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WASTEWATER RECLAMATION IN INDUSTRY

Combining Membrane Bioreactor (MBR) and Membrane Capacitive Deionization (MCDI) Technologies

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CONTENT

- Introduction
- Proposed Concept
- Premilinary Financial Performance Indicators
- Conclusion
- Q&A
- Example of MBR & MCDI study by LUT teams

Introduction

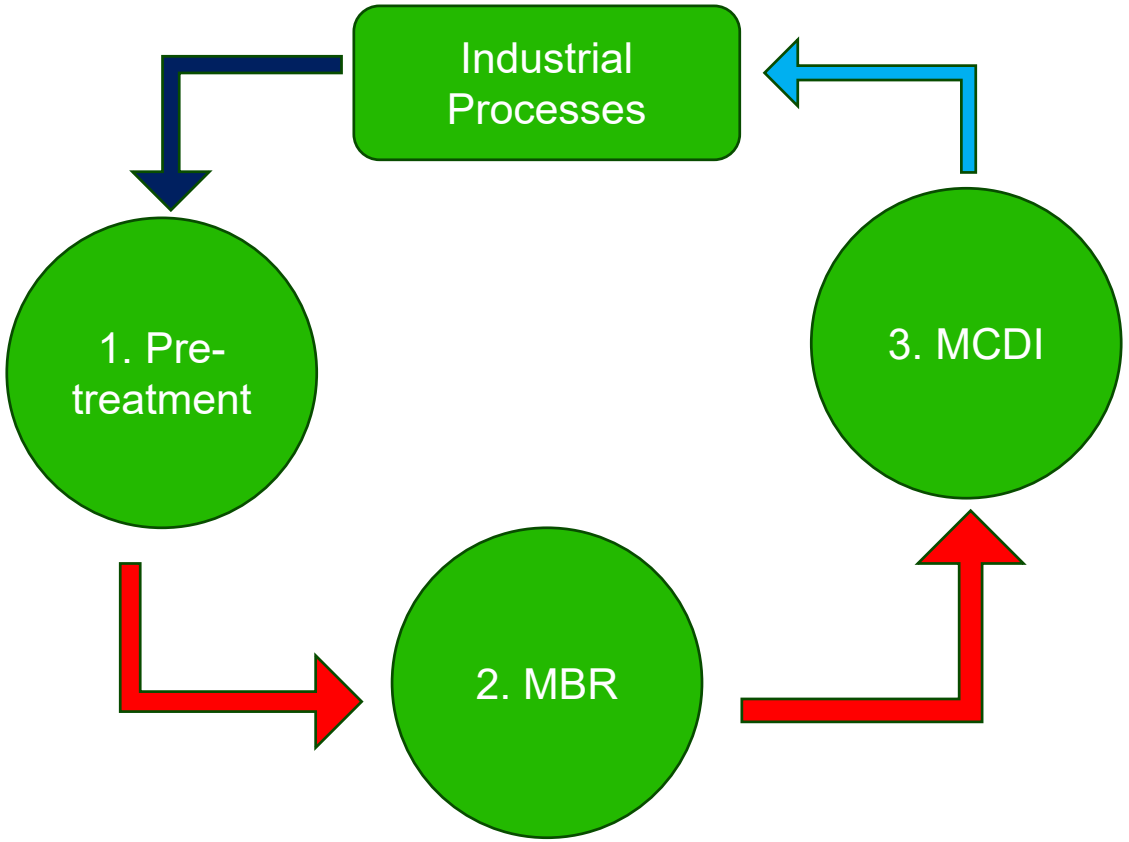
TYPICAL WASTEWATER CHARACTERISTICS

Parameter	Value	Unit	Feed limit for reuse	Estimated Removal Efficiency
pH	7		6 to 9	
Total hardness	251	mg/l as CaCO3	50	80%
Chloride	806.31	mg/l	100	88%
TDS-105°C	2016	mg/l	1000	50%
Conductivity (25°C)	3130	uS/cm	200 to 1500	52% - 94%
Total alkalinity (p-value)	<0.150	mmol/l	0.1	
Total alkalinity (m-value)	5.01	mmol/l	2.5	50%
Colour	N/A	mg/L Pt/Co	20	
TSS-105°C	112	mg/l	Absent	100%
Bacteria	N/A	-	Low bacteria count and absent of pathogenic bacteria	99%
BOD5	580.3	mg/l		>90
COD	1408.5	mg/l		>90

- In comparison to the characteristics of wastewater, total dissolved solids (TDS), presence of particles (TSS), and bacteria are main challenges in the treatment process.
- Although COD (organic matter) in feed limit has not been specified, a maximum level for COD (160mg/L) has been established for reuse purpose*.
- **In overall, these contaminations should be removed at least 50%**

*According to Royal Decree 1620/2007 (Spain) and Decree 174/1994 (Canary Islands, Spain

PROPOSED CONCEPT



- **Pre-treatment technology:** remove large solids and debris from wastewater (TSS)
- **Membrane Bioreactor (MBR) technology:** remove organic (COD), TSS, bacteria
- **Membrane Capacitive Deionization (MCDI):** remove TDS
- **Fit-for-purpose reuse**

Proposed concept

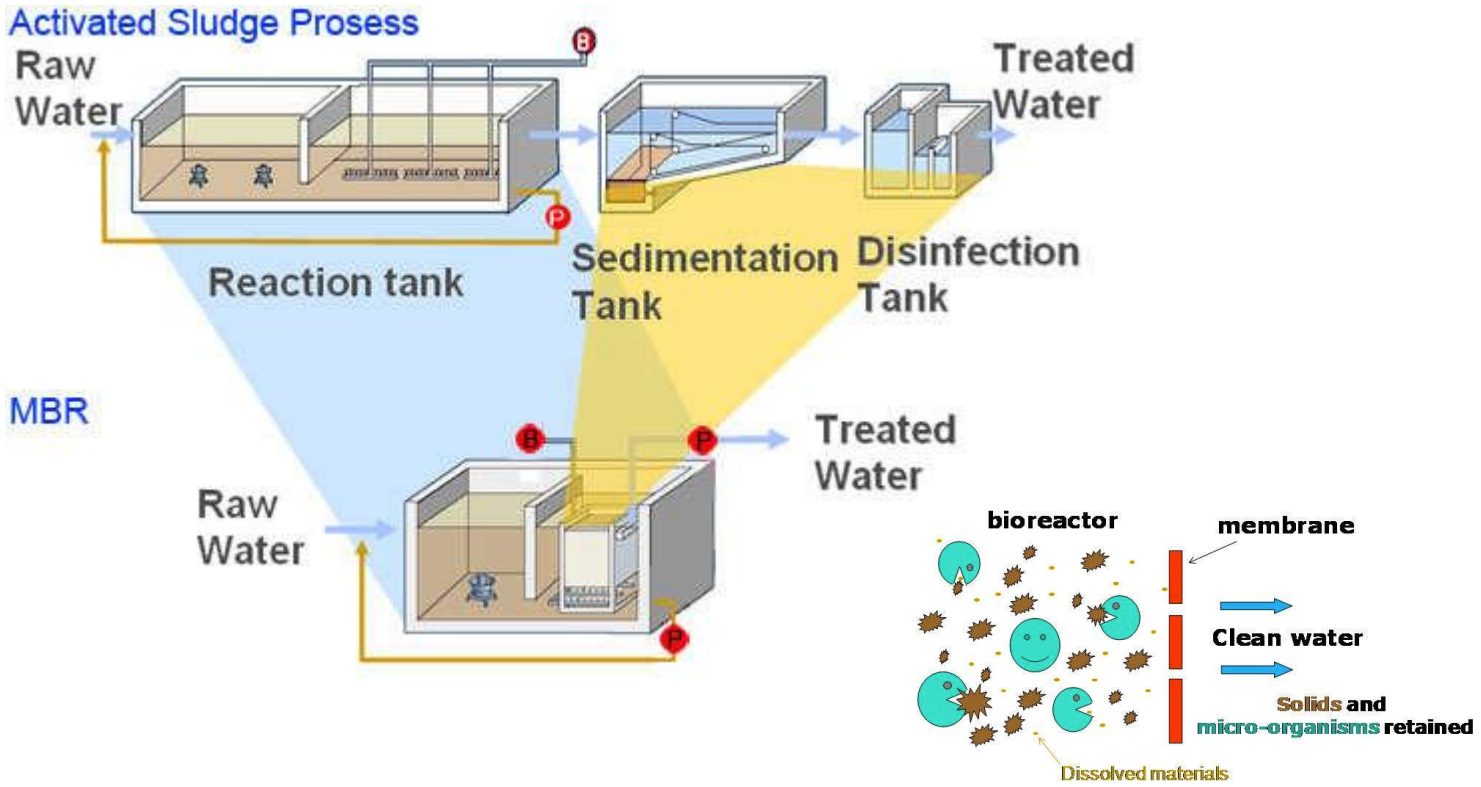
PRE-TREATMENT EQUIPMENT

- Cross flow filtration
- Filtration of particle size down to 0.3 um
- Ultrasonic self-cleaning

Proposed concept

MEMBRANE BIOREACTOR (MBR)

- MBR technology is a combination of the conventional biological sludge process (growth of biomass) with a micro- or ultrafiltration membrane system.
- The biological unit is responsible for the biodegradation of the waste compounds and the membrane module for the physical separation of the treated water from the mixed liquor.

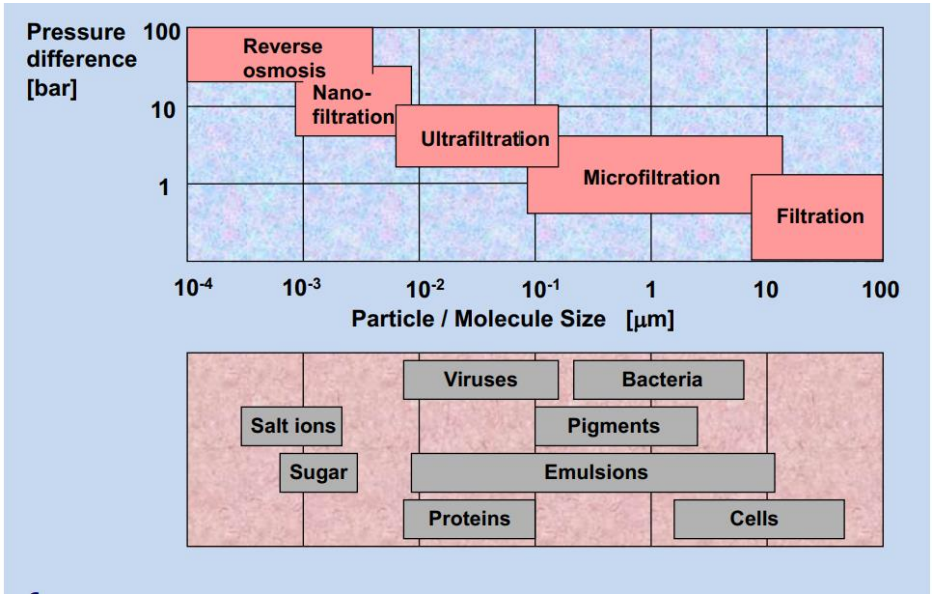


Judd, S. (2011) The MBR Book: Principles and Applications of Membrane Bioreactors for Water and Wastewater Treatment. Second Edition, Elsevier, Oxford.
https://environmentclearance.nic.in/writereaddata/Online/TOR/20_Mar_2017_182733947DGF5W8RAPrefeasibilityReport.pdf
https://upload.wikimedia.org/wikipedia/commons/2/2c/MBR_Schematic.jpg

Proposed concept

MEMBRANE BIOREACTOR (MBR)

- The pore diameter of the membranes is 0.01 - 0.1 µm.
- Particulates and bacteria can be kept out of permeate and the membrane system replaces the traditional gravity sedimentation unit (clarifier) in the biological sludge process.

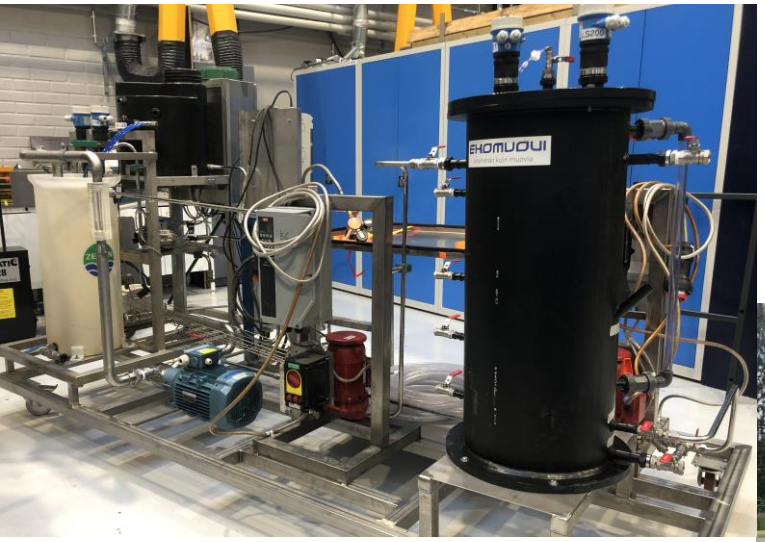


(actual membrane at LUT)

Typical flux: 30 l/m2.h, "overflux“ up to 50 l/m2.h
Full backflush with 350 mbar
Straight plates, defined gap of 6-8 mm
Material: Polyethersulfone
Pore Size (nominal): 0.04 µm

Proposed concept

MBR PILOT AT LUT



Membrane area: 1 m²

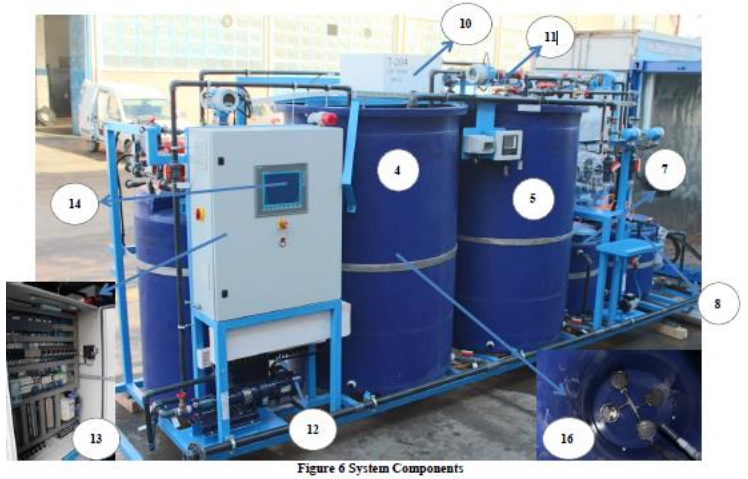


Figure 6 System Components

Membrane area: 8 m²

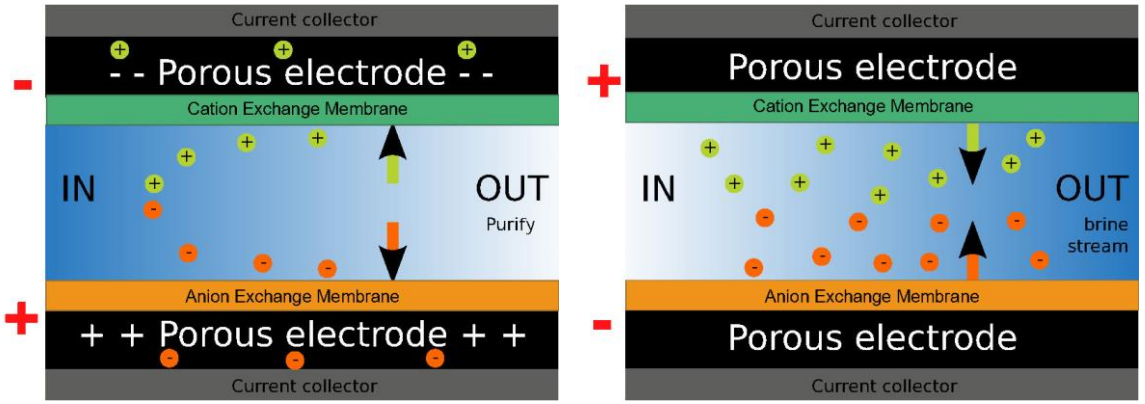
Proposed concept

COMPARISON OF MBR TECHNOLOGY VS. CONVENTIONAL BIOREACTORS

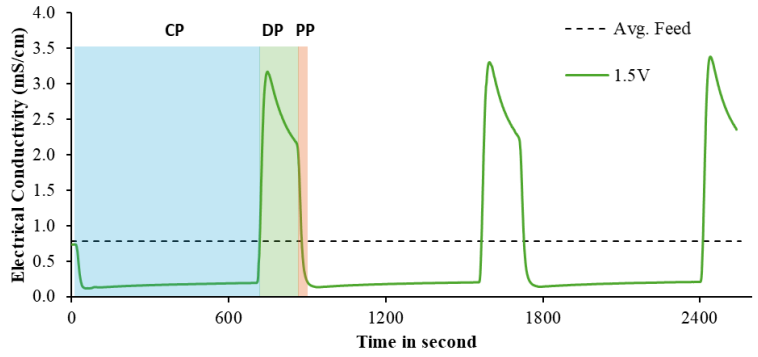
	MBR	Conventional Biological Treatment
Effluent Quality	High (low suspended solids, turbidity, pathogens)	Moderate to high (may need additional treatment)
Space Requirements	Compact (integrated system)	Larger footprint (separate units)
Sludge Production	Lower (longer sludge retention times)	Higher
Flexibility	High (handles load fluctuations well)	Moderate

Proposed concept

MEMBRANE CAPACITIVE DEIONIZATION (MCDI)



Schematic MCDI principle for adsorption/charge (left) and desorption/regeneration (right) process



In practice, each cycle consisted of three phases:

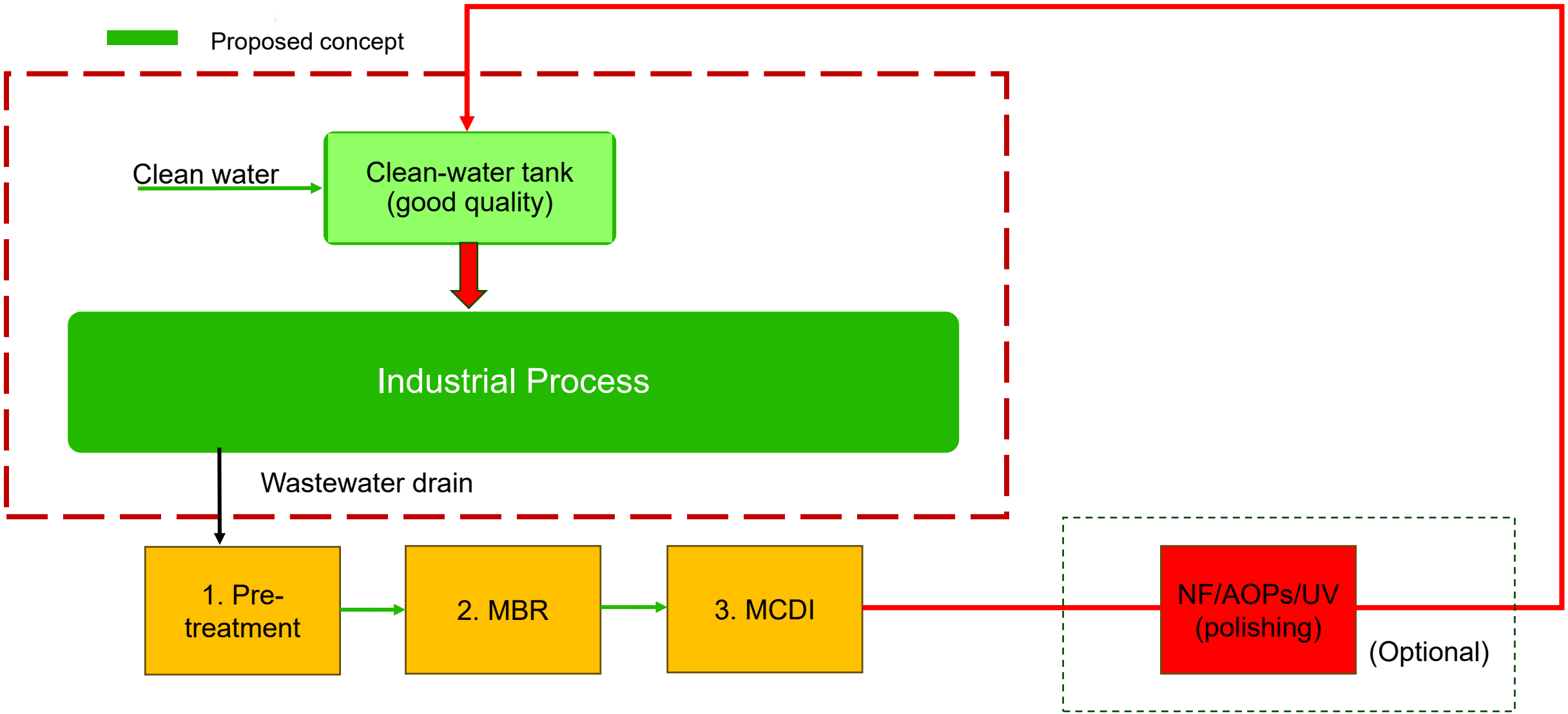
- Charge phase CP: with positive polarity for desalination generating purify stream (product water)
- Discharge phase DP: for electrode regeneration by applying negative voltage generating brine stream (waste)
- Pre-charge phase PP: for purging the brine out of module before desalination begins

MCDI pilot at LUT

Proposed concept

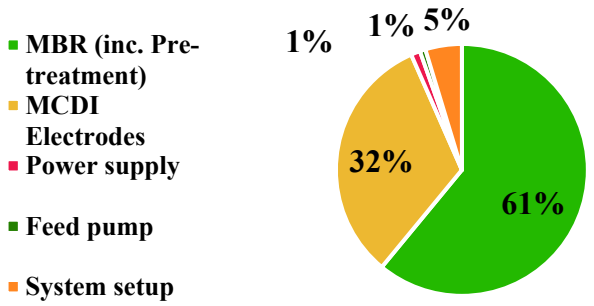
COMPARISON MCDI WITH RO

	MCDI	RO
Water Recovery	Achieves up to 90% water recovery. Less brine.	Achieves 50-85% water recovery. Significant amount of brine.
Specific Energy Consumption	Generally < 1 kWh/m³ More energy-efficient for low to moderate salinity water.	Seawater: 3-6 kWh/m³ Brackish water: 1-2.5 kWh/m³
Working Pressure	Does not need high-pressure pumps, typically a longer membrane lifespan	Seawater: 55-69 bar Brackish water: 7-41 bar
Water Quality	Flexible in adjusting water quality.	Produces high purity water.
Fit-for-Purpose Applications	Suitable for applications requiring specific ion compositions (e.g., agricultural irrigation, laundry…).	Ideal for high purity water needs (e.g., drinking water, medical applications).


Proposed concept
Clean water
Clean-water tank
(good quality)
Industrial Process
Wastewater drain
1. Pre-
treatment
2. MBR
3. MCDI
NF/AOPs/UV
(polishing)
(Optional)

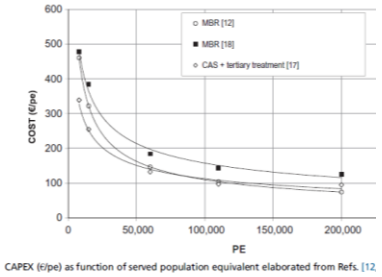
Premilinary Financial Performance Indicators

CAPEX 1.37M EUR

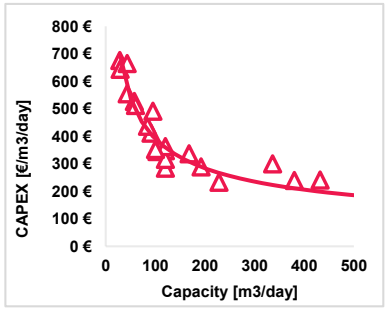


Design capacity:
360 m³/day

MBR

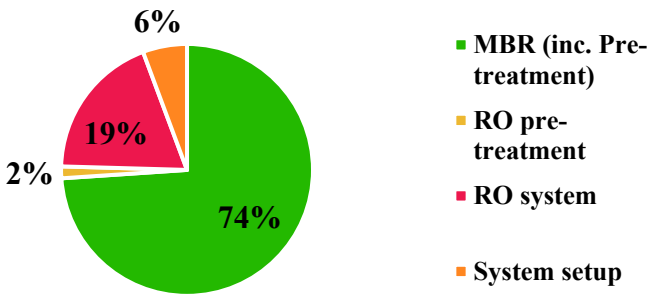


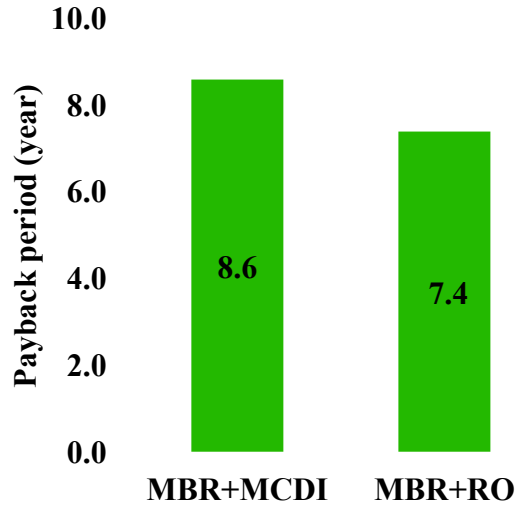
CAPEX (€/pe) as function of served population equivalent elaborated from Refs. [12



RO

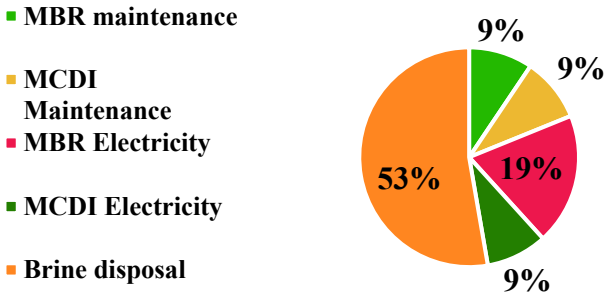
CAPEX 1.14M EUR





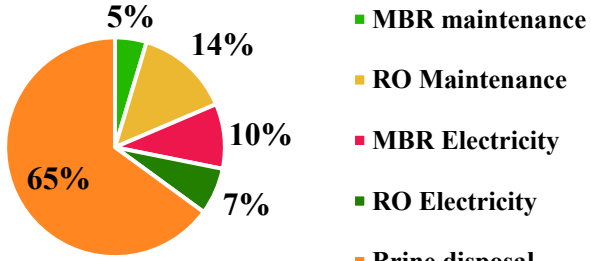
Discount Rate:10.0%

OPEX 44k EUR/yr
Water cost: 1.55 EUR/m3



MBR+MCDI

OPEX 89k EUR/yr
Water cost 2.07 EUR/m3



MBR+RO

Water rate, 1.51 €/m3, HSY
Wastewater rate, 1.77 €/m3, HSY
Price of electricity: 0.08 €/kWh (https://stat.fi/index_en.html)
MBR: https://doi.org/10.1016/B978-0-12-819854-4.00013-7
RO: https://doi.org/10.1016/j.scitotenv.2021.152842
MCDI: https://doi.org/10.1016/j.seppur.2015.03.031

CONCLUSION

MBR is highly effective in removing organic contaminants; however, the actual performance and membrane fouling have not been fully studied in the industry.

Although RO provides better water quality reuse compared to MCDI, its operational costs are excessively high (twice). Theoretically, MCDI offers higher water recovery and better energy efficiency, while providing more flexibility in tuning water quality compared to RO.

Example of MBR & MCDI study by LUT teams

MEMBRANE BIOREACTOR AND PROMISING APPLICATION FOR TEXTILE INDUSTRY IN VIETNAM

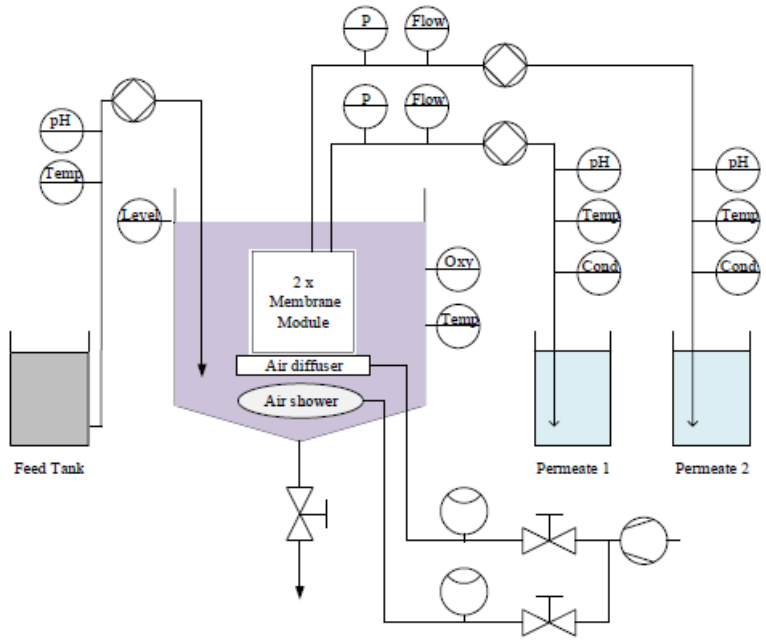
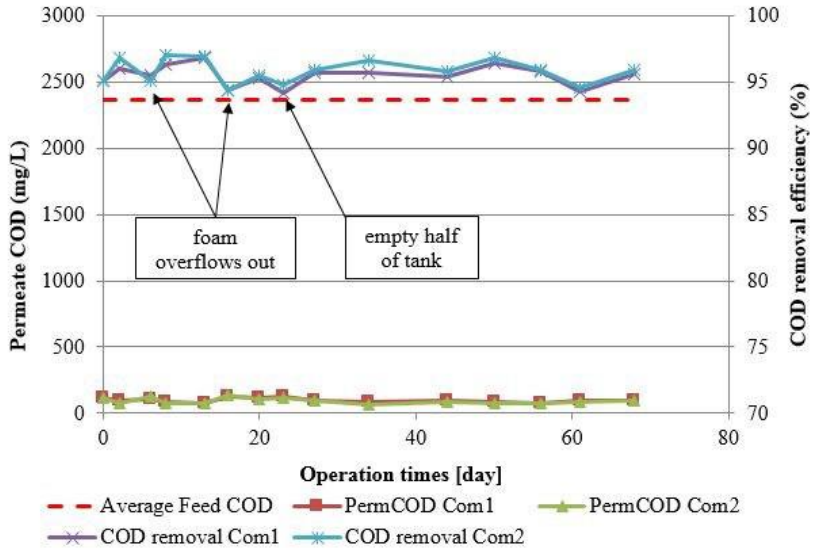


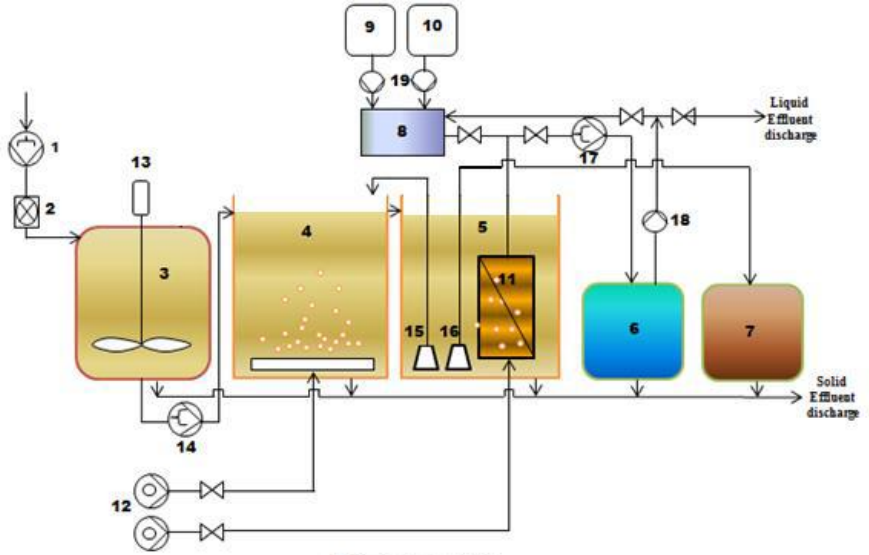
Fig. 2. Schematic diagram of membrane bioreactor



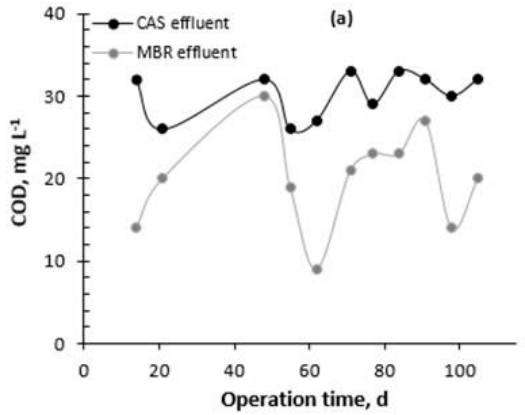
https://doi.org/10.1016/j.procir.2016.01.083

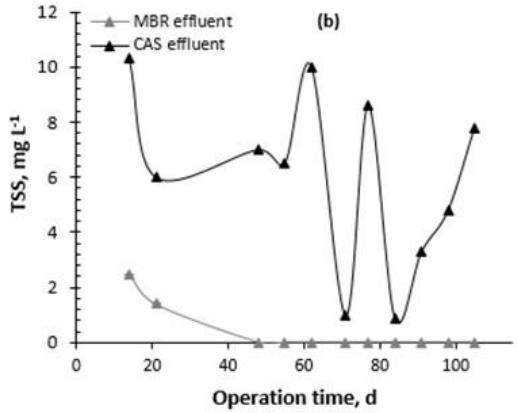
Example of MBR & MCDI study by LUT teams

INCORPORATING SUBMERGED MBR IN CONVENTIONAL ACTIVATED SLUDGE PROCESS FOR MUNICIPAL WASTEWATER TREATMENT: A FEASIBILITY AND PERFORMANCE ASSESSMENT



1. Influent pump
2. Basket filter
3. Anaerobic tank (600L)
4. Aerobic reactor (2000L)
5. Membrane Filtration tank (2000L)
6. Permeate tank (250 L)
7. Sludge tank (250L)
8. CIP tank (60L)
9. NaOCl dosing tank (100L)
10. Citric acid dosing tank (100L)
11. Flat-sheet membrane
12. Air blowers
13. Mixture
14. Influent pump
15. Submersible circulation pump
16. Excess sludge removal pump
17. Permeate pump
18. Permeate backwashing pump
19. Chemical dosing pumps



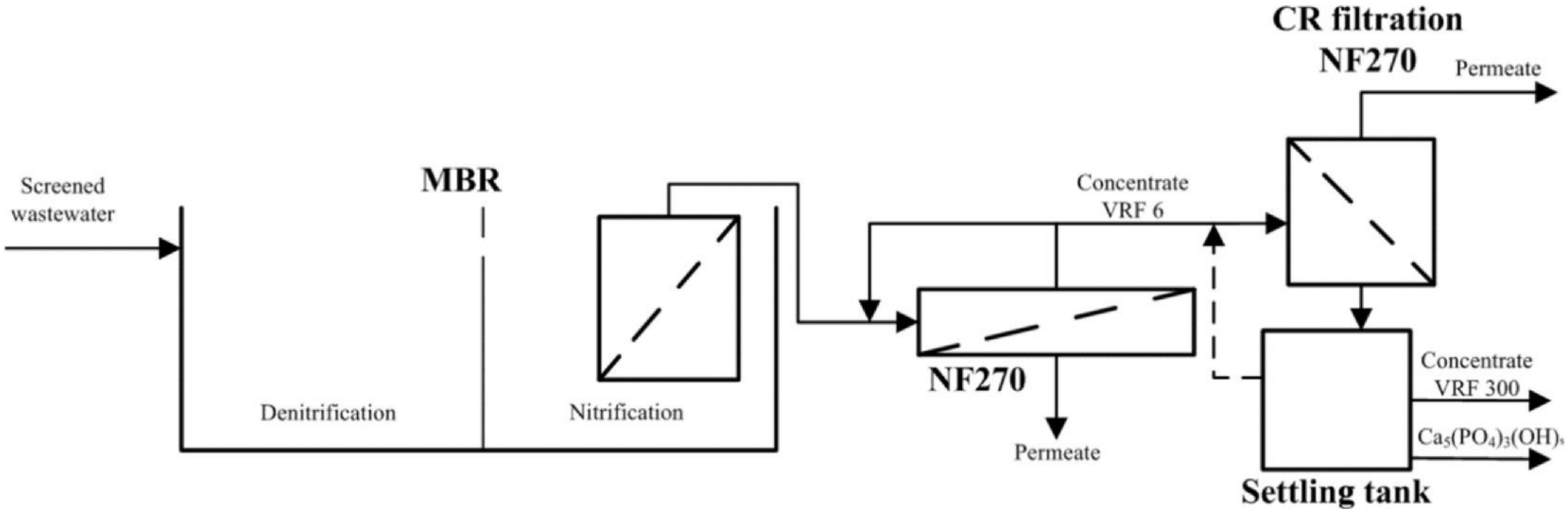


Concentrations of (a) COD; and (b) TSS in MBR and CAS effluents.

10.4172/2155-9589.1000158

Example of MBR & MCDI study by LUT teams

TWO-STAGE NANOFILTRATION FOR PURIFICATION OF MEMBRANE BIOREACTOR TREATED MUNICIPAL WASTEWATER – MINIMIZATION OF CONCENTRATE VOLUME AND SIMULTANEOUS RECOVERY OF PHOSPHORUS



https://doi.org/10.1016/j.seppur.2020.117255

Example of MBR & MCDI study by LUT teams

MODULAR DESALINATION CONCEPT WITH LOW-PRESSURE REVERSE OSMOSIS AND CAPACITIVE DEIONIZATION: PERFORMANCE STUDY OF A PILOT PLANT IN VIETNAM IN COMPARISON TO SEAWATER REVERSE OSMOSIS

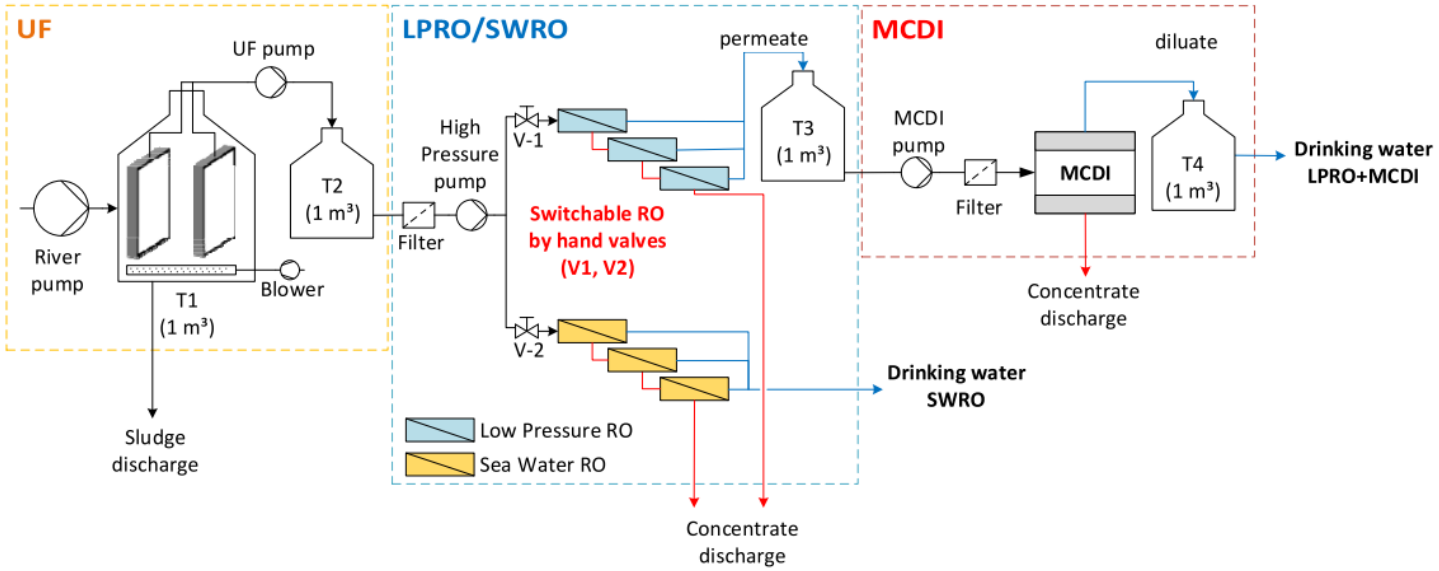


Fig. 2. Scheme of pilot-scale plant in Can Gio consisting of ultrafiltration UF pre-treatment, low-pressure and seawater reverse osmosis (LPRO/SWRO) and membrane capacitive deionization (MCDI).

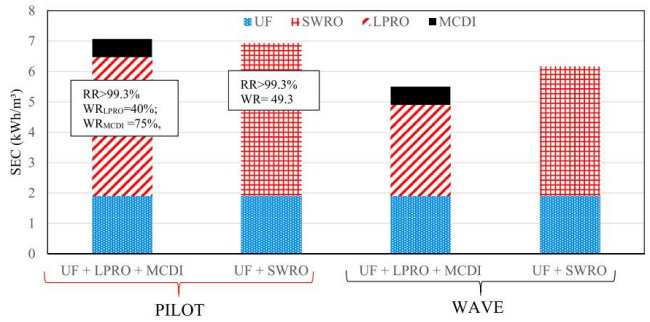
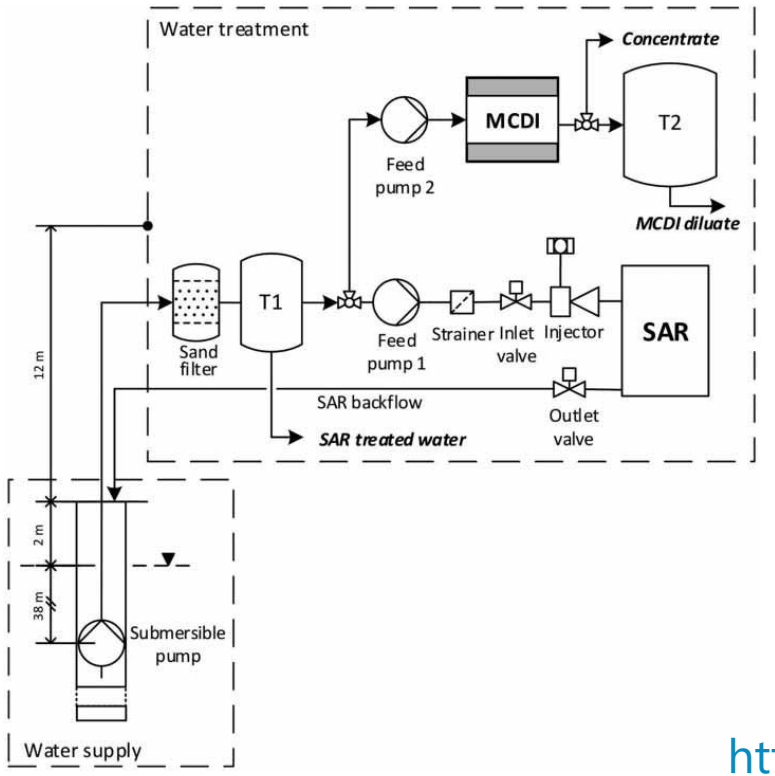


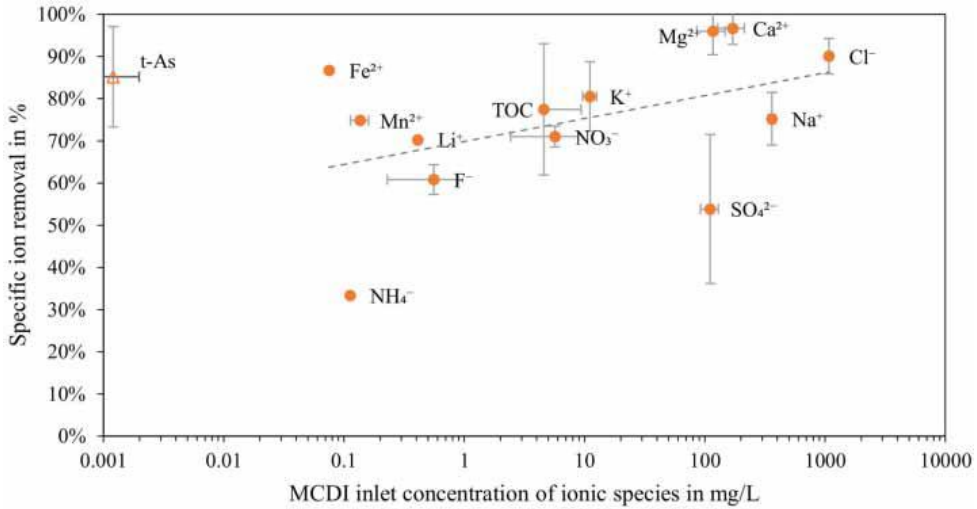
Fig. 10. Overall evaluation of combined system with single-step SWRO. Inlet EC = 34.7 mS/cm.

https://doi.org/10.1016/j.jenvman.2022.117078

Example of MBR & MCDI study by LUT teams

MODULAR TREATMENT OF ARSENIC-LADEN BRACKISH GROUNDWATER USING SOLAR-POWERED SUBSURFACE ARSENIC REMOVAL (SAR) AND MEMBRANE CAPACITIVE DEIONIZATION (MCDI) IN VIETNAM





https://doi.org/10.2166/wrd.2020.031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Thanks for your listening
Kiitos! Cám ơn!