E4WATER

Economically and Ecologically Efficient Water Management in the European Chemical Industry

Reduction of fresh water intake by desalination

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Content of the presentation

- Introduction
- Approach for the technology selection
- Insight in technologies with cooling tower blow down (CTBD) as the raw water source

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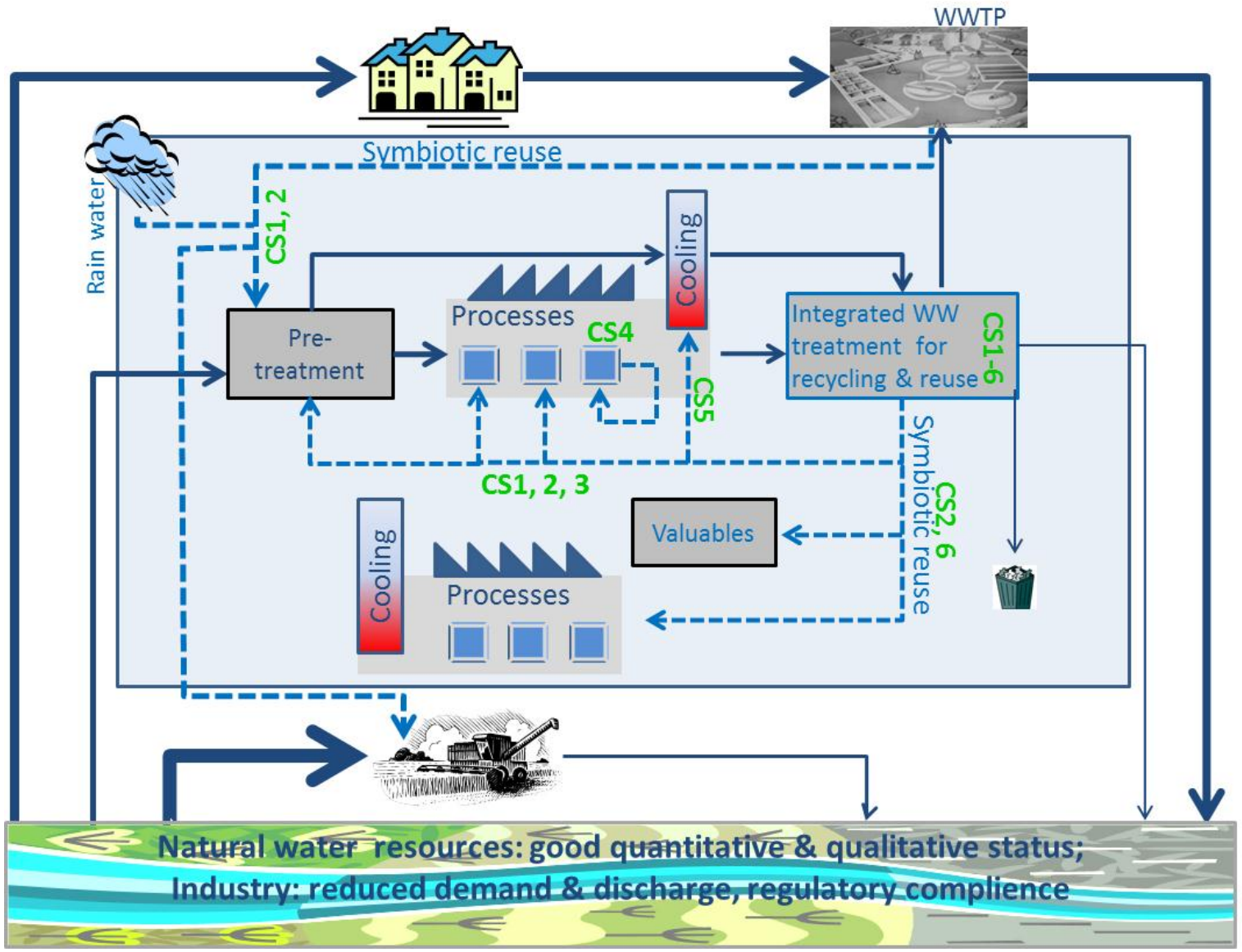
Why desalination?



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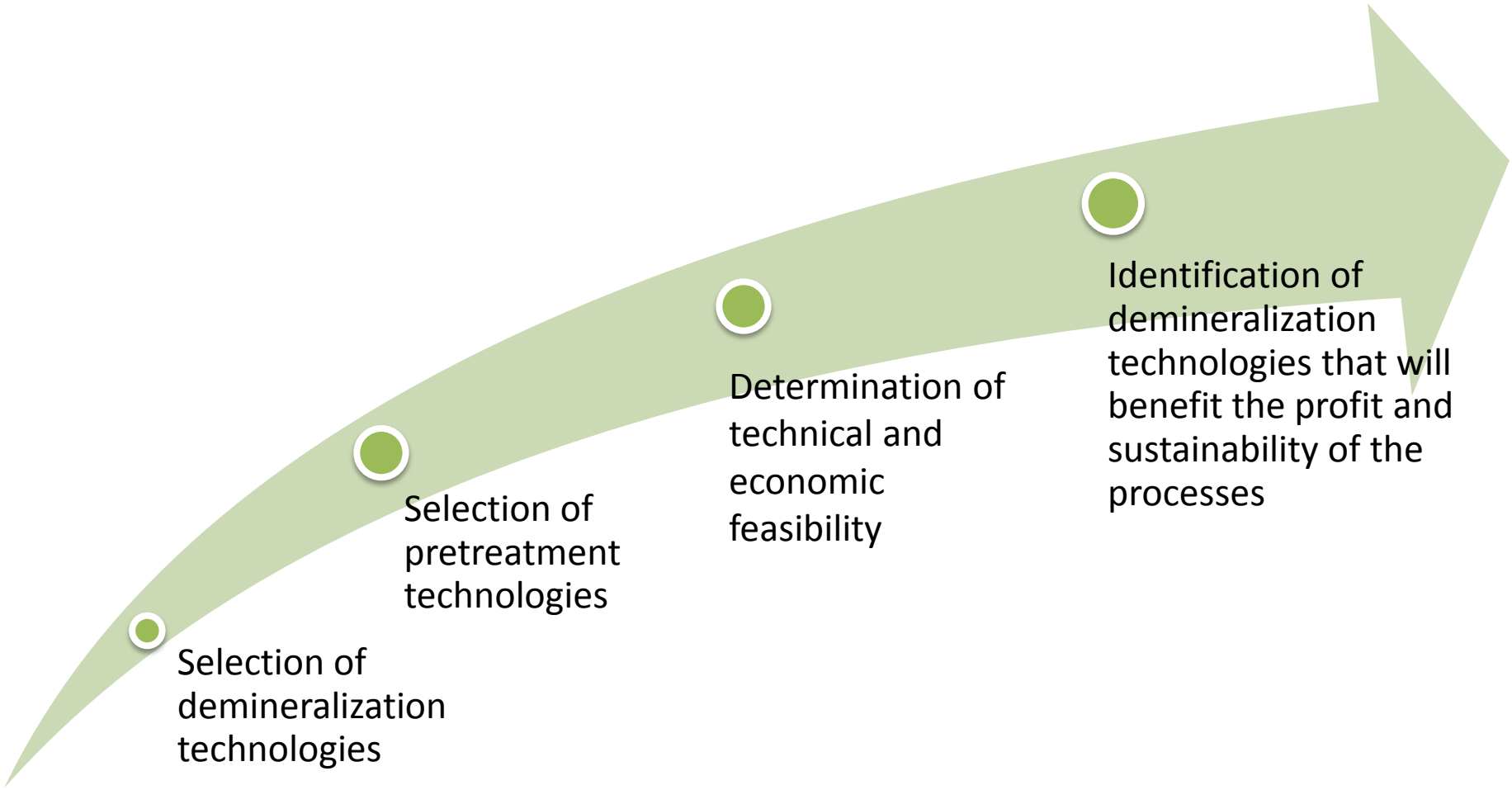
How to select the right desalination technology?



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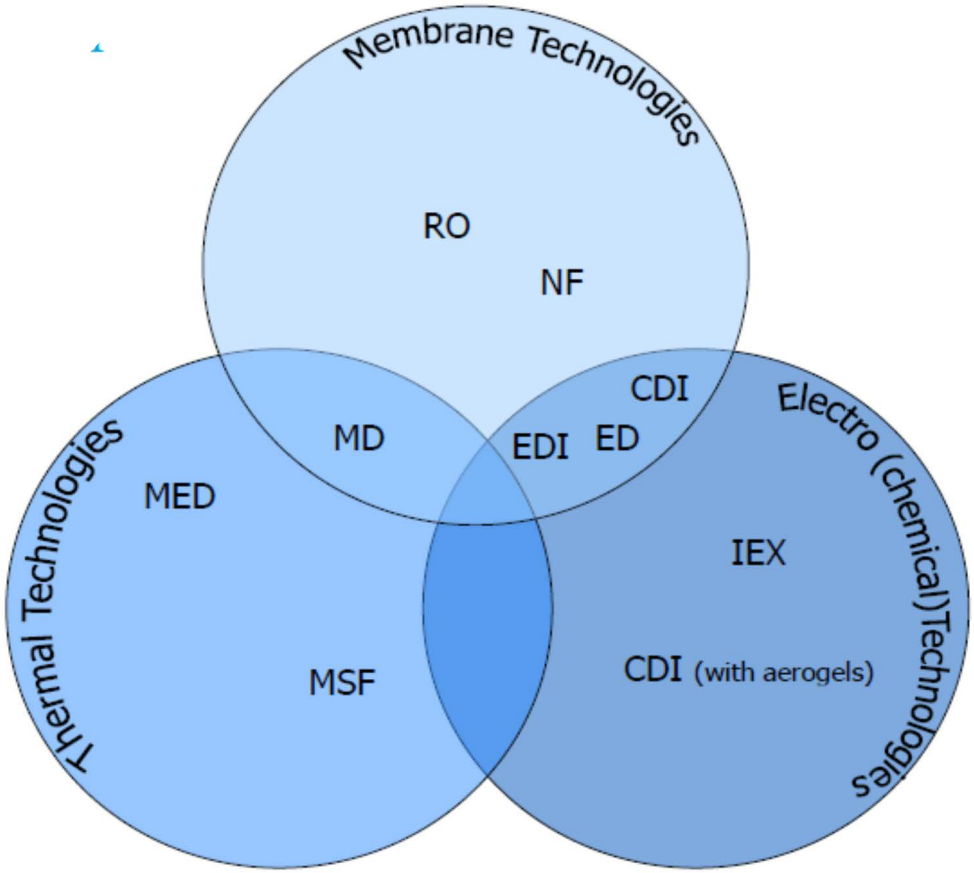
Desalination principles



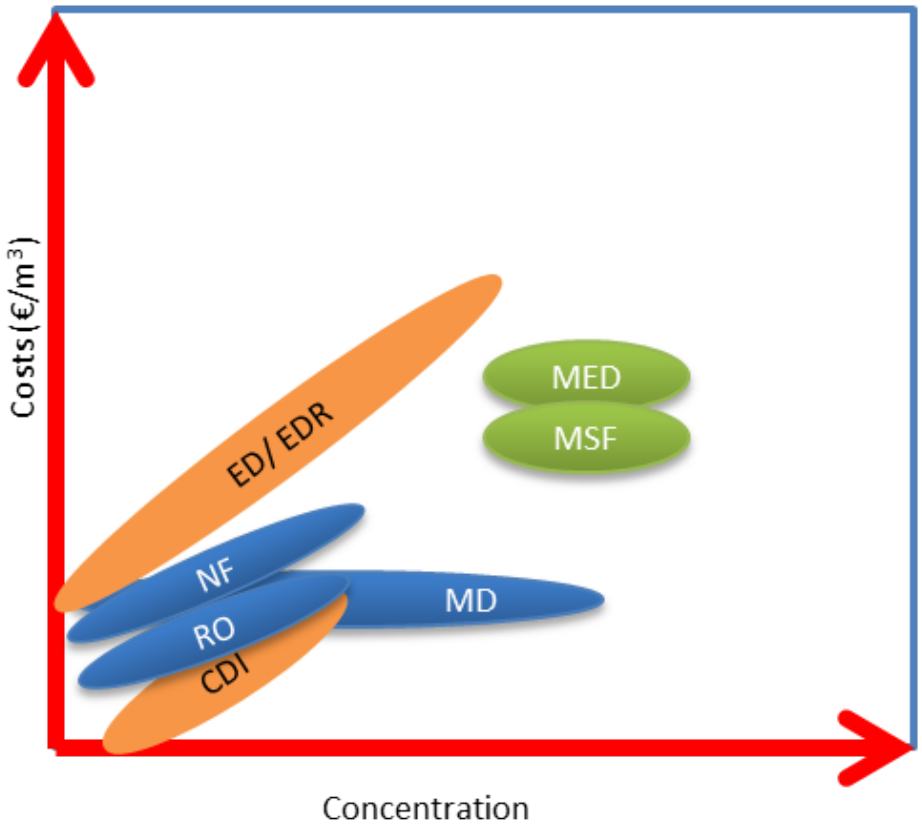
Selection of desalination technology

- Dependent on quality water source and requirements water reuse

- Extensive desalination
  - Reverse osmosis
  - Evaporation
  - Membrane distillation
- Mild desalination
  - ED(R)
  - Nanofiltration

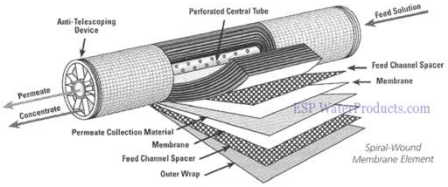
	Min. influent conductivity (µS/cm)	Max. influent conductivity (µS/cm)	Effluent conductivity possibility (µS/cm)	Reference costs (€/m^3)	Other considerations	Does technology meet main requirements for different streams
RO	<100	25.000	0.1 - 500	0.21 – 5*	Mature technology, used to desalinate SW/BW	Yes (P,I,D)
NF	500	25.000	500 - 1.000	0.25 - 5*	Mature technology, used to desalinate BW	Not as standalone technology
ED/EDR	1.000	8.000	100 – 8.000	0.13 - 5*	Mature technology used to desalinate BW	Not as standalone technology
MD	<100	near crystallization	<10	0,26 - 5*	Innovative technology, can treat SW and BW	Yes (P,I,D)
MSF	8.000	50.000	<10	0.42 - 5*	Mature technology, generally used for large volumes of SW	Yes (P,I,D), comparable to MED, higher cost expected
MED	8.000	50.000	<10	0.5 - 5*	Mature technology, generally used for large volumes of SW	Yes (P,I,D)
IEX	<100	3.000	<1	no good indication found for desalination example	Mature technology, used as a polishing step	Yes (P)
EDI	<100	50	<1	No good indication available	Innovative technology, used as a polishing step	Not as standalone technology
CDI	<100	8.000		No good indication available	Innovative technology, used to desalinate BW	Not as standalone technology

Costs vs.concentration for desalination technologies

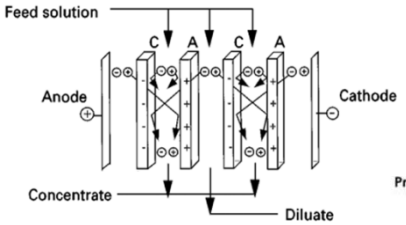


Final technology selection for selected water sources and water reuse options

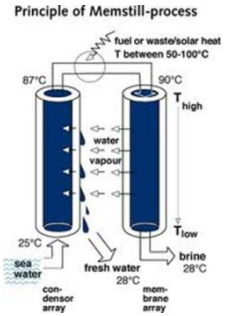
- Reverse osmosis



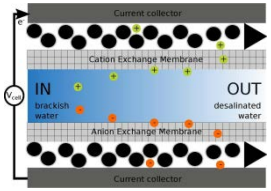
- Nanofiltration
- Electrodialysis



- Membrane distillation



- Capacitive deionization



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Technology-water source selection

	Dow			INOVYN (B)			INOVYN (S)
Desalination Technology	**Biox Waste-water**	**Spuikom Rainwater**	**Cooling Tower Blow Down**	**External wastewater (EWW)**	**Phreatic drainage water and rainwater (FW)**	**Untreated dock water (DW)**	**MBR effluent**
Ion Exchange	X	X	X	X	X	X	X
Electrodialysis	X		X	X	X	X	X
Capacitive Deionization	X		X	X	X	X	X
Membrane Distillation	X	X	X			X	X
Nanofiltration / Reverse Osmosis			X				X

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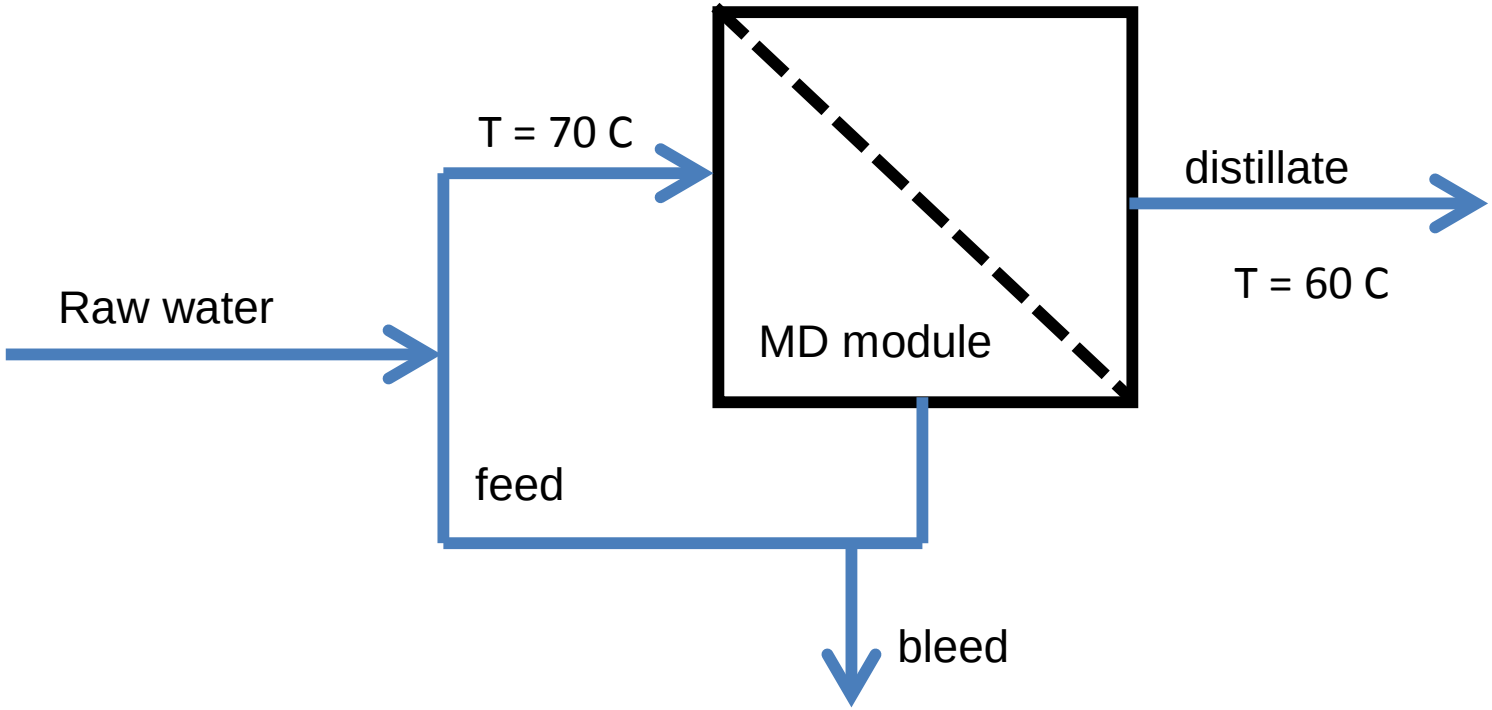
Laboratory setup MD experiments



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MD results with different water sources

Water	Membrane	Concentration factor (-)	Recovery (%)
LHC3 CTBD	PTFE	5.3	81
Elsta CTBD	PTFE	5.3	81
Elsta CTBD	PE	9.6	90
Spuikom	PE	6.7	85
Biox effluent	SUPOR R	5.9	83

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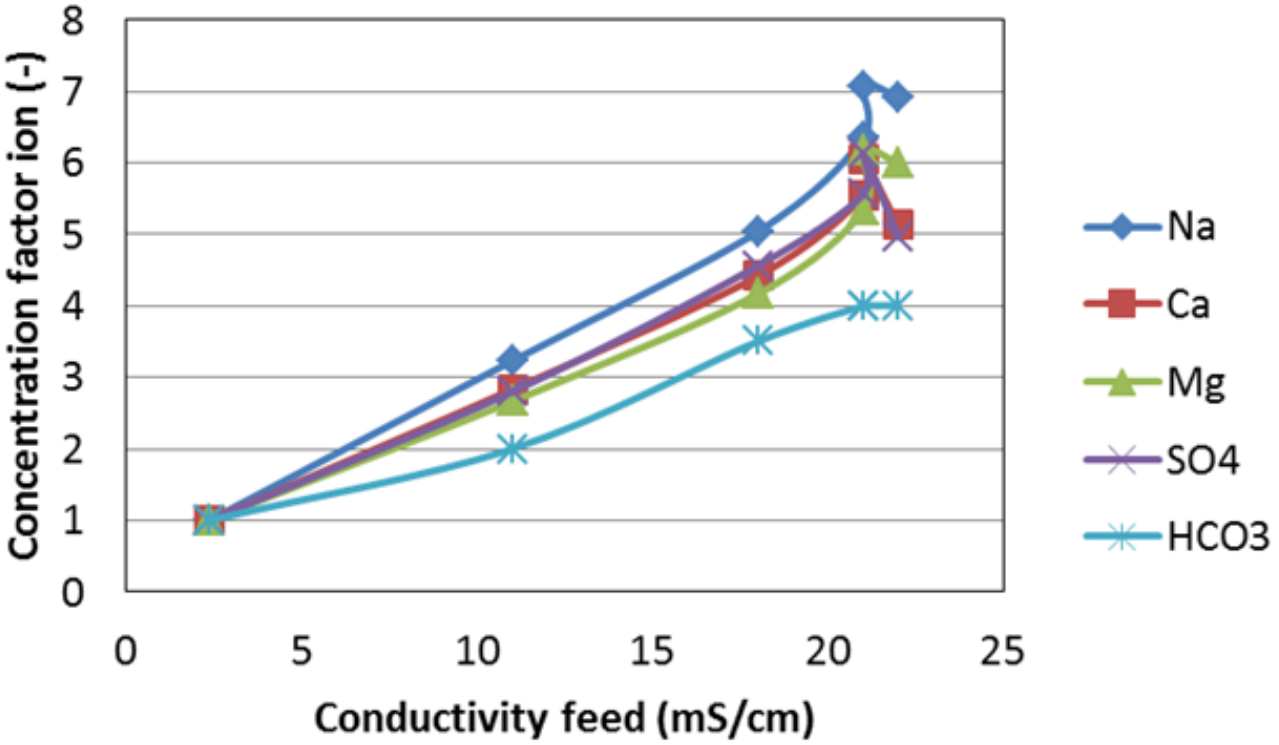
Element analysis MD experiment with ELSTA CTBD



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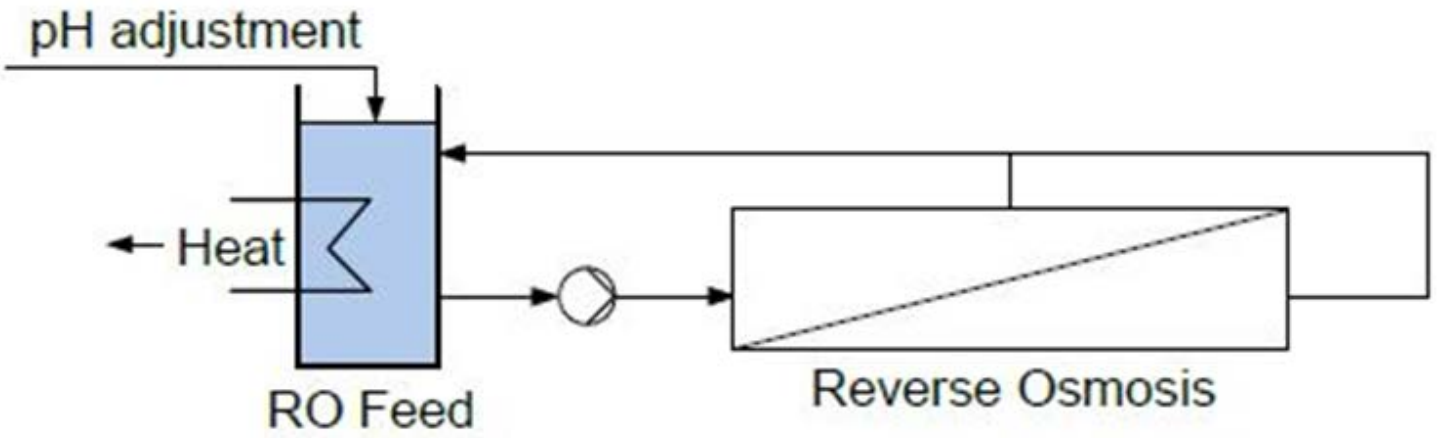
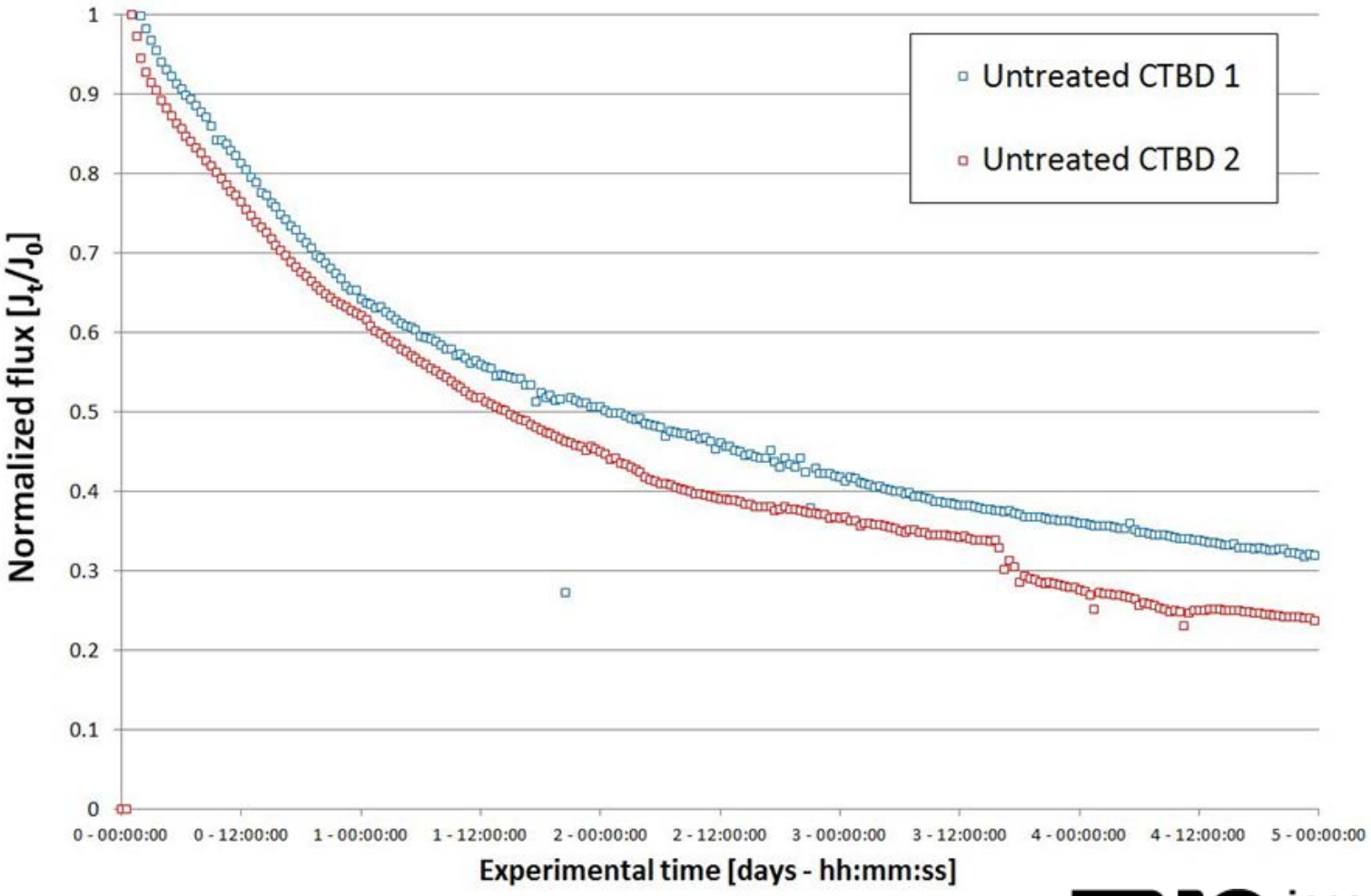
Laboratory RO/NF experiments with ELSTA CTBD



Fouling Filmtec BW30 with ELSTA CTBD



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RO on CTBD with different pretreatments

	Normalized flux after 5 days [J_5/J_0]	Permeate produced [kg]	Flux decline per Permeate [%/kg]
Raw CTBD 1	**0.23**	**9.9**	**7.7**
Raw CTBD 2	**0.32**	**10.8**	**6.3**
UF 1	**0.41**	**12.0**	**4.9**
UF 2	**0.43**	**12.9**	**4.4**
UF 2	**0.41**	**11.6***	**5.1**
PAC/UF	**0.53**	**14.4**	**3.3**
PAC/UF	**0.62**	**17.6**	**2.2**
Fe^{3+} 2	**0.37**	**10.7**	**5.9**
Fe^{3+} 3	**0.29**	**8.6***	**8.3**
Fe^{3+} 4	**0.37**	**9.4****	**6.7**

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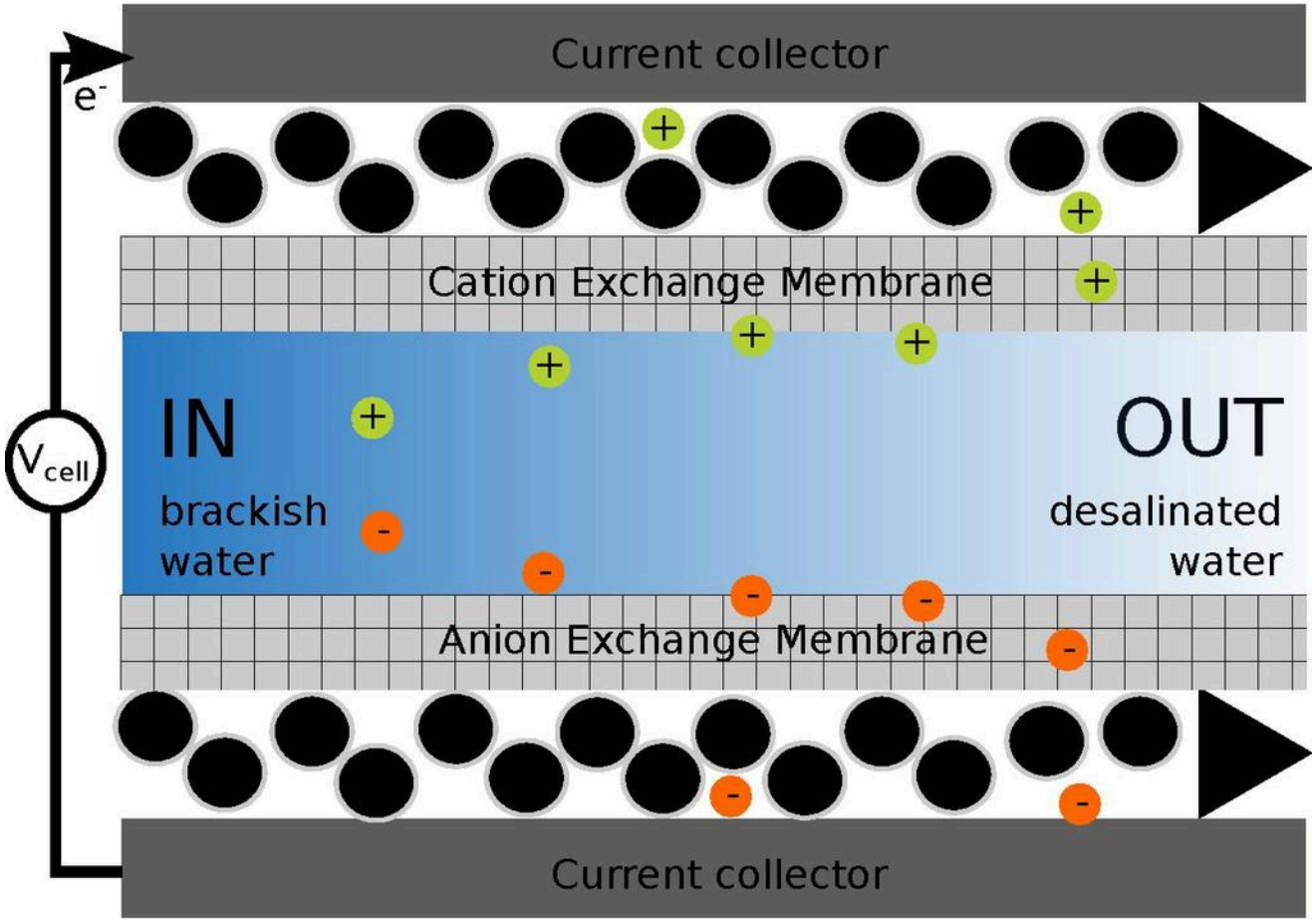
Capacitive deionisation (CDI) of CTBD



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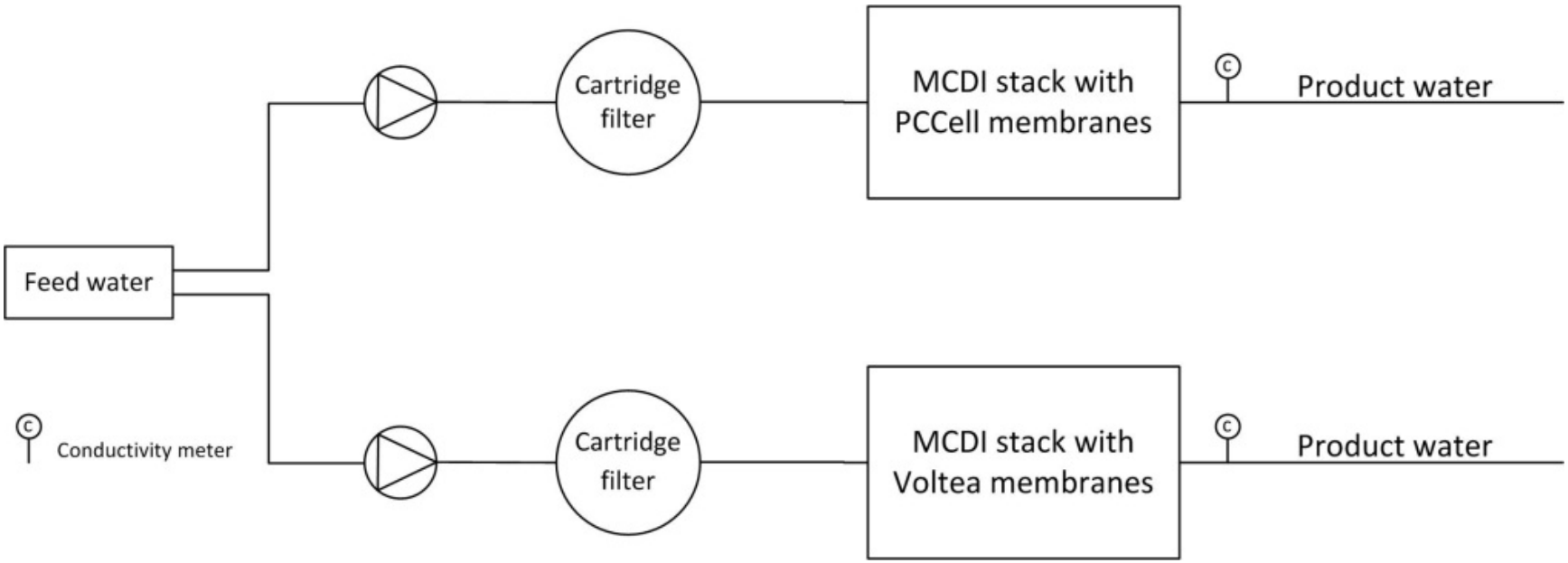
Laboratory setup CDI experiments



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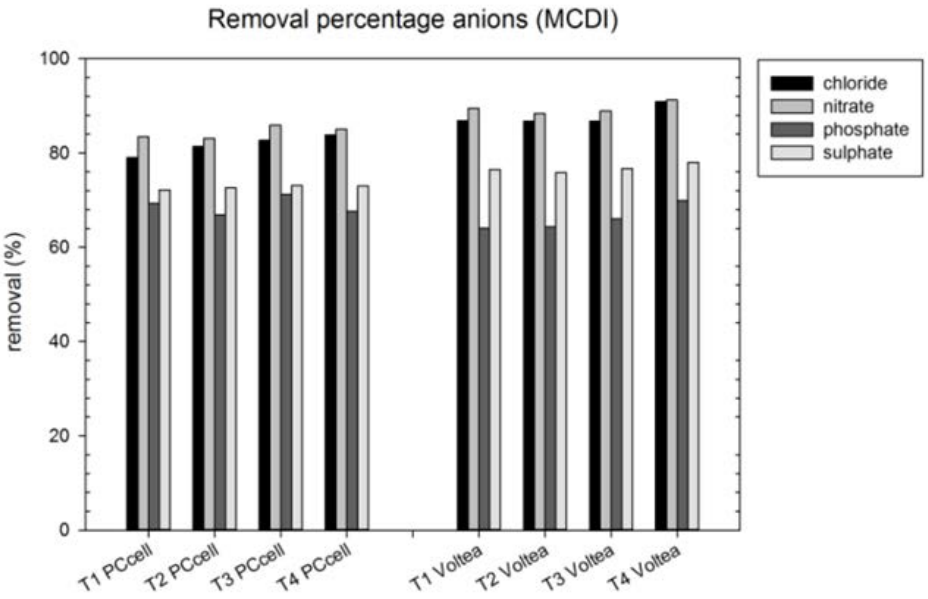
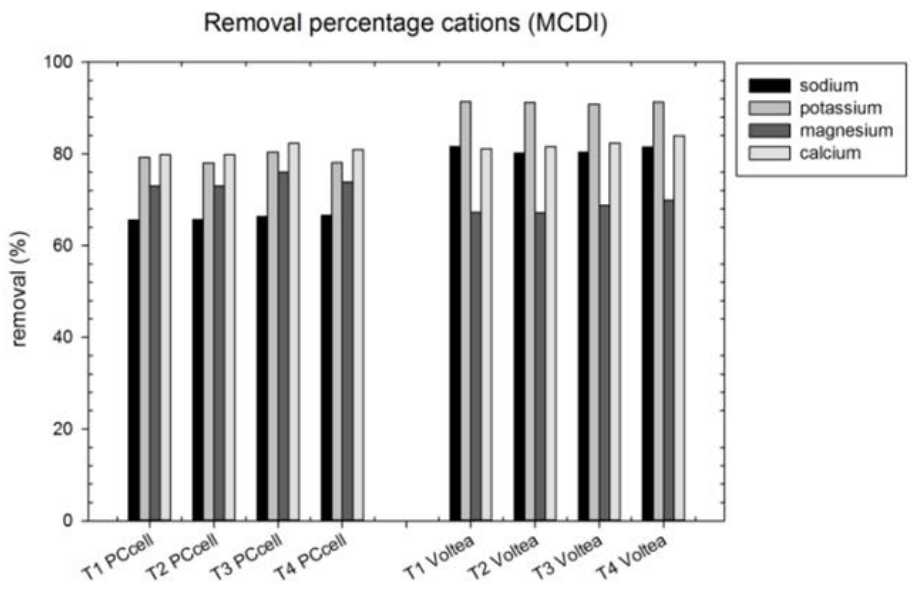
Removal of ions from CTBD with CDI





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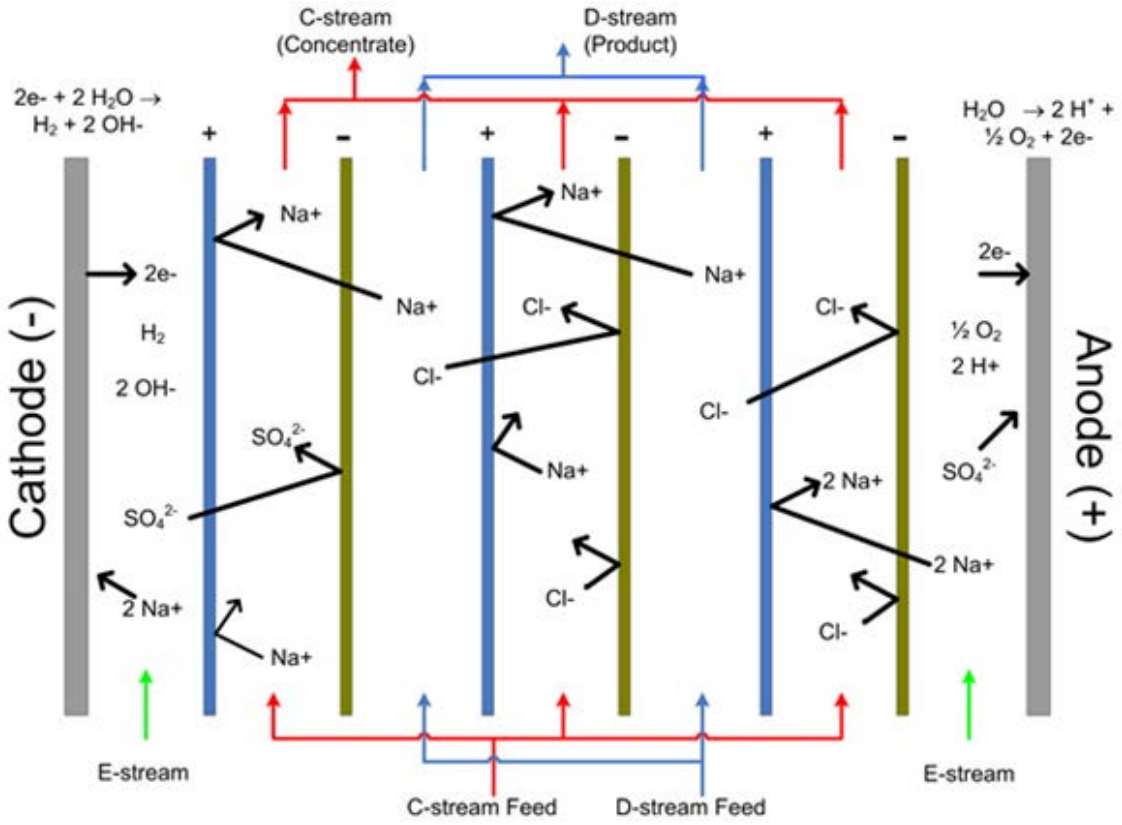
Laboratory experiments Electrodialysis reversal (EDR) of CTBD



Electrodialysis, overall results (1)

	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5
Recovery	80%	87%	87%	87%	87%
with:			reversal	anti-scalent	GE IEM
Precipitation?	NO	YES	YES	YES	YES
Energy [kWh/m^3][1]	0.31	0.61	0.53	0.70	0.31
CE	80%	80%	89% (62%)	83%	77%

- Selectivity towards ions :
  - $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$
  - $NO_3^- \approx Cl^- > SO_4^{2-} \approx HCO_3^-$ for GE membranes: $SO_4^{2-} > NO_3^- \approx Cl^-$
  - PO_4^{3-} too low ($P < 0.05$ mol/l)

[1] Retrieved experimental energy usage corrected for the electrode reactions by subtracting 1.8 V from the cell potential

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Electrodialysis, overall results (2)

	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5
Recovery	80%	87%	87%	87%	87%
with:			reversal	Anti-scalent	GE IEM
EC_{start} [mS/cm]	3.8	3.8	3.5	3.9	3.7
$EC_{diluate}$ [mS/cm]	1.0	1.1	1.1	1.0	1.0
$EC_{concentrate}$ [mS/cm]	11.9	16.0	13.0	17.0	14.2
pH_{start}	7.8	7.5	7.4	6.9	7.6^{d} 3.7^{c}
$pH_{diluate}$	7.4	6.1	6.7	4.8	7.0
$pH_{concentrate}$	8.0	7.8	7.8	8.0	4.3

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Conclusions

- Selection of desalination technology based on raw water quality, requirements for reuse and additional defined KPI's (e.g. maturity, costs, scale of operation)
- Desalination technologies may require different pretreatment steps, which have taken into account in the final selection procedure.
- Supporting laboratory experiments have been useful for the final selection of desalination technology on demo scale.

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