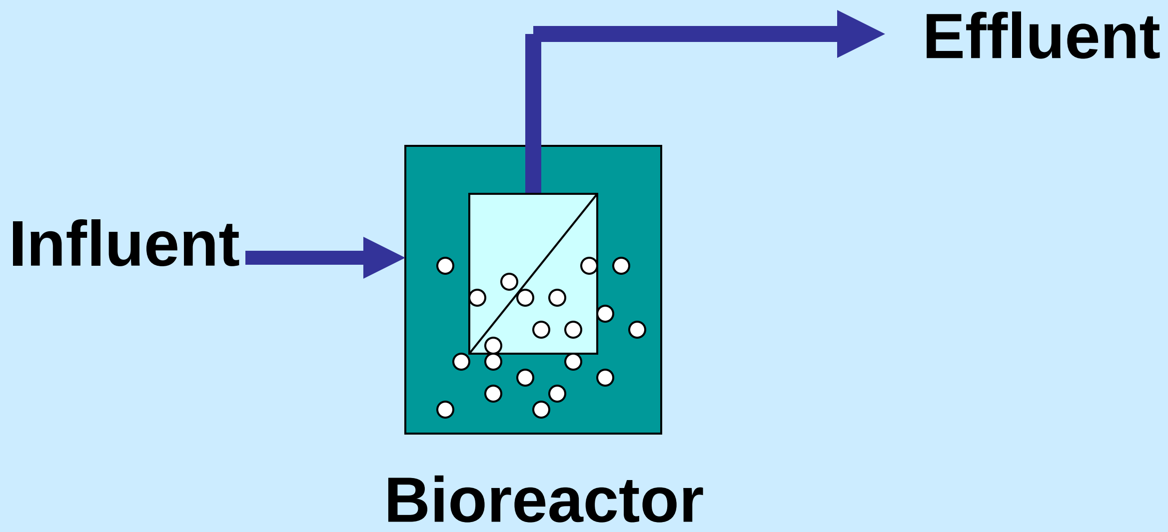
- Small foot print
- Concentrate sludge, less excess sludge
- Reduce sludge disposal (scheduled wastes)
- Better solid-liquid separation
- Option for water recycling
- Compactness, modular, clean plant
- Simplicity in operation
- Less operating cost

MBR for Wastewater Treatment



Activated Sludge Membrane System

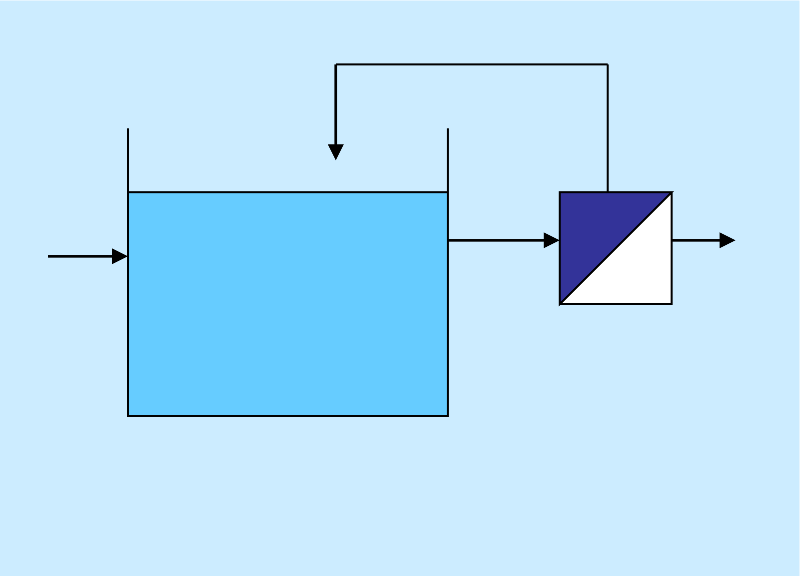
MBR for Wastewater Treatment



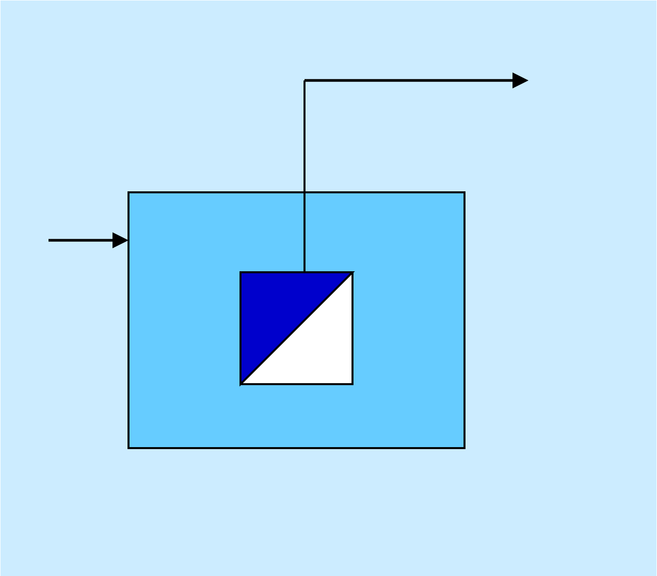
Activated Sludge Membrane System

Features of MBR

- ✓ Solid/liquid separation



External or side stream membrane

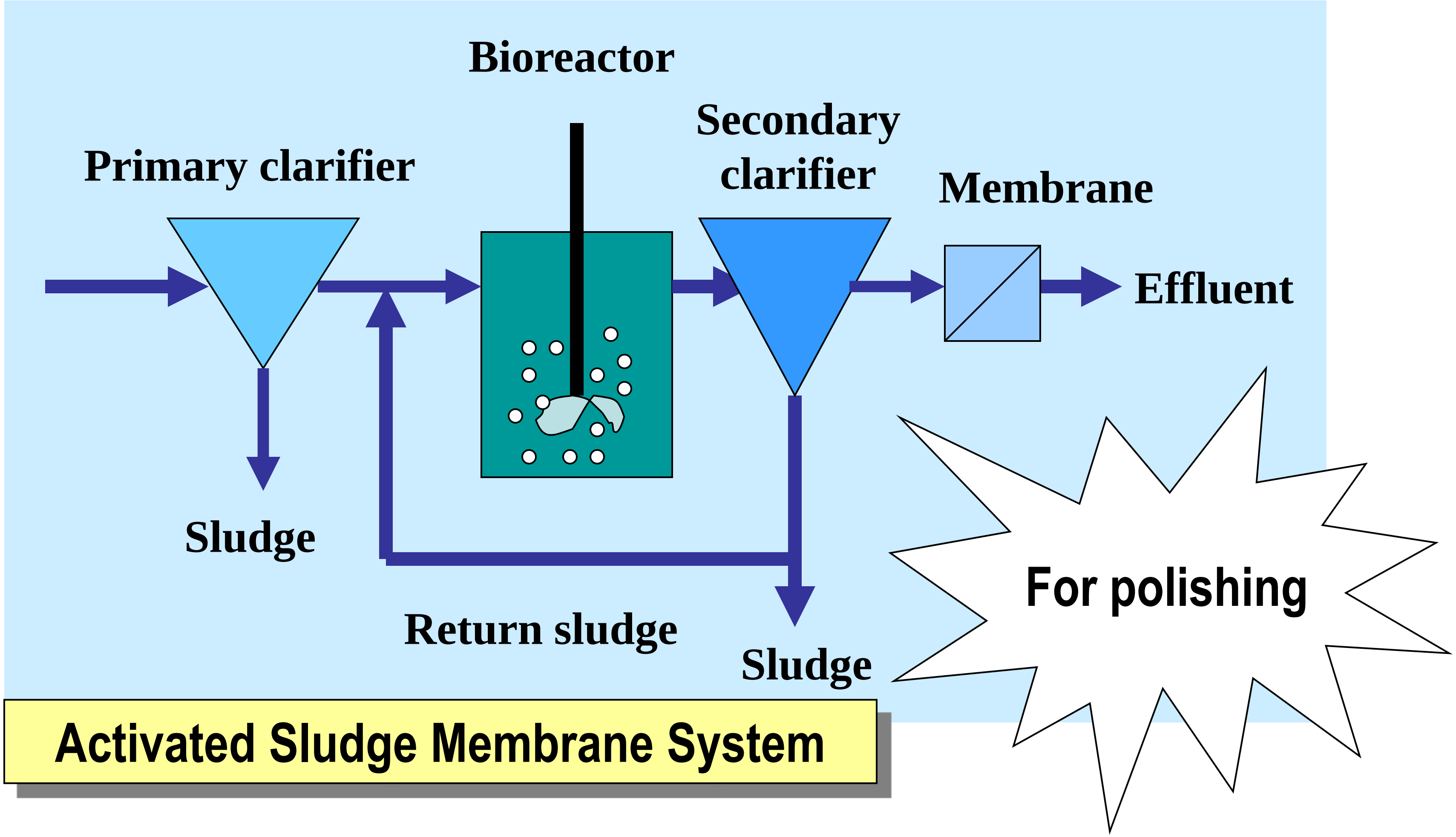


Immersed membrane

MBR for Wastewater Treatment

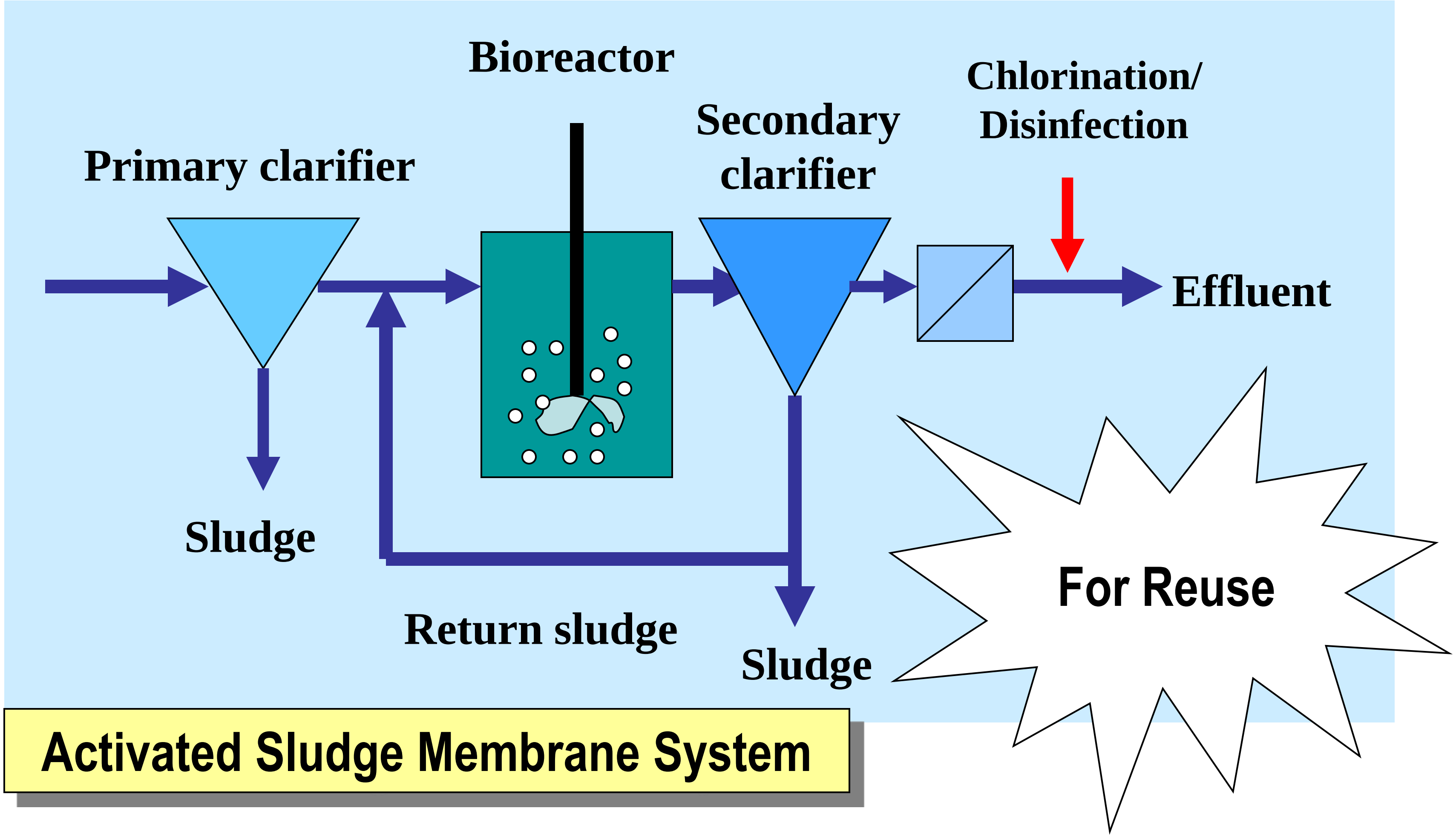
- To remove organic matter
- To remove nitrogen compounds (nitrification & denitrification)
- To remove phosphorus compounds

MBR for Wastewater Treatment - First Generation



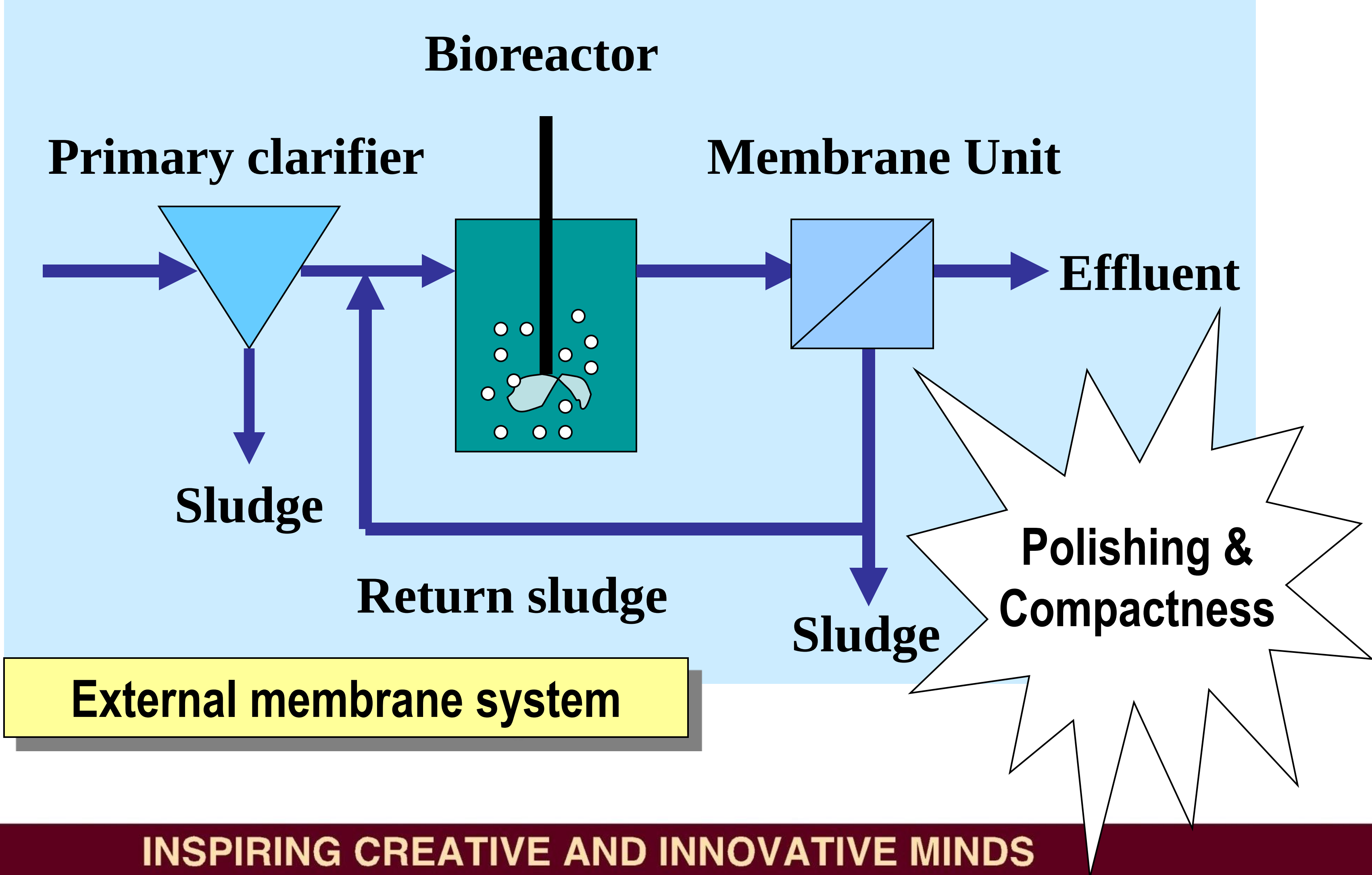
Activated Sludge Membrane System

MBR for Wastewater Treatment - Second Generation



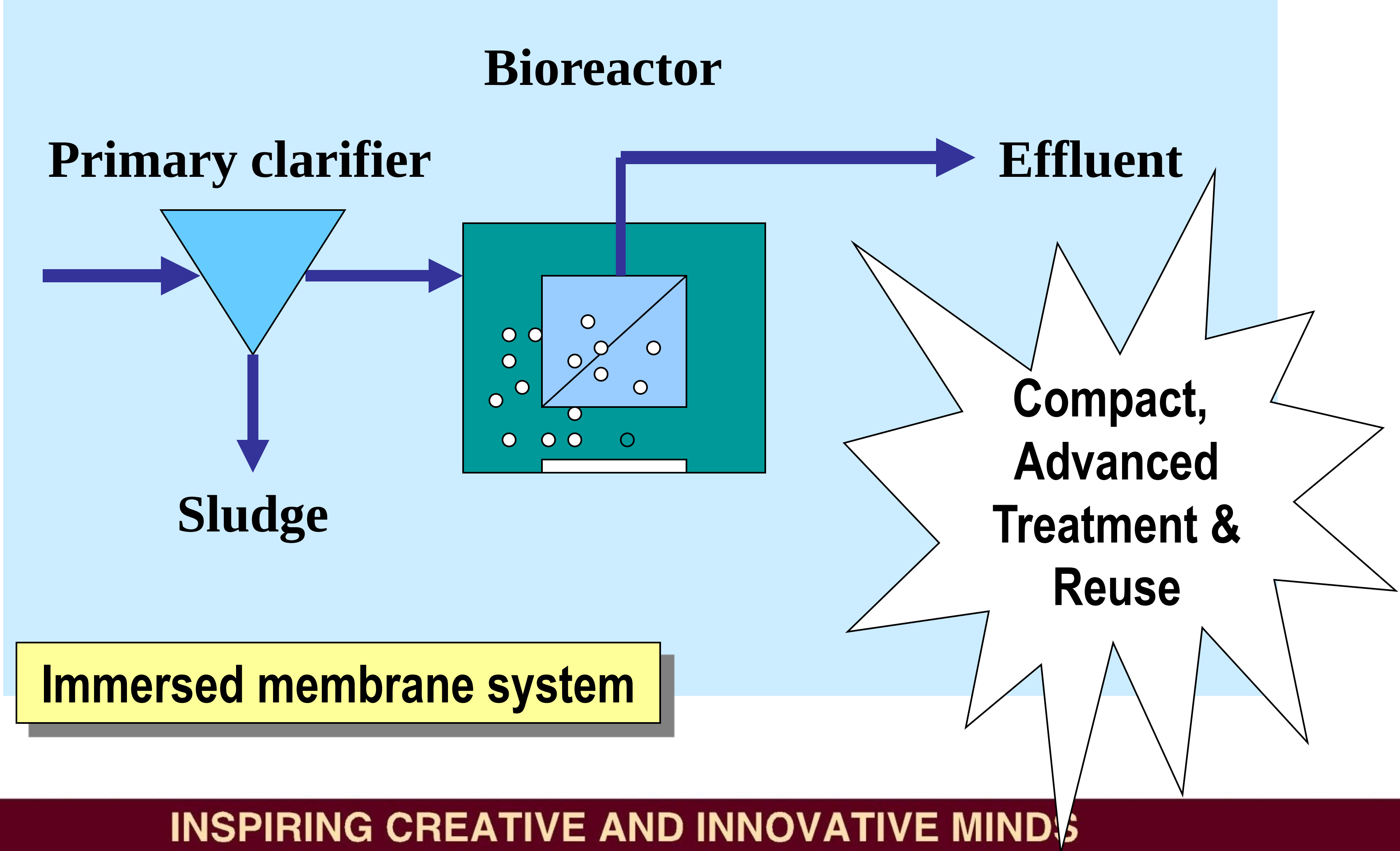
Activated Sludge Membrane System

MBR for Wastewater Treatment - Third Generation



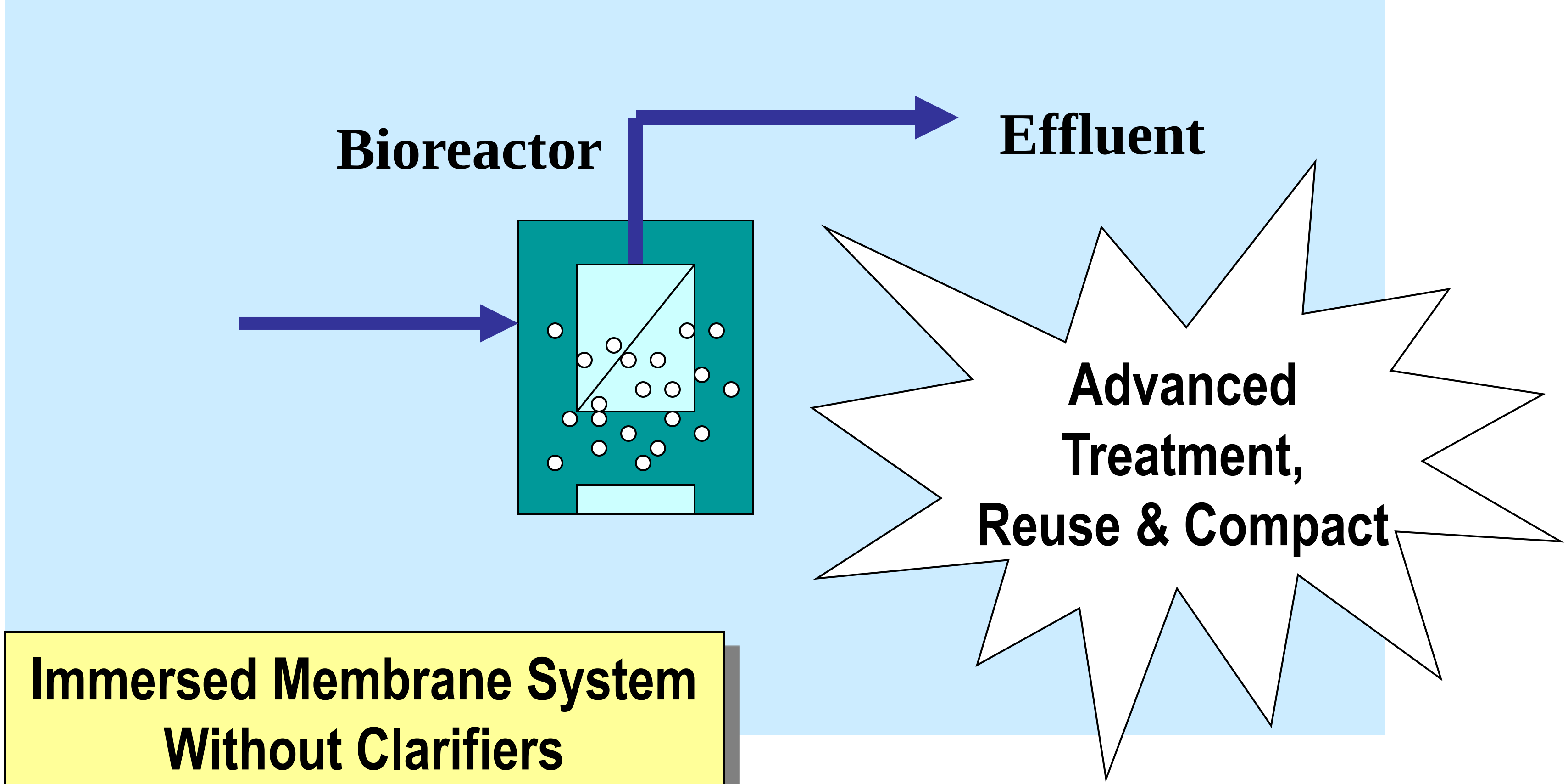
External membrane system

MBR for Wastewater Treatment - Fourth Generation



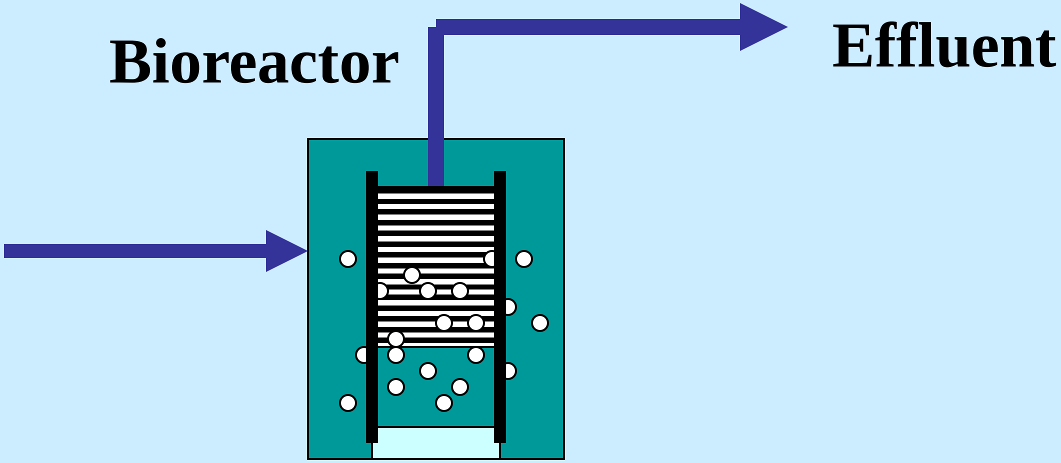
Immersed membrane system

MBR for Wastewater Treatment - Fifth Generation



Immersed Membrane System Without Clarifiers

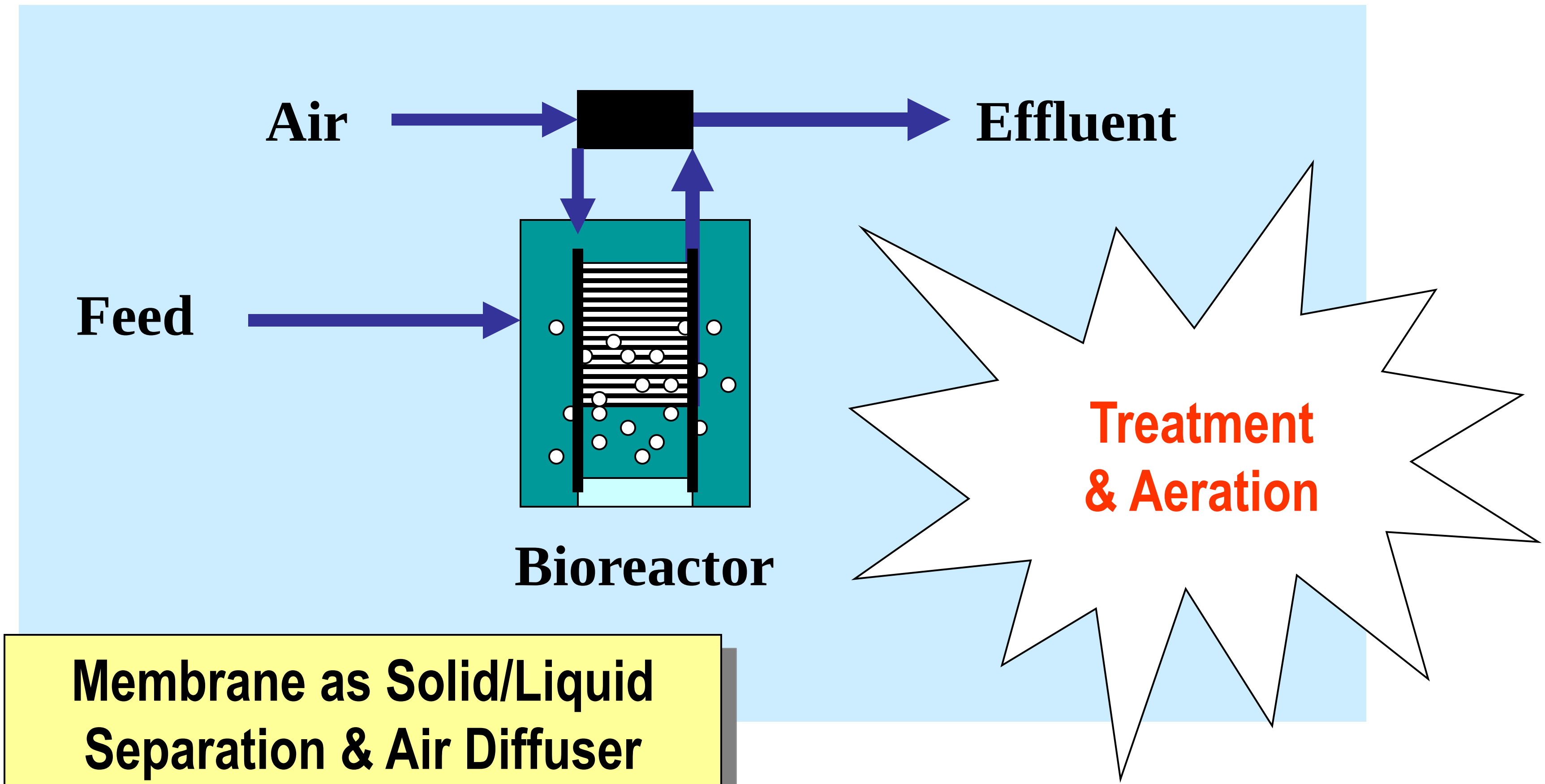
MBR for Wastewater Treatment - Sixth Generation



Improvement on energy saving & cleaning methods using strong bubble aeration & hollow fiber

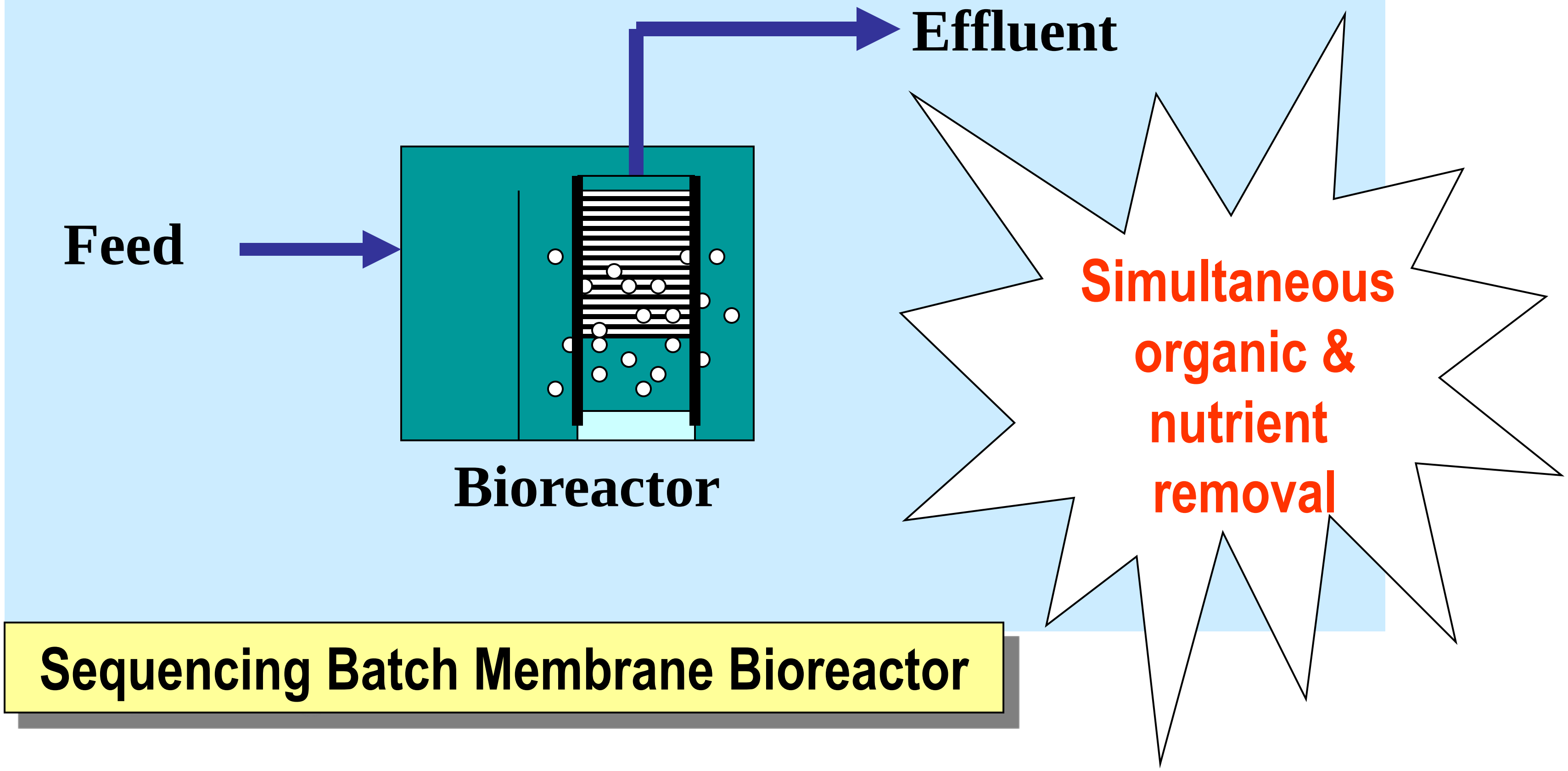
Membrane System Without Clarifiers

MBR for Wastewater Treatment - Seventh Generation



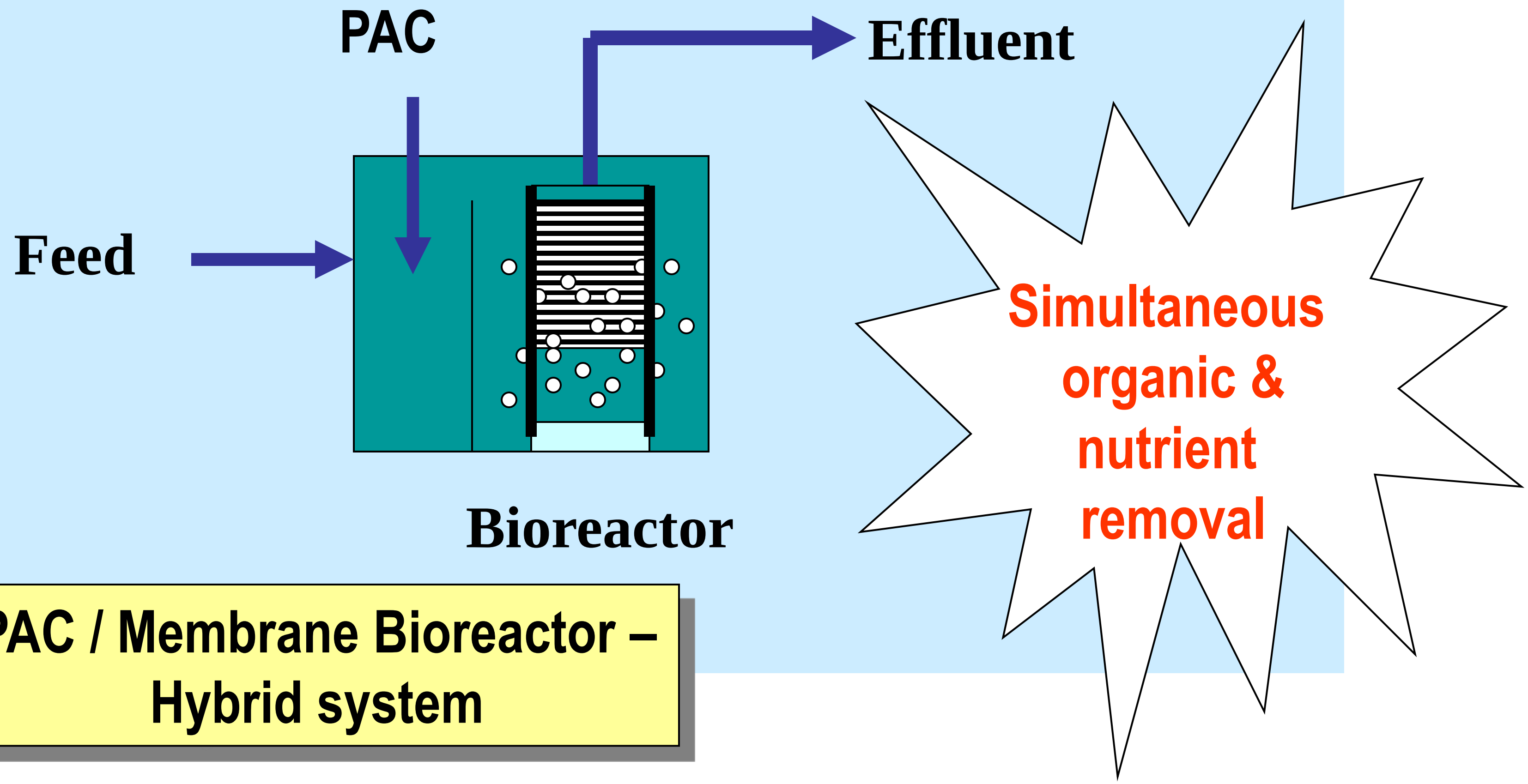
Membrane as Solid/Liquid Separation & Air Diffuser

MBR for Wastewater Treatment - Eighth Generation



Sequencing Batch Membrane Bioreactor

MBR for Wastewater Treatment - Ninth Generation

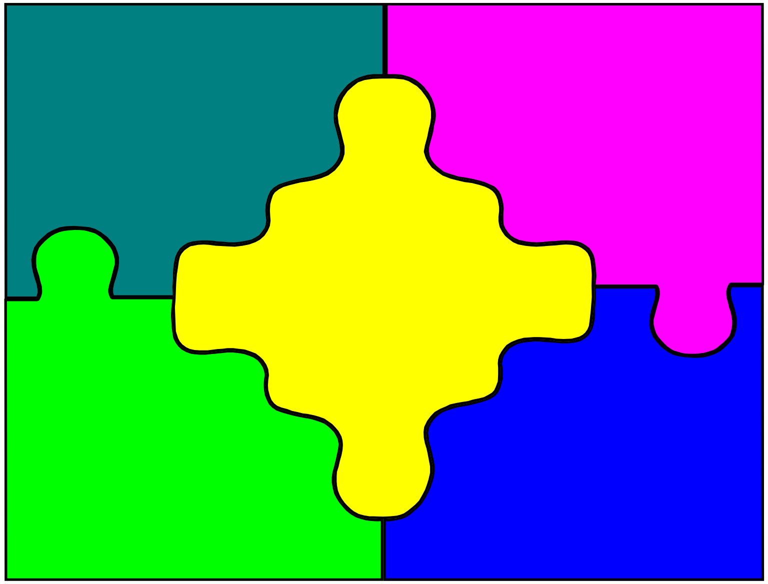


PAC / Membrane Bioreactor – Hybrid system

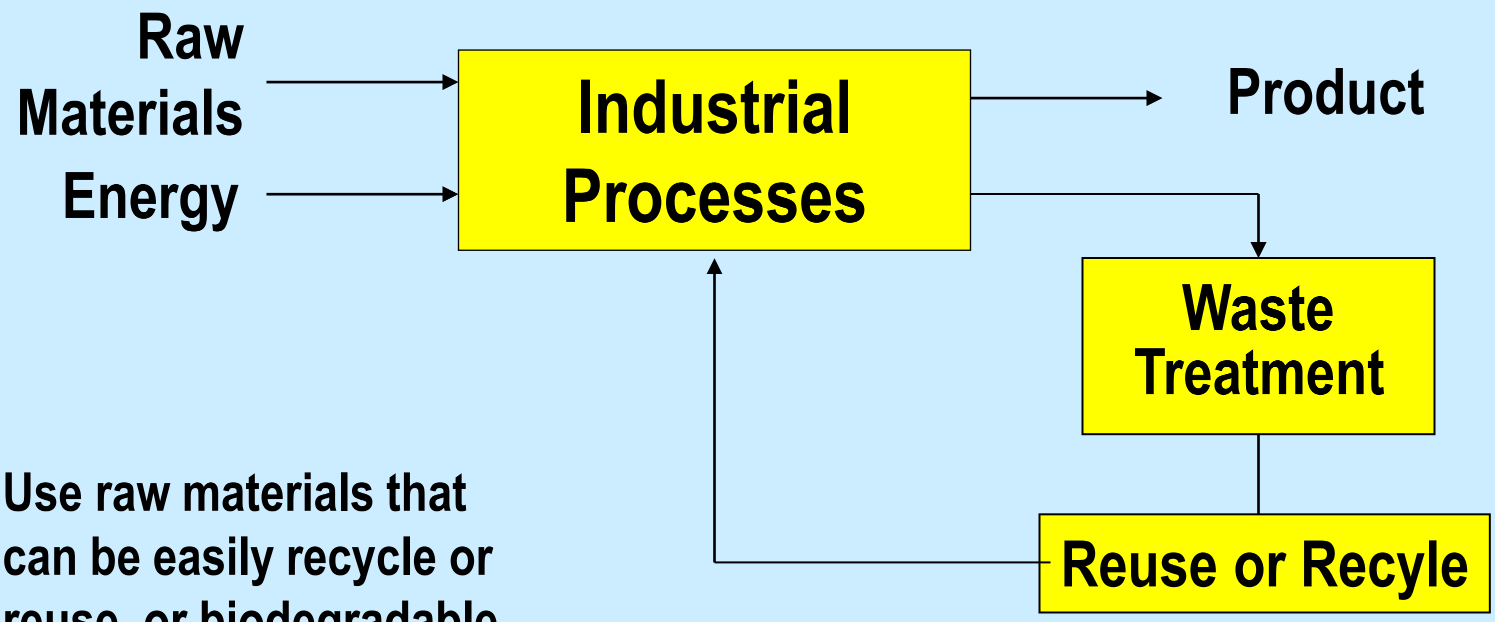
Problems of Membrane Bioreactor

- Overflow of mixed liquor
- Irregular condition of sludge
- Biofouling during anaerobic stage
- Low water level during influent low flowrate
- Old sludge, less productivity

Part 5.
End-of-Pipe vs Zero Discharge



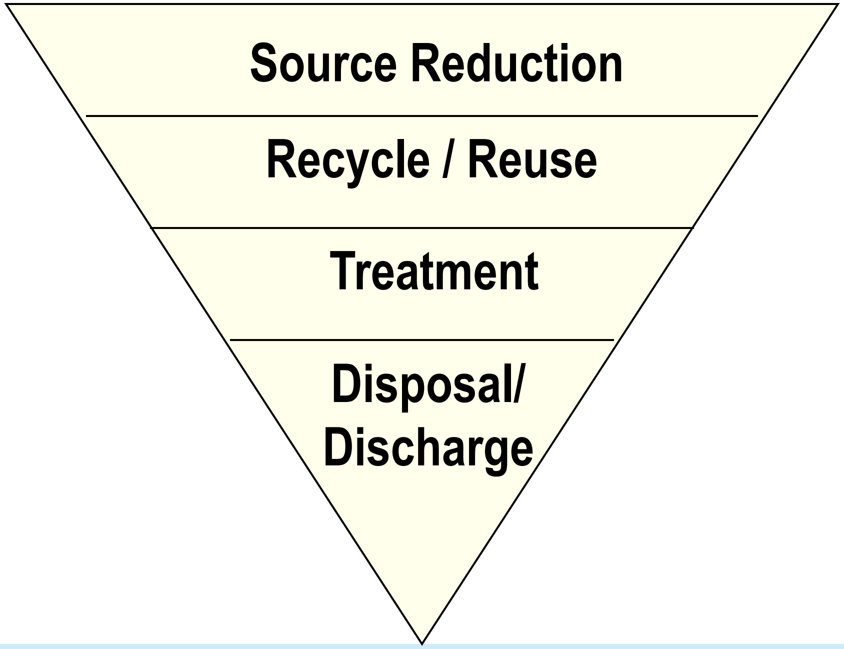
Zero Discharge Engineering

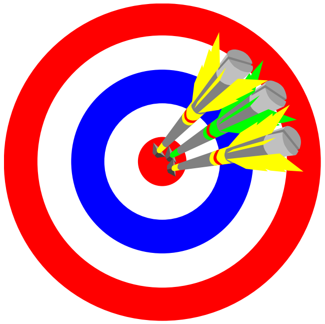


Use raw materials that can be easily recycle or reuse, or biodegradable

Principles and Priority in Waste Management within Zero Discharge Society

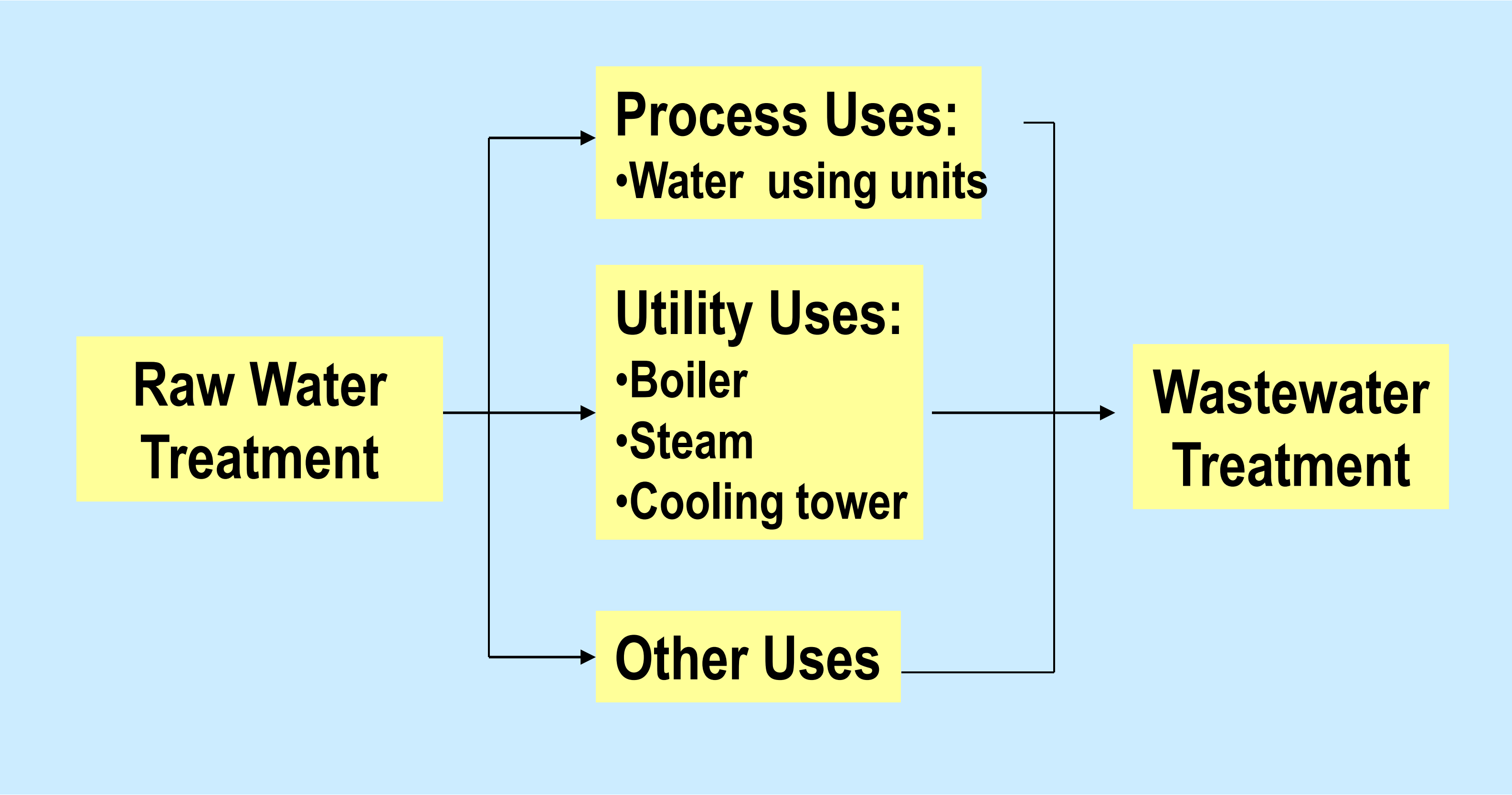
Pollution should be prevented or reduced whenever possible	PRINCIPLE 1



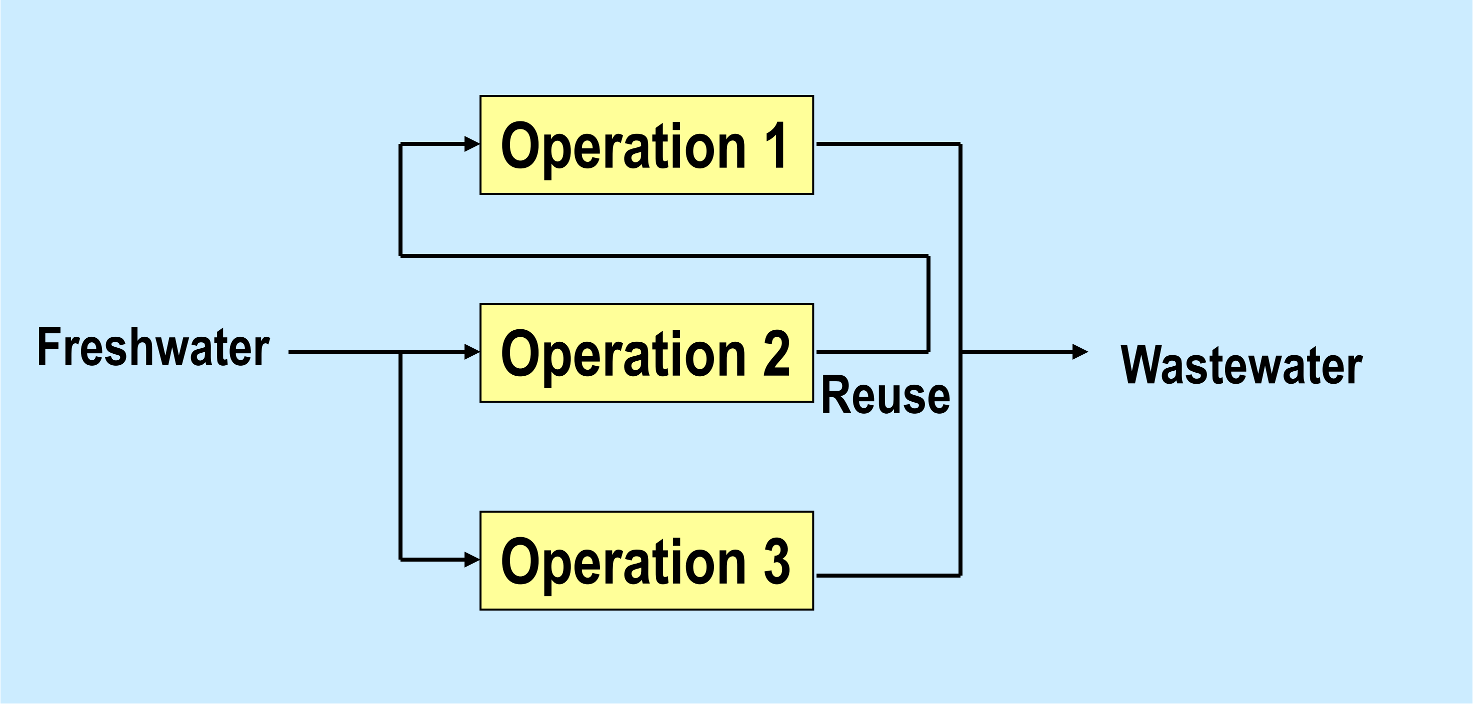


Disposal or discharge to the environment should be employed only as a last resort	PRINCIPLE 2

Typical Water Uses in A Chemical Process Industry

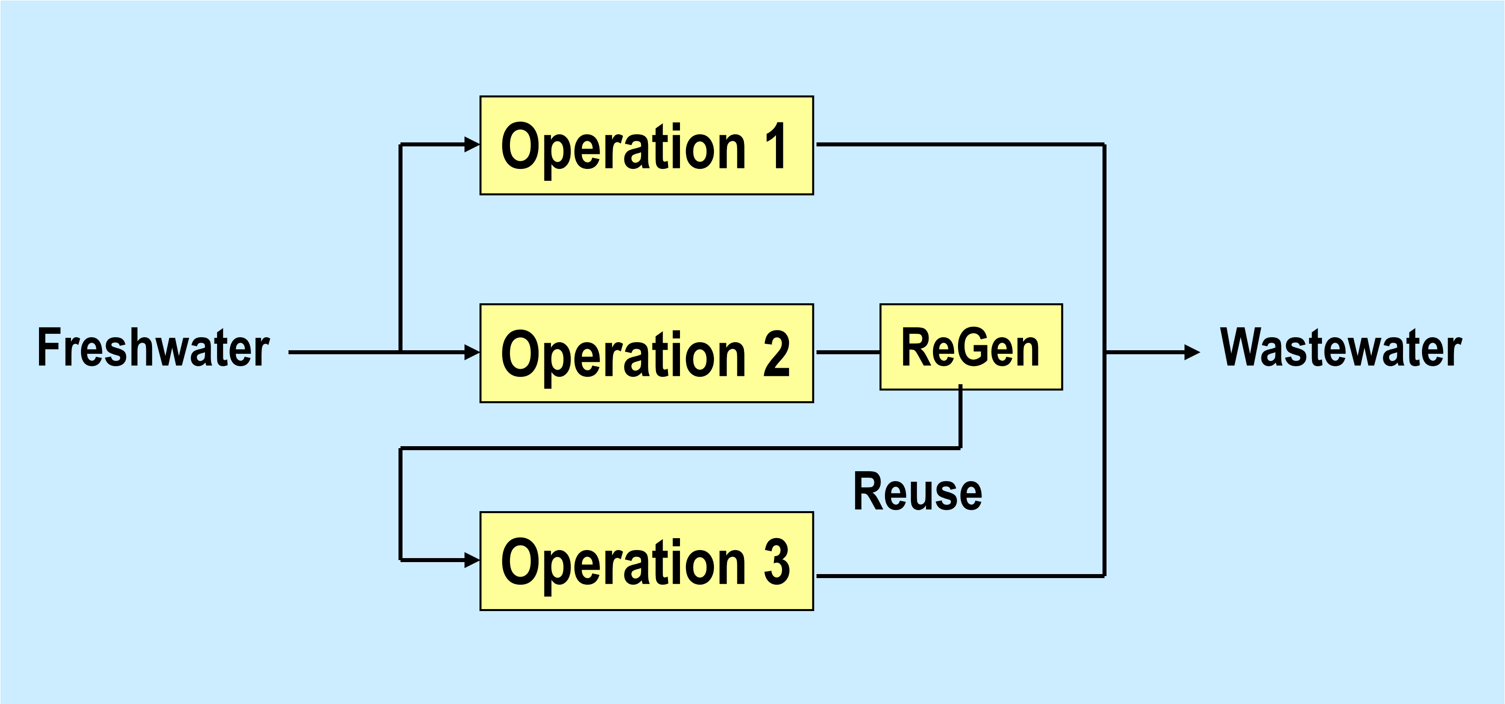


Regeneration, Flowrate Changes & Multiple Contaminants



Wastewater minimization through reuse

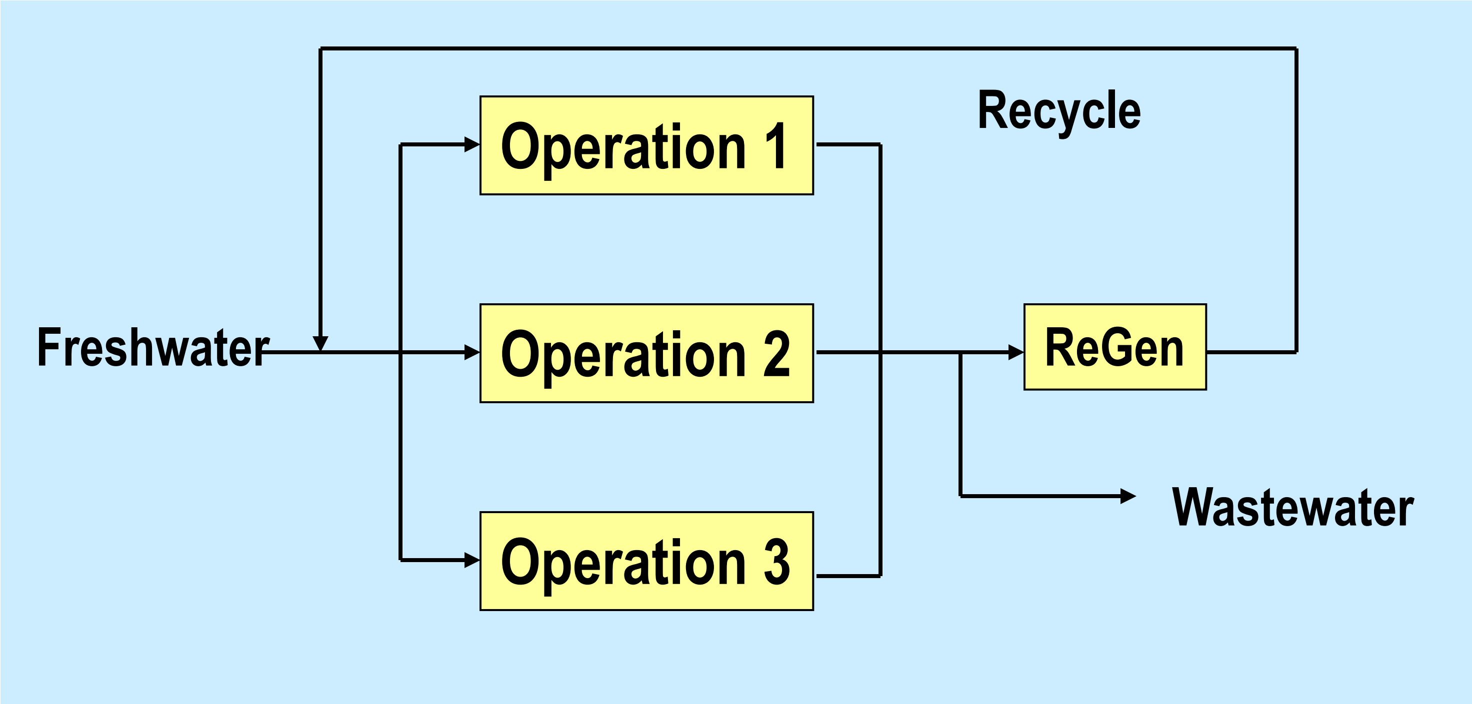
Regeneration, Flowrate Changes & Multiple Contaminants



Wastewater minimization through regeneration & reuse

Note: ReGen=Regeneration

Regeneration, Flowrate Changes & Multiple Contaminants



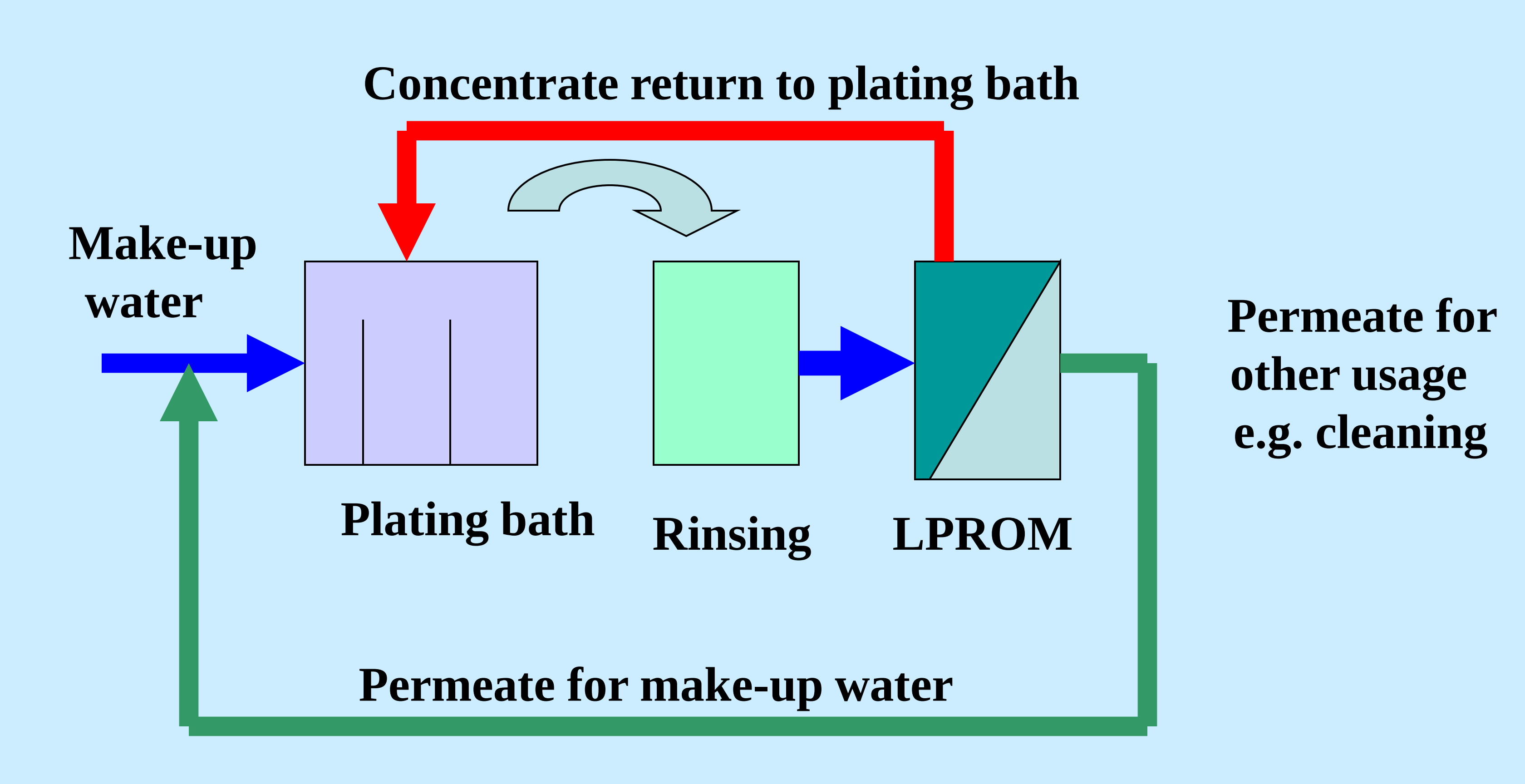
Wastewater minimization through regeneration & reuse

Note: ReGen=Regeneration

Strategies for Industrial Water Reuse & Wastewater Minimization

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

Low-Pressure Reverse Osmosis Membrane for Electroplating Waste Minimization

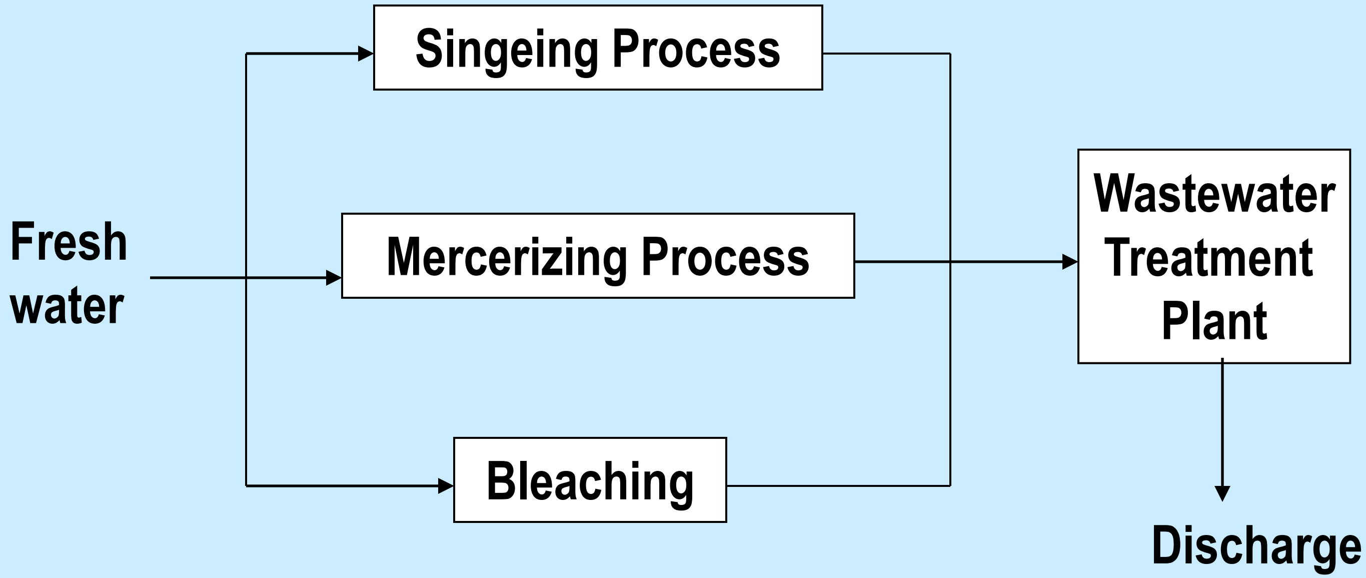


Specification of LPROM Unit

Materials	Sulphonated polysulphone
Configuration	Spiral wound
Thickness	150 - 175 μm (<1 μm active layer)
Surface area	0.465 m^2
pH range	2-11 for continuous operation
Temperature	2-45^{o}C
Pressure	Maximum of 125 psig
Charge	Negative
Characteristics	Low pressure & chlorine resistance

Wastewater Minimization in Textile Plant

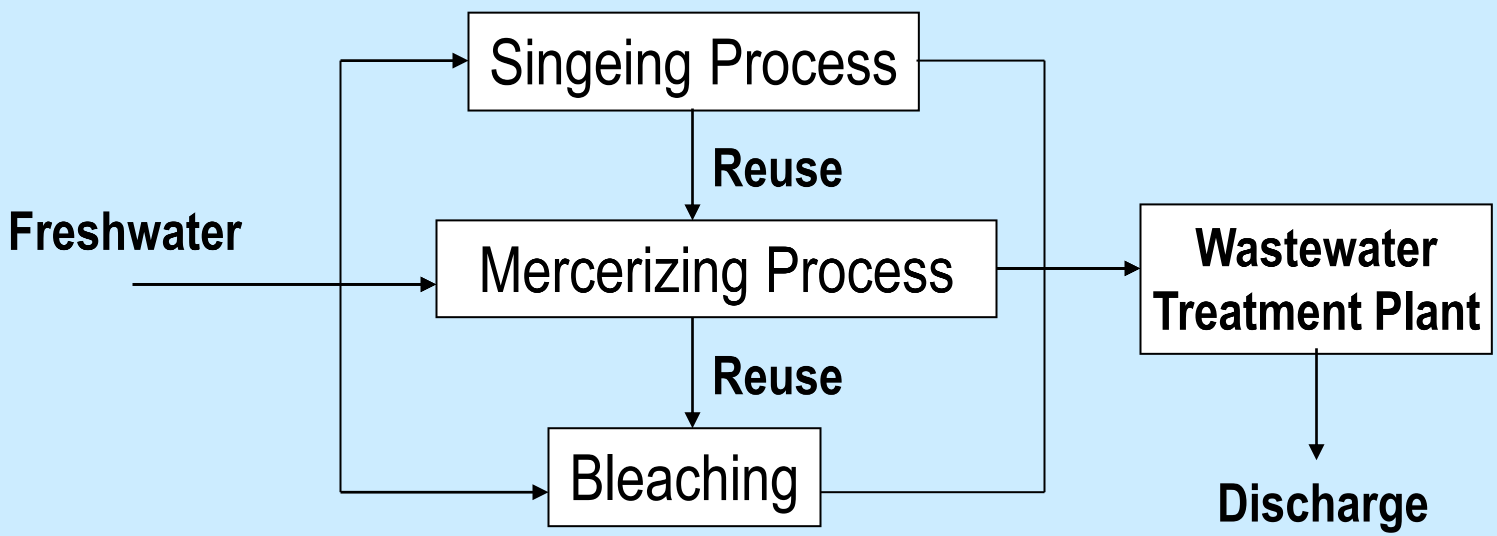
ORIGINAL DESIGN



Old textile plant (installed 1957), with 200 employees and using 1000 te/day freshwater, and produce around 900 te/day wastewater

Wastewater Minimization in Textile Plant

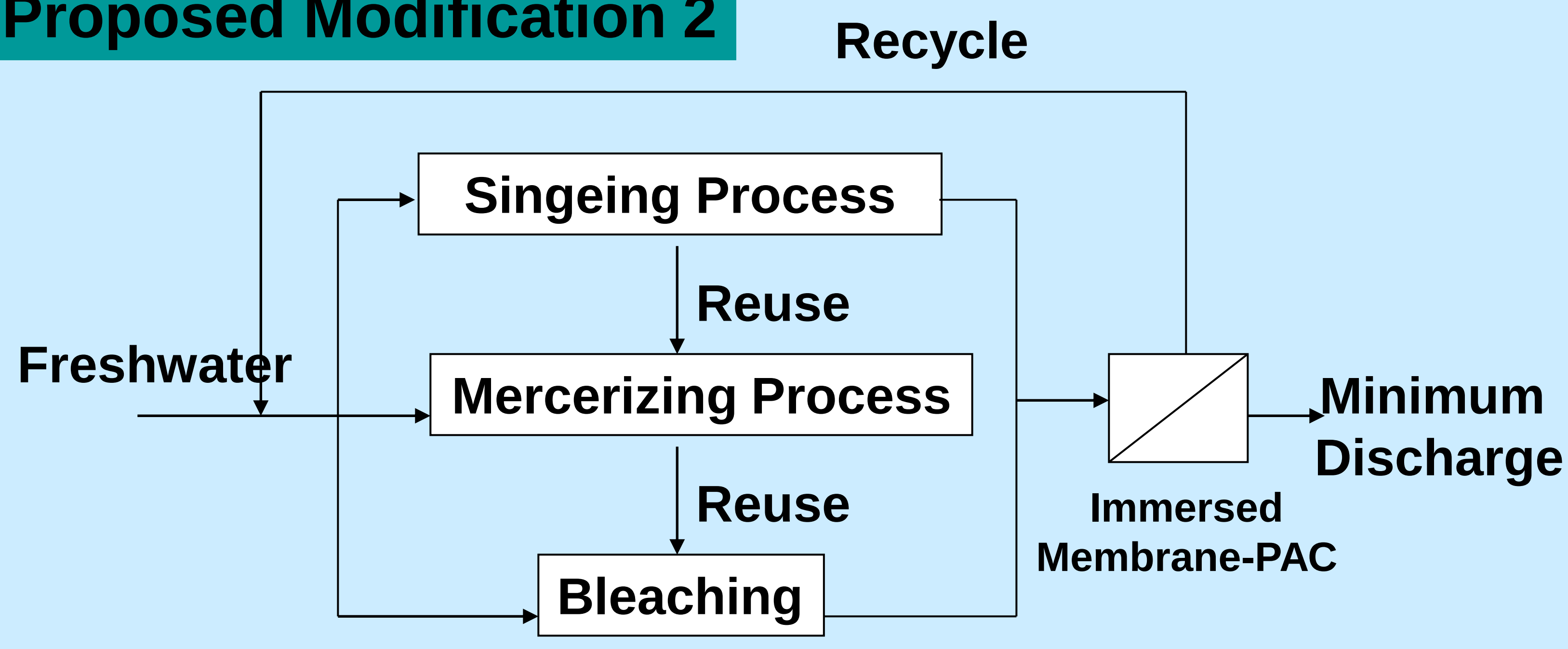
Proposed Modification 1



Using Water Pinch Analysis (WPA) to design the minimize wastewater generation and freshwater consumption

Wastewater Minimization in Textile Plant

Proposed Modification 2



Using Water Pinch Analysis (WPA) to design the minimize wastewater generation and freshwater consumption plus immersed membrane-PAC

Conclusions

- Membrane technology is growing fast and very instrumental for implementation of zero discharge concept
- Zero discharge can absorb the cost by waste reuse and recycling
- Zero discharge is much cheaper than allowing pollution to take place