The BrineMine – Project

Results and economical considerations

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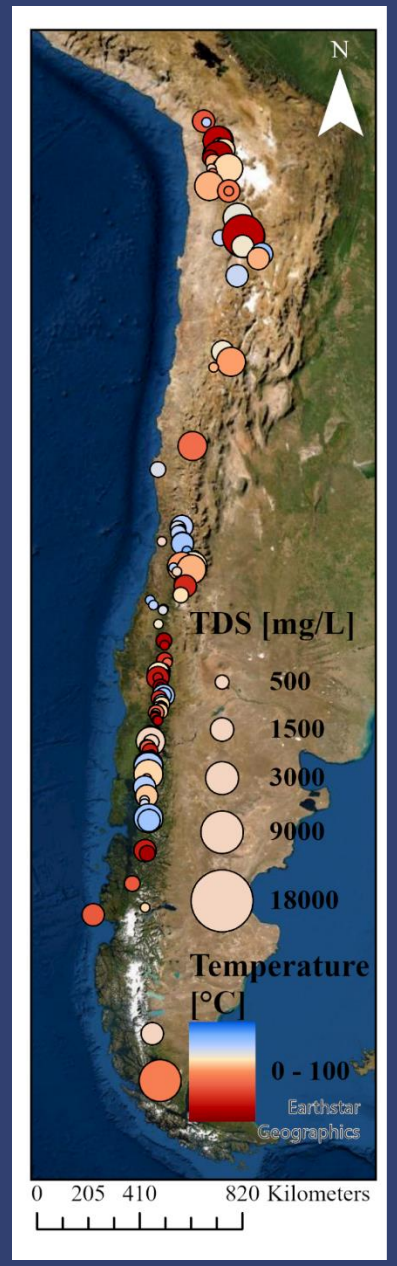
BrineMine

Exploration

Development of extraction strategies

Prototype development and operation

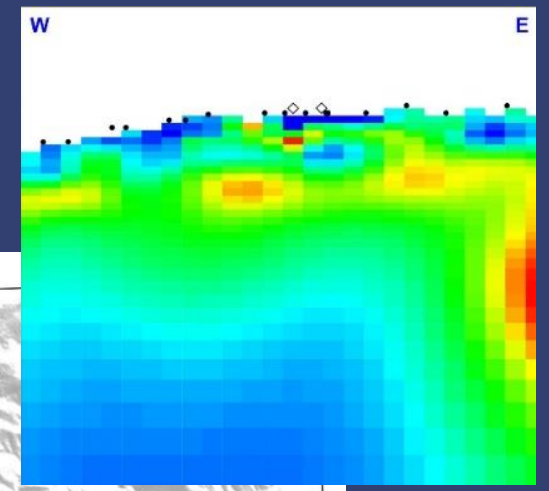


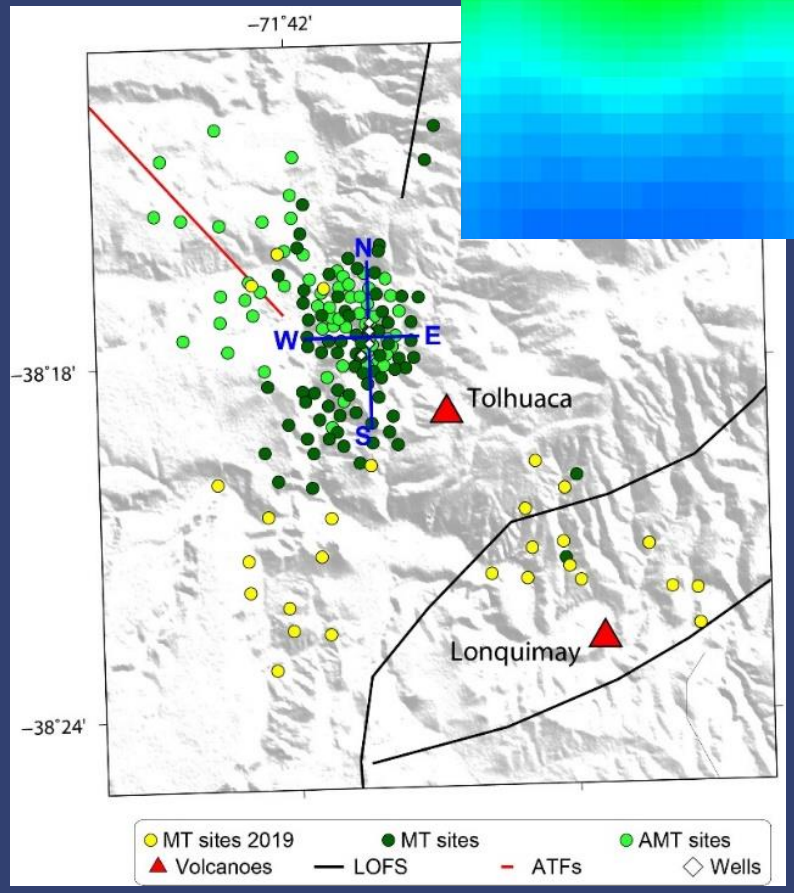
Geochemical Exploration

- **12 out of 30** worldwide critical raw materials occur in geothermal brines
- Attractive raw material extraction rates due to large volumes of circulated brine in geothermal plants
- Abundance of hydrothermal springs in Chile (n > 500)
- Goal: Identification of valuable major and trace elements in Chilean thermal waters and their origin

Geophysical Exploration

- Goal: Identification and quantification of reservoirs



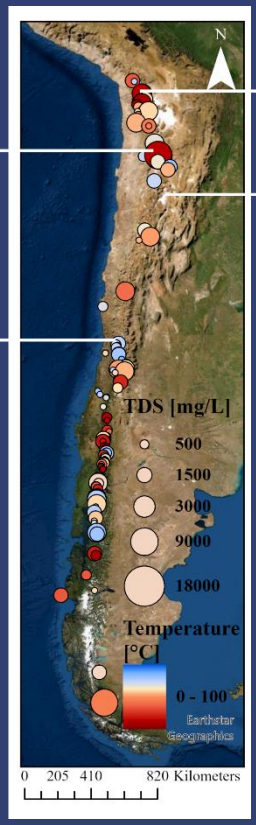


Pavez [2021]

Economic potential of geothermal brines as raw material source

El Tatio
Lithium 61 mg/L
Rubidium 6.7 mg/L
Caesium 15.8 mg/L

Termas Jahuel
SiO2 380 mg/L



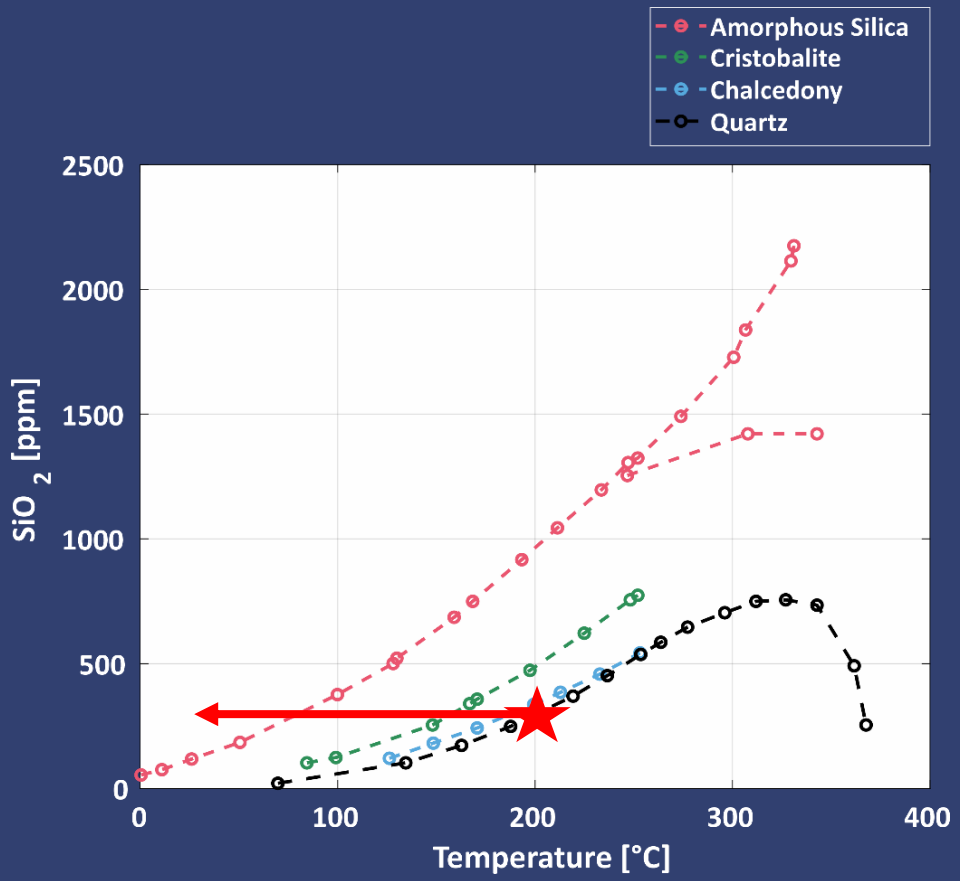
Puchuldiza-Tuja
Boron 1020 mg/L

Gorbea
Magnesium 1150 mg/L

Flowrate	80 [L/s]
Availability (runtime/year)	90 %
∑ Annually circulated brine	2,270,592 m³
Extraction rate for raw materials	50 %

Compound	Circulated mass per year [t]	Specific price [$/t]	Resulting economic potential [$/yr]
SiO_2	690	$ 300	$ 129,424
Mg	2,089	$ 2,000	$ 2,611,181
H_3BO_3	10,414	$ 600	$ 3,905,414
Cs	29	$ 63,000,000	$ 1,130,073,638
Rb	12	$ 15,920,000	$ 121,095,13
$LiCO_3$	585	$ 9,000	$ 3,289,614

lithium	caesium	boron	rubidium	magnesium	silicon
3	55	5	37	12	14
Li	Cs	B	Rb	Mg	Si
6.941	132.91	10.811	85.468	24.305	28.086
Battery technology	Photoelectric cells	Fertilizers	Biomedical research / electronics	Lightweight construction	Construction



Fournier & Rowe (1966)

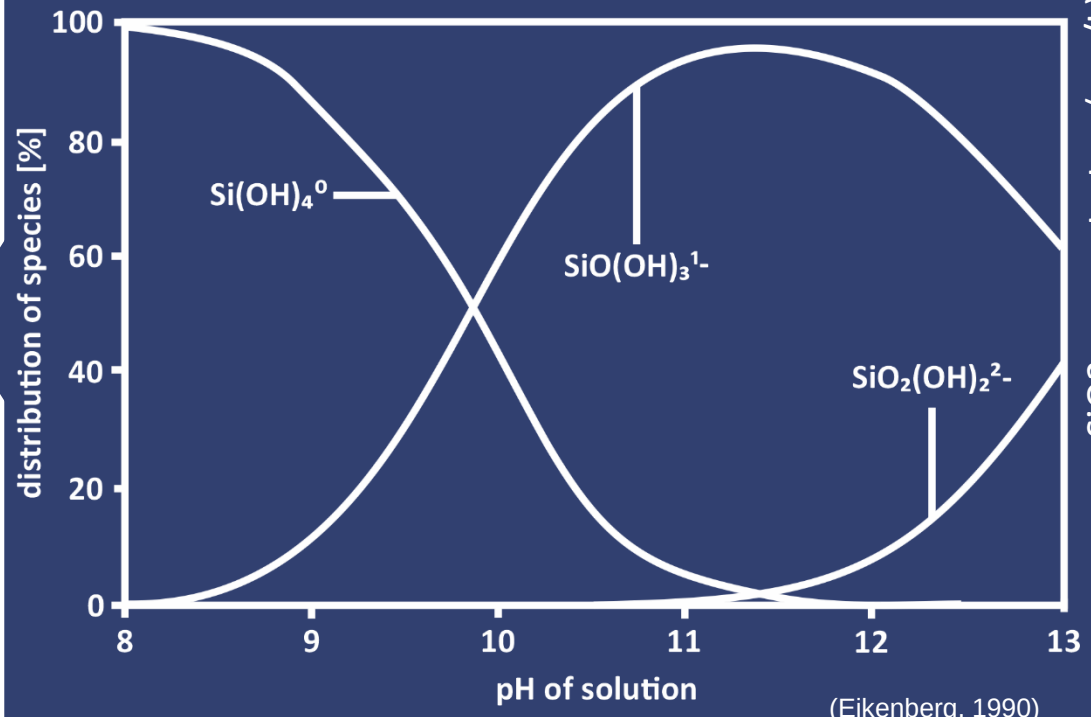
Wateronline.com

Augustinus et al. 2018

Construction

Silica is a limiting factor for geothermal energy production and associated raw material production.

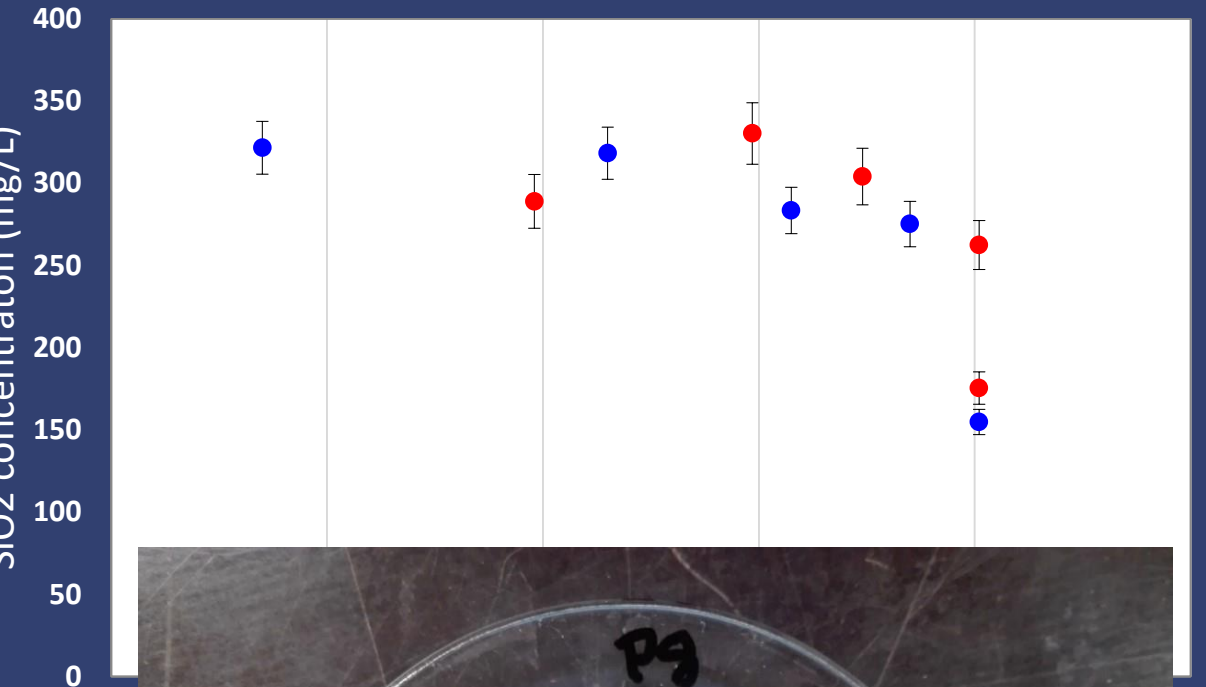
Laboratory studies



(Eikenberg, 1990)

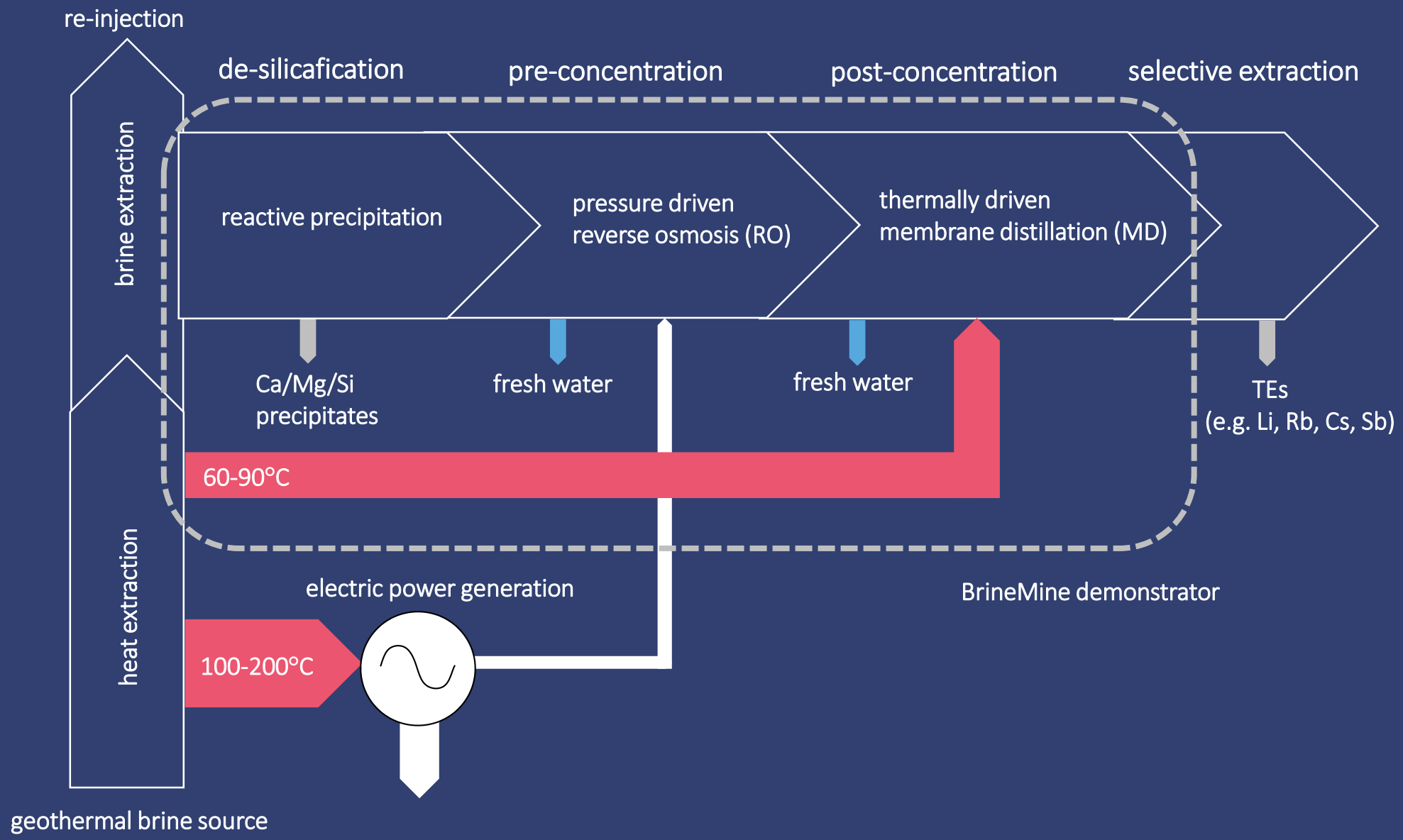
H_3SiO_4 –
+ xOH^-
+ Ca^{2+}

$CaSiO_{3-x}(OH)_{2x}.yH_2O$



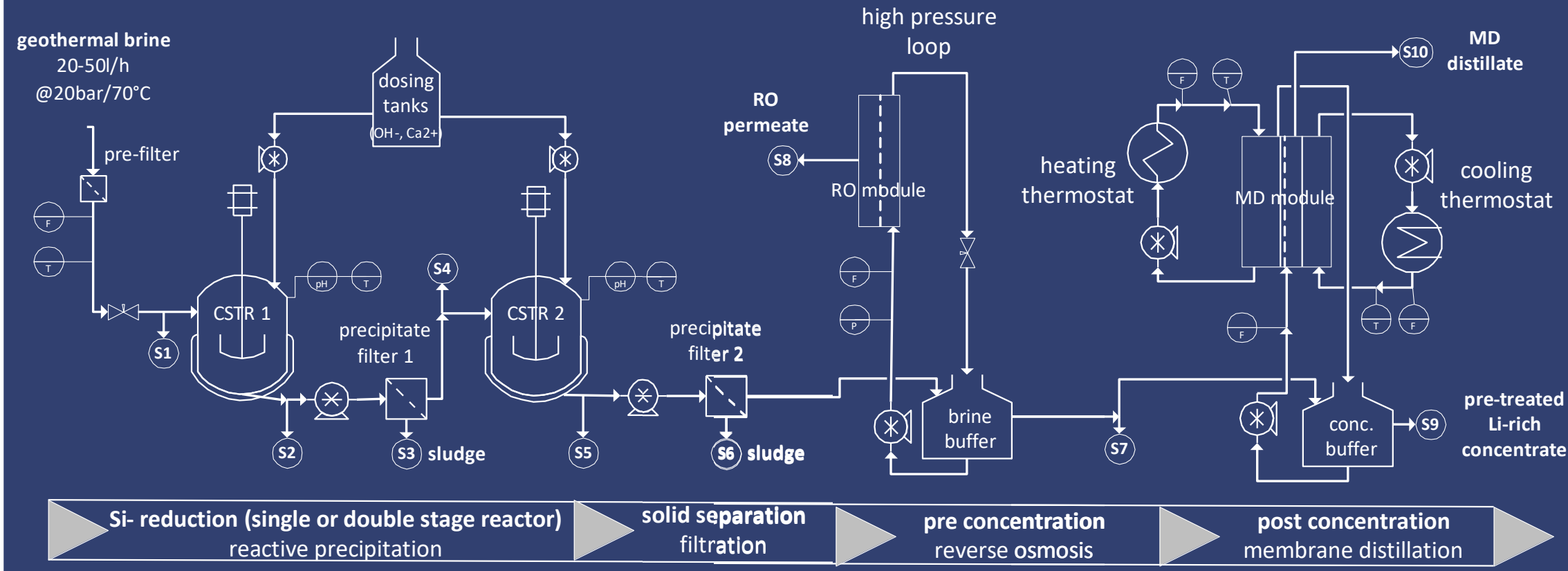
Spitzmüller et al. [2021]

Fundamental extraction approach



Demonstrator Development

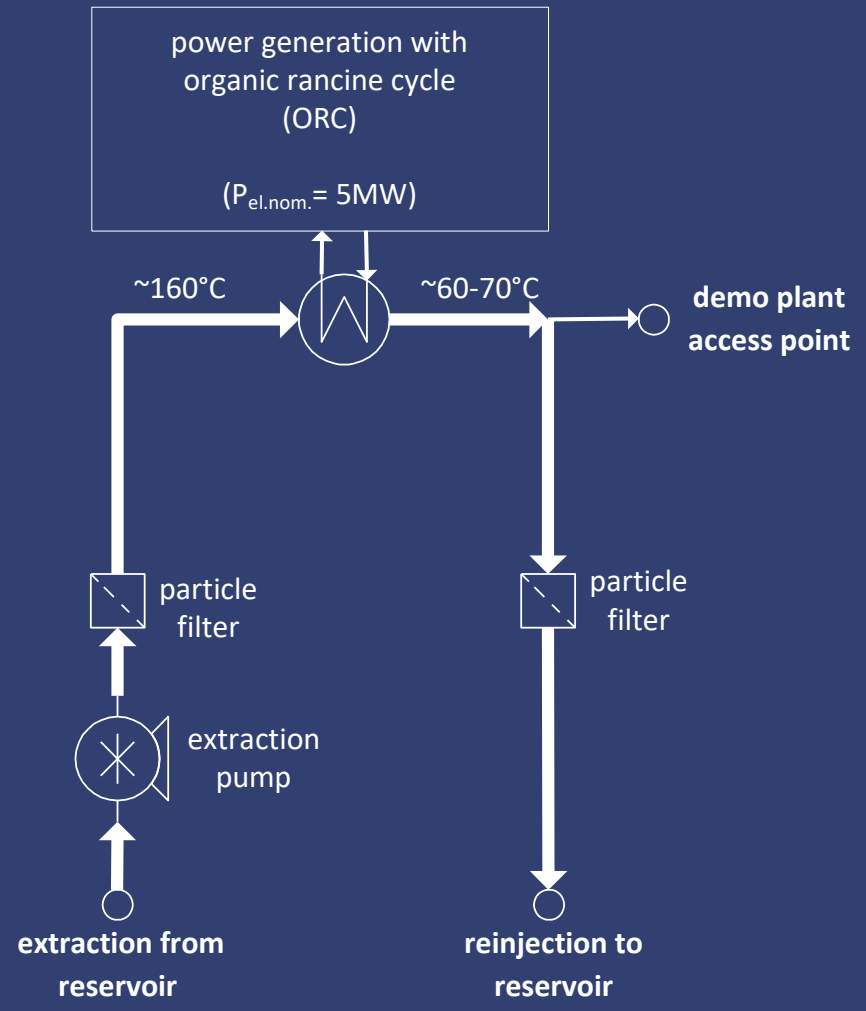
Hydraulic Design



Demonstration Site Conditions

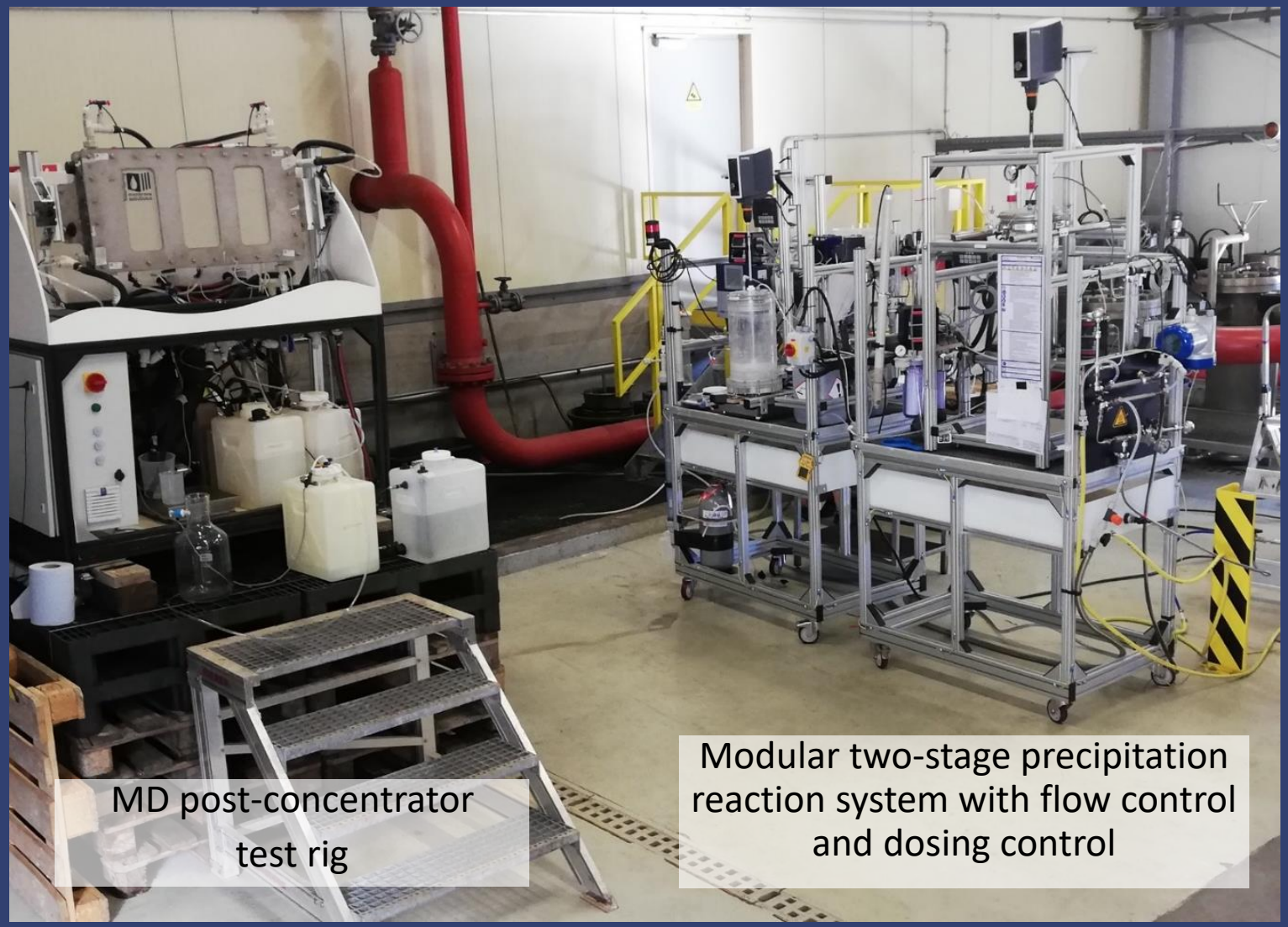
Showcase Upper Rhine Graben (URG) -> Geothermal Power Plant Insheim

parameter	unit	Insheim inflow
pH	-	5.3
temperature	[°C]	57
TDS	mg/L	105255
Li^+	mg/L	164
Na^+	mg/L	28937
K^+	mg/L	4290
Ca^{2+}	mg/L	7566
Mg^{2+}	mg/L	119
SiO_2	mg/L	186
Cl^-	mg/L	63692
SO_4^{2-}	mg/L	143
Br^-	mg/L	179
F^-	mg/L	16



Demonstrator Prototype (1st Generation)

Commissioning and Field Test

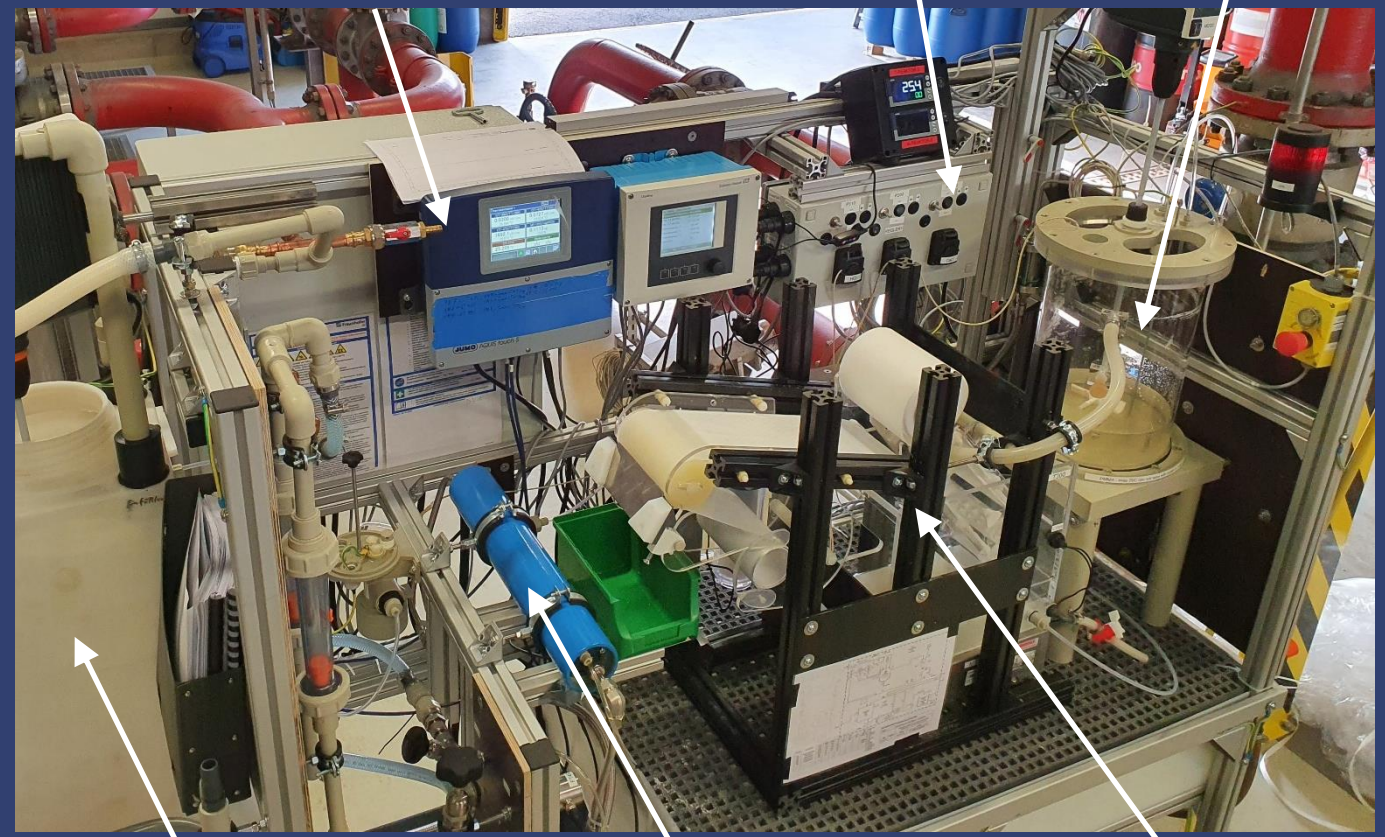


- Flexible, automated test rig
- Assembly and pre-commissioning in workshop at Fraunhofer ISE, Freiburg
- Transport to Power Plant Insheim (URG)
- Test phase: July/August 2020

Final Demonstrator (2nd Generation)

Commissioning and Field Operation

- Transport to power plant Insheim (URG)
- Initial commissioning and test phase: Febr./March 2021



MD-membrane stack for post concentration

Demonstrator Operation

Impressions

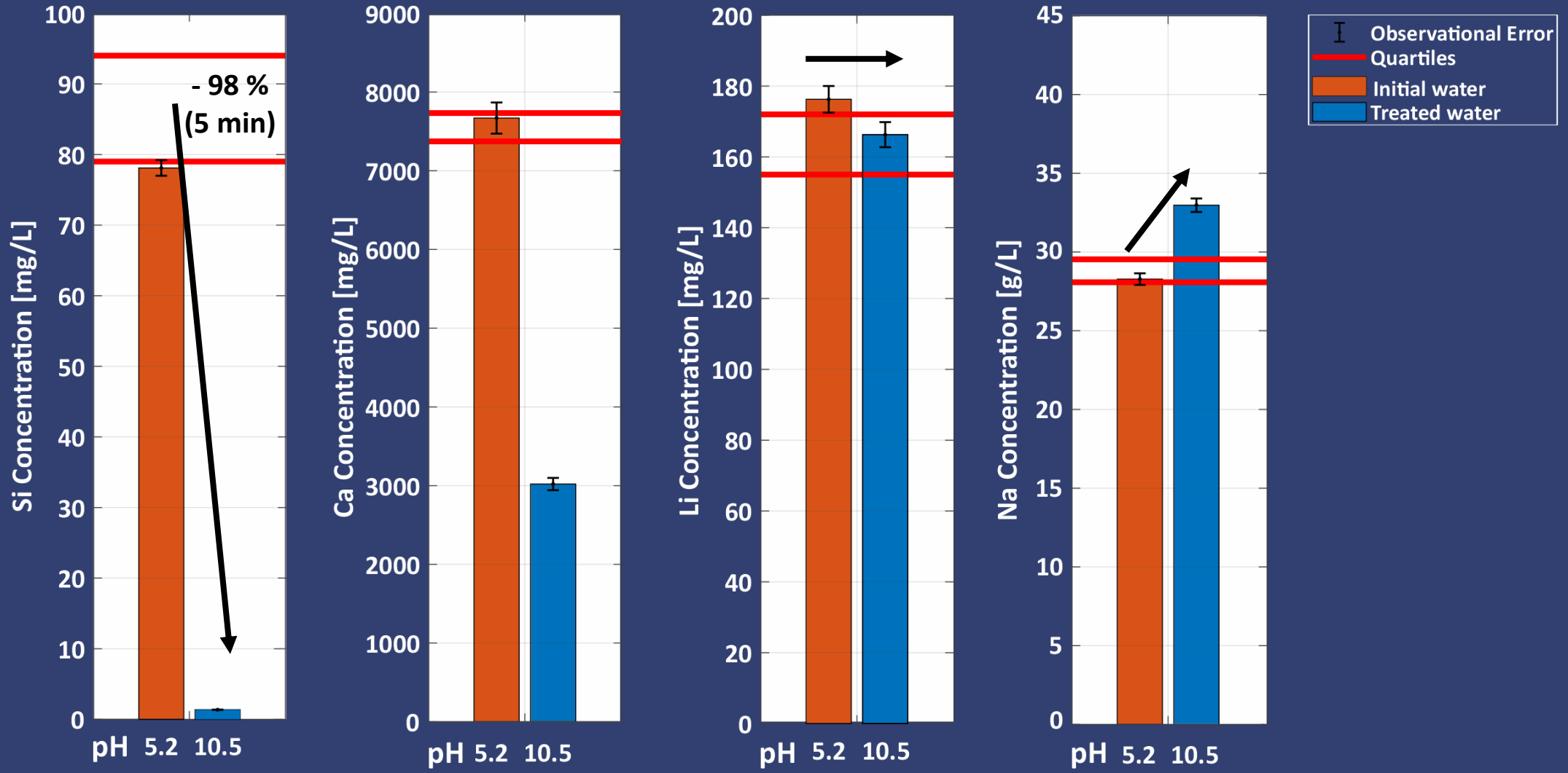
Thermal brine inlet reactor

Dosing reactants

Settling of Ca-Si precipitates

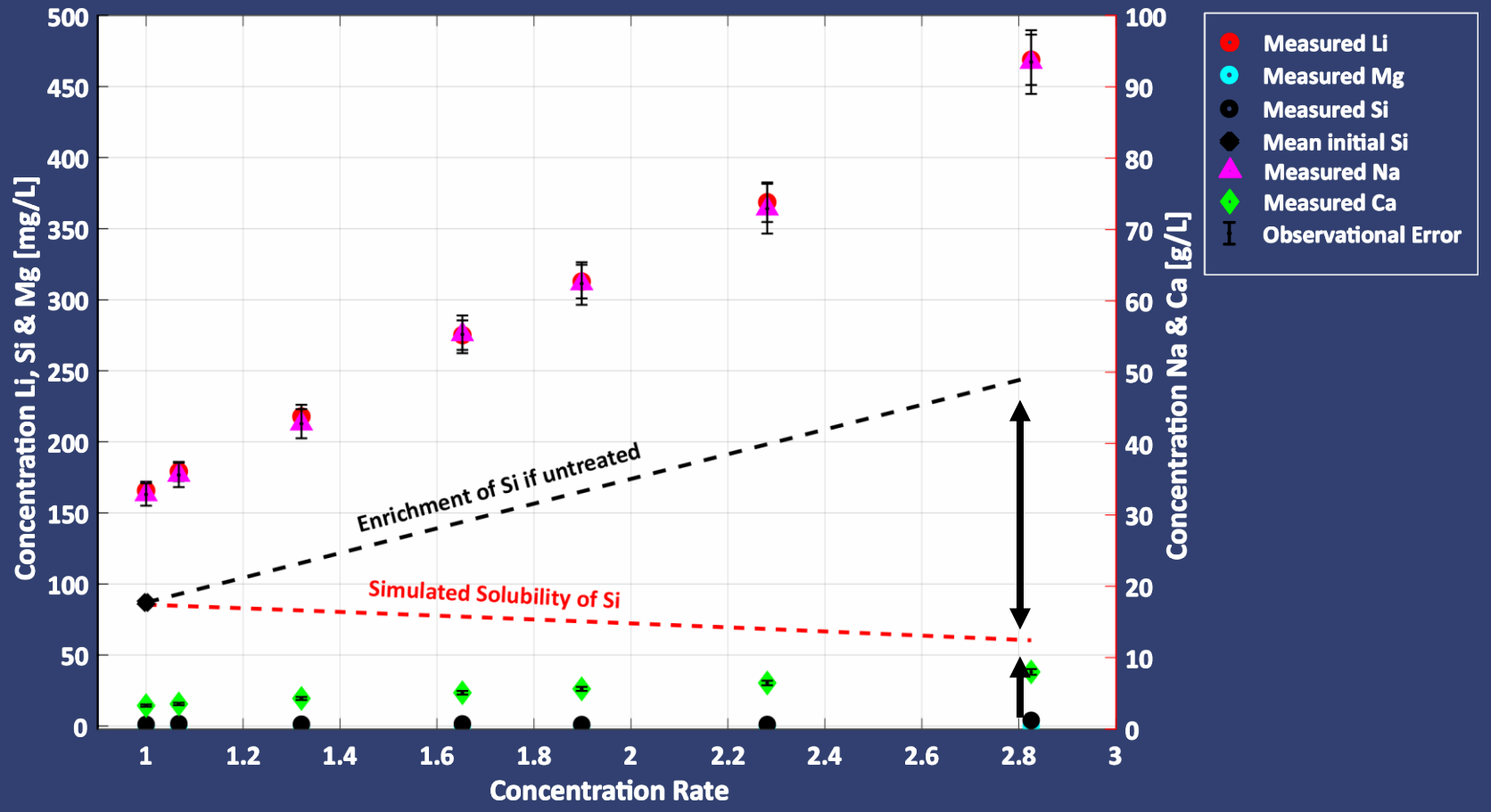
Band filter for continuous precipitate extraction

Continuous Operation of Silica Precipitation



Post Concentration of Brine with Membrane Distillation

- Pre-treated water was concentrated up to almost factor 3 (Li 470 mg/L)
- Si reaches only up to 4 mg/L (Saturation 60 mg/L)
- Black line shows calculated value for Si if it is not reduced
- Red line shows that Si is super saturated from the first concentration step

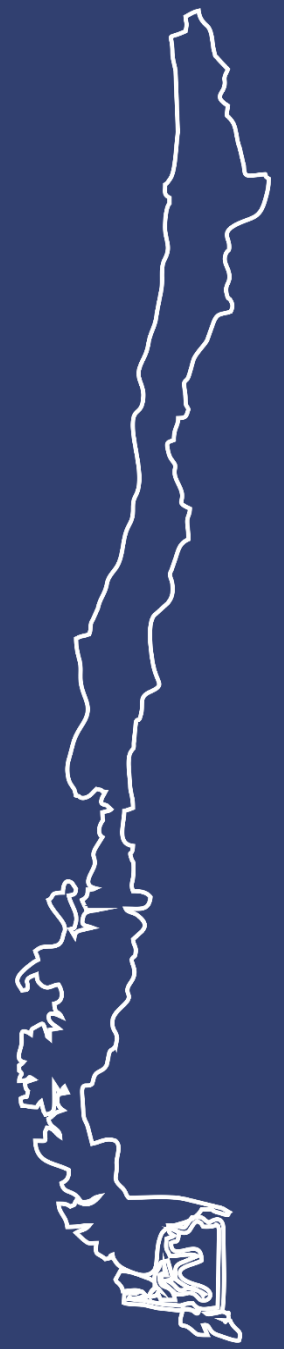


Conclusions

There is an enormous potential for raw materials in thermal waters and further exploration will bring even more to light.

A treatment strategy for controlled silica precipitation was developed from scratch and transferred to a large scale prototype.

The prototype could reproduce the approach in a fully operating geothermal power plant with highly corrosive brines making an enrichment of raw materials possible.



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