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INTEGRALE  
MOBIELE  
PROCESWATERVOORZIENING  
VOOR EEN  
ECONOMISCHE  
DELTA



# **NH<sub>4</sub>NO<sub>3</sub> removal from condensate**

## **The efficiency of ED-RO-MD and the impact on corrosion behaviour**

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# INTERREG IMPROVED

Economical and ecological industrial water production



Interreg  
Vlaanderen-Nederland  
EUROPESE UNIE  
Europees Fonds voor Regionale Ontwikkeling



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 **Provincie  
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Voor ieder van ons

 **Provincie Zeeland**

 **west-vlaanderen**  
de gedreven provincie

# MOBILE PILOT, 3 MODULES

## MODULE 1: WATER TREATMENT

- ▶ Different water qualities from different sources
- ▶ Plug-and-play with sensoring for selection of optimal technology

## MODULE 2: DISTRIBUTION

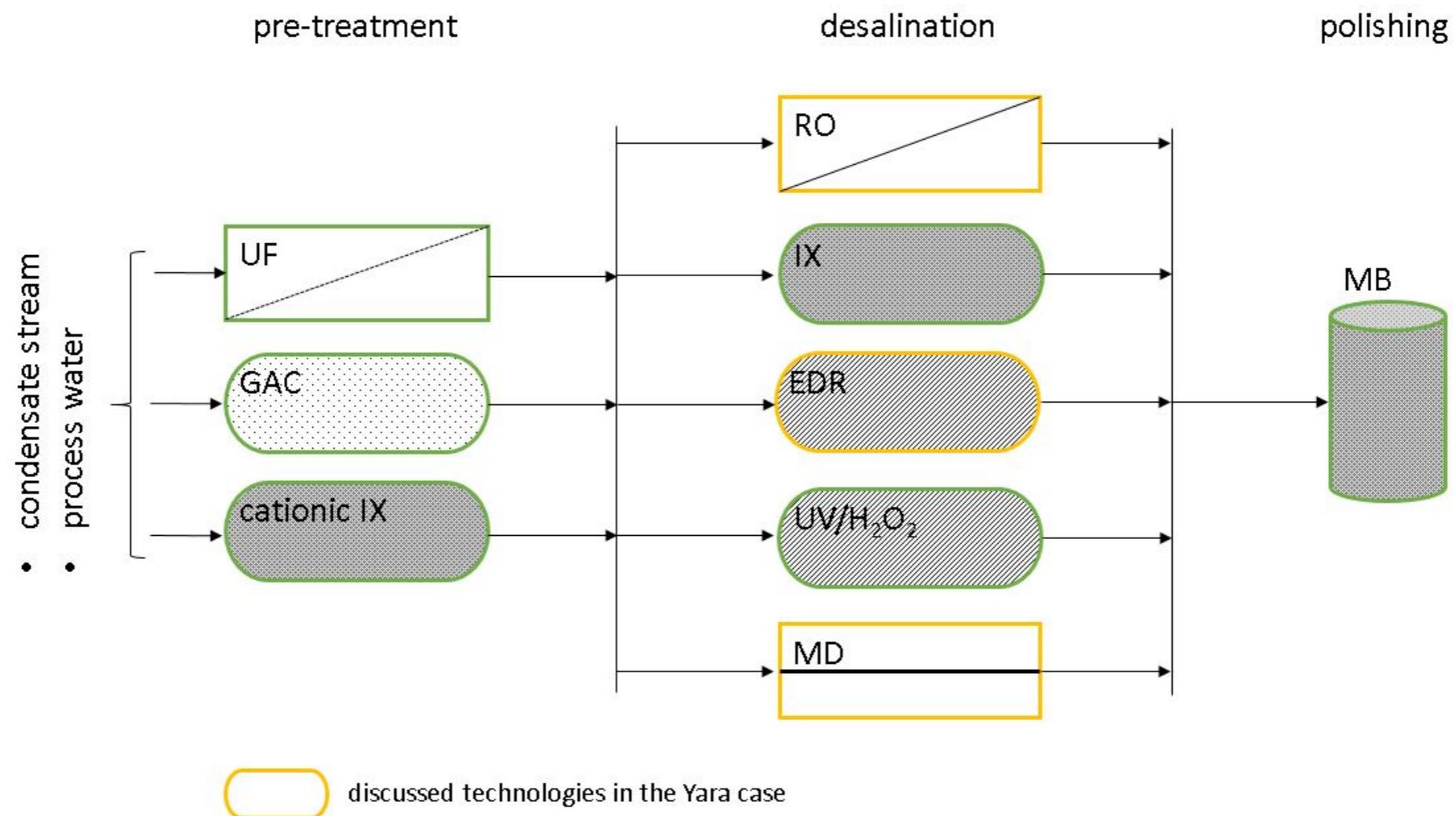
- ▶ Simulation of piping
- ▶ Development on-line flow cytometrie + sensoring water quality

## MODULE 3: SIMULATION PROCESS

- ▶ Model cooling tower
- ▶ Tensile tension test for corrosion experiments + simulation flow-accelerated/stress cracking corrosion

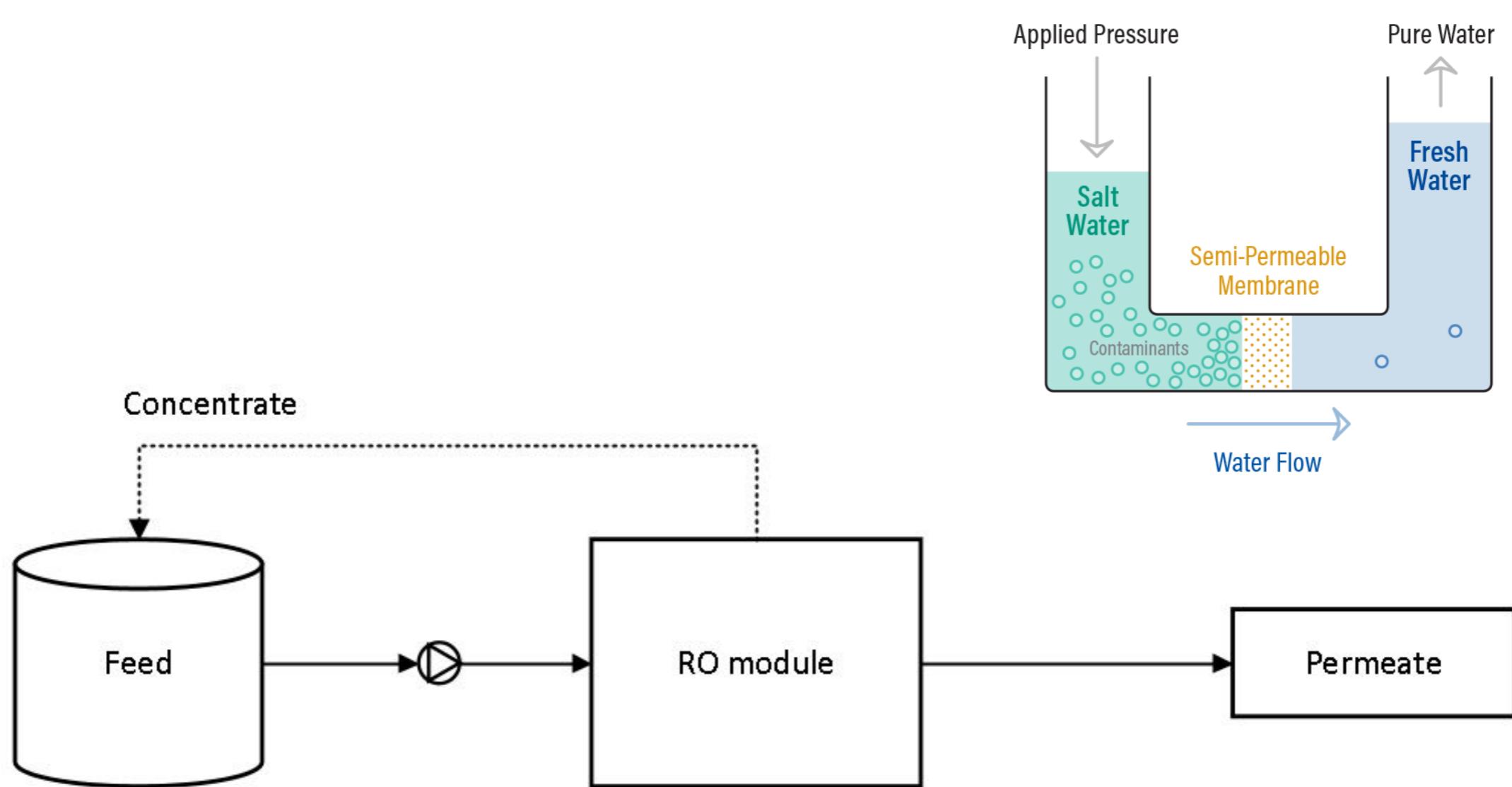
## MODULE 1: WATER TREATMENT - PLUG-AND-PLAY

- ▶ Process condensate:  $\text{NH}_4\text{NO}_3$  contamination at low concentrations
- ▶  $\text{CO}_2$  condensate:  $\text{NH}_3$  contamination + primary alcohols + TOC



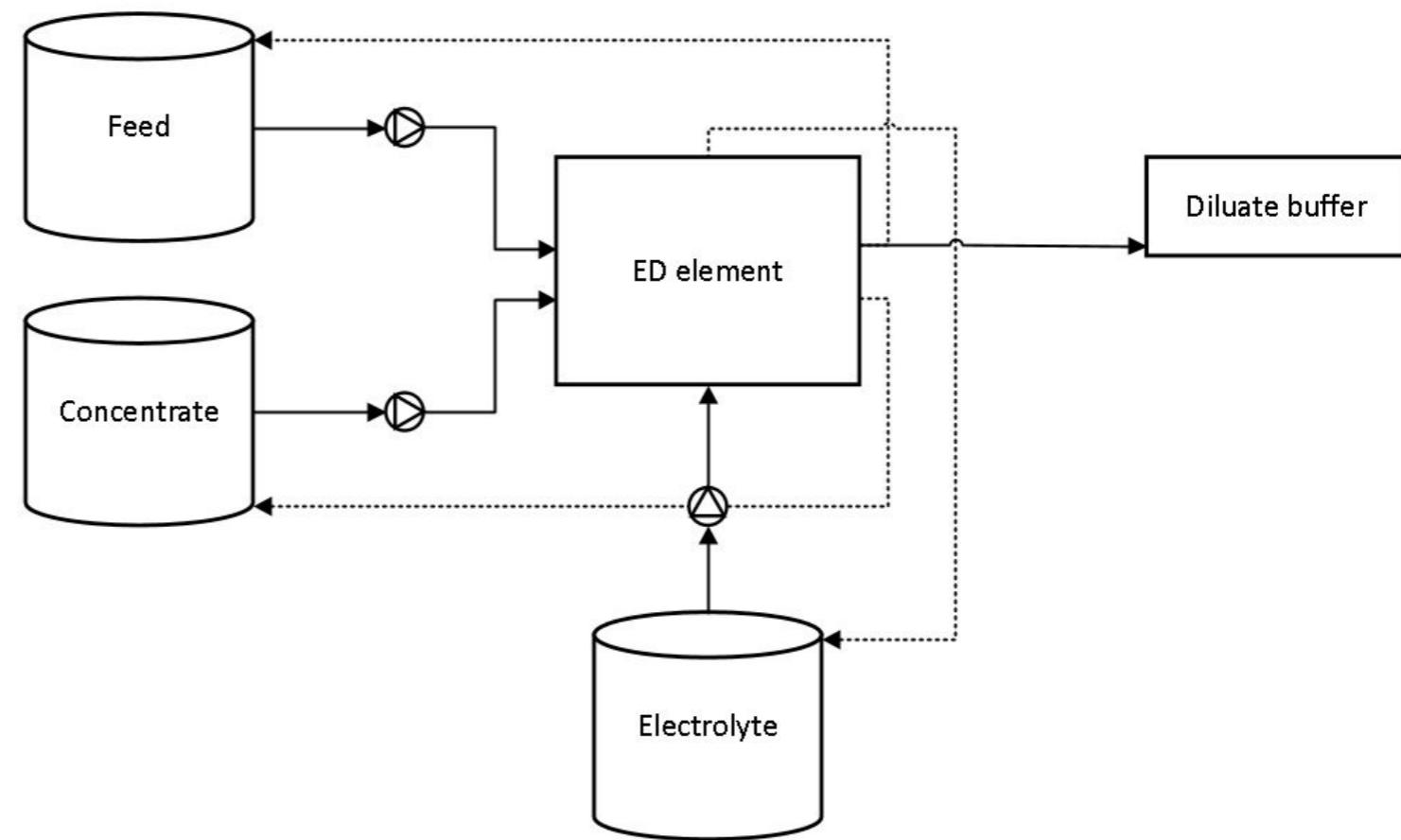
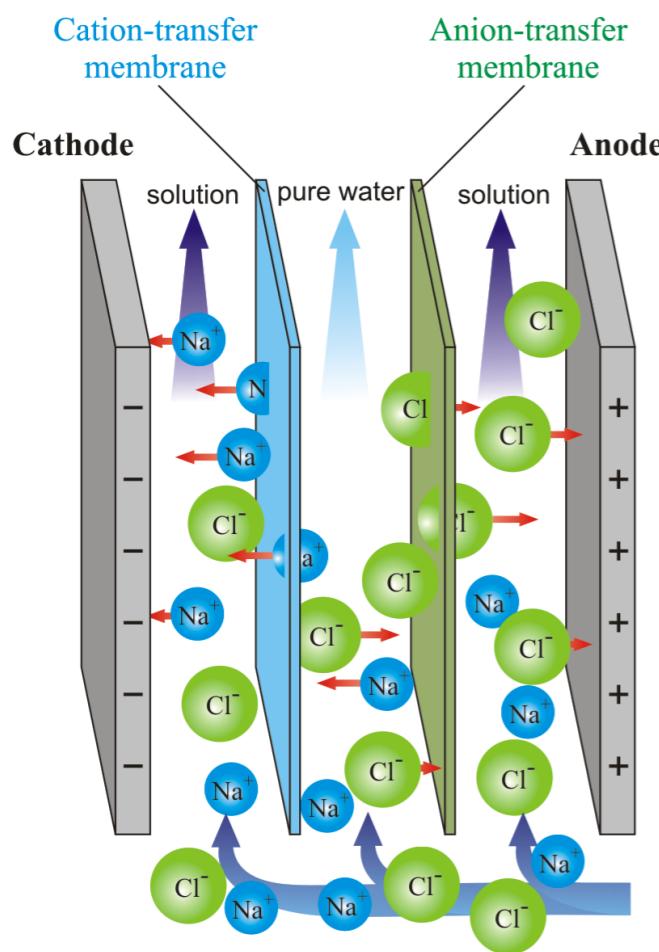
# MODULE 1: WATER TREATMENT - REVERSE OSMOSIS

- ▶ State-of-the-art
- ▶ Transport of the bulk solution



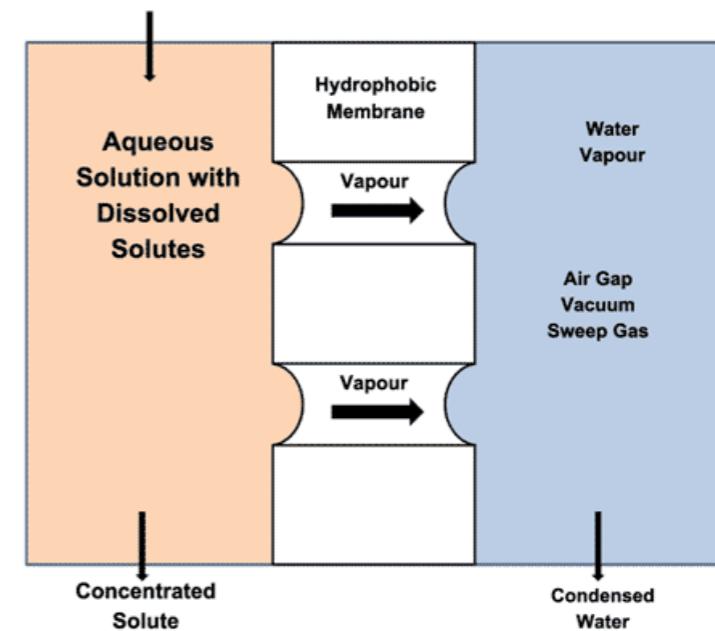
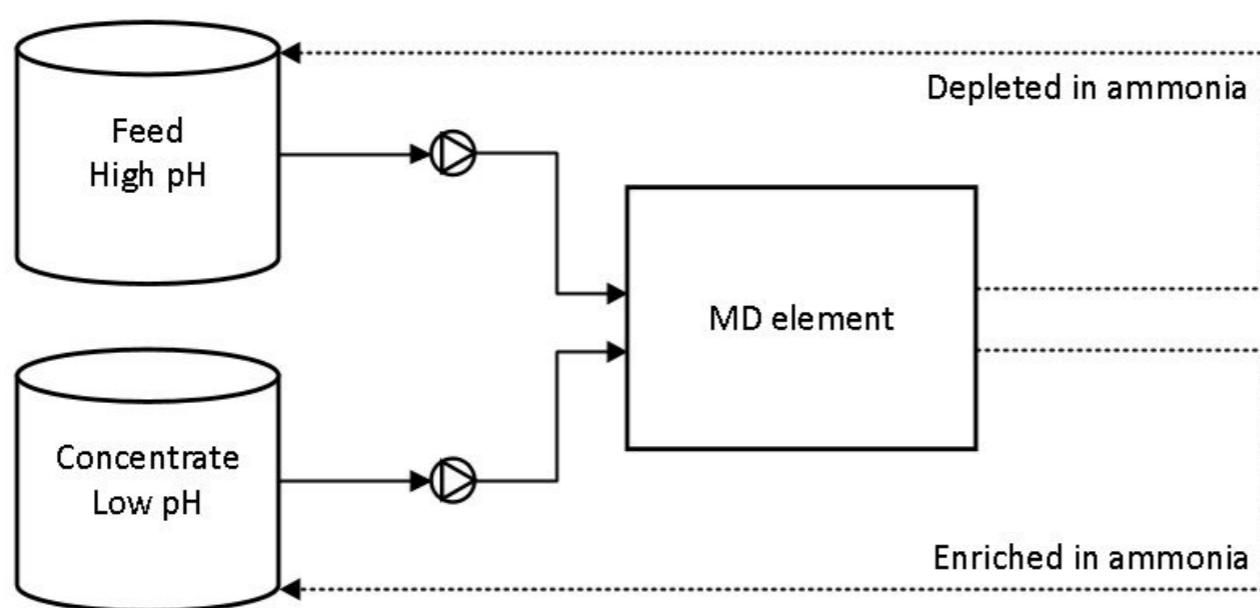
# MODULE 1: WATER TREATMENT - ELECTRODIALYSIS

- ▶ Less known technology
- ▶ **Transport of the contaminants**

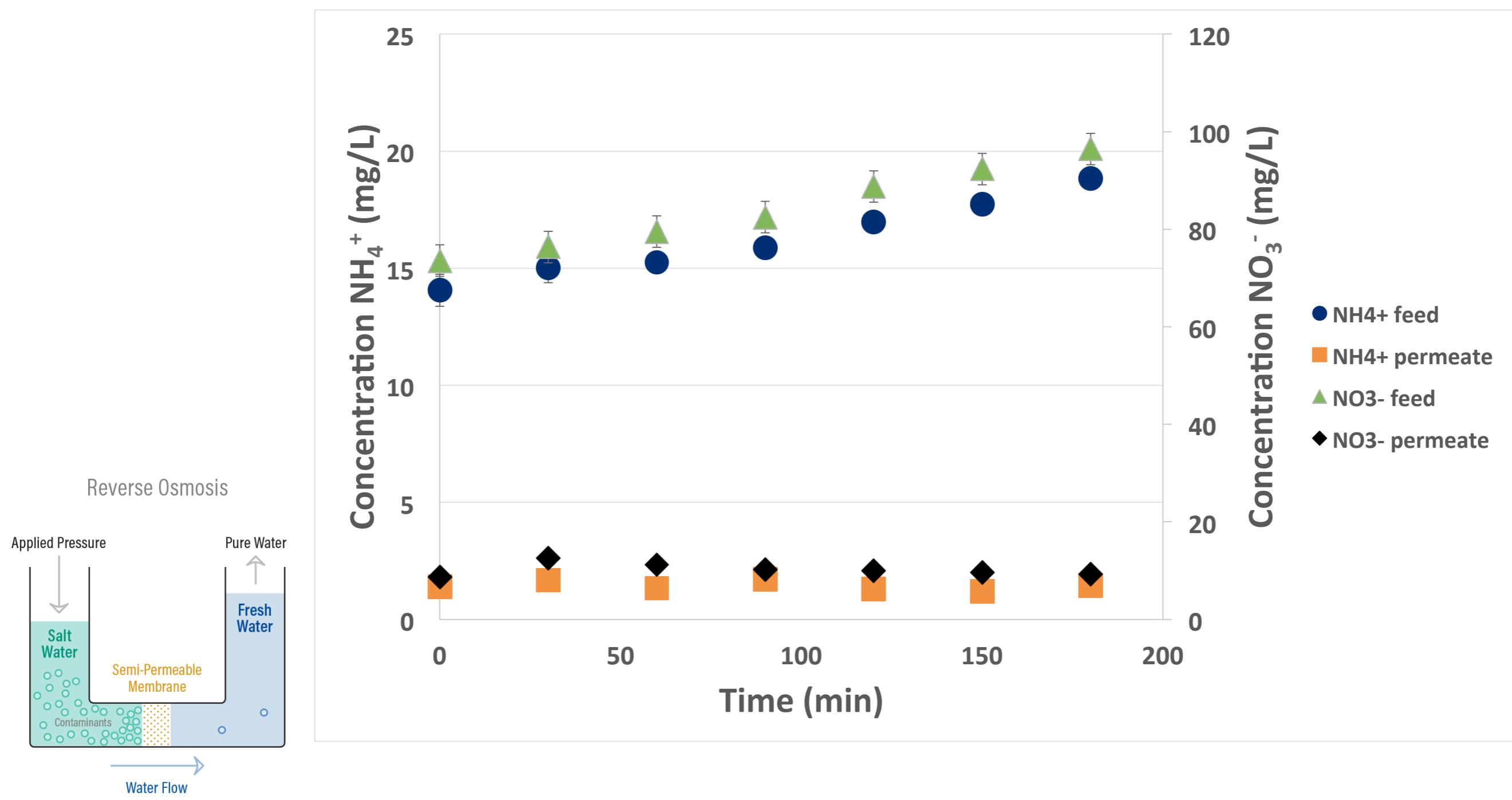


# MODULE 1: WATER TREATMENT - MEMBRANE DISTILLATION

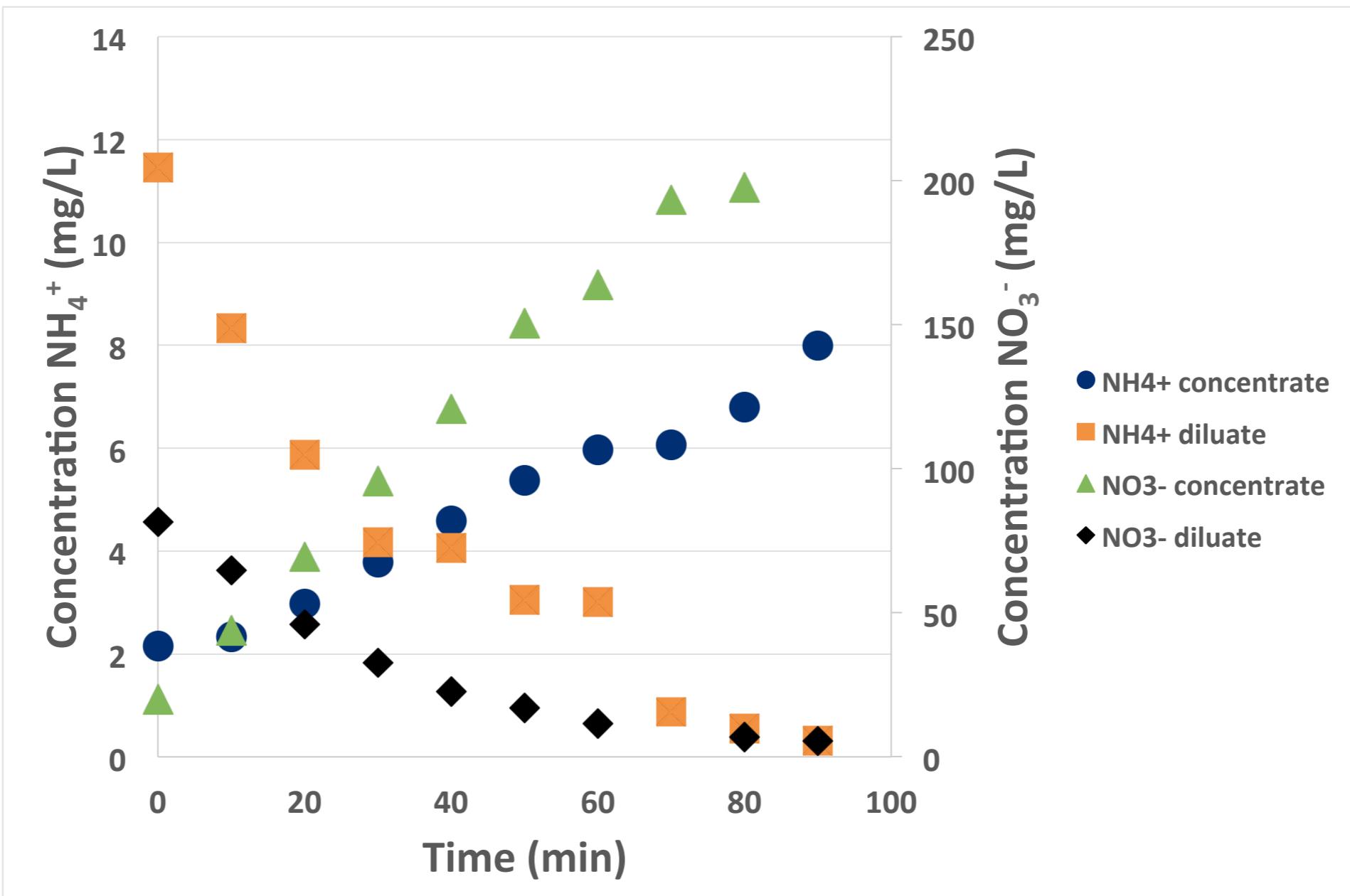
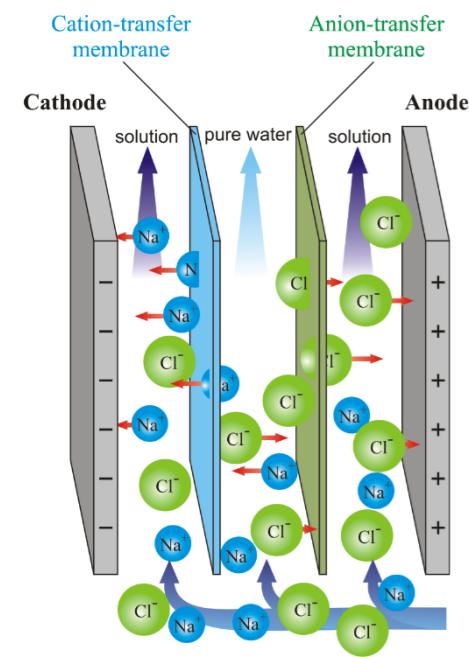
- ▶ Novel technology
- ▶ Transport of the contaminants
- ▶ **Volatility of ammonia**



# MODULE 1: WATER TREATMENT - PROCESS CONDENSATE

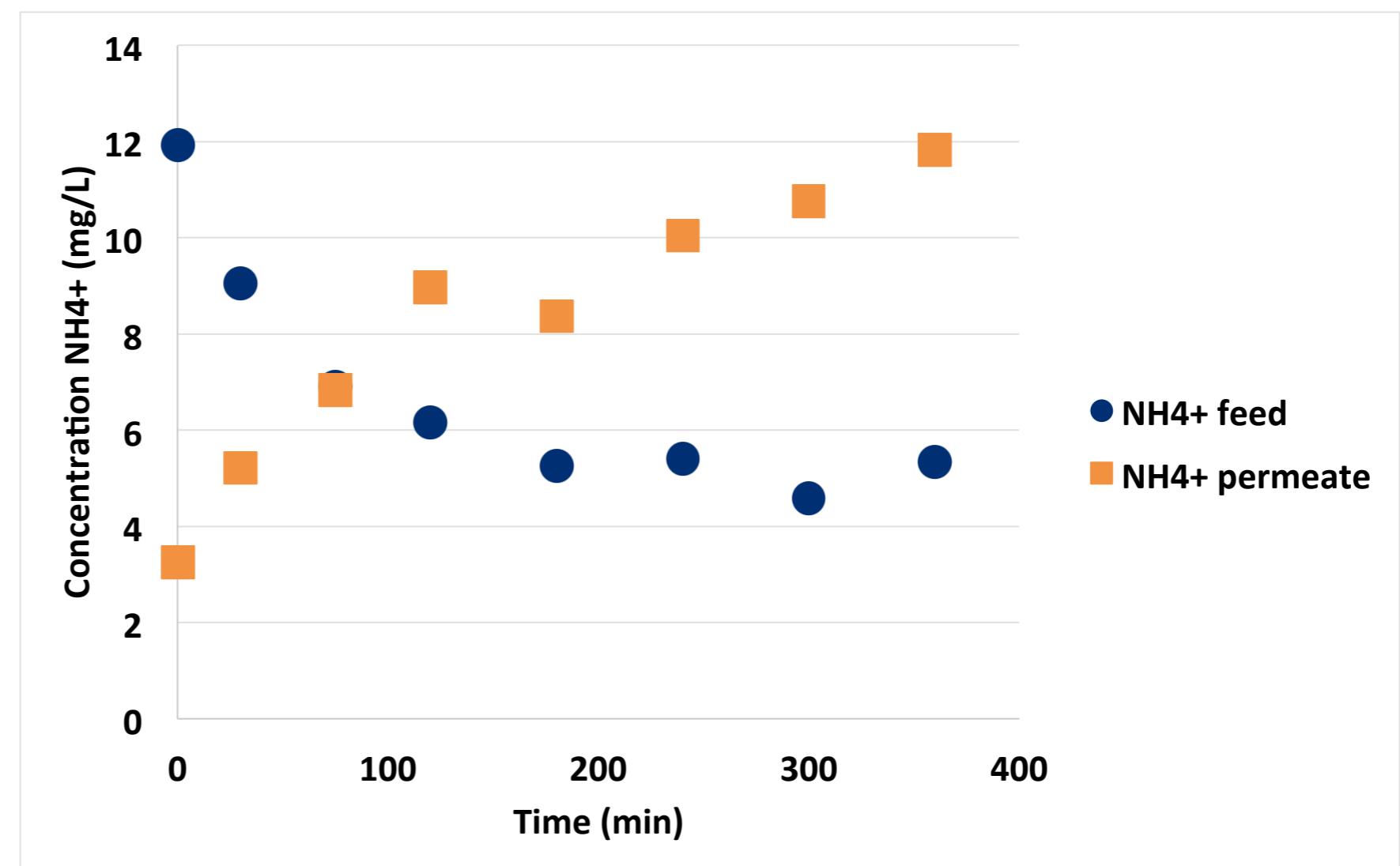
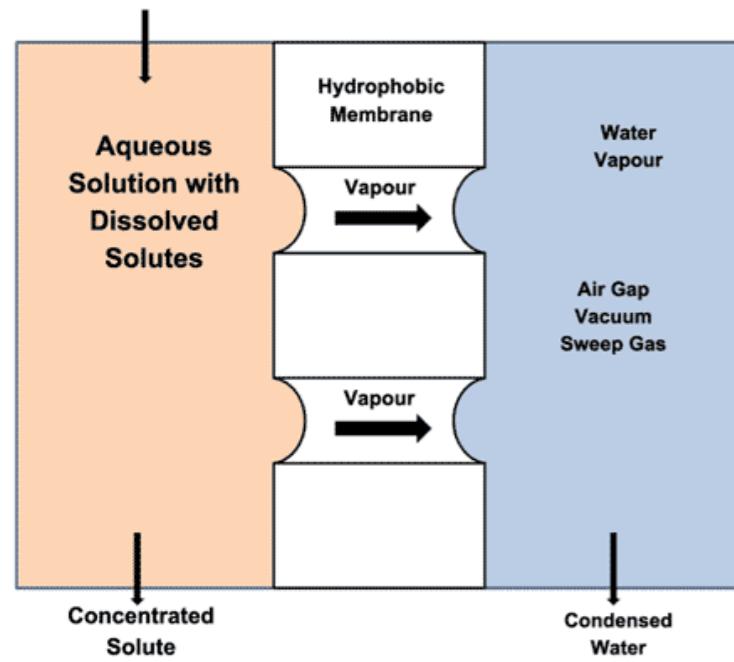


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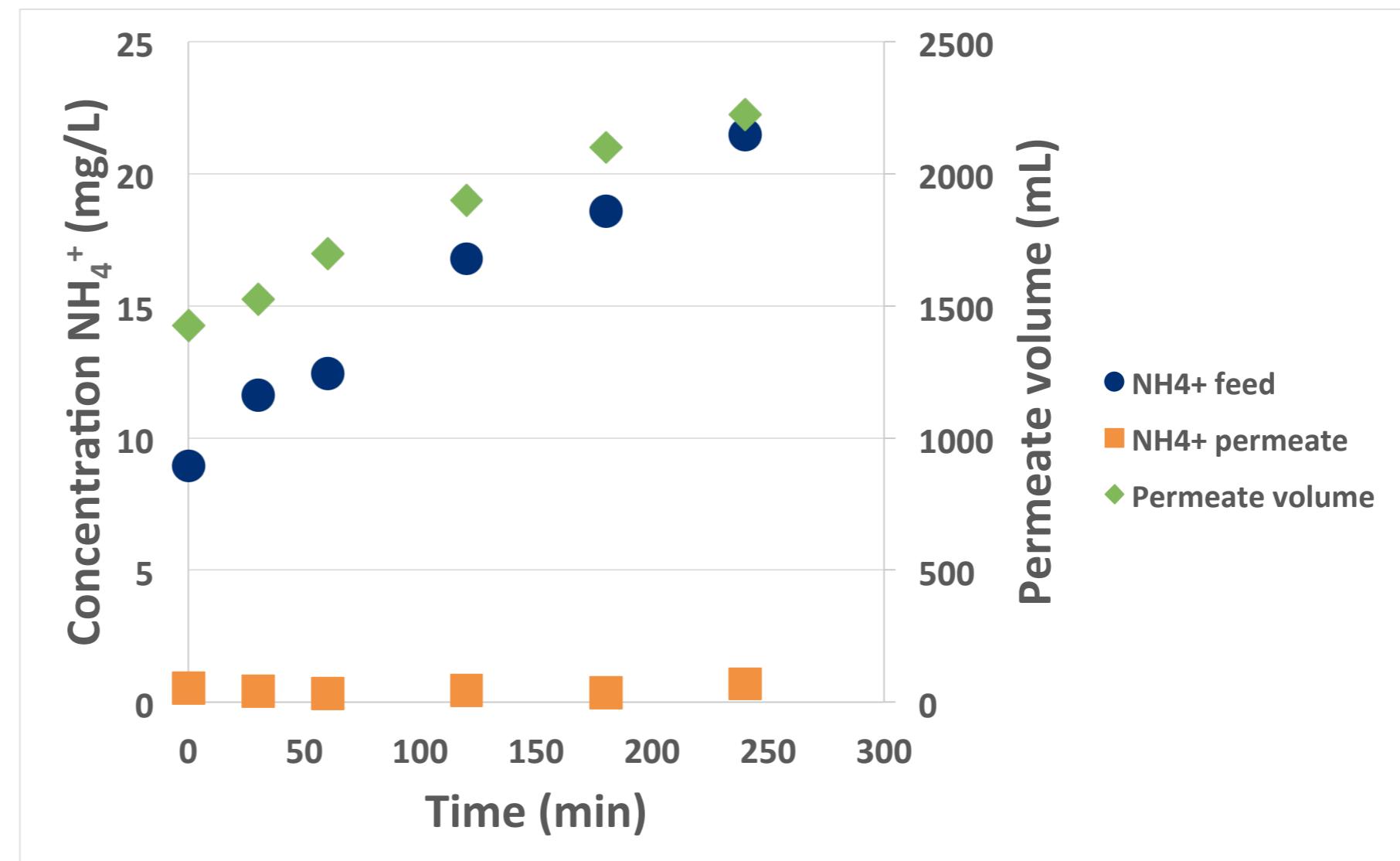
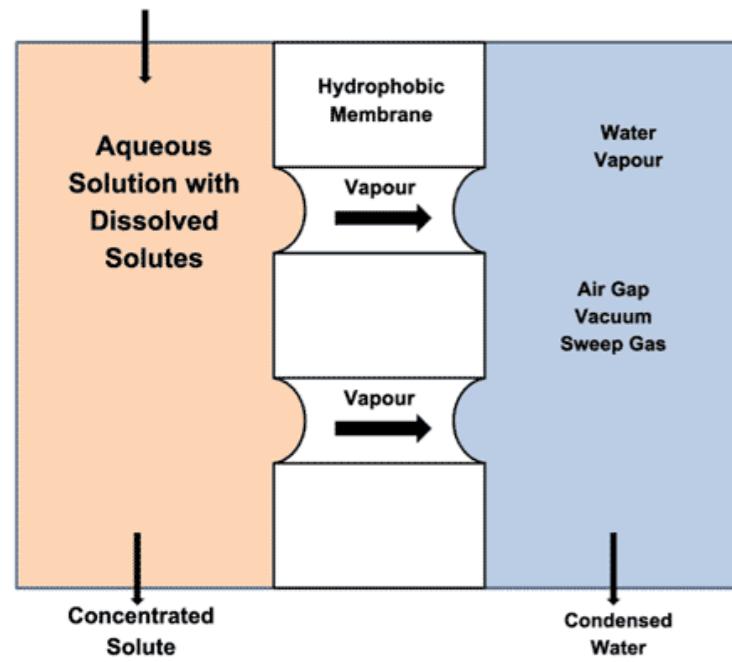
## Membrane Stripping



# MODULE 1:

## WATER TREATMENT - PROCESS CONDENSATE

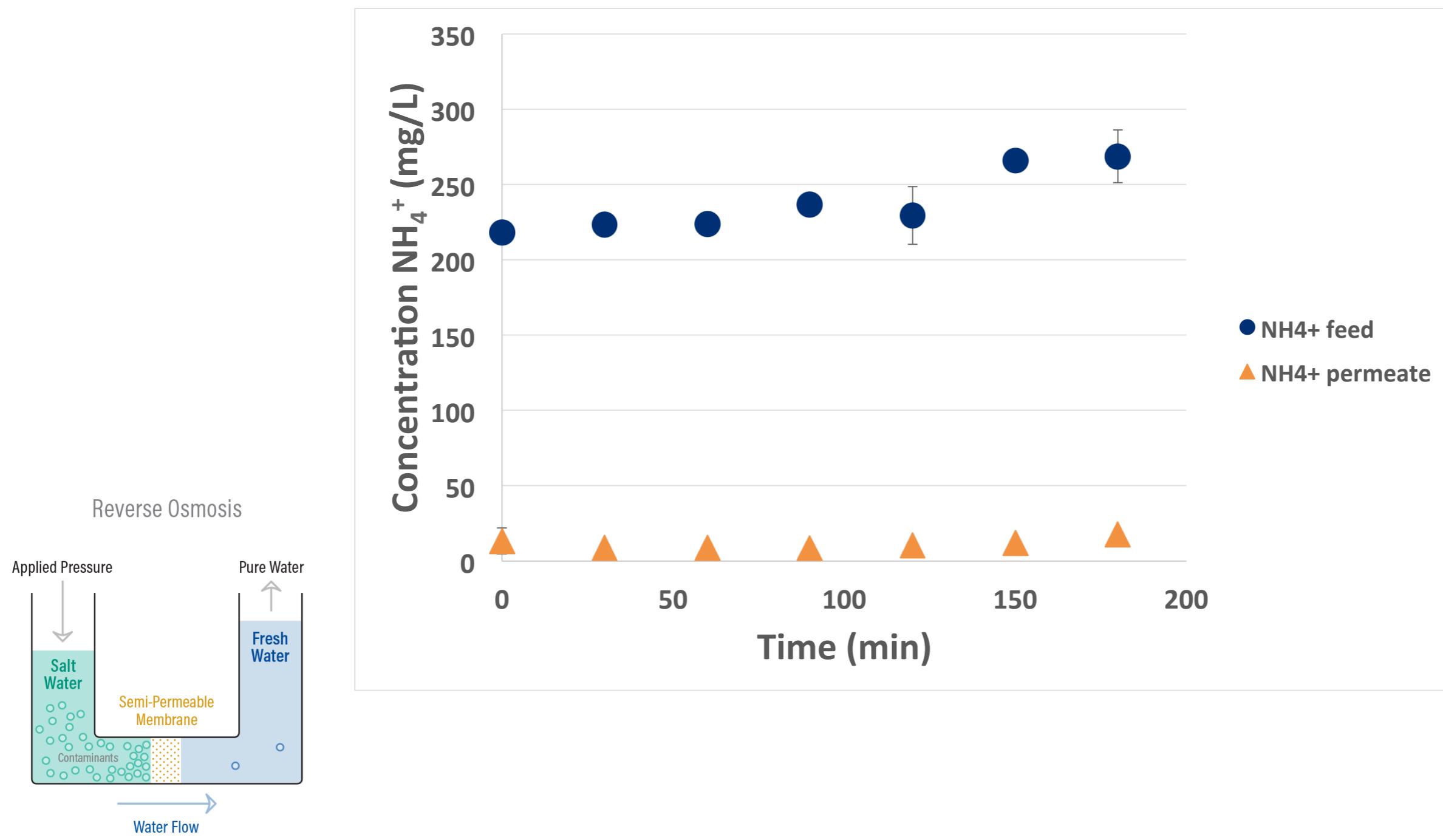
### Membrane Distillation



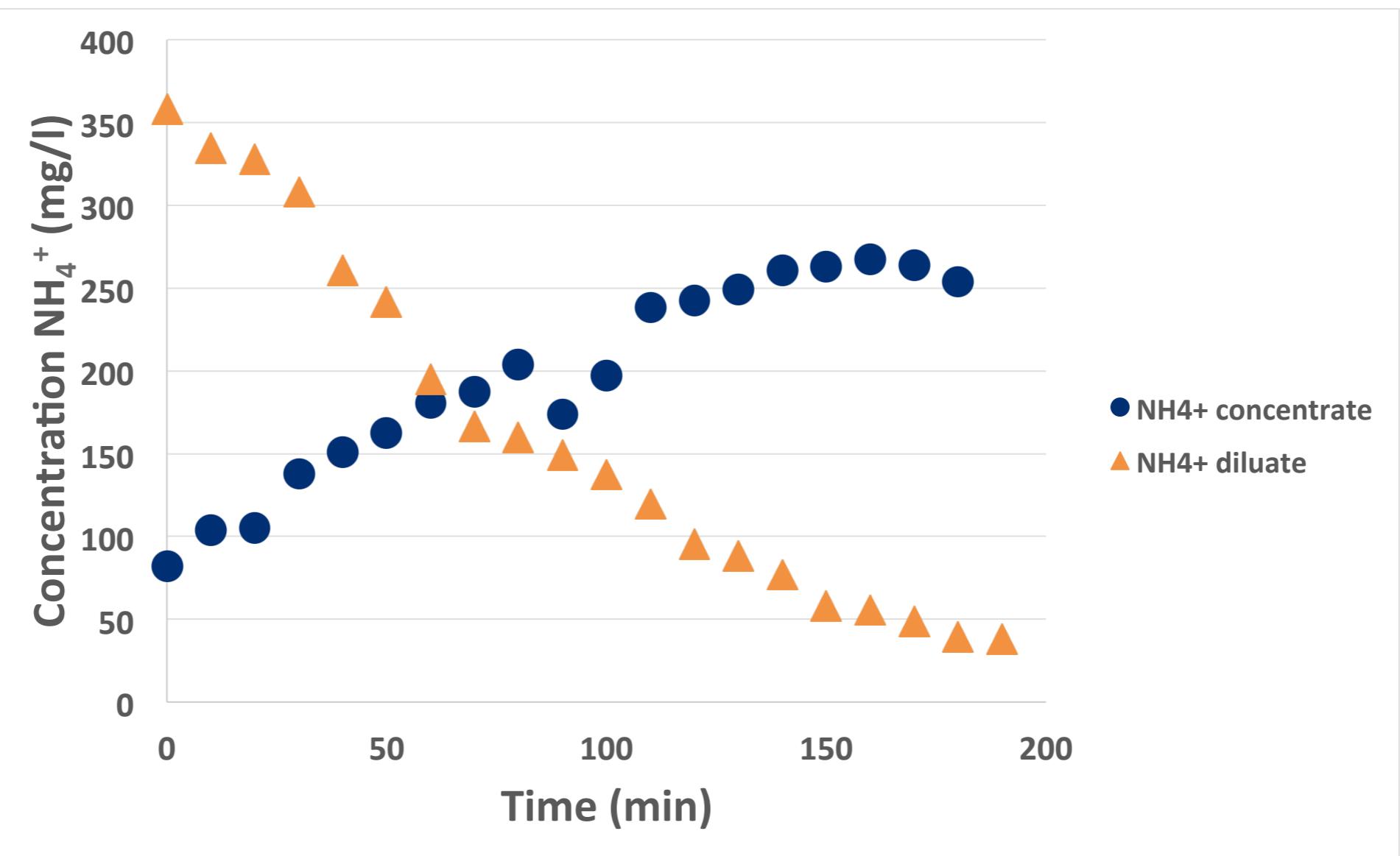
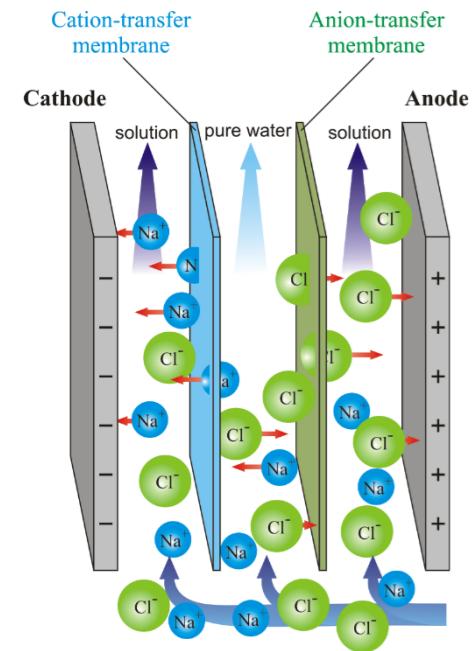
**Table 1.** Removal efficiency for ED-MS and rejection efficiency for RO-MD

	RO	ED	MS	MD
NH <sub>4</sub> <sup>+</sup>	93 %	97 %	55 %	99 %
NO <sub>3</sub> <sup>-</sup>	86 %	92 %	-	99 %

# MODULE 1: WATER TREATMENT - CO<sub>2</sub> CONDENSATE

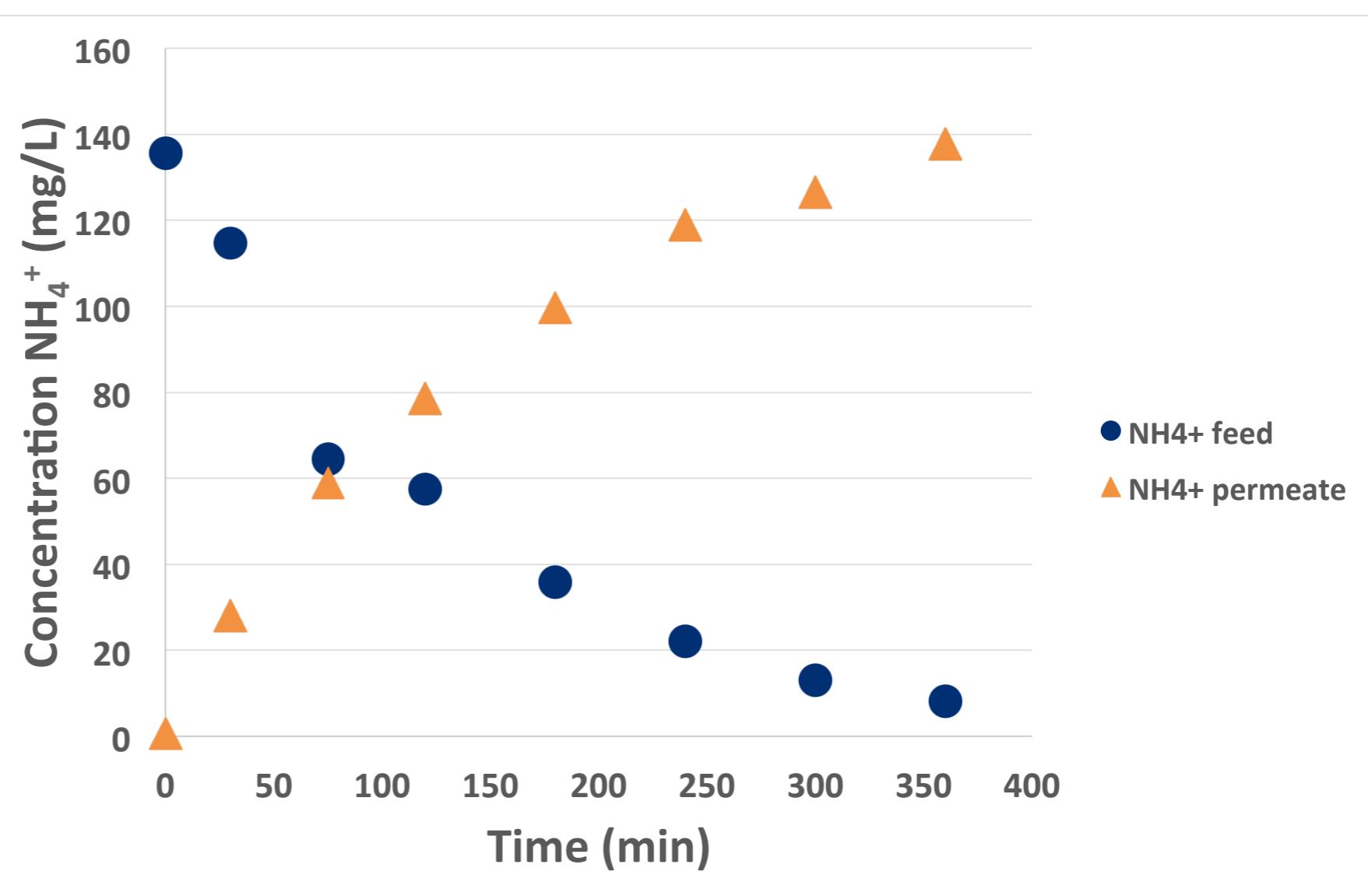
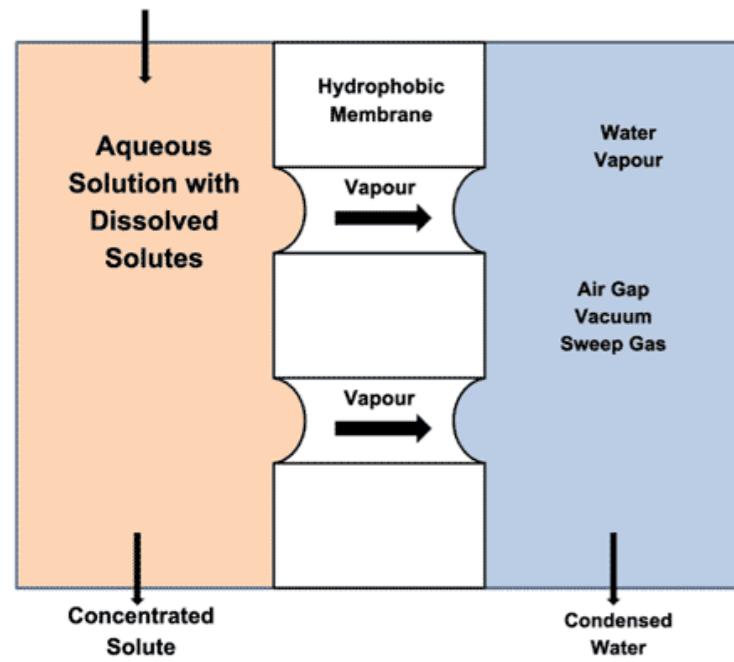


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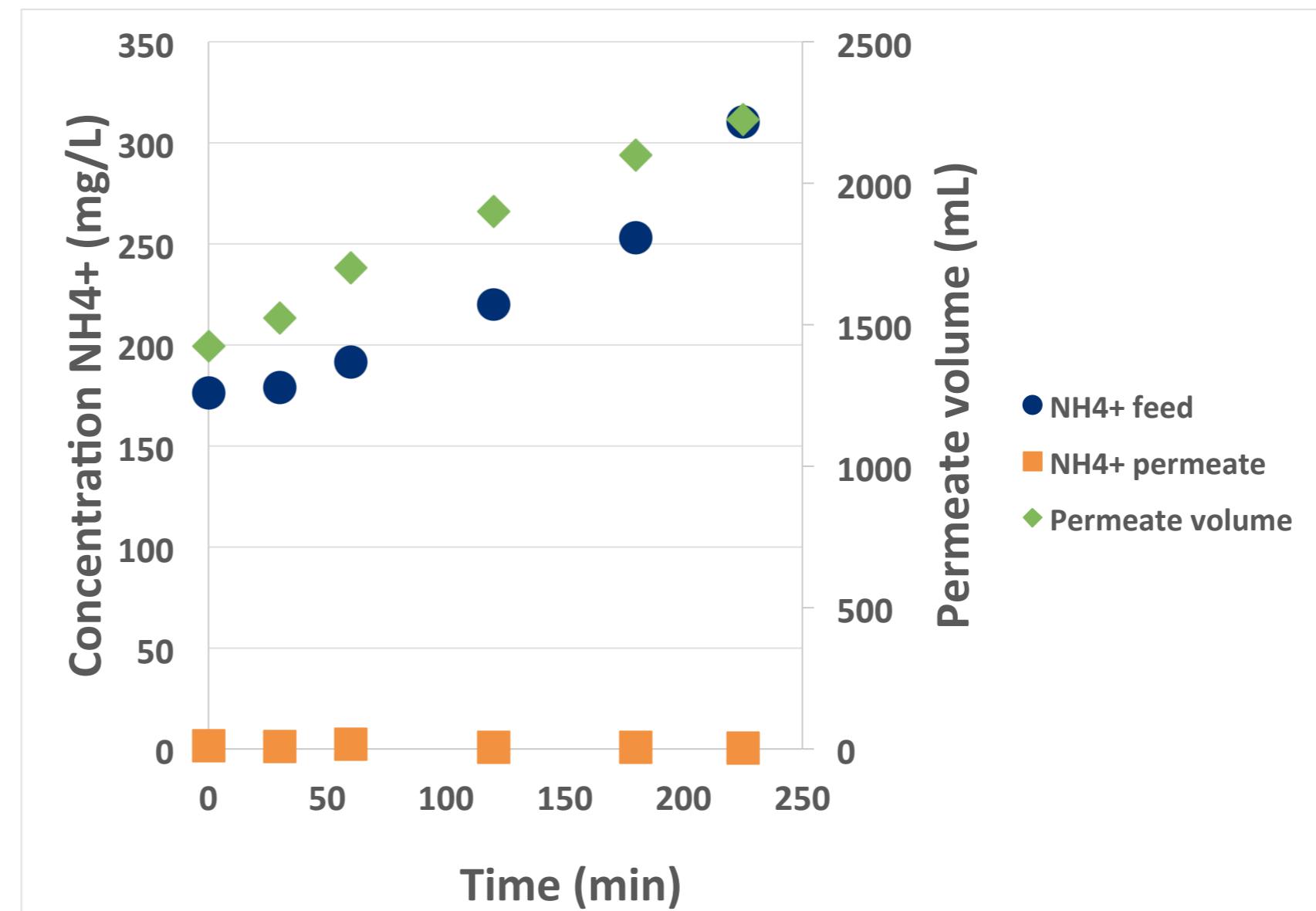
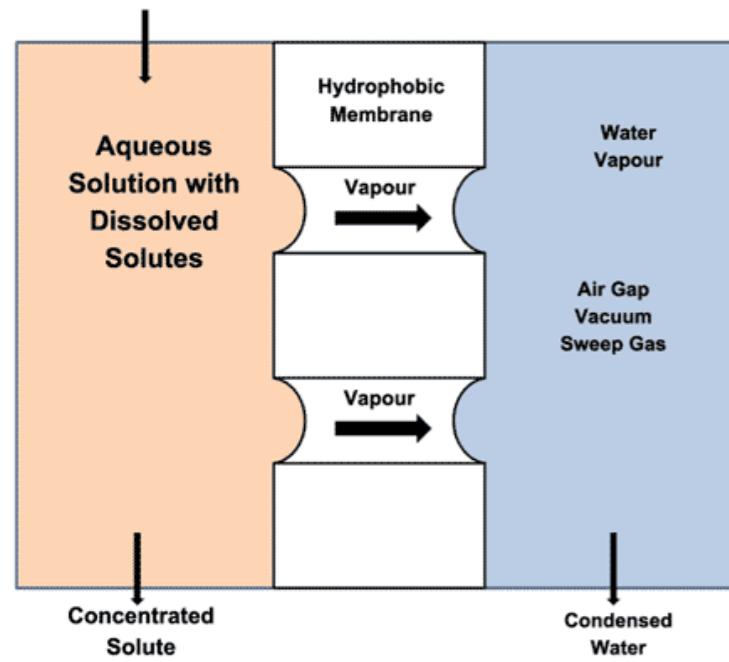
## Membrane Stripping



# MODULE 1:

## WATER TREATMENT - CO<sub>2</sub> CONDENSATE

### Membrane Distillation

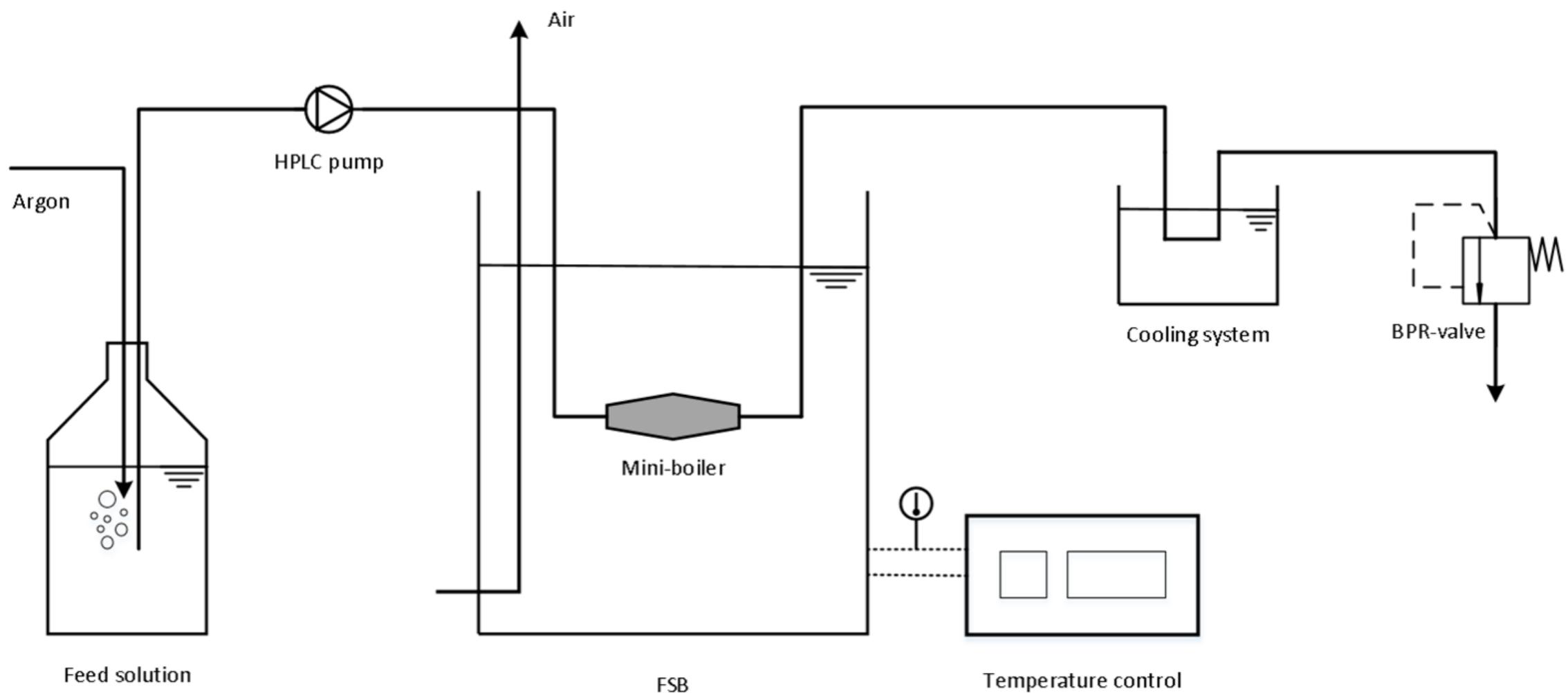


**Table 1.** Removal efficiency for ED-MS and rejection efficiency for RO-MD

	RO	ED	MS	MD
NH <sub>4</sub> <sup>+</sup>	95 %	84 %	94 %	99 %

## MODULE 3: SIMULATION PROCESS - HYDROTHERMOLYSIS

- ▶ Total Organic Carbon removal in different technologies
- ▶ Degradation under boiler conditions: formation of **organic acids**



## MODULE 3: SIMULATION PROCESS - PROCESS CONDENSATE

	Formate [mg/l]	Acetate [mg/l]	TOC [mg/l]
Process condensate	-	0.022	< 1
ED diluate	-	-	
RO permeate	-	0.017	< 1
ED diluate after boiler	0.059	0.052	2.36
RO permeate after boiler	0.165	0.112	3.22

- ▶ More organic acid formation after RO treatment: **different kind of TOC removed**

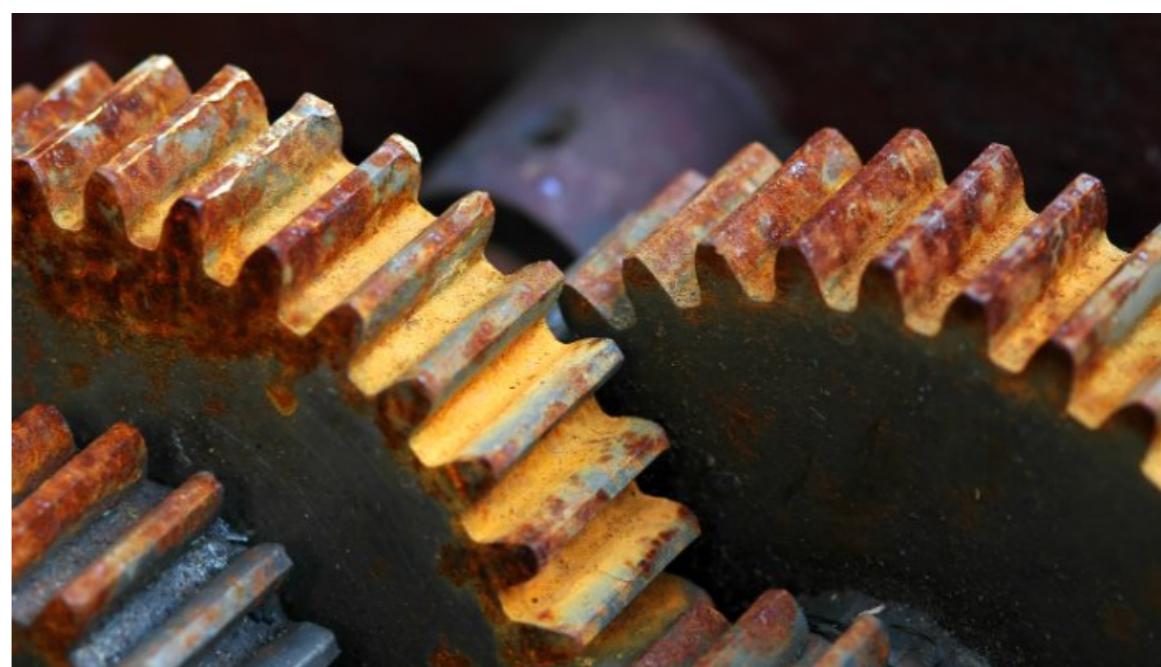


## MODULE 3: SIMULATION PROCESS - CO<sub>2</sub> CONDENSATE

	Formate [mg/l]	Acetate [mg/l]	TOC [mg/l]
CO <sub>2</sub> condensate	1.324	12.745	504
ED diluate	15.731	1.836	
RO permeate	0.420	0.671	
ED diluate after boiler	14.995	1.937	453
RO permeate after boiler	1.010	0.664	342

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- ▶ Less TOC removal with ED treatment: **larger amount of organic acids**



## COMPARISON BETWEEN THE TECHNOLOGIES

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$$SRE = \frac{1 - \frac{C_{product}}{C_{start}} * \frac{V_{product}}{V_{start}}}{t * A}$$

	Technique	Removal efficiency	Production efficiency	SRE (m-2.h-1)
Process condensate	ED	20.26	1.00	20.26
	RO	27.91	0.25	6.98
	MD	17.72	0.44	7.80
$\text{CO}_2$ condensate	ED	9.77	1.00	9.77
	RO	28.67	0.25	7.17
	MD	21.75	0.44	9.57

# CONCLUSION

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- ▶ **Treatment of the process condensate**
  - Good removal efficiencies with all the technologies
  
- ▶ **Treatment of the CO<sub>2</sub> condensate**
  - Difficulties with the present of the primary alcohols and the high amount of TOC

**Water treatment technology tailored to the condensate stream**





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