

**CRITICAL RAW MATERIALS FOR UNCONVENTIONAL WATER SOURCES:
ENSURING SUPPLY THROUGH CIRCULAR ECONOMY**

SEA4 VALUE

Mining value from brines

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13 Novembre 2024 – Càtedra ATL



What is Sea4Value?



Call: SC5-09-2018-2019

Timeline: June 2020 – May 2024 (Extension Nov 2024)

TRL 3 -5

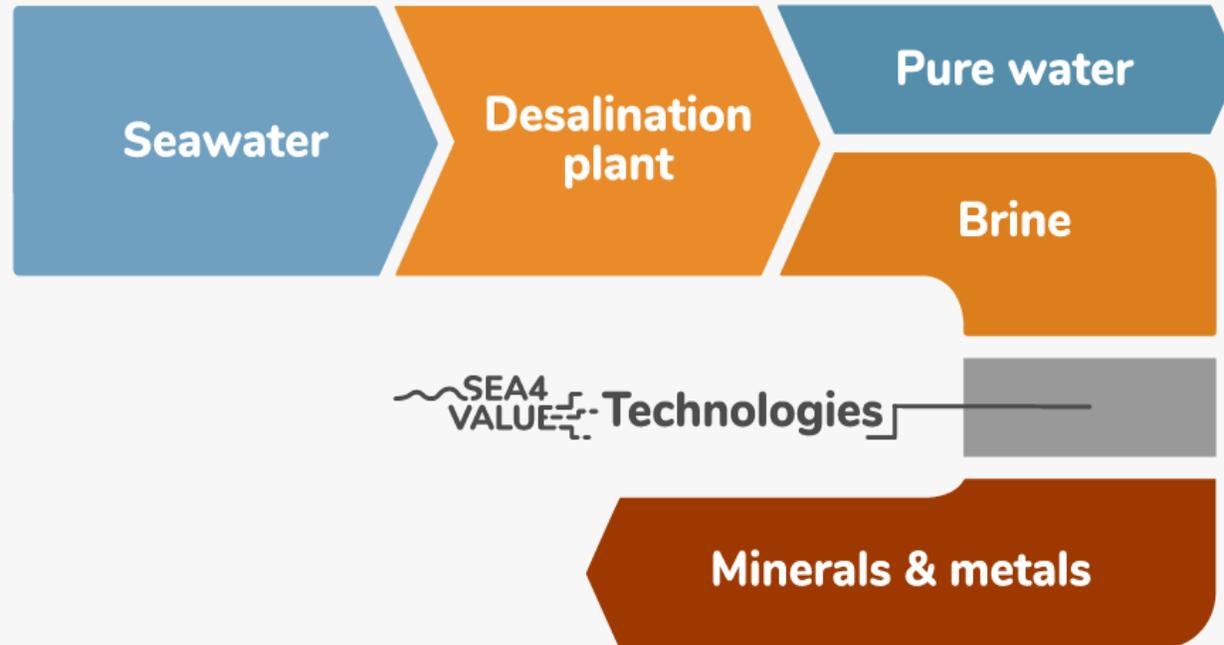
Budget: 7M€

Partners (Coordinator) : 17 (Eurecat)

Sea4Value is a H2020 project that have designed and implemented disruptive technologies for recovering minerals and metals from seawater desalination brines.



Circular Supply

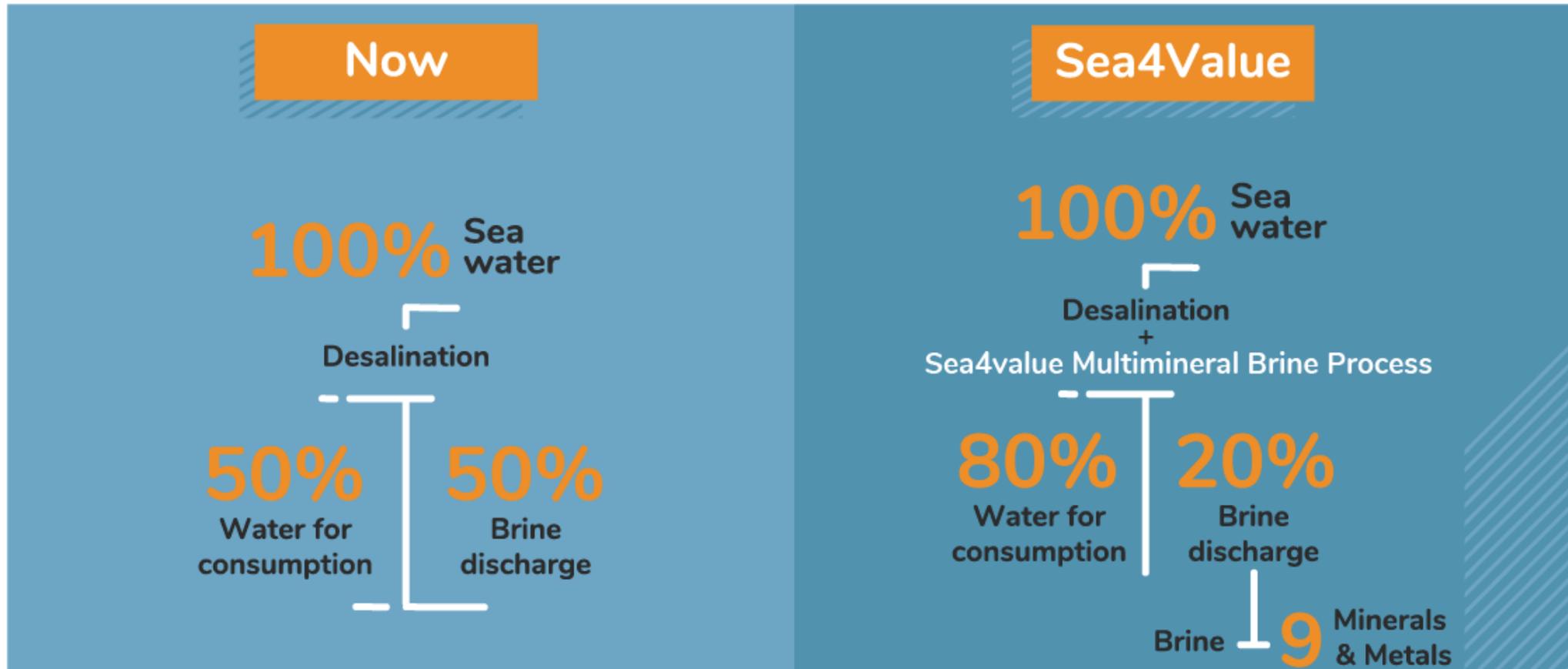


To apply a circularity approach to convert seawater brines as a resource of raw materials recovery

- New RM mines
- Lower environmental impact
- Higher water recovery



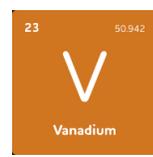
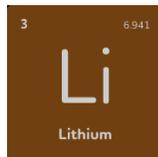
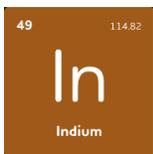
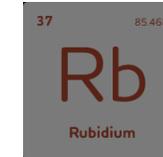
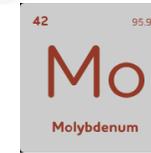
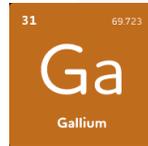
Not only metals and minerals...



Which metals and minerals?

CRITICAL

STRATEGIC



9 minerals and metals



Abundance of CRM in seawater brine

Detailed Analysis of the Brine obtain from the Atlantic Ocean.

Element	Concentration in µg/L	Element	Concentration µg/L
Li	126.65	In	0.03
Be	0.63	Sb	0.41
B	4,058.11	Ba	15.74
Sc	3.73	Bi	0.32
V	11.69	Ag	0.37
Ga	1.32	Cl	28,841.07
Rb	208.50	Sulfate	4,020.22
Mo	37.02	Na	15,788.66
Ru	0.19	K	564.08
Rh	0.61	Mg	1865.54
Pd	30.07	Ca	587.35

Generic Characteristics of the Brine

Salinity	50-90 g/L
Temperature	12-20°C

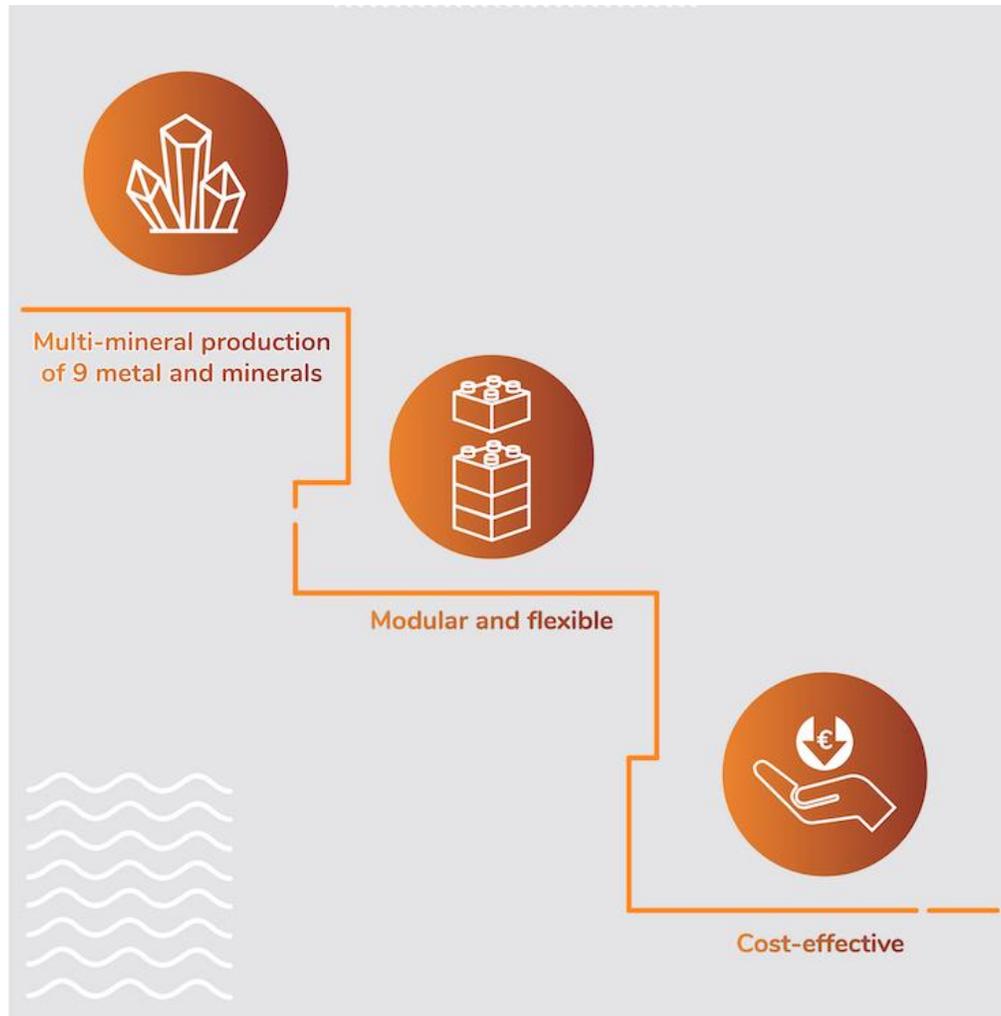


Element	Abundancy total in the ocean (tons)	Reserves minerals in land (tons)	Production in 2017 (tons)	Total Presence in SWDP brine (ton/yr)
Mg	1.68×10 ¹⁵	2.20×10 ⁹	1.10×10 ⁶	8.46×10 ⁷
Be	7.80×10 ⁵	1.00×10 ⁵	2.30×10 ²	3.93×10 ⁻²
Li	2.21×10 ¹¹	1.60×10 ⁷	4.30×10 ⁴	1.11×10 ⁴
Ni	8.58×10 ⁹	7.40×10 ⁷	2.10×10 ⁶	4.33×10 ²
Sr	1.05×10 ¹³	6.80×10 ⁶	2.02×10 ⁵	5.31×10 ⁵
Rb	1.56×10 ¹¹	9.00×10 ⁴	n.a.	7.87×10 ³
Ba	2.73×10 ¹⁰	2.90×10 ⁸	7.70×10 ⁶	1.38×10 ³
Co	5.07×10 ⁸	7.10×10 ⁶	1.10×10 ⁵	2.56×10 ¹

USGS. National Minerals Information Center. Mineral commodity Summaries

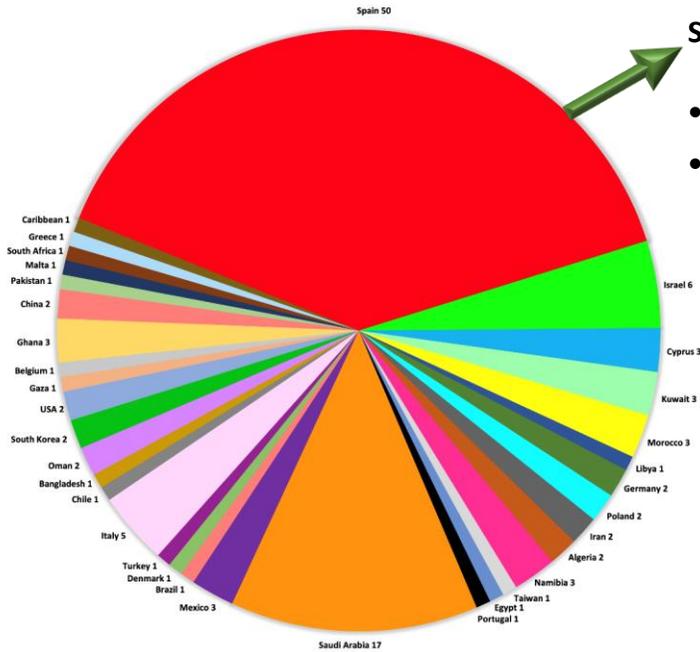
Why is this approach different?

Because it is developing **9** new highly **disruptive technological solutions** to integrate them in a **multimineral and modular process**, which will be the first industrially viable brine mining method



Brine Composite Catalogue

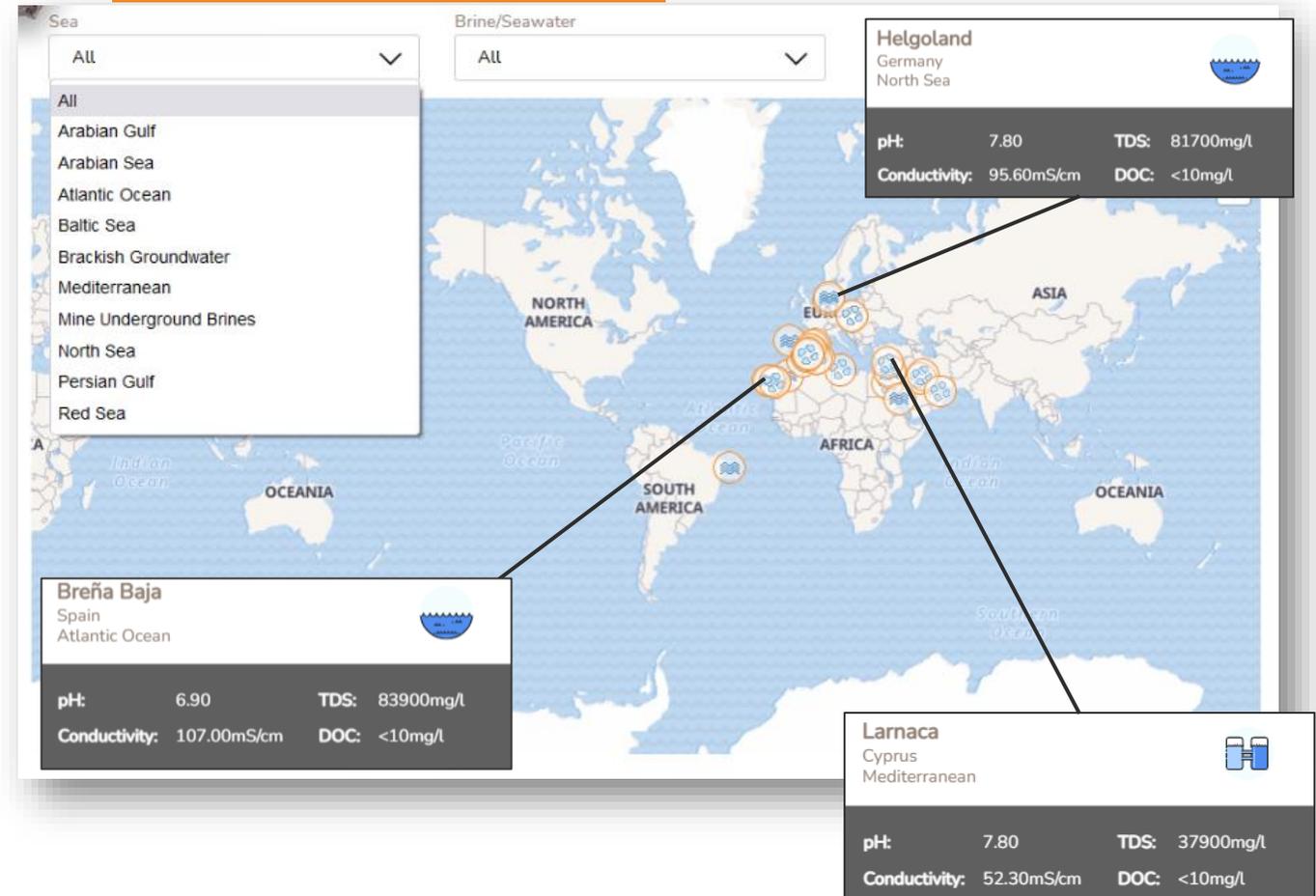
Brine from where?



Summary:

- 131 samples
- 34 countries

<https://sea4value-db.eu/>



The screenshot shows the SEA4 VALUE web application interface. It features a world map with orange circular markers indicating brine sample locations. Three callout boxes provide detailed data for specific locations:

- Helgoland:** Germany, North Sea. pH: 7.80, TDS: 81700mg/l, Conductivity: 95.60mS/cm, DOC: <10mg/l.
- Breña Baja:** Spain, Atlantic Ocean. pH: 6.90, TDS: 83900mg/l, Conductivity: 107.00mS/cm, DOC: <10mg/l.
- Larnaca:** Cyprus, Mediterranean. pH: 7.80, TDS: 37900mg/l, Conductivity: 52.30mS/cm, DOC: <10mg/l.

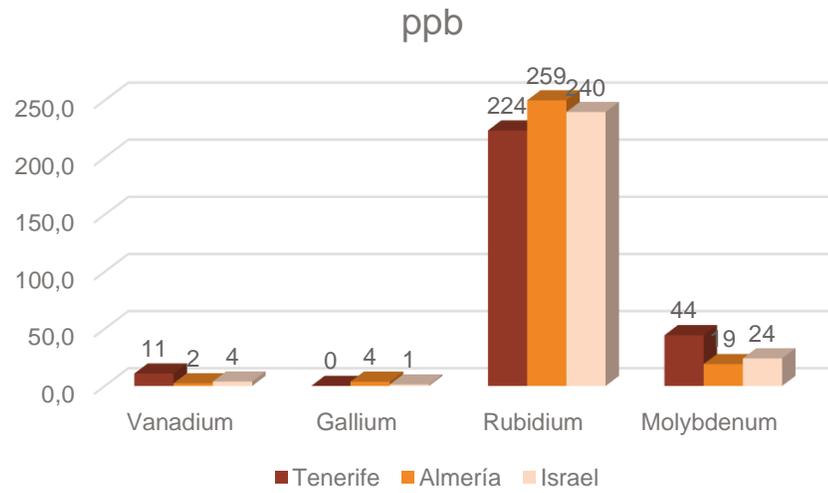
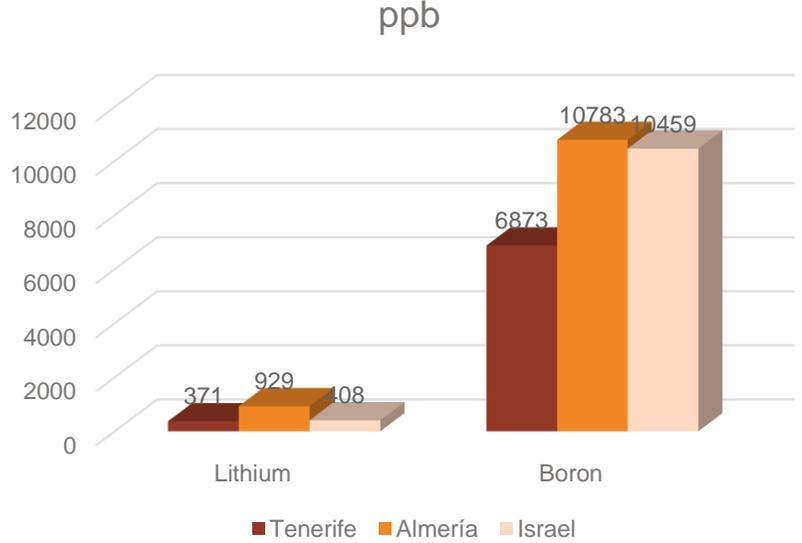
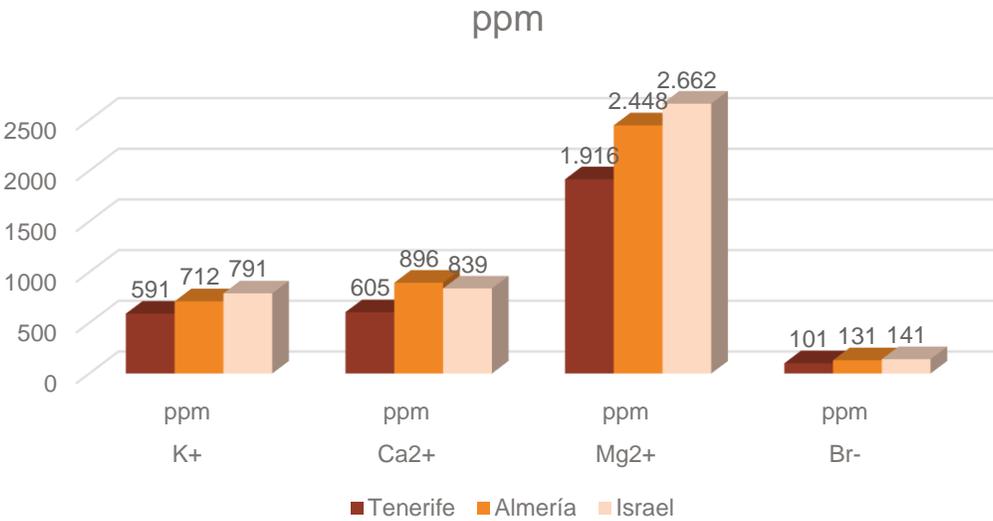
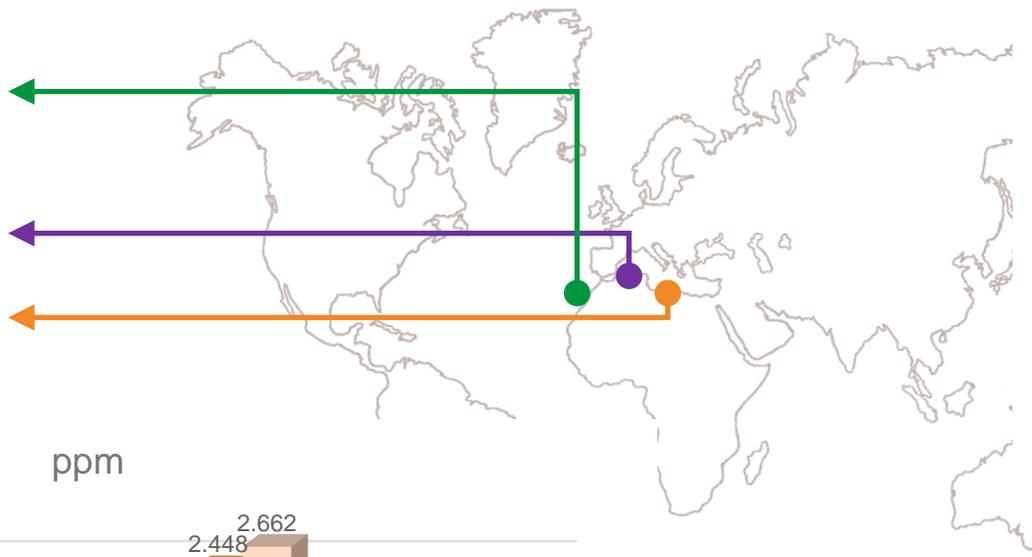
The interface also includes dropdown menus for 'Sea' and 'Brine/Seawater' types, and a list of categories such as Arabian Gulf, Atlantic Ocean, Baltic Sea, Brackish Groundwater, Mediterranean, Mine Underground Brines, North Sea, Persian Gulf, and Red Sea.

Development of an online platform to provide information on the **composition of brine** in desalination plants. Database enables operators and designers to **identify the optimal geographic locations to maximize metal and mineral recovery** from brine.

Brine to test and Demo Site

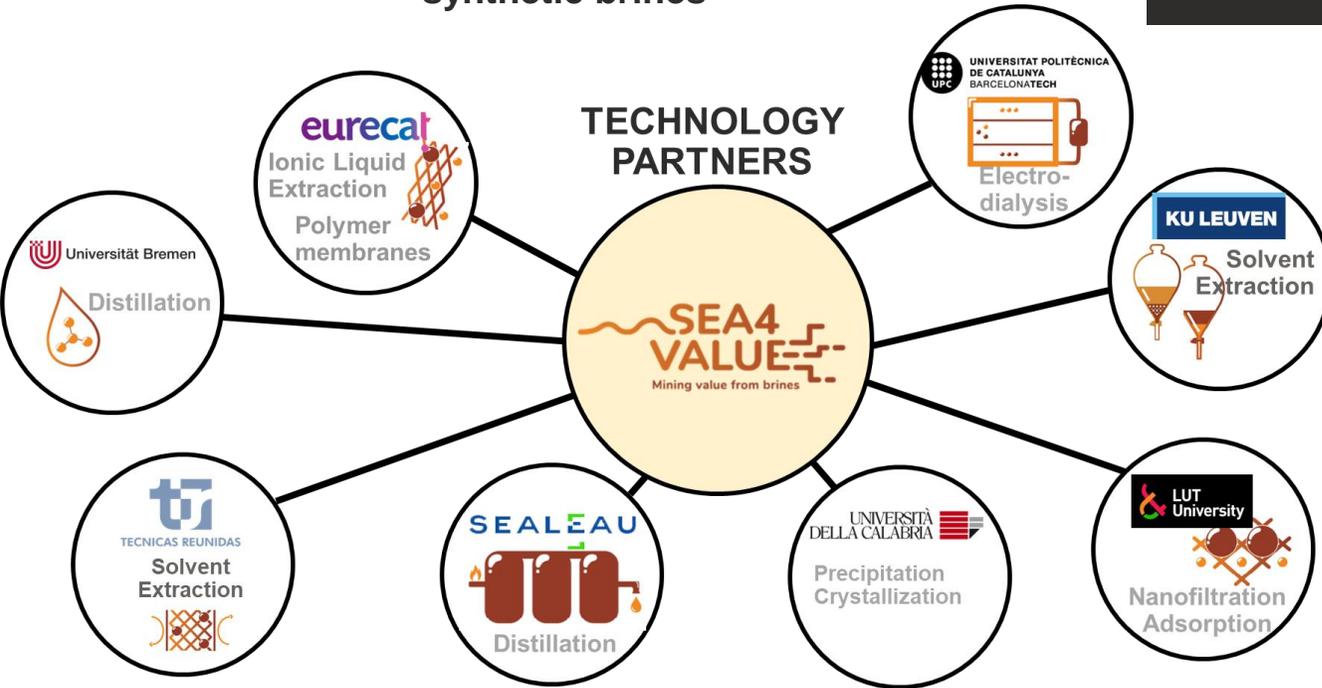
BRINE TO TREAT WITH THE MOVING LAB

Sea	Country	Conductivity mS/cm
Atlantic	Spain	79
Mediterranean	Spain	92
Mediterranean	Israel	100

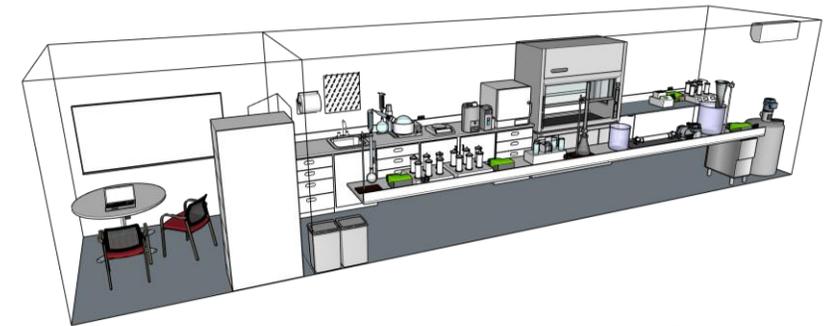


From lab development to evaluation in a relevant environment with real brines

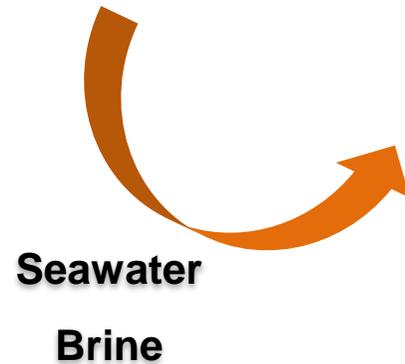
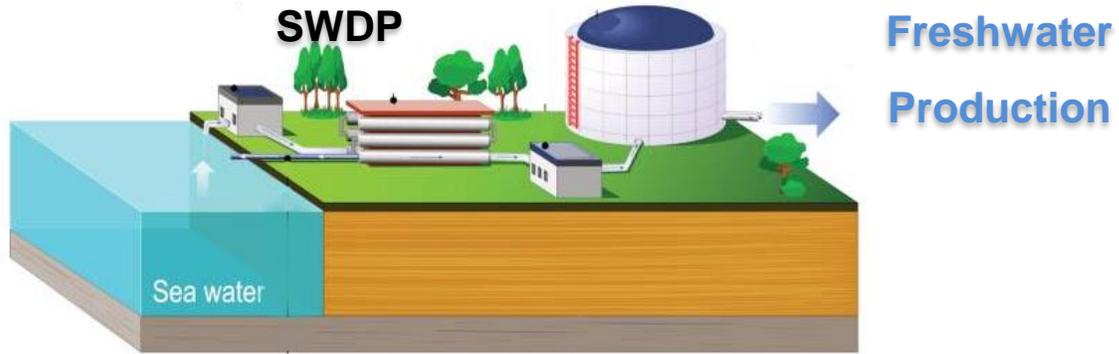
9 technologies developed in research labs with synthetic brines



Evaluated with real brines in an integrated treatment scheme (Moving Lab)



Brine Mining Process

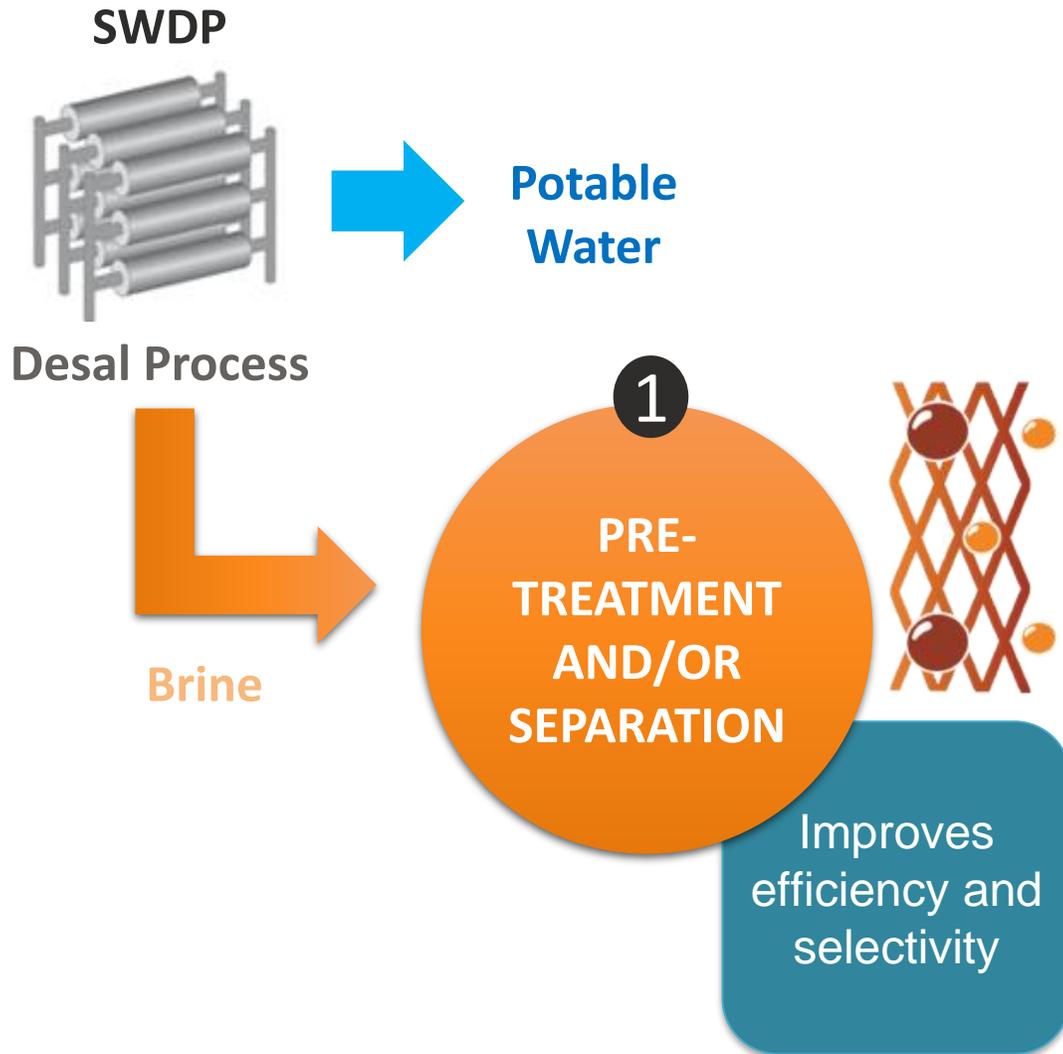


Brine mining Process

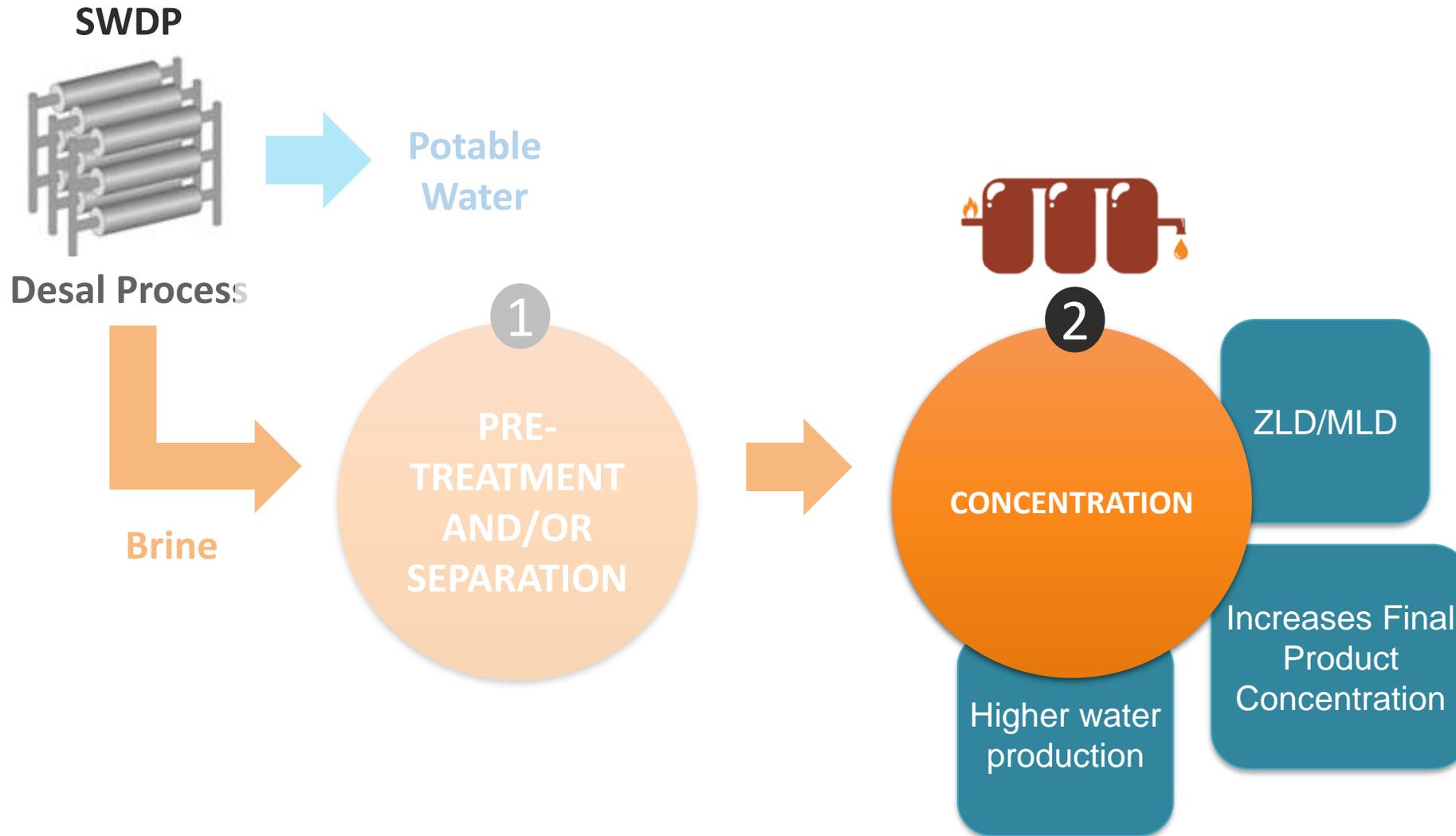
Steps and technologies ?



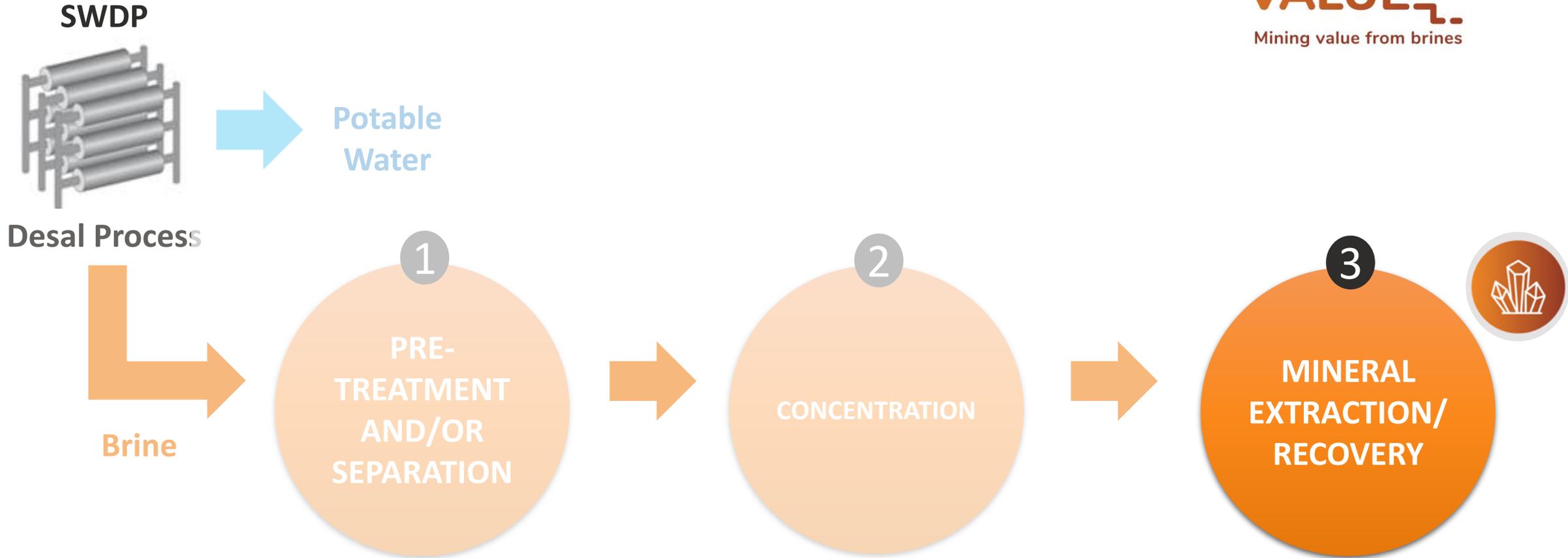
Brine Mining Process



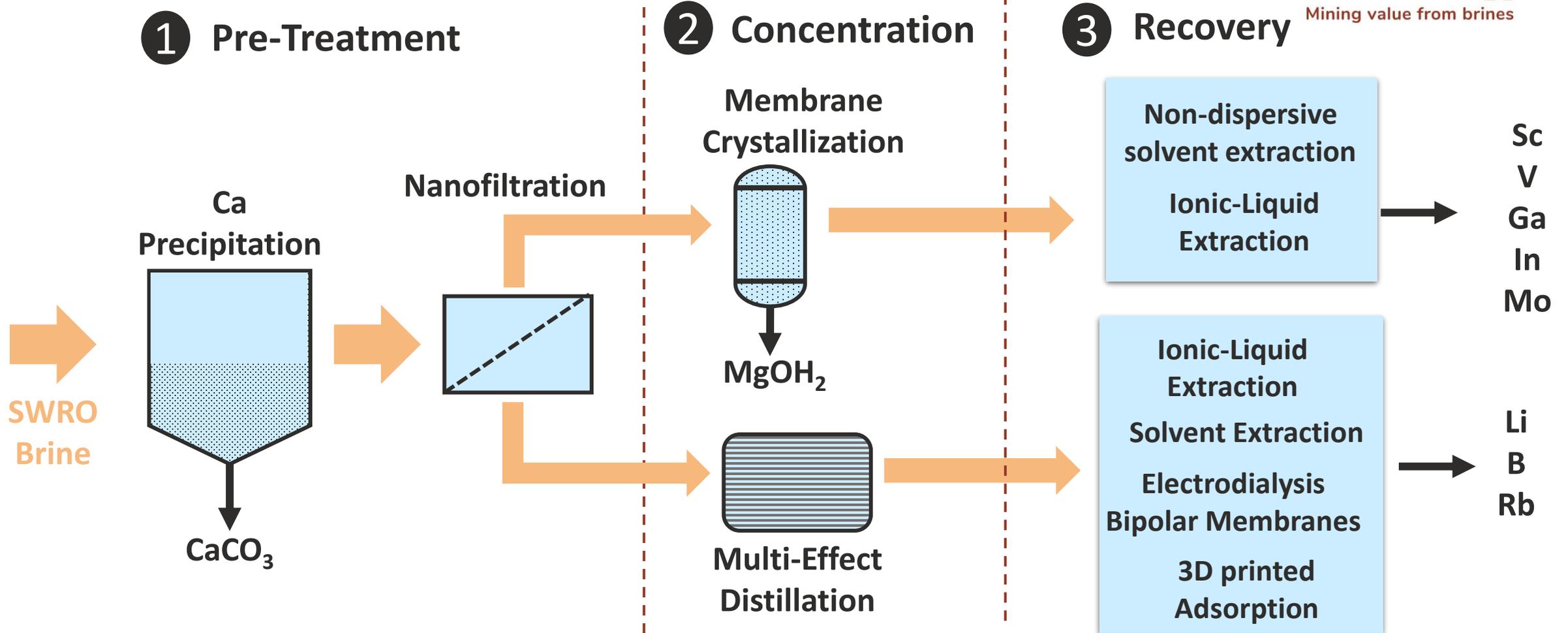
Brine Mining Process



Brine Mining Process



Sea4Value Brine Mining Concept



Adapted from: Figueira, M. (2023). Evaluation of the nanofiltration of brines from seawater desalination plants as pre-treatment in a multimineral brine extraction process.,

Sea4Value Moving Lab

Integration of Brine Mining Process

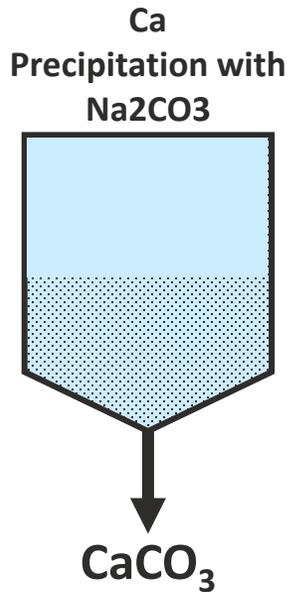


1 Pre-Treatment – Calcium Precipitation



>97% Purity
CaCO₃ (Aragonite)

SWRO
Brine

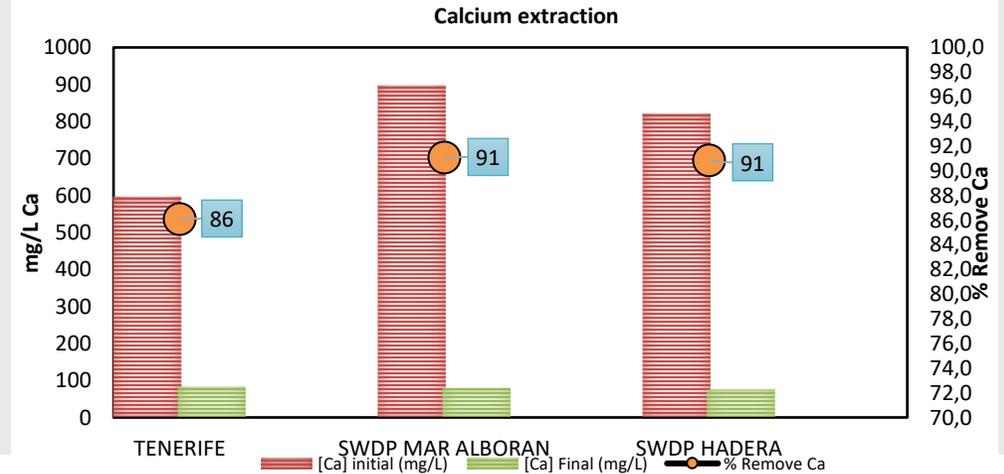


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		SWRO BRINE	AFTER PRECIPITATION
Li ⁺	ppm	0.40	0.31
K ⁺	ppm	591	568
Ca ²⁺	ppm	605	119
Mg ²⁺	ppm	1916	1831
Cl ⁻	ppm	29979	29471
Br ⁻	ppm	101.4	98.9
SO ₄ ²⁻	ppm	4254	4169

80-90% removal



Molinari et al. 2021

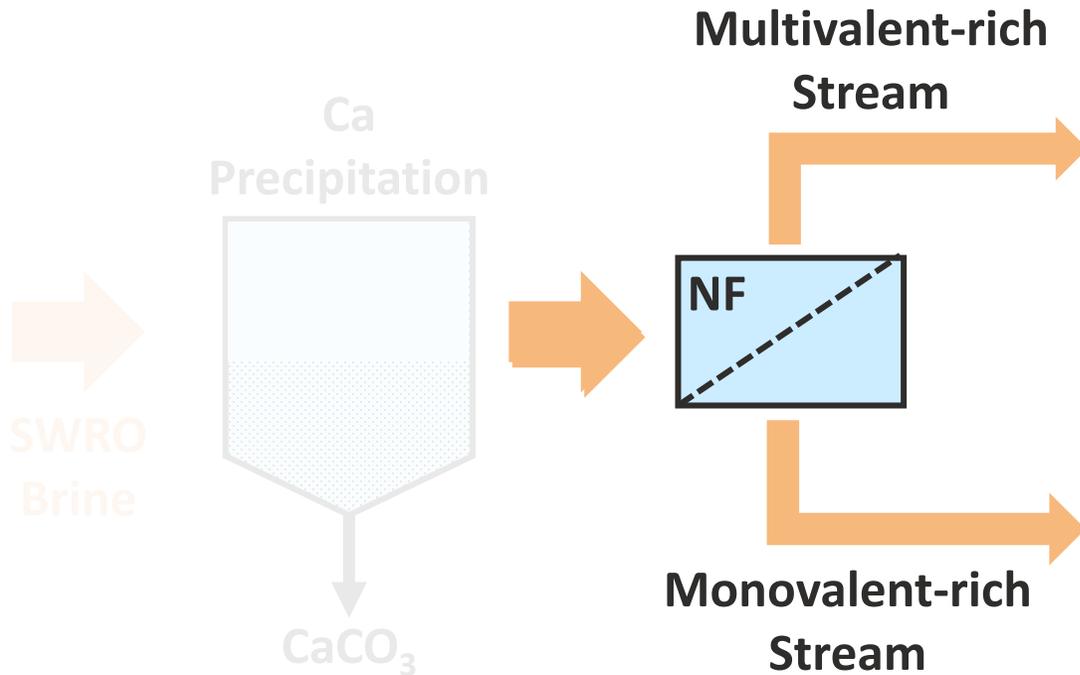
<https://doi.org/10.1016/j.jclepro.2021.129645>



1 Pre-Treatment – Nanofiltration

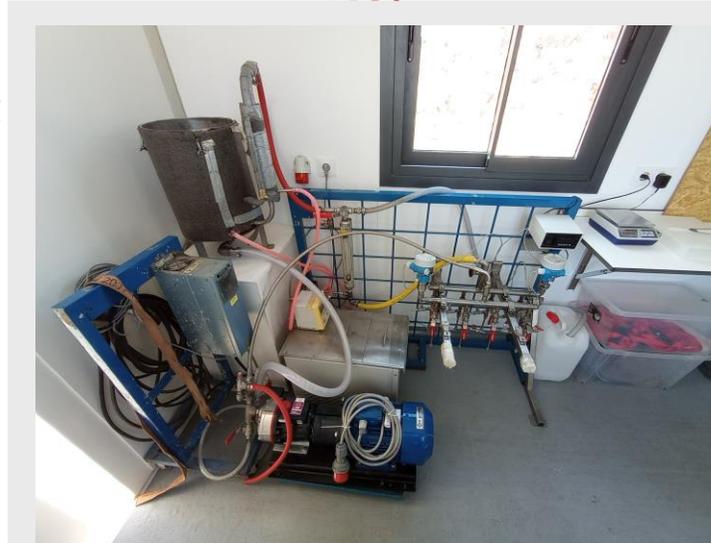


- Synthesis of novel NF PEM coated membranes with improved properties for selective polyvalent /monovalent separation



Figueira et al. 2023

<https://doi.org/10.1016/j.seppur.2023.124232>



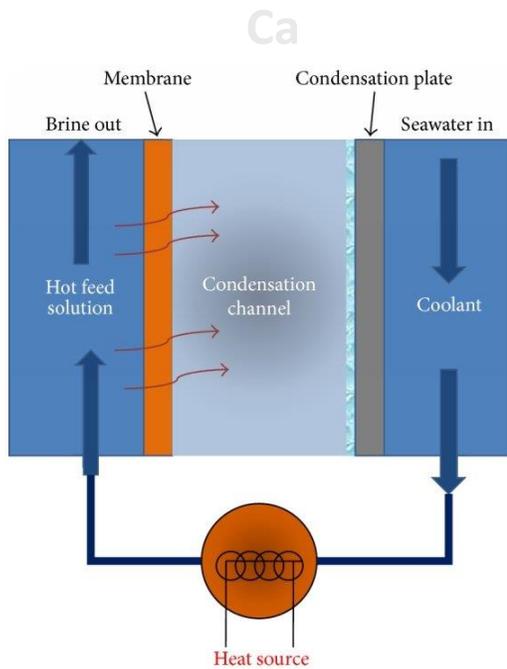
> 80% rejection
 Ca^{2+} , Mg^{2+} , SO_4^{2-}



		MONOVALENT	MULTIVALENT
Li^+	ppm	0.27	0.33
K^+	ppm	517	570
Ca^{2+}	ppm	23	157
Mg^{2+}	ppm	110	2533
Cl^-	ppm	25431	30958
Br^-	ppm	92.0	101.4
SO_4^{2-}	ppm	23	6040



2 Concentration – Membrane Crystallization



Membrane Crystallization



**x3.5
Concentration
Factor**

98% recovery of Mg

		FEED	EFFLUENT
Li^+	ppm	0.33	0.77
K^+	ppm	570	1227
Ca^{2+}	ppm	157	9
Mg^{2+}	ppm	2533	33
Cl^-	ppm	30958	63661
Br^-	ppm	101.4	213.5
SO_4^{2-}	ppm	6040	12463

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**>98% Purity
 $MgOH_2$**



2 Concentration – Multi-Effect Distillation

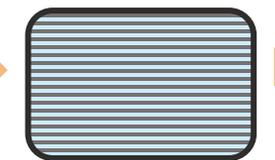
- Very high corrosion resistance
- High strength, hardness and stiffness to min. 80 °C
- Operation under vacuum conditions with low heat (65-70°C)
- Low creep tendency
- Low water absorption
- High chemical resistance (hot saline solution, hot water, steam, cleaning agents)
- Good processability
- Low weight
- Resilient and durable
- Cost-effective
- Drinking water compliance

Imholze et al. 2024

<https://doi.org/10.3390/inventions9050111>

Membrane
Crystallization

x3.7
Concentration
Factor



Multi-Effect
Distillation

 Universität Bremen

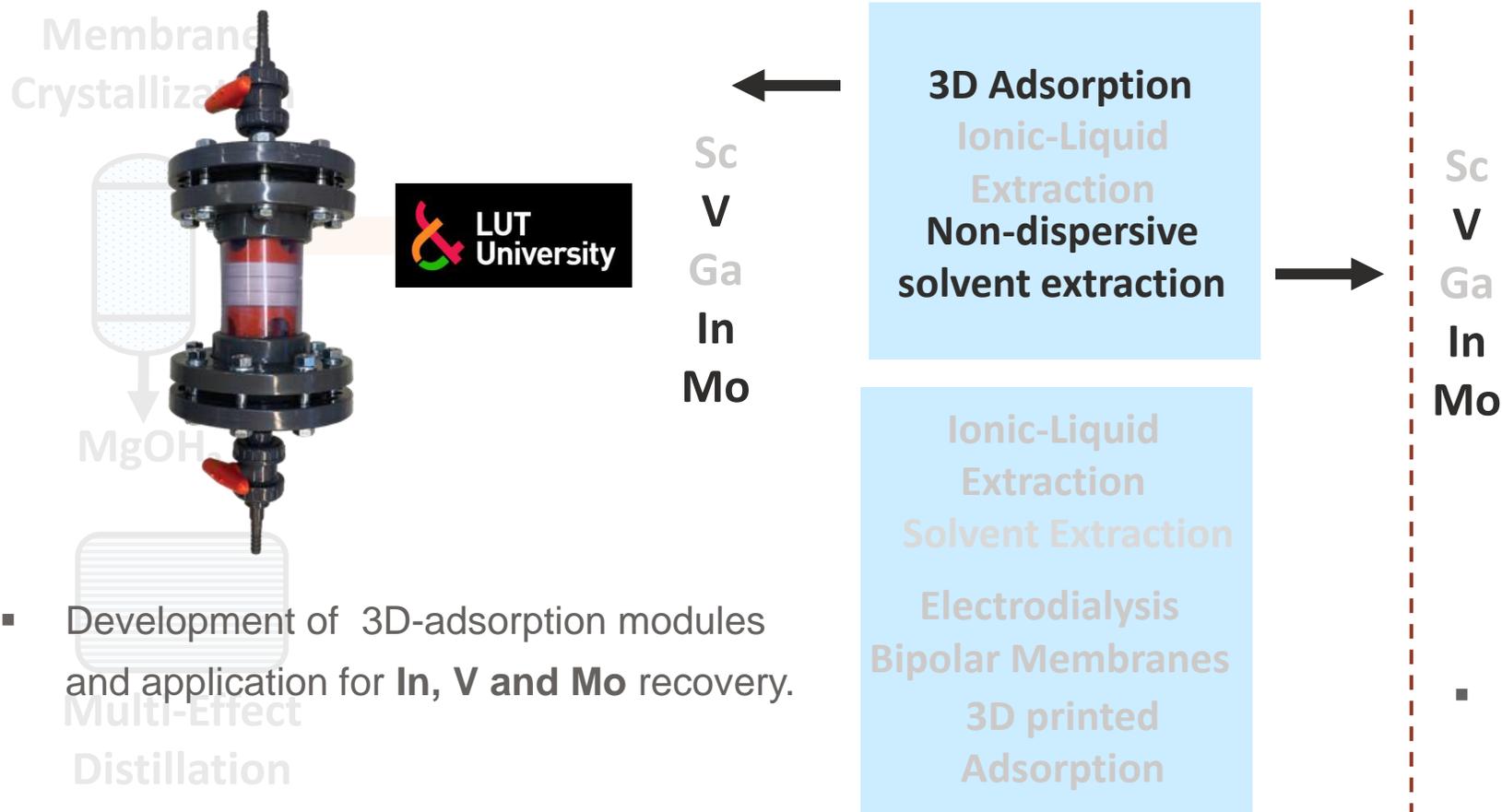
SEALEAU



		FEED	EFFLUENT
Li ⁺	ppm	0.27	1.08
K ⁺	ppm	517	1780
Ca ²⁺	ppm	23	45.2
Mg ²⁺	ppm	110	293
Cl ⁻	ppm	25431	67175
Br ⁻	ppm	92.0	255.8
SO ₄ ²⁻	ppm	23	28



3 Recovery – Multivalent Stream



- Development of a process for the recovery of **Ga** with ionic liquids (98% recovery). Validated at lab scale with synthetic brines

3 Recovery – Multivalent Stream 3D Adsorption Modules



Brine	Operation				Eluant Concentrations			Adsorption rate		
	Brine flow rate	Eluent flow rate	Initial E.C.	Final E.C.	V	Mo	In	V	Mo	In
	(mL/min)	(mL/min)	(mS/cm)	(mS/cm)	(ppb)	(ppb)	(ppb)	(%)	(%)	(%)
Tenerife	2.5	0.9	225.4	194.7	1028	8878	<0.010	70.8	75.1	-

- Adsorption efficiencies of > 70% were obtained for vanadium and molybdenum.

Arifur et al. 2021

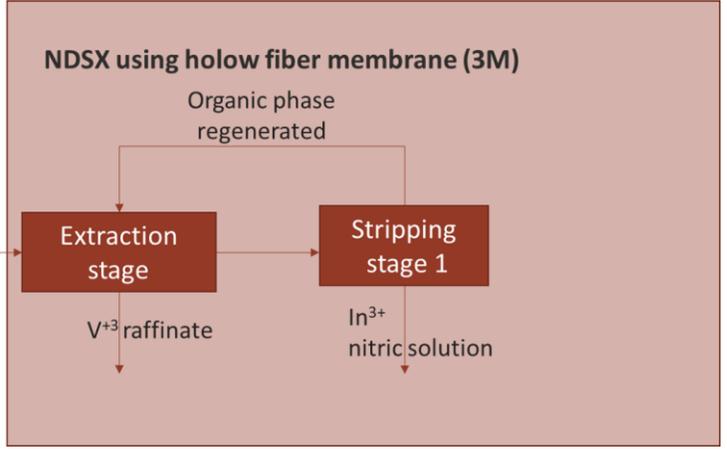
<https://urn.fi/URN:NBN:fi-fe2021110554033>



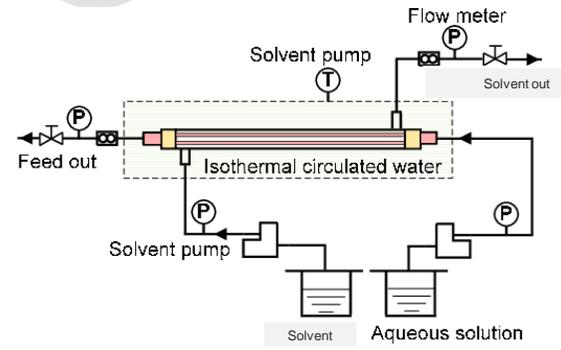
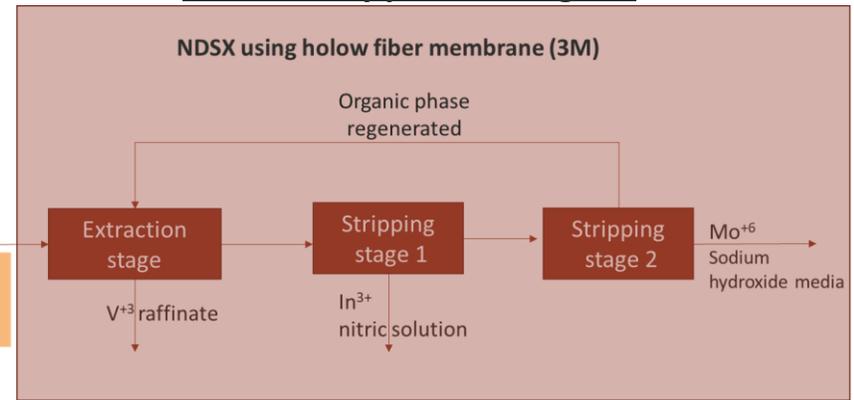
3 Recovery – Multivalent Stream Non-dispersive solvent extraction



In recovery process diagram



Mo recovery process diagram



91% of the initial indium is recovered

For molybdenum tests, 98% was recovered with respect to the initial one



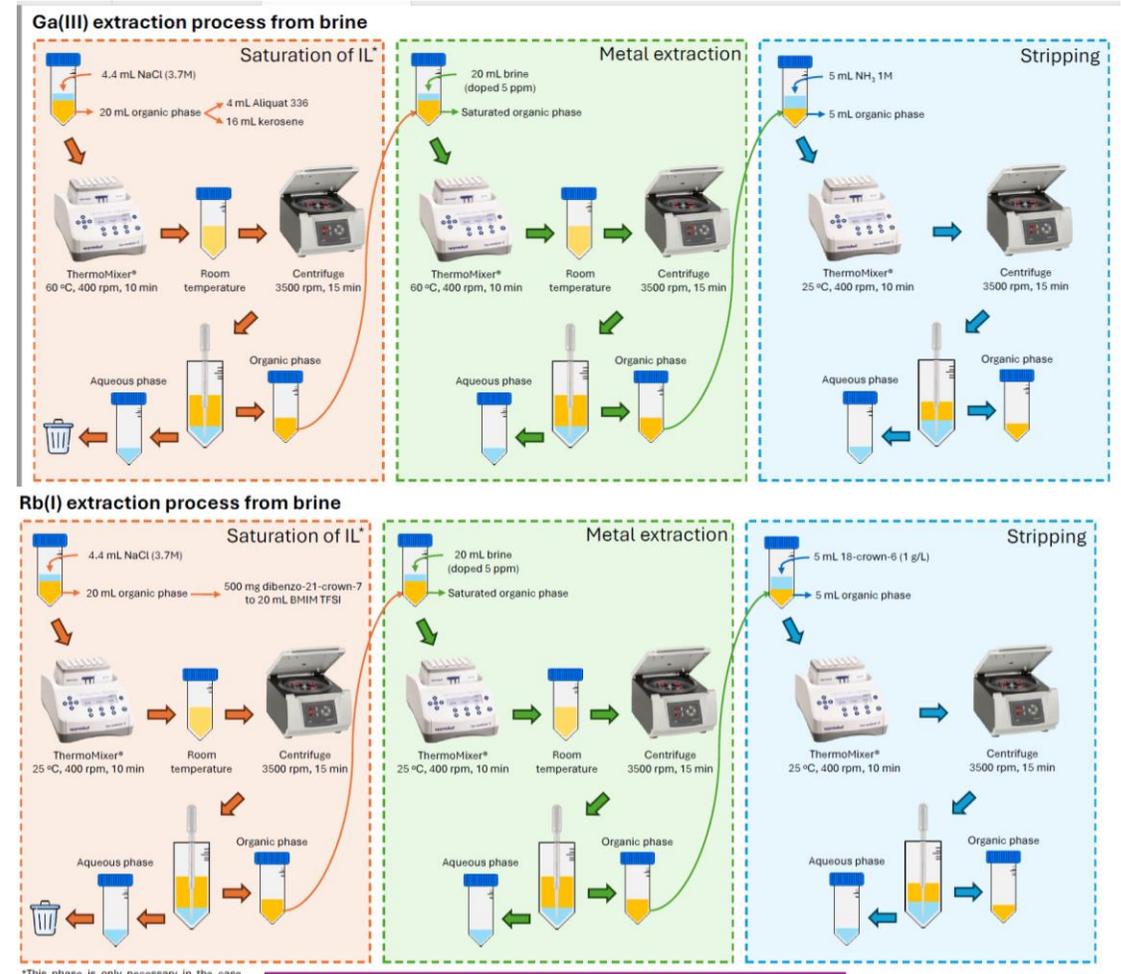
pH	[In] (ppm)	[V] (ppm)	[Mo] (ppm)	[Na] (g/L)	[K] (g/L)	[Mg] (ppm)	[Ca] (ppm)	[Cl] (g/L)
1, 2	103	10	2	84	2,1	2	7	111
1, 1	1	19	52	88	2,2	2	20	59



3 Recovery – Multivalent and monovalent Stream - Ionic liquids



- Development of a process for the recovery of **Ga** with liquid-liquid (98% recovery) tested at lab scale with synthetic brines
- Recovery of **Rb** from monovalent ion stream with liquid-liquid extraction (86% recovery) tested at lab scale with synthetic brines



3 Recovery – Multivalent Stream



- Production of **boric acid** using ED + **EDBP** with 80% current efficiency and 2,5 concentration factor.



Figueira et al. 2023

[https://www.sciencetalks-journal.com/article/S2772-5693\(23\)00096-8/fulltext](https://www.sciencetalks-journal.com/article/S2772-5693(23)00096-8/fulltext)

3D Adsorption
Non-dispersive solvent extraction
Ionic-Liquid Extraction

Solvent Extraction
Electrodialysis
Bipolar Membranes
3D printed Adsorption

Li
B
Rb



Li
B
Rb

Efficient Extraction of Target Metals

- Development of a process for lithium recovery based on solvent extraction technology. **Li** extraction reached **98%** after 3 stages. Obtention of Li_2CO_3 (97,2% purity)

KU LEUVEN



Raiguel et al. 2023

<https://doi.org/10.1080/07366299.2023.2206440>



Final steps

Development of models and the PSP

- Development of most of the mathematical models to simulate and predict the performance of each technology

Moving lab in operation until November 2024 to test the remaining technologies for selective ion concentration

Sustainability, exploitation and future market uptake assessment

- Life Cycle Assessment for each technology
- Market analysis. Market framework for each M&M has been set
- Compiling the information about the **Sea4Value products for quality, quantity, and impurities**
- Transfer from Innovation to Practice: **Standardisation needs** has been formulated for brine mining

Conclusions

- New **local source of minerals and metals** + lowering dependence on imports
- New **technological solutions** for SWDPs and other processes e.g., mining effluents. More research is needed to bring them to the market
- Map of **brines composition** for EU Raw Material Information System





THANK YOU!

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@Sea4value