Osmotic dilution to combine water reuse and desalination to produce safe water at lower cost: A design study.

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Introduction

Alternative water resources

Water reuse

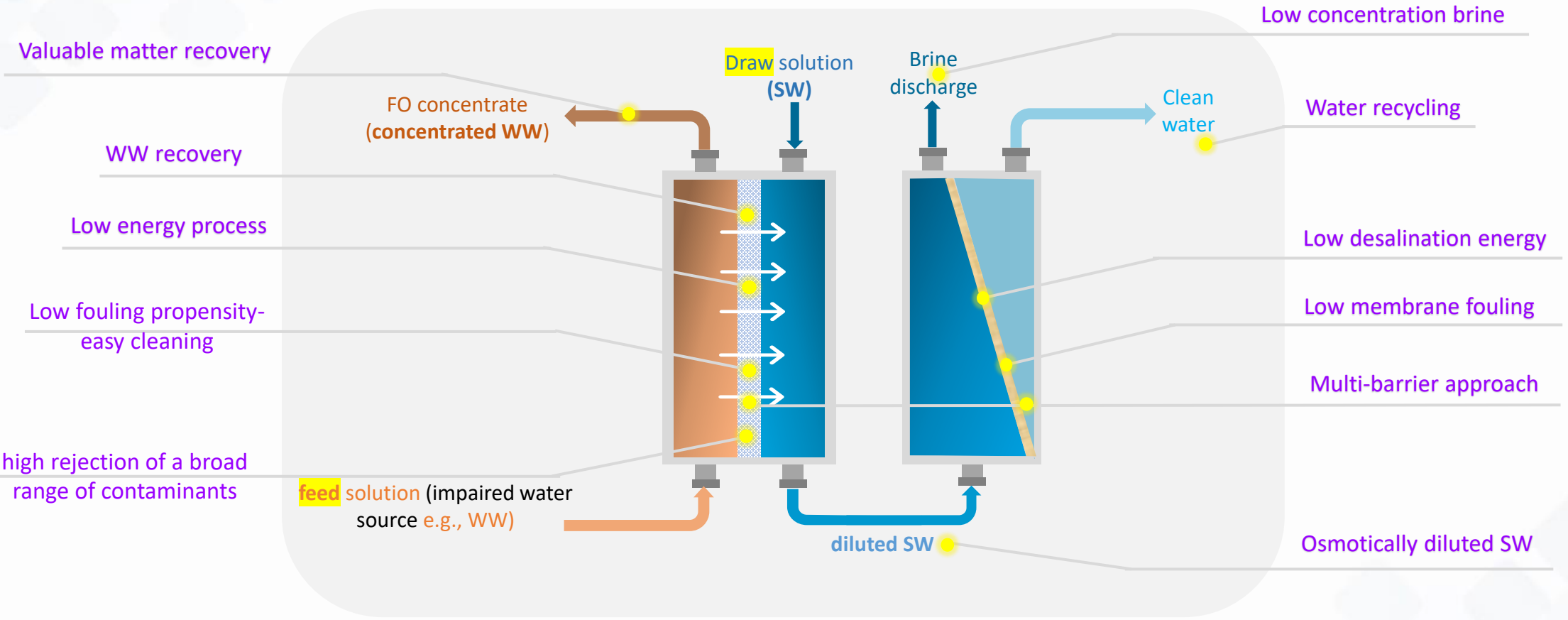
Desalination

Combining water reuse and desalination

- Lowers water intake cost
- Optimize energy efficiency of water treatment

FO: Forward Osmosis; **RO:** Reverse Osmosis**; WW:** Wastewater; **SW:** Seawater

FO – RO hybrid



Combining water reuse and desalination through FO-RO hybrid

Can a FO-RO hybrid system achieve 90 % WW recovery and desalination energy below 1 kWh/m³?

Forward factory

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Can a forward osmosis-reverse osmosis hybrid system achieve 90 % wastewater recovery and desalination energy below 1 kWh/m^3? A design and simulation study

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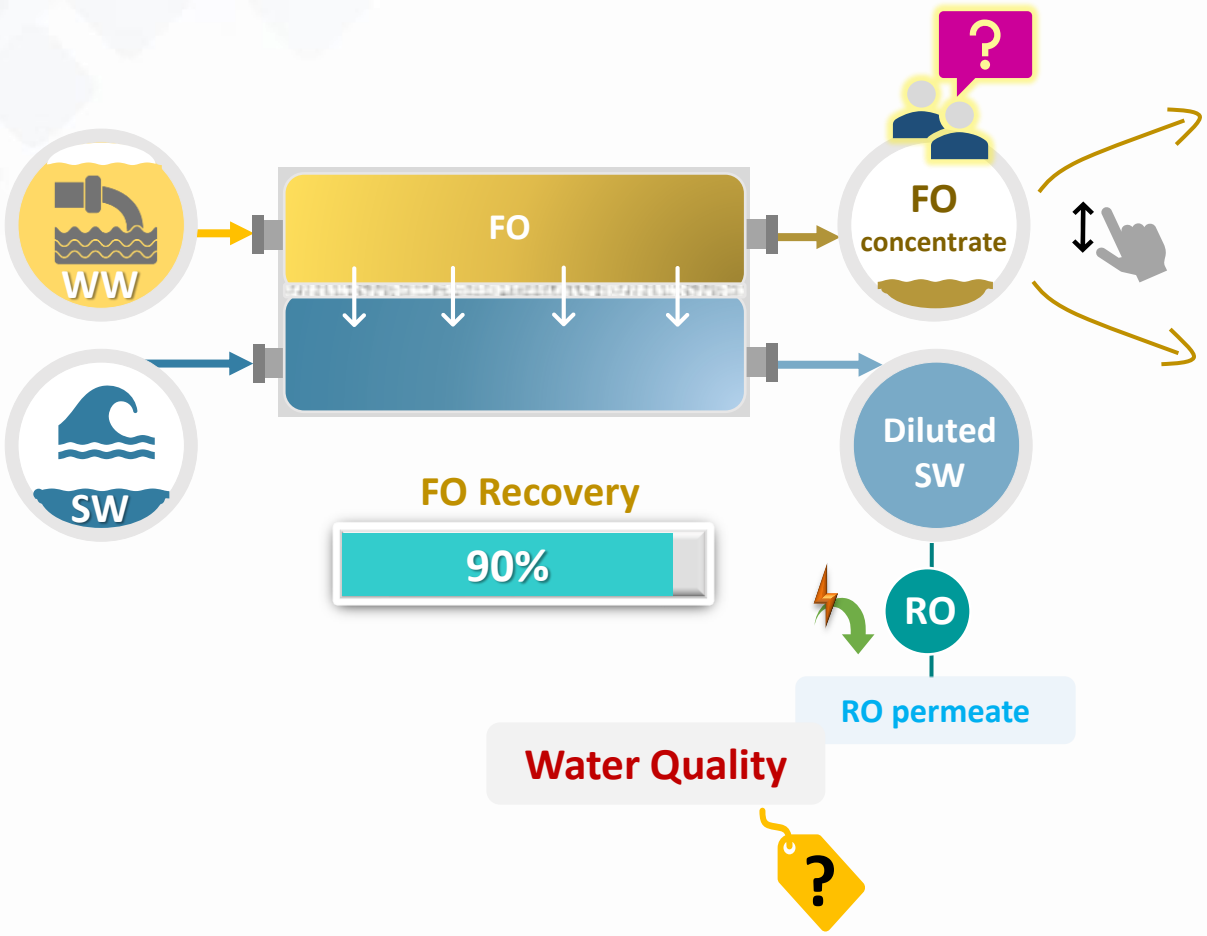
Optimal configuration - **80:20** WW-to-SW volume ratio and initial WW salinity of **0.5 g/l.**

For more info: Scan this QR code (open access)

What about the water quality produced from RO?



How can the FO concentrate stream be treated or utilized effectively?

- Less in volume
- Highly concentrated (10 times concentrated WW)

Thanks to the high rejection capabilities of FO

Resource recovery

Organic matter → Biogas

Nutrients → Biofuels

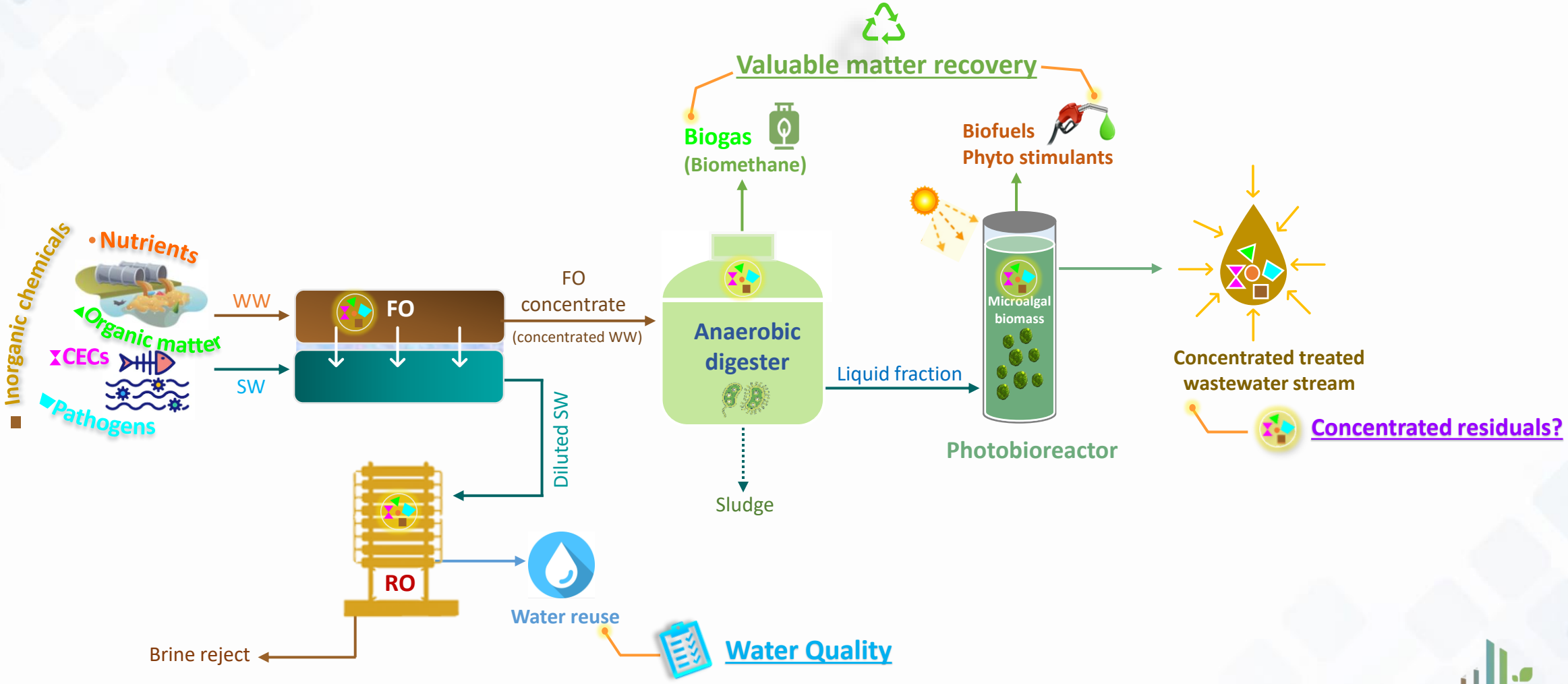
On the other hand

FO → Concentrated WW stream with pathogens, Inorganic chemicals, CECs

CECs: Contaminants of Emerging concern

Research Focus

Evaluating FO-RO-AD-PBR hybrid: Valuable matter recovery, fate of pollutants & Water Quality



CECs: Contaminants of Emerging concern; **AD:** Anaerobic digestor; **PBR:** Photobioreactor

Forward Factory

Evaluating FO-RO-AD-PBR System: Resource recovery; Safe water reuse; fate of entering pollutants

Study on existing literature

The study identified the type and magnitude of **interactions** between each **pollutants** and the **processes**.

Interactions
- Rejection
- Degradation
- Removal
- Combinations of above

Processes
- Forward Osmosis (FO)
- Reverse Osmosis (RO)
- Anaerobic digestion (AD)
- Photobioreactor (PBR)

From the literature study, **a specific value was selected** to represent the interaction between the pollutant and the process.

Development of Excel based model

An Excel model was developed for the **FO-RO-AD-PBR** system.

Simulating model for various operating conditions

- **Water quality**
- **Resource recovery**
- **Assess the fate of pollutants**

Pollutants Concentration

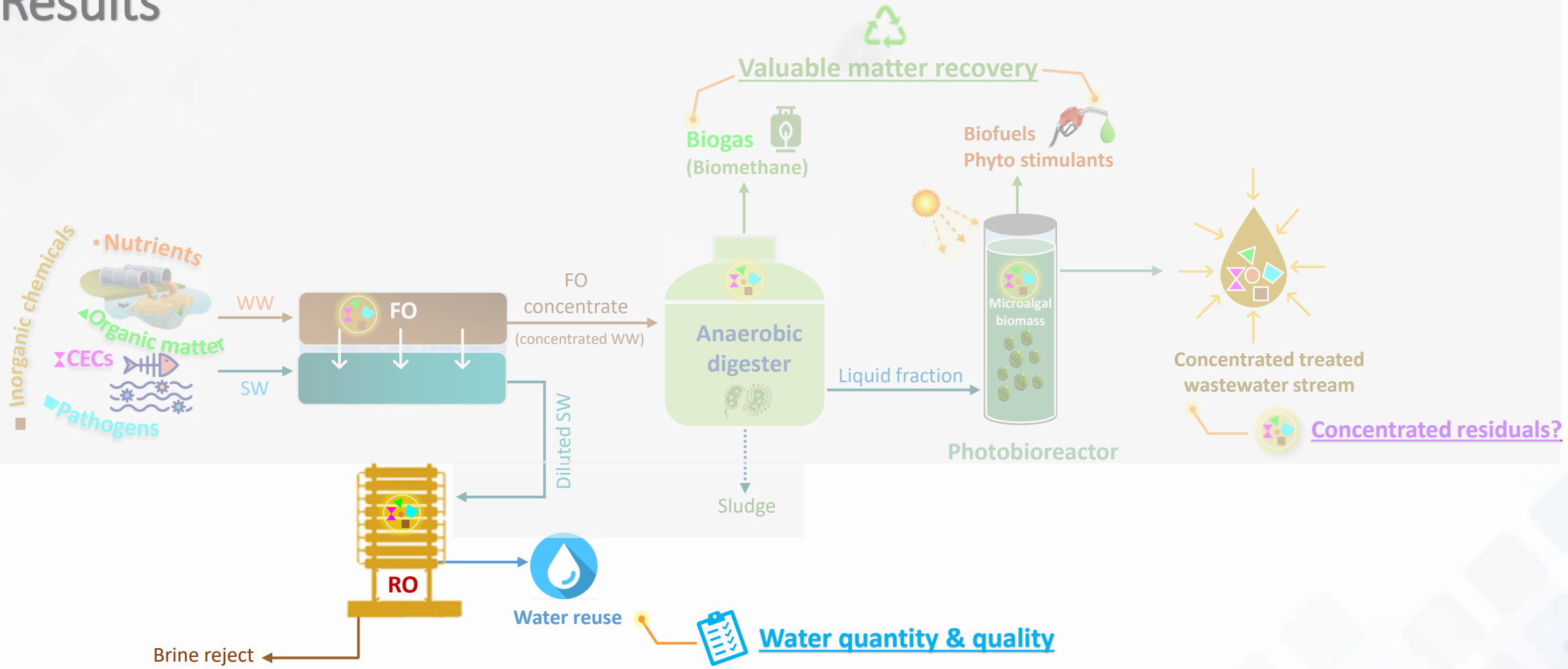
		WW	SW
Inorganic chemicals	NaCl (mg/l)	500	35000
	Boron (mg/l)	1	5
Organic matter	COD (mg/l)	508	1
Nutrients	Ammonium (mg/l)	25	0
	Phosphorous (mg/l)	5.6	0.2
Pathogens	Bacteria (CFU/100ml)	1.0E+07	2.0E+02
	E.coli (CFU/100ml)	6.6E+06	5.0E+02
	Virus (Genome copies/L)	5.8E+08	0.0E+00
CECs	PFAs (µg/L)	50	0.0005
	Microplastics (µg/L)	20	100
	Pharmaceuticals (µg/L)	2	2

Pollutants interaction with processes chosen from literature

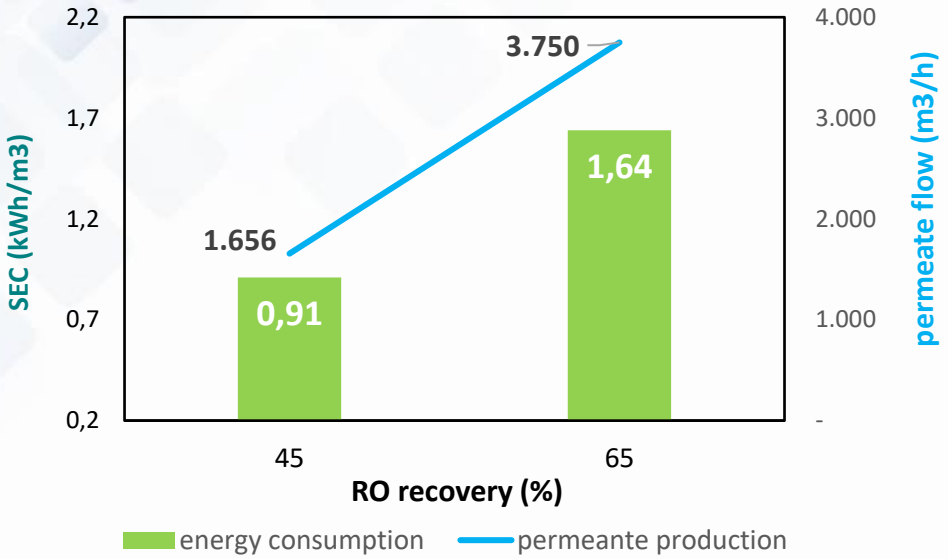
	FO: rejection *TFC*	RO: rejection *High rejection*	AD: removal *Mesophilic*	PBR: removal *C. vulgaris*
Inorganic chemicals	RSD:0.15 g/l	99.5%	0 %	0%
	46 %	86%	0 %	21.4%
Organic matter	97%	96%	90%	97%
Nutrients	74%	99%	-71%	97%
	75%	99.98%	49%	92%
Pathogens	LRV: 3.40	LRV: 4	LRV: 2	LRV: 2.73
	LRV: 4.90	LRV: 4	LRV: 2	LRV: 2.73
	LRV: 6.10	LRV: 4	LRV: 2	LRV: 1.05
CECs	98%	99%	50%	37%
	100%	99.9%	44%	84%
	95%	95%	90%	90%

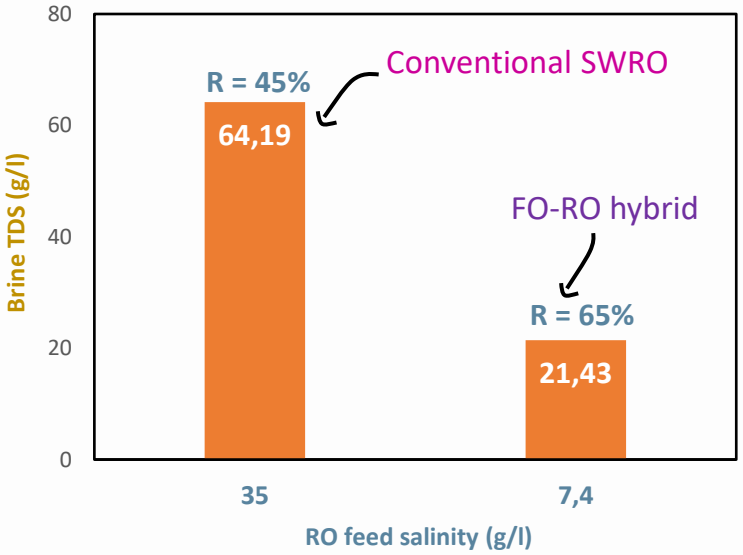
AD: Anaerobic digester; **PBR:** Photobioreactor; **E.coli:** Escherichia coli; **CFU:** Colony-forming units; **NaCl:** Sodium Chloride; **COD:** Chemical oxygen demand; **PFAs:** Per- and polyfluoroalkyl substances; **LRV:** Log reduction value; **RSD:** Reverse salt diffusion; **TFC:** Thin film composite; **CTA:** Cellulose triacetate

Results


Valuable matter recovery
Biogas
(Biomethane)
Biofuels
Phyto stimulants
Inorganic chemicals
Nutrients
Organic matter
CECs
Pathogens
WW
SW
FO
FO
concentrate
(concentrated WW)
Anaerobic
digester
Liquid fraction
Microalgal
biomass
Photobioreactor
Concentrated treated
wastewater stream
Concentrated residuals?
Diluted SW
Sludge
RO
Water reuse
Water quantity & quality
Brine reject

Results: Water for reuse - Quantity





TDS: Total Dissolved Solids

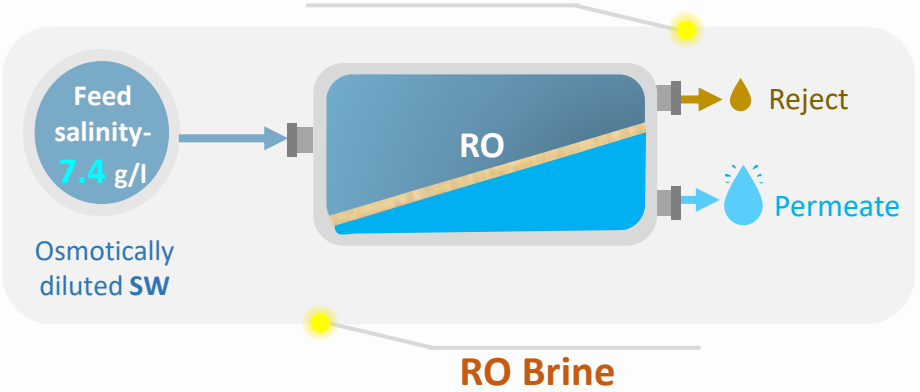
Low Energy

FO-RO		Conventional SWRO
1.64	<	2.81 (2 pass)
65	>	45

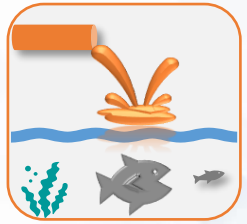
High Recovery

With same plant design

RO permeate production and energy consumption



- ✓ Low brine volume
- ✓ Brine Salinity (21.43 g/l) < SW salinity (35 g/l)
- ✓ Safer discharge



Conclusion

Water Quality

- ✓ Produce safe water for reuse
- ↓ Lower energy consumption
- ↓ Lower brine concentration & volume

Resource recovery

- Organic matter → Methane (Biogas production)
- Nutrients → Microalgae (pathway to harvest)

Fate of pollutants

- − Partial to substantial removal of contaminants
- ? How to manage the concentrated treated WW stream?

Next steps

- Model refinement and validation through experimental data
- Sensitivity analysis of the model
- Cost-benefit analysis
- Evaluate the system against alternative schemes, potentially incorporating up to a three-stage FO process, to develop a decision support system that optimizes the selection of an efficient treatment train.

Thank you for your kind attention.

Also, thanks to…

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