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Membrane Research Group

Osmotic MBR and Pressure-Retarded Osmotic MBR for Wastewater Treatment

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Presentation Overview

- Introduction
  - *Membrane Bioreactor (MBR)*
  - *Osmotic MBR*
  - *Pressure-Retarded Osmotic MBR*
- Objectives
- Materials and Methods
- Results and Discussion
- Concluding Remarks

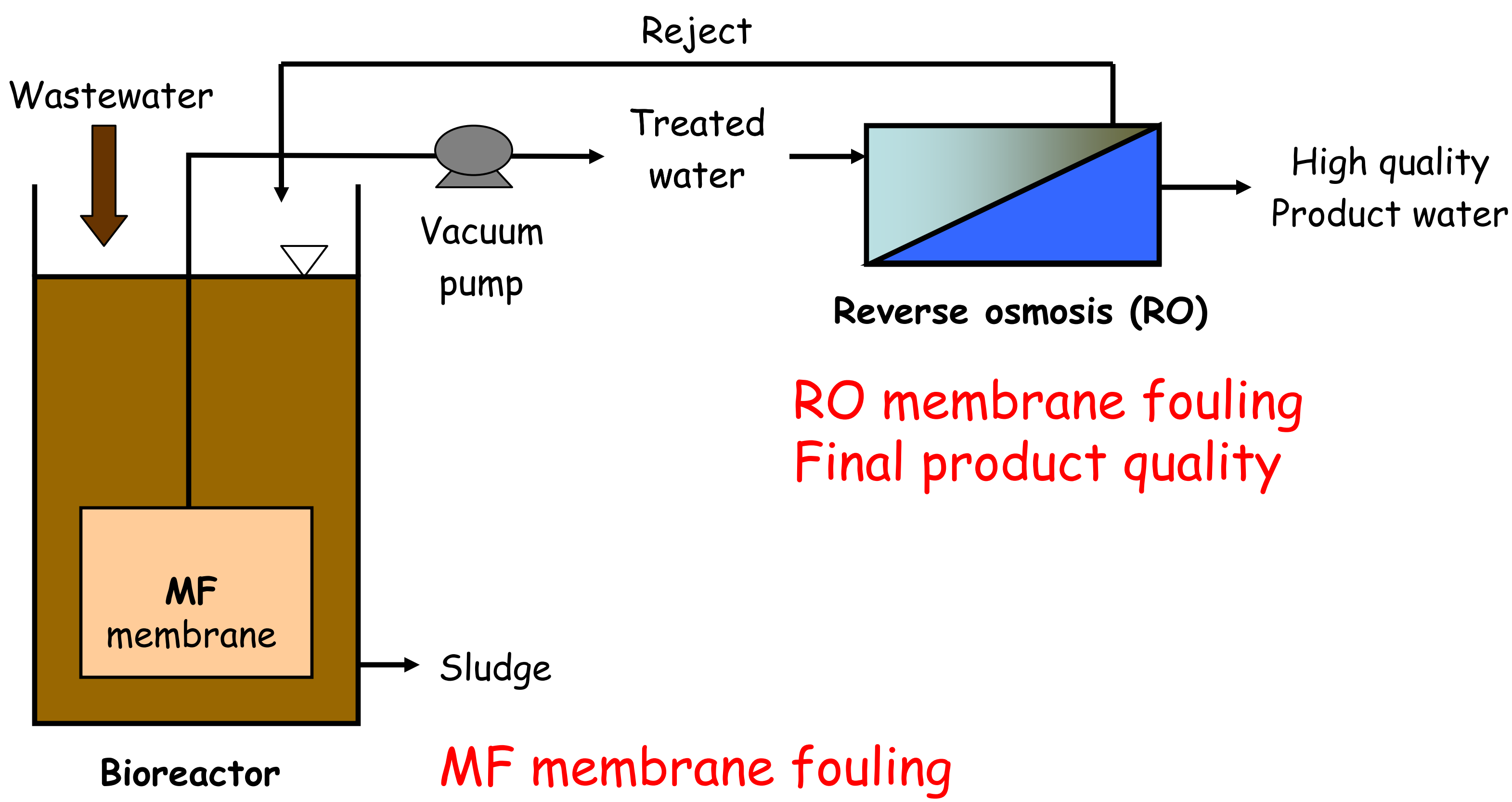
Introduction

- Membrane bioreactors (MBRs)
  - *Rapidly growing field*
  - *Replacing conventional waste water treatment plants*
- MBR + Forward osmosis (FO)
  - *Wastewater treatment*
  - *Potable water reuse*
- MBR + Pressure-retarded osmosis (PRO)
  - *Wastewater treatment*
  - *Renewable energy production*

Membrane Bioreactor

- Reduced footprint
- High solids removal from effluent
- Reduced disinfection needs
- Modular
- Removal efficiencies:
  - *95% COD*
  - *90% nutrients*

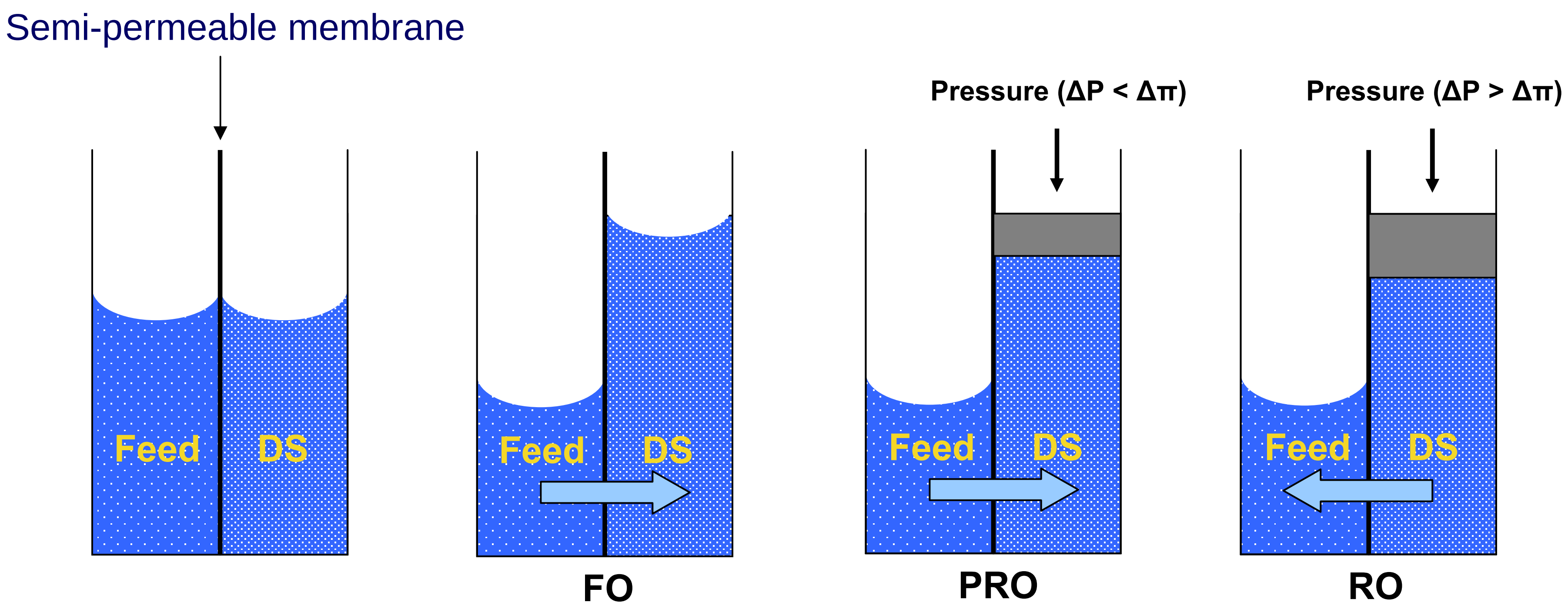
Membrane Bioreactor



RO membrane fouling
Final product quality

MF membrane fouling
MF permeate quality

Forward osmosis and Pressure-Retarded Osmosis



Feed = Feed solution, low salinity, high water chemical potential

DS = Draw solution, high salinity, low water chemical potential

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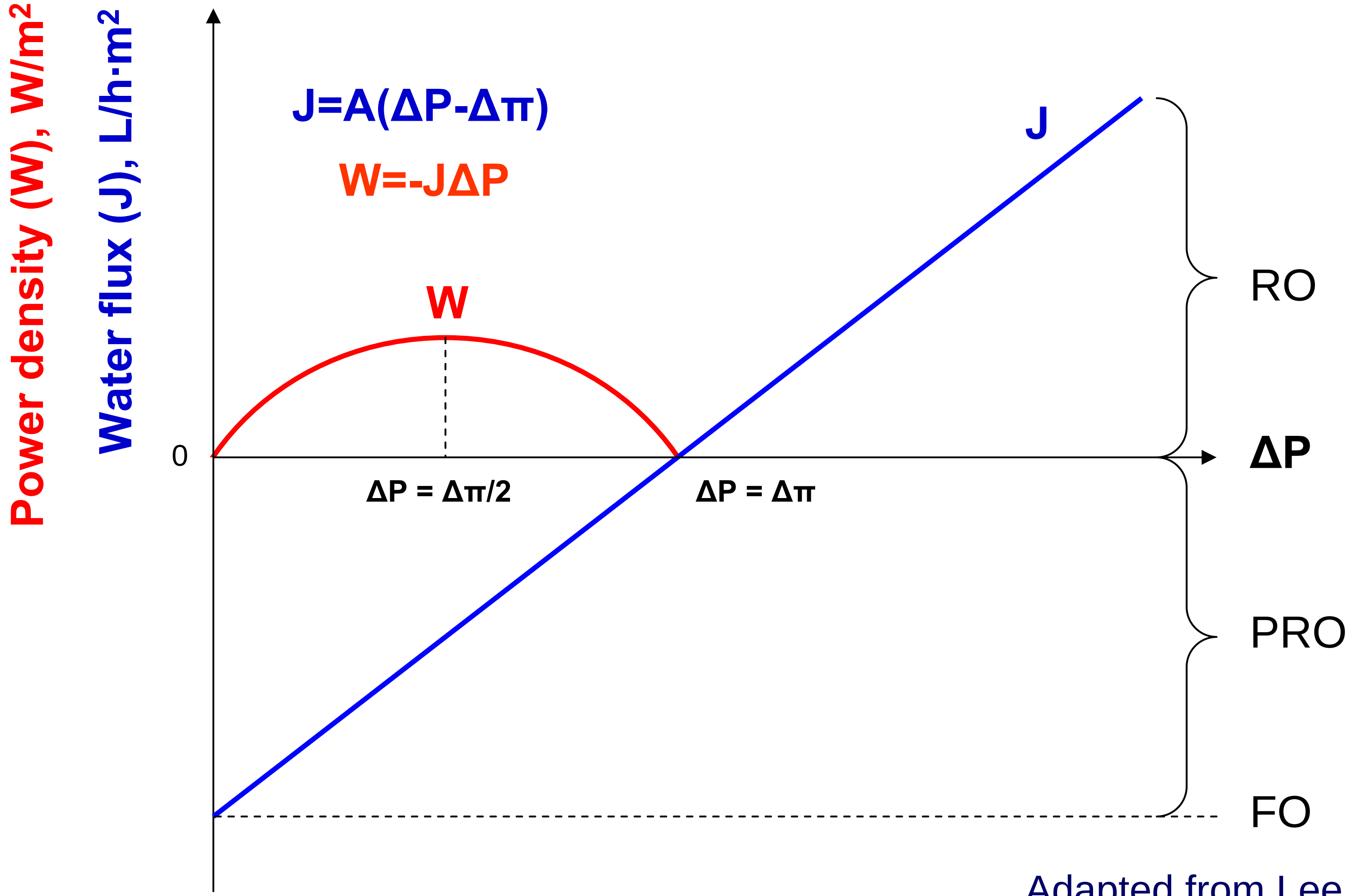
Forward Osmosis and Pressure-Retarded Osmosis



Adapted from Lee et al., 1981

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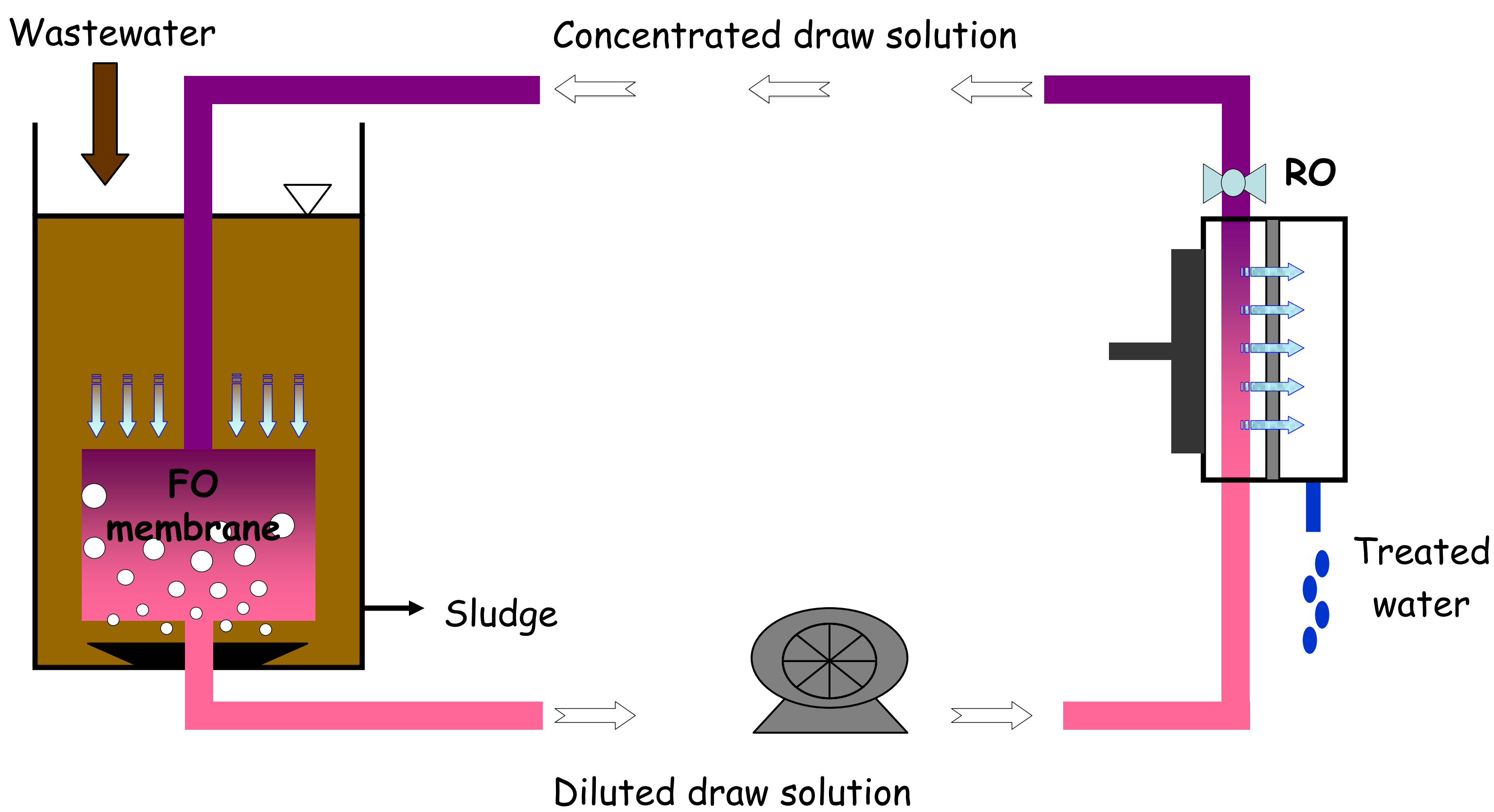
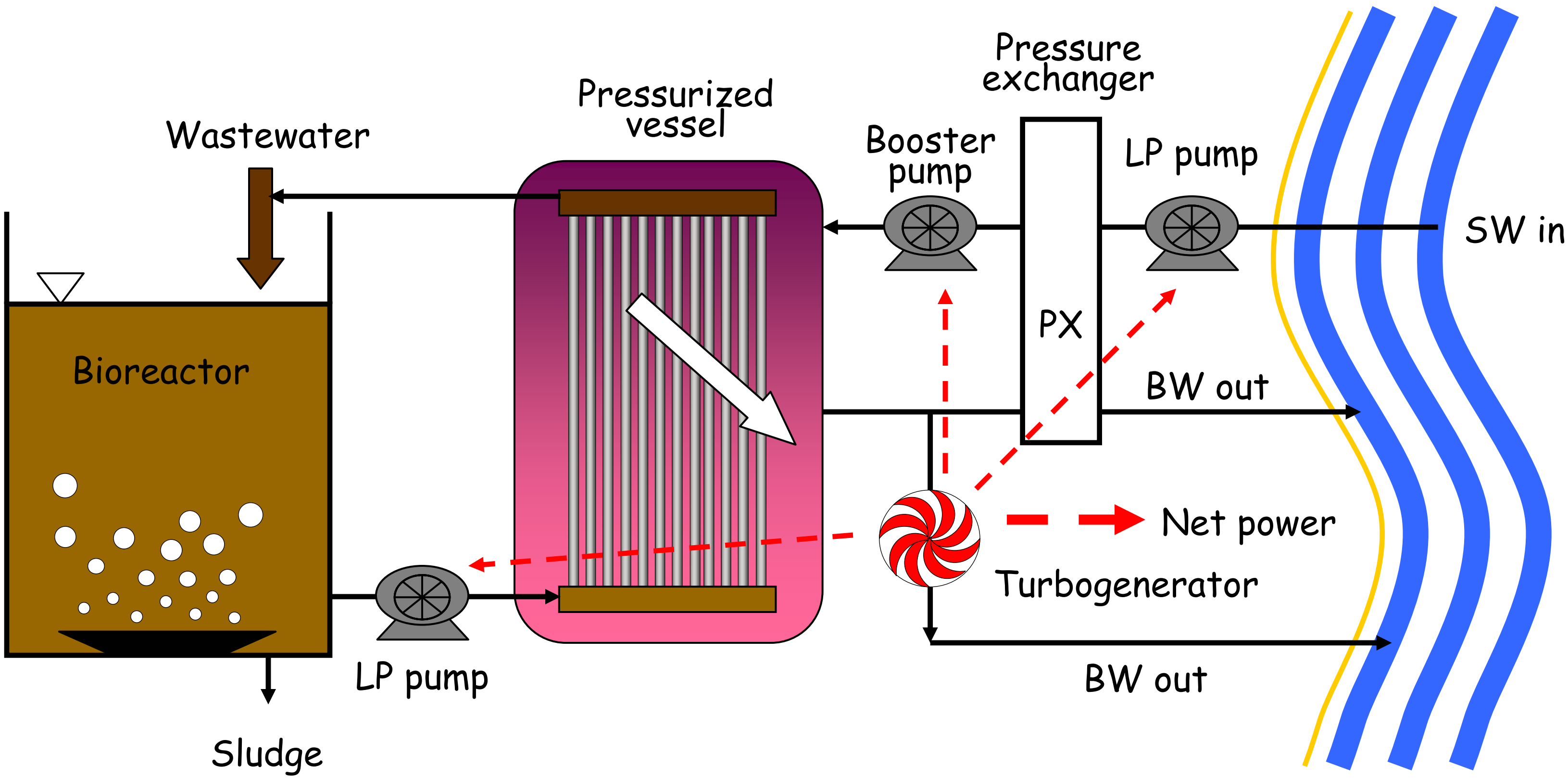
The Osmotic Membrane Bioreactor for Water Reuse



The Pressure Retarded Osmotic Membrane Bioreactor



Possible Advantages of Osmotic Membrane Processes

- Low pressure / low energy operation
- High rejection of contaminants
  - Soluble constituents
  - Hormones and PPCPs
- Reduced fouling potential

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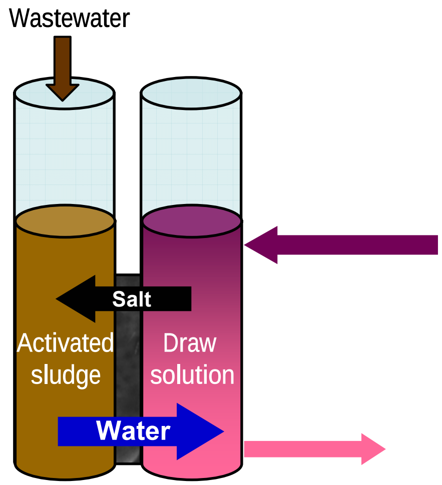
Possible Problem Associated with Osmotic Membrane Process

Salt accumulates inside bioreactor due to concentration gradient between draw solution and activated sludge



Reverse salt transport

Reduces driving force
Hinders biological processes

Objective

Evaluate the feasibility of novel osmotic MBR systems to treat wastewater for potable reuse or for power generation

- OsMBR
  - *Membrane fouling*
  - *Water quality*
  - *Reverse salt transport*
- ProMBR
  - *Membrane fouling*
  - *Power output*

Materials & Methods

Membranes

- Flat-sheet cellulose triacetate (CTA) membrane (Hydration Technologies, Inc., Albany, OR)
  - *Semi-permeable (similar to RO membranes)*
    - Membrane A
    - Membrane B
    - Membrane C
  - *Only commercially available FO membranes*

Solution Chemistries

- Reactor solution
  - *Doubly deionized water (DDW)*
  - *Mixed liquor*
    - 5.5 g MLSS/L OsMBR
    - 1.0 g MLSS/L ProMBR
- Draw solution
  - *5 to 70 g NaCl/L solution*
- Synthetic feed solution (OsMBR)
  - *Meat extract (5 g/L)*
  - *Glucose (1 g/L)*
  - *$(NH_4)_2SO_4$ (0.6 g/L)*
  - *K_2HPO_4 (0.14 g/L)*
  - *$NaHCO_3$ (1 to 2 g/L)*

HRT = 3 d

SRT = 15 d

→

*F/M = 0.25 g COD/g MLSS*d*

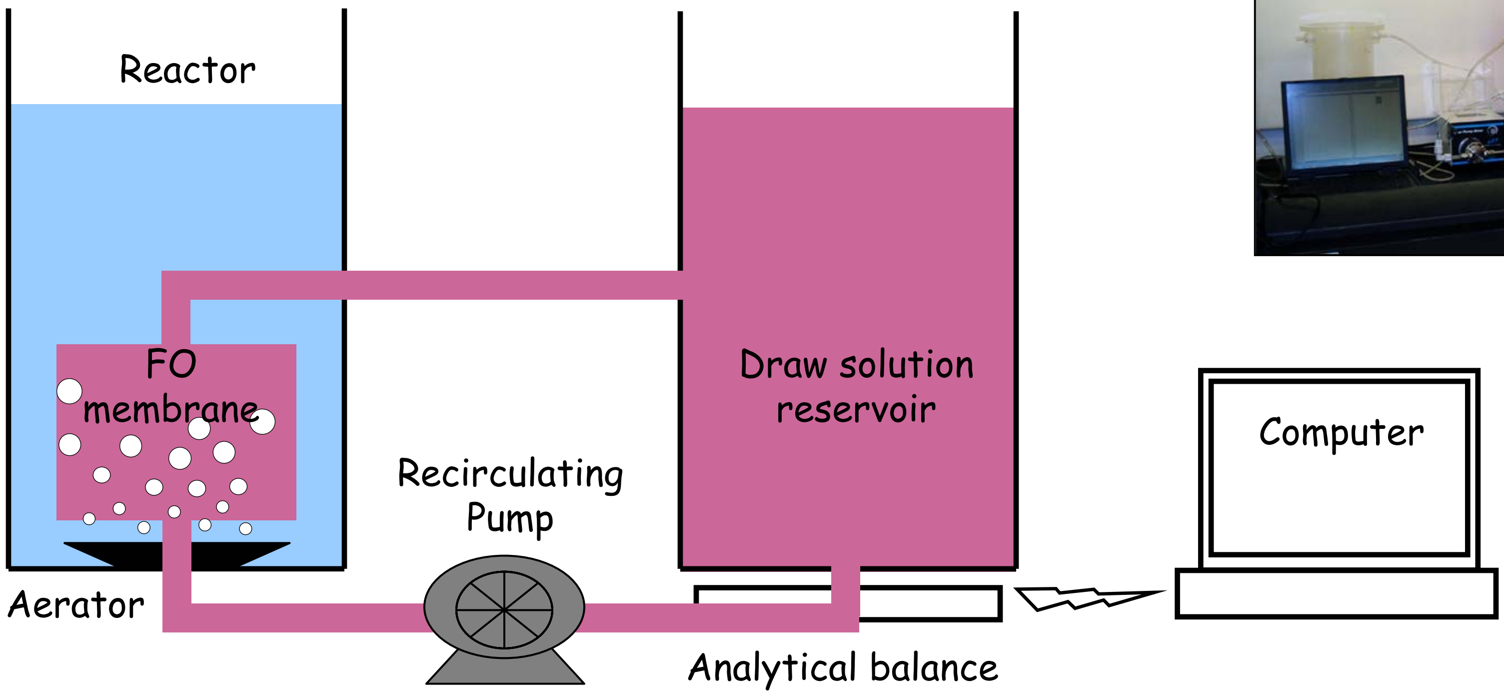
COD = 4.5 g/L

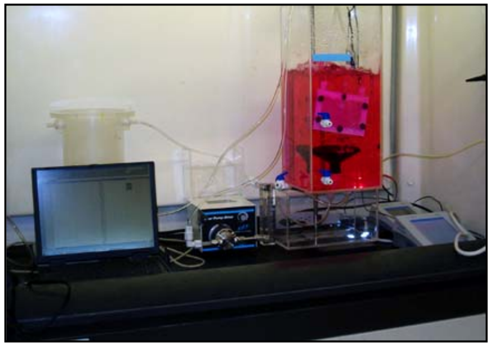
TOC = 1.3 g/L

NH_4-N = 0.065 g/L

C:N:P = 100:5:1

Batch OsMBR Process

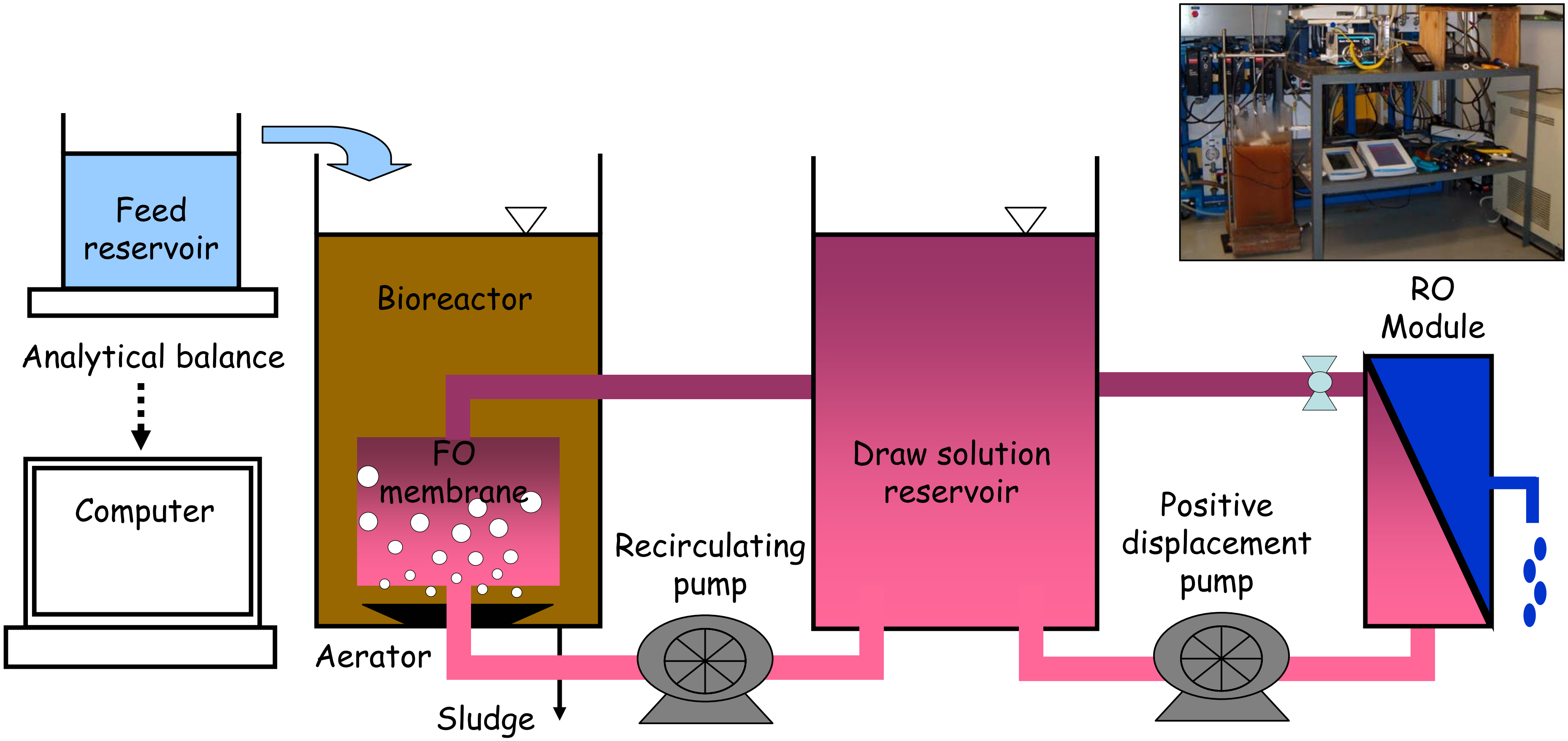




Reactor solution is DDW

Draw solution concentration decreases from 70 to 30 g NaCl/L

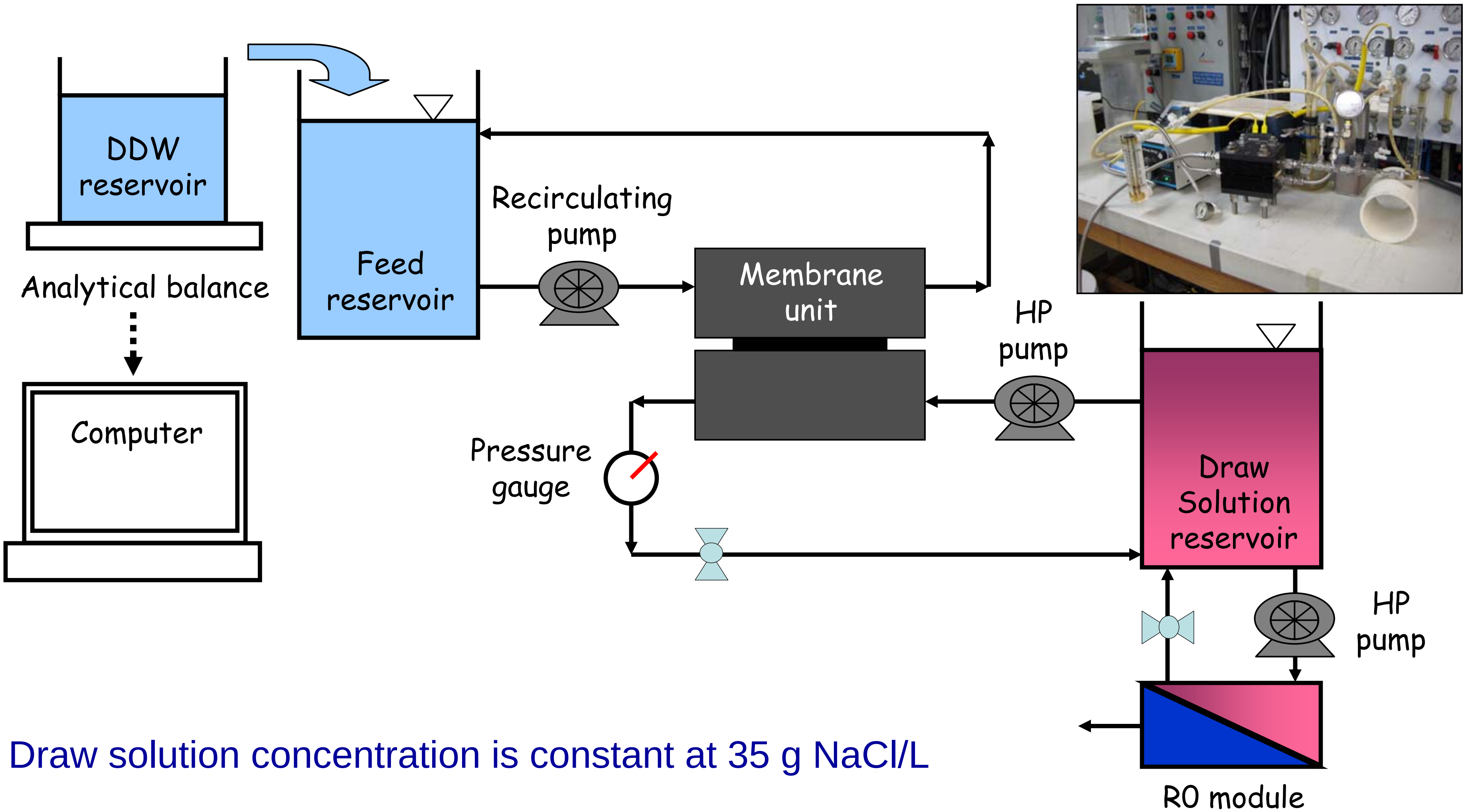
Bench Scale OsMBR System



Reactor solution is activated sludge

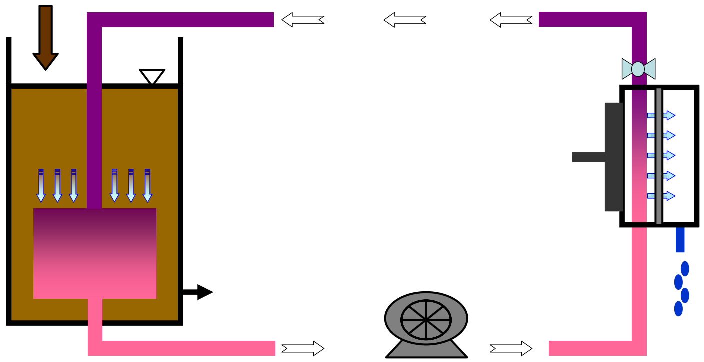
Draw solution concentration is constant at 50 g NaCl/L

Bench Scale ProMBR System



Draw solution concentration is constant at 35 g NaCl/L

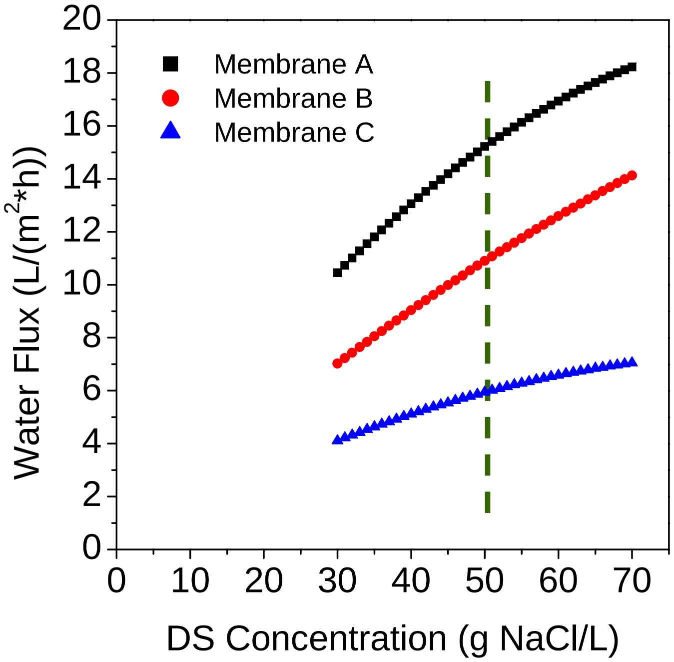
OsMBR Results

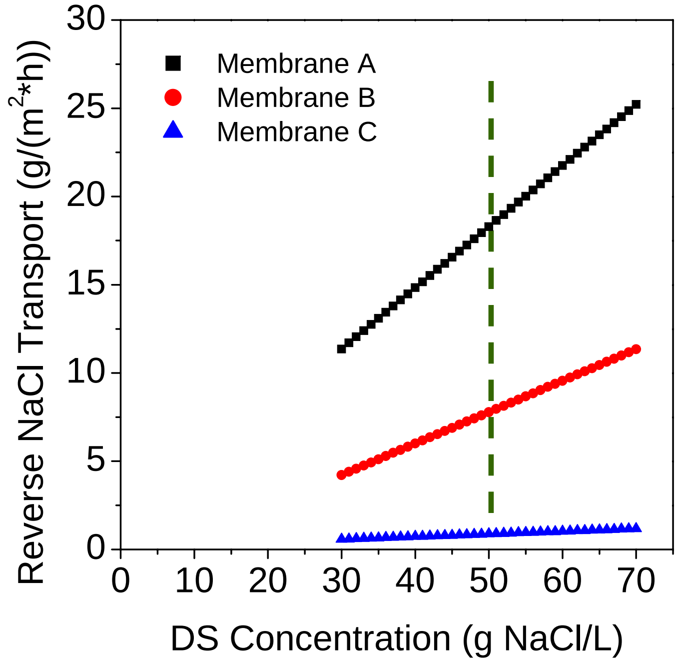


Membrane Flux Characterization

Batch experiment

Reactor solution is DDW

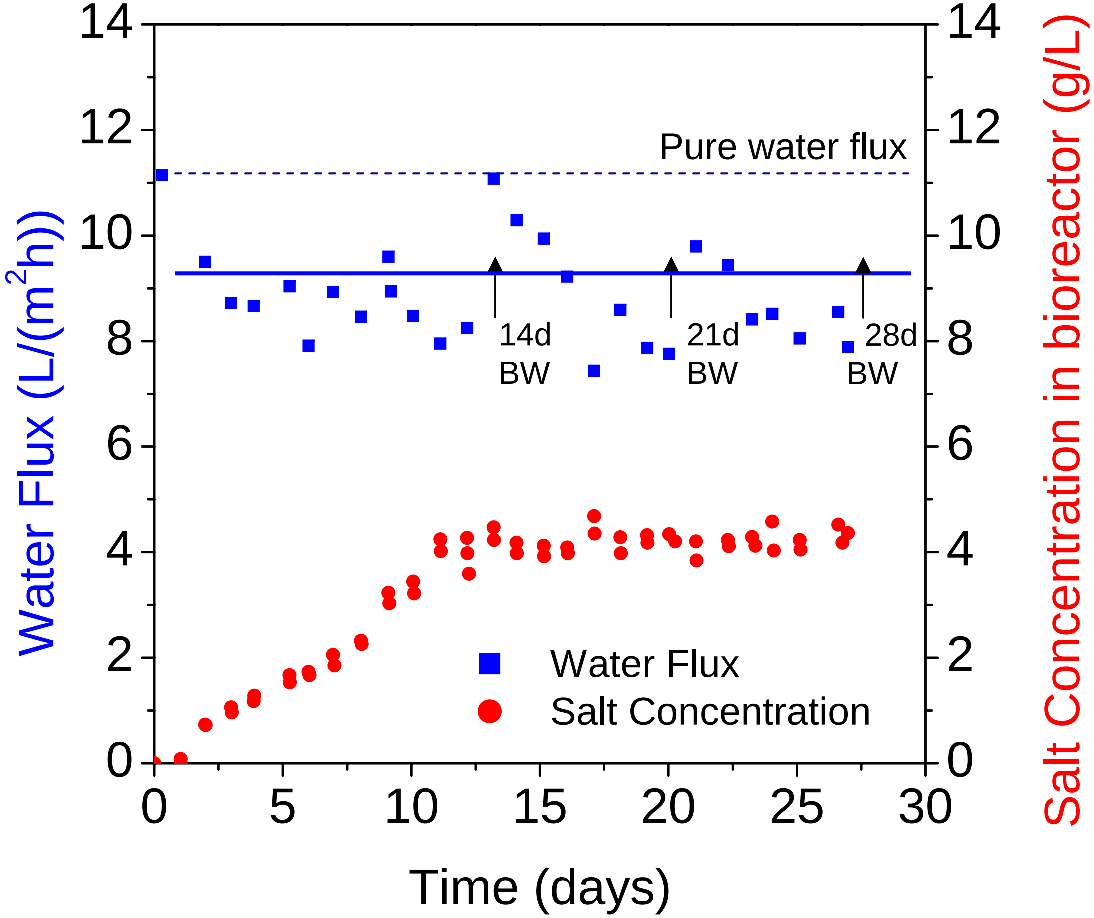




OsMBR Flux Performance

Continuous flow experiment

Membrane B
C_B = 5.5 g MLSS/L
C_{DS} = 50 g NaCl/L



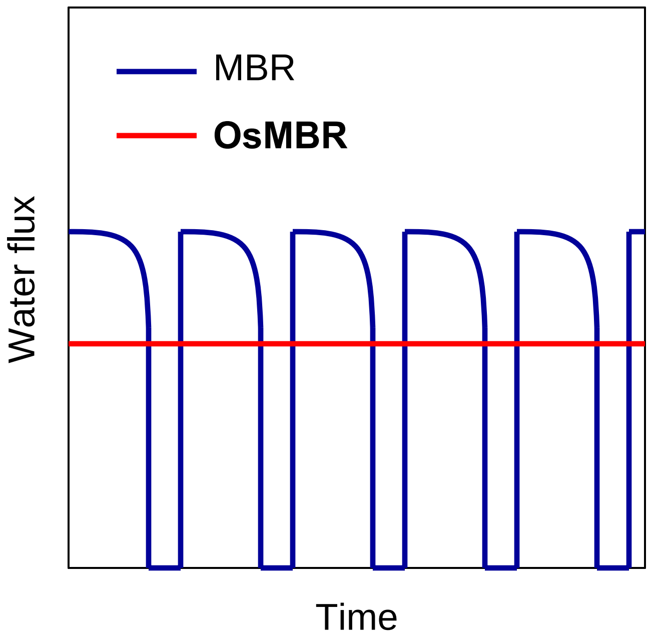
Operation Comparison

Membrane	Material	Pore size	Flux	Filtration time	Backwashing time	BW/day	Net flux	Ref.
		μm	$L/(m^2 \cdot h)$	min	min		$L/(m^2 \cdot h)$	
Hollow fiber	Polyethylene - Polysulfone	0.1	20	5-45	0.25-15[a]	24-274	15.0-18.0	2, 3, 4
Tubular	Polypropylene	0.2	8-22	30	0.25	48		5, 6
Flat sheet	C-PVC – Stainless steel	0.2-0.4	17-22	3-8	1-4[a]	120	8.7-11.0	7, 8
OsMBR	CTA	Semi-permeable	9	10,080	60	0.14	9.0	This study

[a] Relaxation time

Simplified Operation

- MBR – 15 minutes production / 1 minute backwashing and/or relaxation
- OsMBR – "smooth operation"



Water Quality

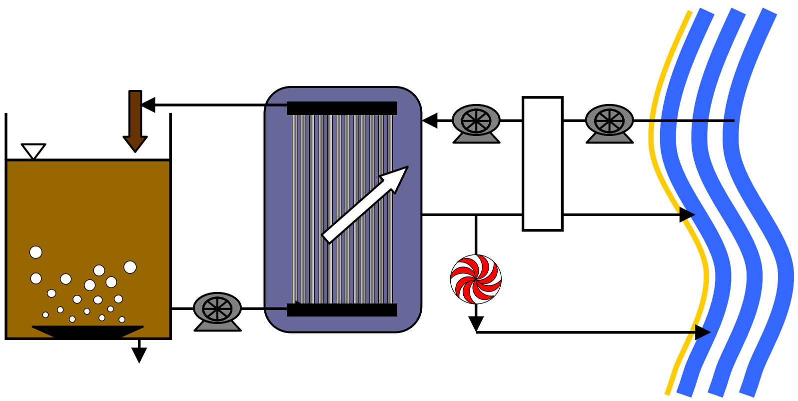
TOC and NH_4-N concentrations

	Feed	Bioreactor	Draw Solution	Product
TOC (mg/L)	1,325 ± 25	140 ± 5	3 ± 0.5	2.5 ± 0.5
NH_4-N (mg/L)	65 ± 5	15 ± 2	1.5 ± 0.5	0.4 ± 0.1

TOC and NH_4-N removal efficiencies

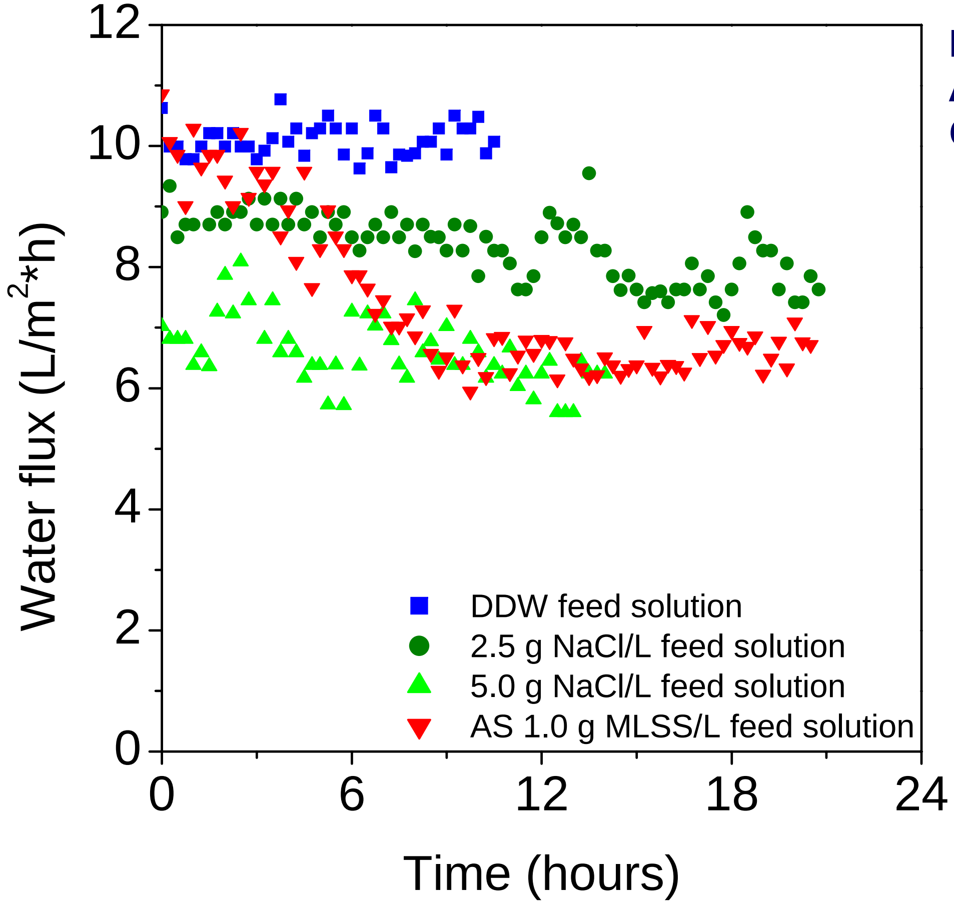
	% Rejection of FO membrane	% Removal of OsMBR process (bioreactor + FO)	% Removal of overall system (OsMBR + RO)
TOC	97.9	99.8	99.8
NH_4-N	90.0	97.7	99.4

ProMBR Results



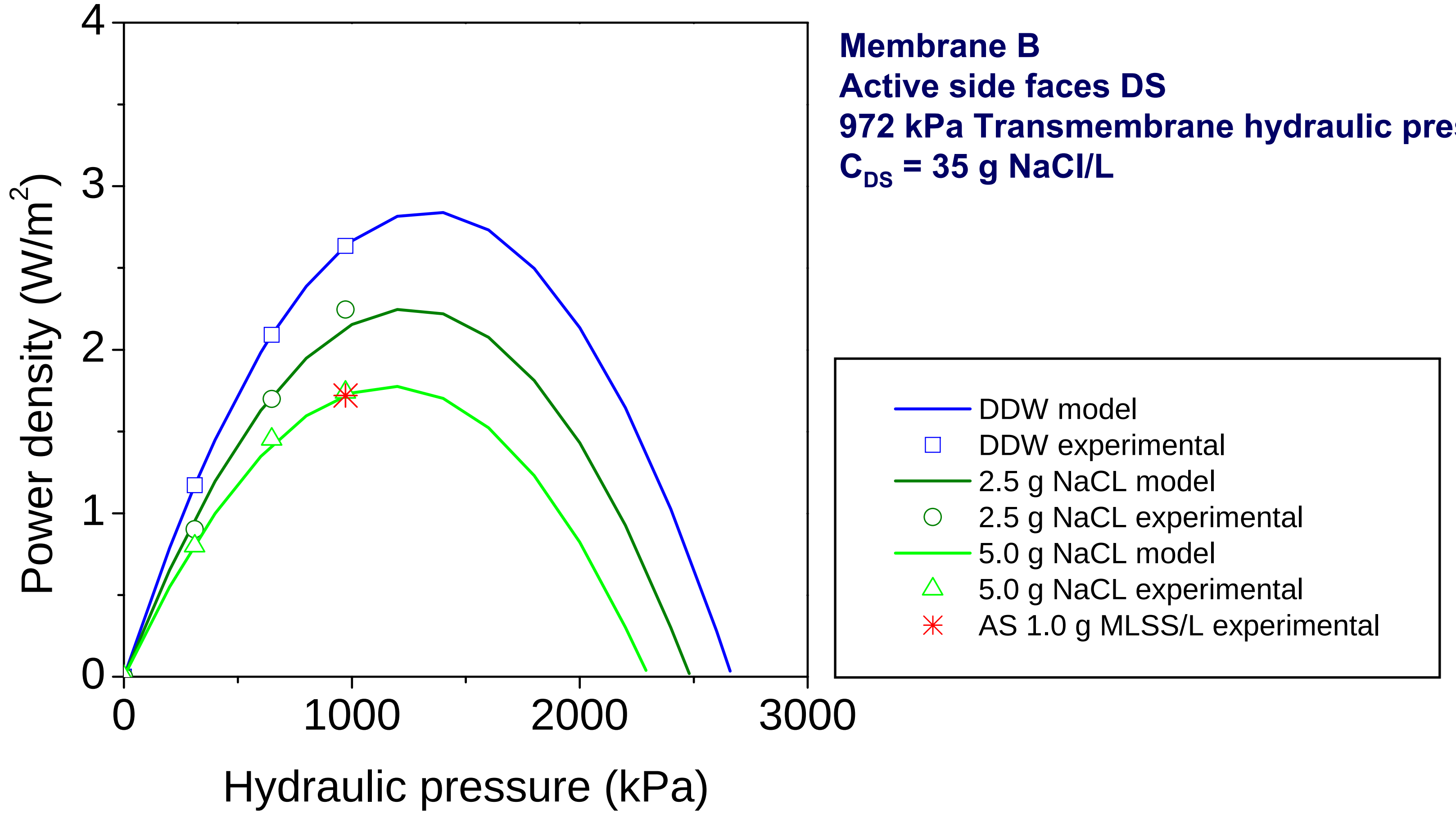
ProMBR Flux Performance

965 kPa (140 psi) transmembrane hydraulic pressure



Membrane B
Active side faces DS
C_{DS} = 35 g NaCl/L

ProMBR Power Performance



Membrane B
Active side faces DS
972 kPa Transmembrane hydraulic pressure
C_{DS} = 35 g NaCl/L

Concluding Remarks

- OsMBR
  - *Long-term water flux (9 LMH) only 18% less than pure water flux (11 LMH)*
  - *Fewer backwash cycles than conventional MBRs due to lower membrane fouling*
  - *OsMBR system removal efficiencies*
    - TOC > 99%
    - NH_4-N > 99%
- ProMBR
  - *Activated sludge water flux (6.5 LMH) 35% less than pure water flux (10 LMH)*
  - *ProMBR power density 1.7 W/m^2 @ 1000 kPa*

Acknowledgements

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Thank You

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