Testing and validation of scaling & corrosion prevention technologies

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Scaling and Corrosion prevention strategies

Scaling prevention	Corrosion prevention
Scaling-inhibitors (additive)	Corrosion-inhibitors (additive)
Operate at certain T-regime	Right material selection
Remove scale building ions	Material protection by coating or cladding
Decrease the pH (by CO_2 addition)	Change acidity of the brine
Keep pressure and prevent degassing	Remove corrosive gas
Remove particles before injection	

Goal WP 3: Develop **innovative technologies** to prevent site-specific scaling, clogging and enhance injectivity

Task 3.1 Testing and evaluating particle filters (**HI**, GFZ, TNO, GEUS, GGW, AGI)

Task 3.2 Development, testing, evaluating selective cation removal filter (**GFZ,** HI, TNO)

Task 3.3 H_2S corrosion prevention: Removal of H_2S by $FeCl_2$ addition (HI, GFZ**)**

Task 3.4 ***Corrosion and the effect of corrosion resistant alloys/ galvanic corrosion*** (**FT**, GFZ)

Task 3.5 ***CO_2-(re)injection and pH control*** **(TNO**, GGW, GEUS, GFZ**)**

Task 3.6 ***Injection temperature optimisation (TNO, GGW, GEUS,*** *GFZ*_**)**_

Field operation

Technology	Who	TRL	Demonstration site	Scheduled
3.1 Particle filter	Hydroisotop	6 to 8	Insheim (DE), Oberlaa (Au)	June 2019, October 2019, April 2020
3.2 Metal extraction	Wageningen University & Research; GFZ Helmholtz Centre Potsdam	5 to 7	Insheim (DE)	June 2020, April 2020
3.3 H_2S removal	Hydroisotop; GFZ Helmholtz Centre Potsdam	7 to 8	Oberlaa (Au)	June 2019
3.4 Corrosion control	FORCE Technology; GFZ Helmholtz Centre Potsdam	5 to 7	Not possible in the field	
3.5 CO_2 reinjection	TNO; Ammerlaan Geothermie	6 to 7	Pinjacker-Nootdorp (NL)	April 2020 → June 2021
3.6 Injection temperature		6 to 7	Pinjacker-Nootdorp (NL)	

3.1 Particle filter – Testing and Evaluating

Test of HydroGeoFilt at the geothermal site in Insheim (27th & 28th of November 2020)

- Ultrasonic device for cleaning of filter candles
- Test of 5 different filter candles (5, 10, 25, 50 and 100µm)
- Inflow of thermal water after heat exchanger (T = 62° C, spec. el. conductivity: 140mS)

→ Successfull operation of the filter system for 5 h without blocking of filter candles and no decrease of flow rate

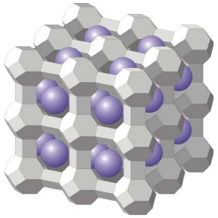
3.2 Selective cation removal filter

Goal: Identify filter materials for removing Ba, Cu, Pb from thermal waters

→ test stability and effectivity of the materials

Filter materials:

- Natural zeolite (clinoptiolite)



Feied et al., 2004

$K_6(Si_{30}Al_6)O_{72}\cdot 20H_2O$

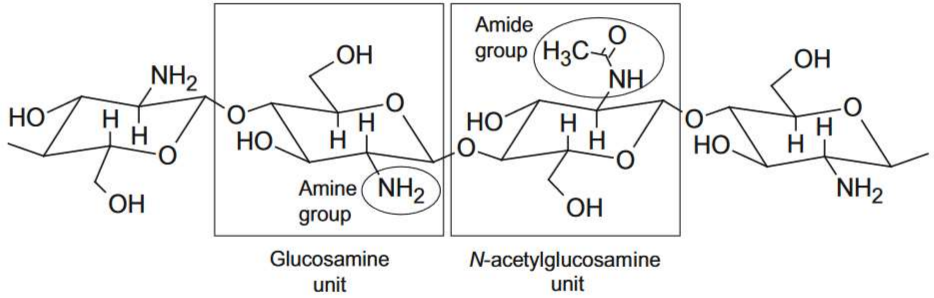
- Magnetite coated quartz

$FeO*Fe_2O_3$

- Chitosan fibres and flakes of different acetylation

→ Temperature stability tests

- Natural zeolite (clinoptiolite)
  - Klinoptilolith-K: $K_6(Si_{30}Al_6)O_{72} \cdot 20H_2O$
  - Klinoptilolith-Na: $Na_6(Si_{30}Al_6)O_{72} \cdot 20H_2O$
  - Klinoptilolith-Ca: $Ca_3(Si_{30}Al_6)O_{72} \cdot 20H_2O$
- Iron oxides: magnetite coated quartz: FeO* Fe_2O_3
- Chitosan fibres and flakes of different acetylation



3.2 Selective cation removal filter

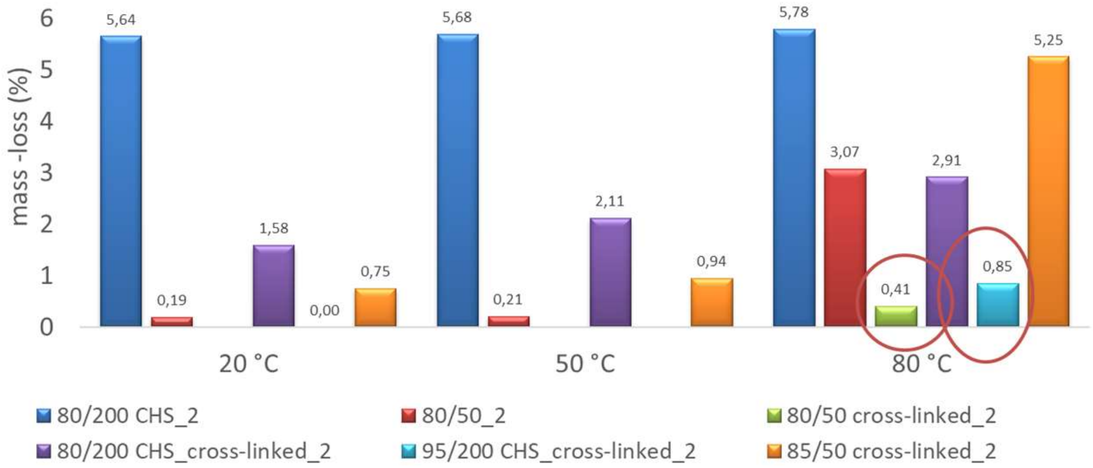
1. Material Characterization and Stability

2. Static Batch experiments

3. Dynamic Flow Through Experiments

4. Field Experiment

Chitosan temperature stability tests



3.2 Selective cation removal filter

1. Material Characterization and Stability

2. Static Batch experiments

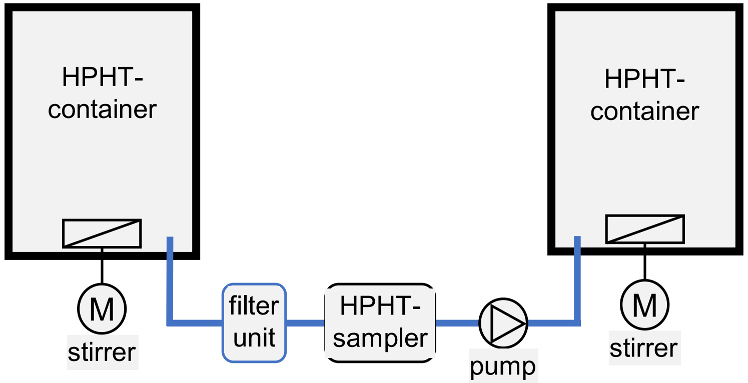
3. Dynamic Flow-Through experiments

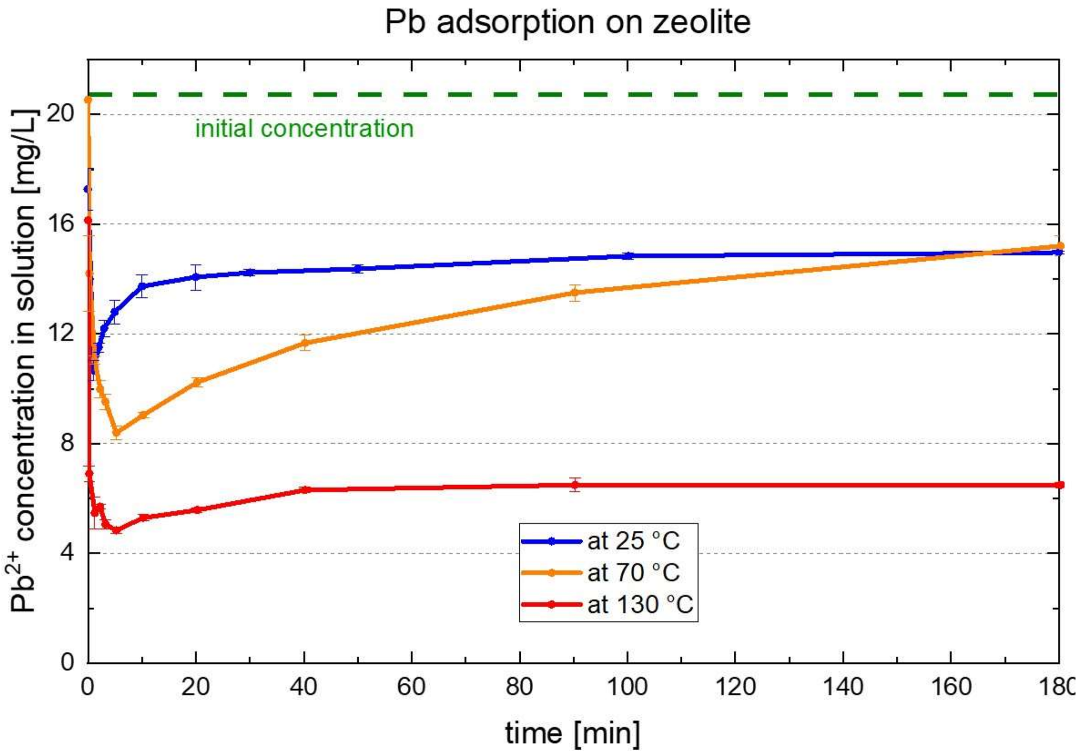
4. Field experiment

Synthetic brine; variation of:

- Adsorbent: chitosan, zeolite
- Temperature: 25° C, 70° C, 115° C
- Cations: Pb^{2+}, Cu^{2+}, Ba^{2+}
- cation concentration: 0.05, 0.1, 0.3, 0.5, 1 mM
- Background salinity: NaCl (0.1 M, 1 M); $CaCl_2$: 0.03 and 0.3 M
- Reaction time: 2, 30, 1440 min

3.2 Selective cation removal filter





3. Dynamic Flow-Through experim

4. Field experiment

3.2 Selective cation removal filter

Insheim, June 2020

Fluid monitoring
„FluMo“

Reaction container with filter material

4. Field experiment

3.2 Selective cation removal filter

Summary on removal of scale forming metals

- Zeolite: suitable für Pb removal; Chitosan for removal of Cu^{2+}, Ba^{2+}
- Magnetite coated sand was not effective
- Zeolite effectivity increases with T
- Chitosan stability decreases with T

- FluMoRe: Equipment prepared for similar experiments
- Upscaling required

Future Research

Extraction of valuable elements from the thermal fluid

→ Example **Lithium extraction**→ adsorption

1. Material Characterization and Stability

   selction of ion sieves

2. Static Batch experiments

3. Dynamic Flow Through Experiments

   FluMoRe

4. Field Experiment

   miniplant

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3.3 Removal of H_2S

In-situ experiment in Oberlaa (Austria; June 2019)

Thermal water with:

- 50 ° C; TDS: 3 g/L (Na-SO_4-Cl); pH: 6.6
- 20-35 mg/L H_2S

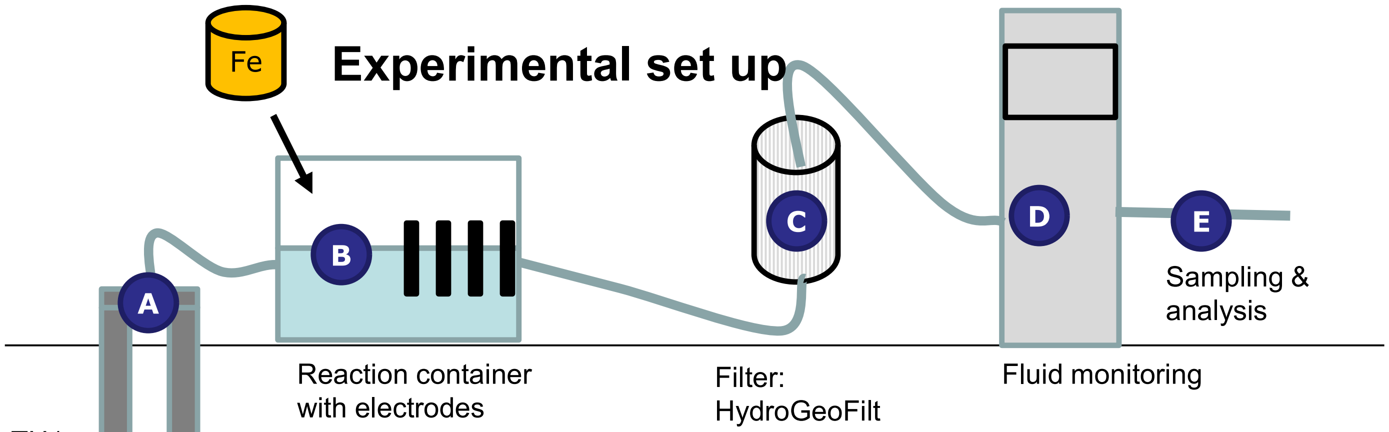
Goal: Determine the effectivity of Fe(III) addition to remove H_2S from the thermal water

$$8\ Fe^{3+} + S^{2-} + 4H_2O \rightarrow 8Fe^{2+} + SO_4^{2-} + 8H^+$$

Test:

- Iron hydroxide
- $FeCl_3$ solution

3.3 Removal of H_2S



B) Reaction container

C) Filter

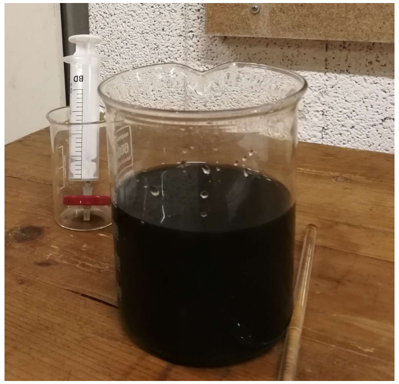
E) Sulphide analysis

3.3 Removal of H_2S

Observations

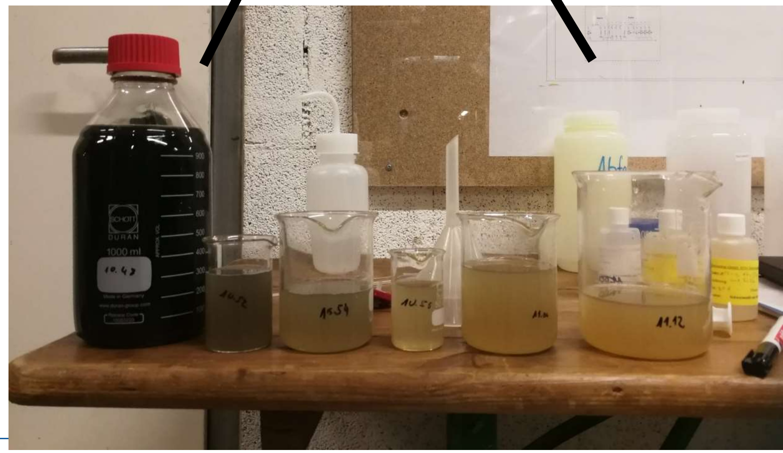
Red $FeCl_3$ solution (40%)

$FeCl_3$ solution diluted with water (1:1000)



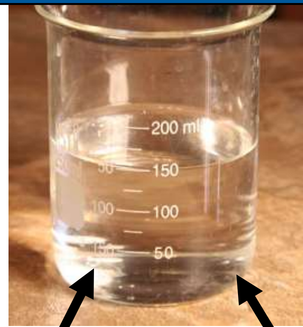
$FeCl_3$ solution diluted with themal water (1: 8000) → **black FeS**

Ageing



Oxidation to **orange iron hydroxides**

filtration



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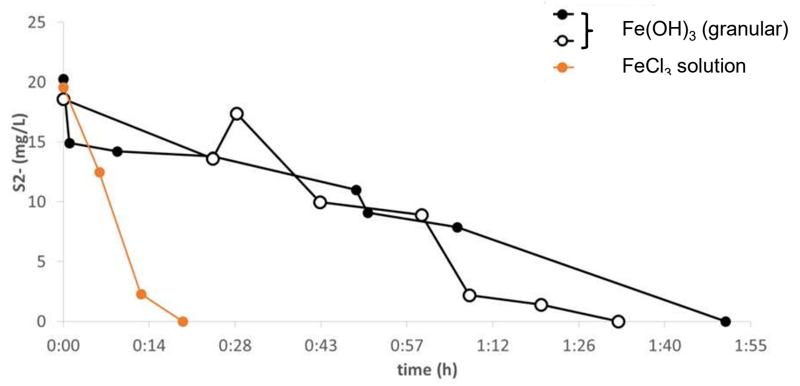
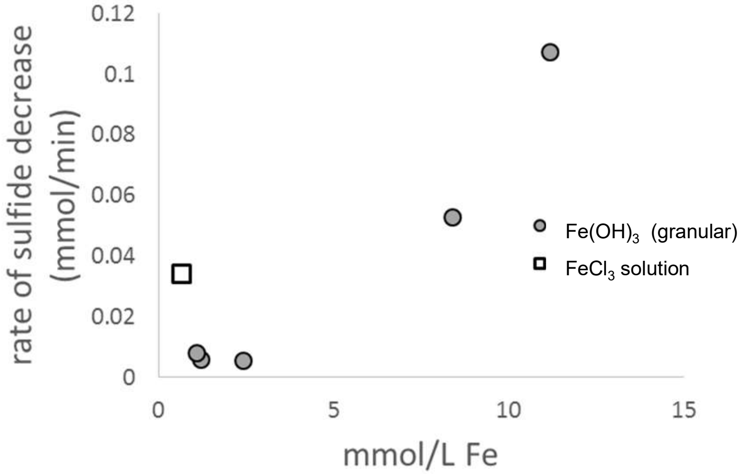
3.3 Removal of H_2S

Results

- H_2S was removed in all experiments
- The $FeCl_3$ solution was more effective
- The effectivity of iron hydroxide increased with the amount Fe added





Next steps:

1. Install reaction tank and filter (< 5 µm)
2. Add during fluid production constantly either iron hydroxide $Fe(OH)_3$ or $FeCl_3$ (faster)

3.4 Galvanic corrosion prevention

Labt tests to investigate galvanic corrosion by Cu with various types of steel

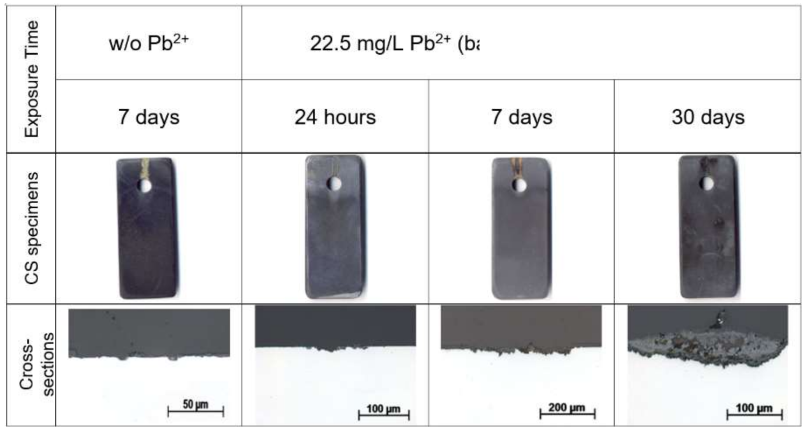
150° C in 1 mM Cu; 1.5 M $CaCl_2$+ 2 M NaCl

→Reaction on C steel increases over time

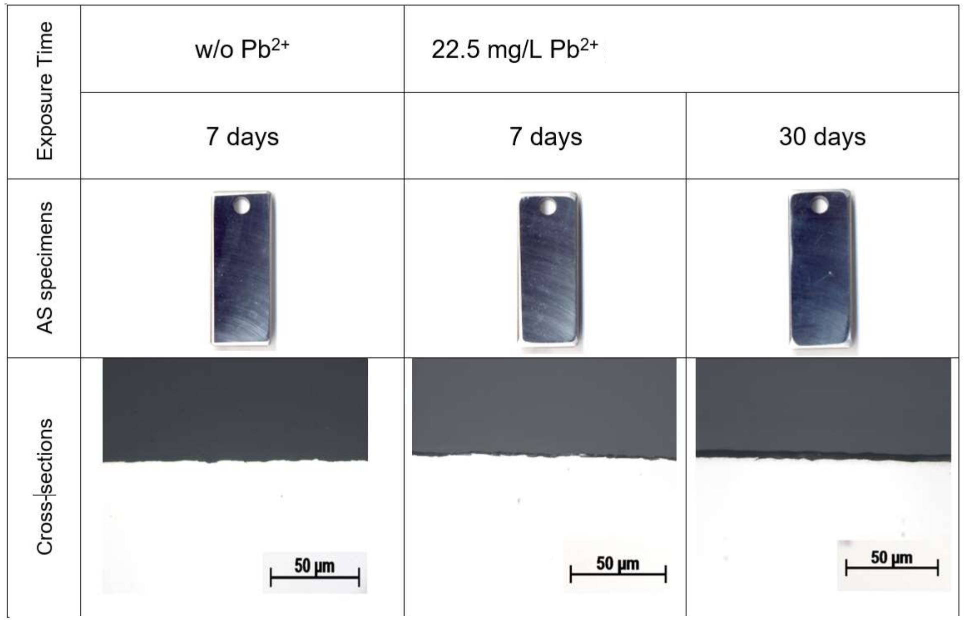
→Highly alloyed steels are corrosion resistant

3.4 Galvanic corrosion prevention

Labt tests to investigate galvanic corrosion by Pb with various types of steel



Uniform corrosion with lead, laurionite layer on the surface, and pitting corrosion under external polarization conditions



Austenitic stainless steels: no significant influence of Pb

Stoljarova, A., Bäßler, R., Regenspurg, S. (2020) Influence Of Precipitating Brine Components On Materials Selection For Geothermal Applications. Proceedings World Geothermal Congress 2020, Reykjavik.

3.5 CO_2 reinjection and temperature control

Experiments ongoing (28.6 – 1.7.2021)

Summary WP 3: Innovative technologies to prevent site-specific scaling, clogging and enhance injectivity

Task 3.1 Testing and evaluating particle filters → long term testing needed

Task 3.2 Development, testing, evaluating selective cation removal filter → partly very effective; upscaling for field

Task 3.3 H_2S corrosion prevention: Removal of H_2S by $FeCl_2$ addition → currently tested by the operator

Task 3.4 *Corrosion and the effect of corrosion resistant alloys/ galvanic corrosion* → right material selection prevents galvanic corrosion by Pb^{2+} and Cu^{2+}

Thank you

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BAM, PTJ

Federal Ministry
for Economic Affairs
and Energy