Enabling PW reinjection in chalk

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On-site acid production for In-line descaling

Investigating novel methods to manufacture utility chemistry on site - offshore.

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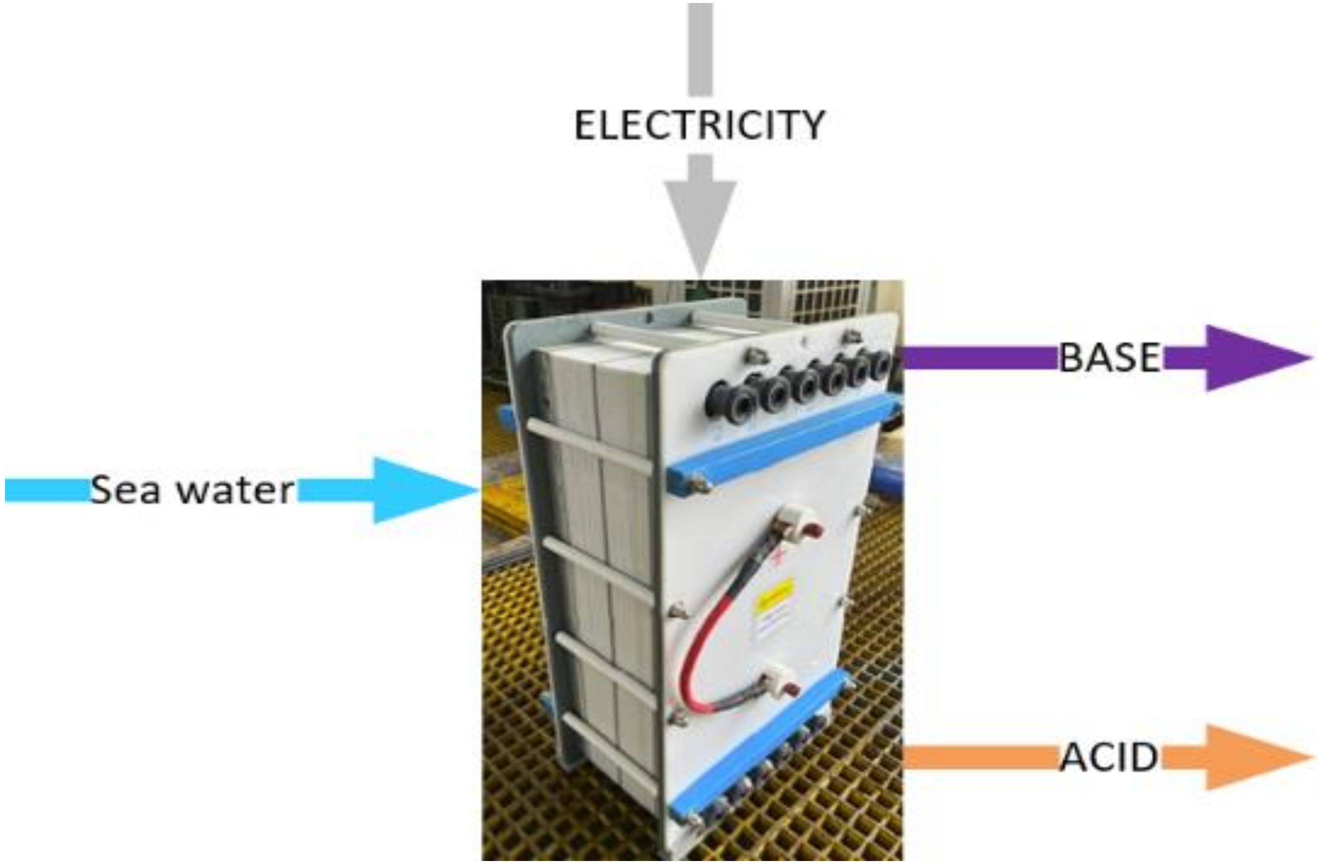
Bipolar membrane technology

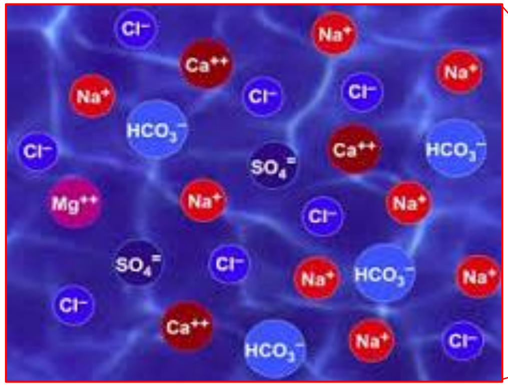


H2S scrubbing

De-scaling

On-site acid production for In-line descaling

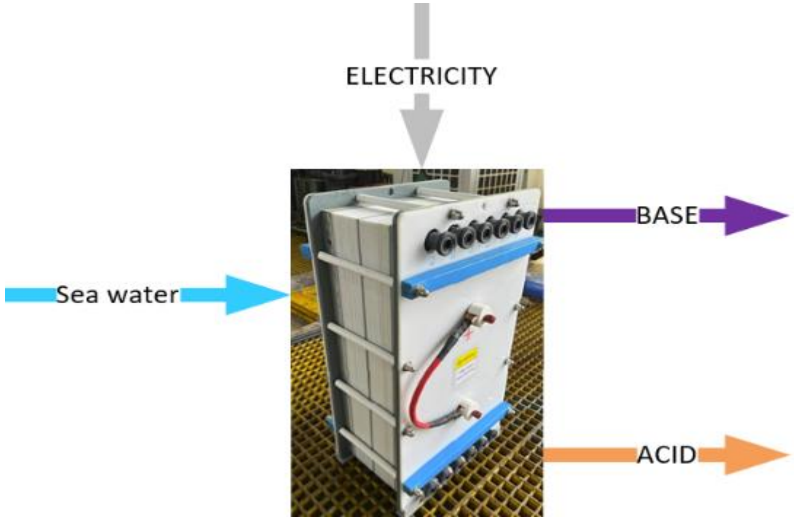
- Seawater is essentially an infinite source of ions for acid and base production.

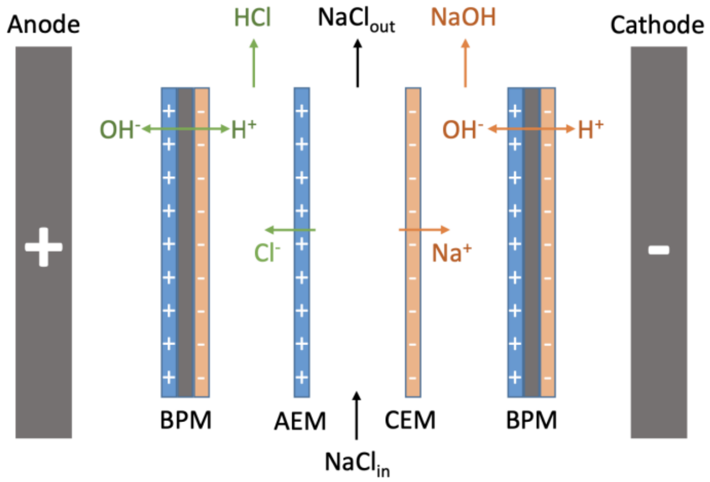


  - Sulfate - $SO4^{2-}$
  - Chlorine - Cl^-
  - Sodium - Na^+
  - Potassium - K^+

- When water is dissociated (split), we produce acid (H^+) and base (OH^-)

  - Sulfuric Acid - H_2SO_4
  - Hydrochloric Acid - HCl
  - Sodium Hydroxide - NaOH
  - Potassium Hydroxide - KOH

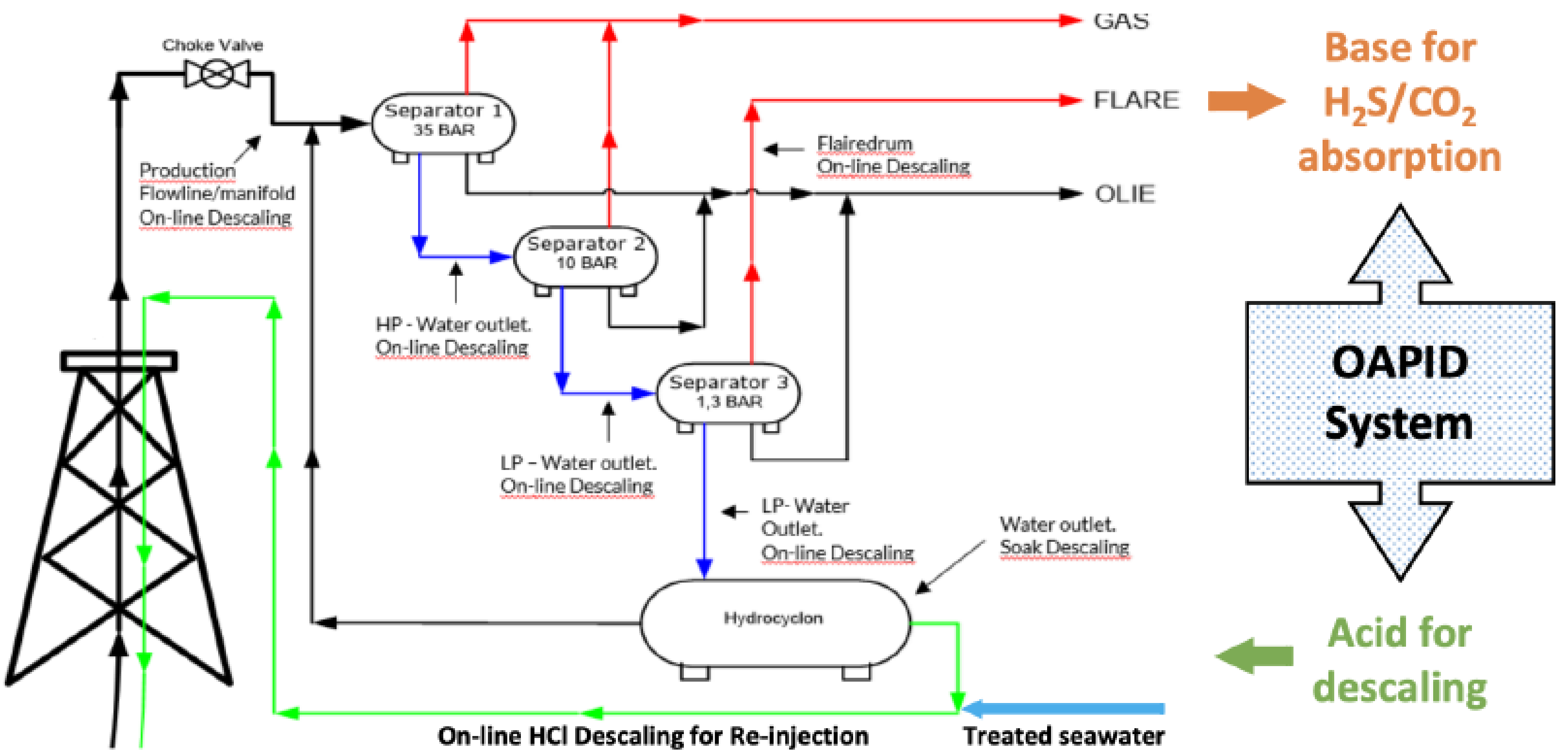




In-situ acid production + injection

Concept highlights :

- Continuous pH control in the water stream
- Potentially enabling produced water re-injection by controlling scale precipitation
- Base product can be used to scrub H2S
- Eliminate transportation of chemicals



Chemical transportation flow chart

Estimated CO_2 emissions for transporting 150 m3 HCL pr. field = 22,851 kg/year

Producing HCL - CO2 footprint

Our preliminary calculations indicates the following:

- 150 m3 HCL conventional produced = 216,000 kg CO_2
- 150 m3 HCL produced in the BMED = 107,000 kg CO_2

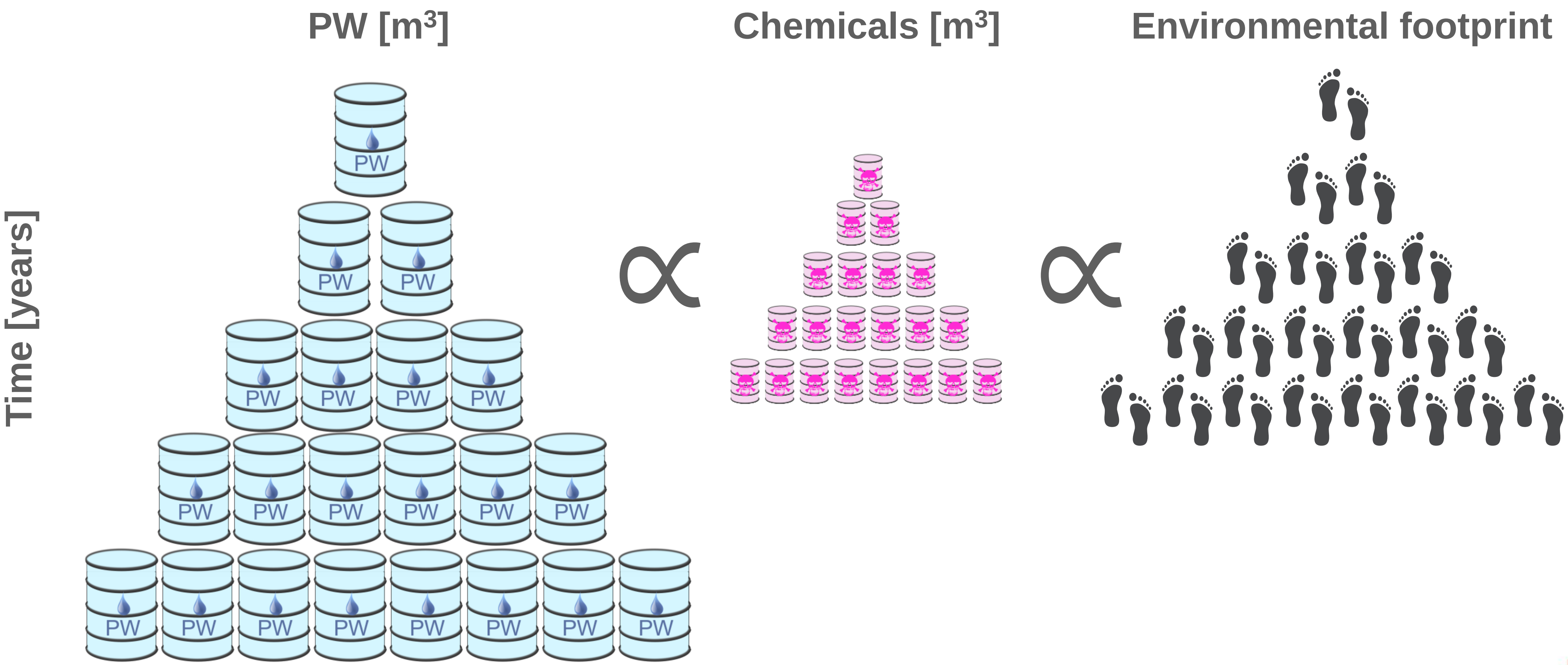
- = 109,000 kg CO_2 difference

DOTC Technology Conference

Enabling produced water reinjection in chalk

Hamed Kermani, Maksim Kurbasov, María Bonto, Karen Feilberg, Hamid Nick

Environmental impact of discharged produced water (PW)

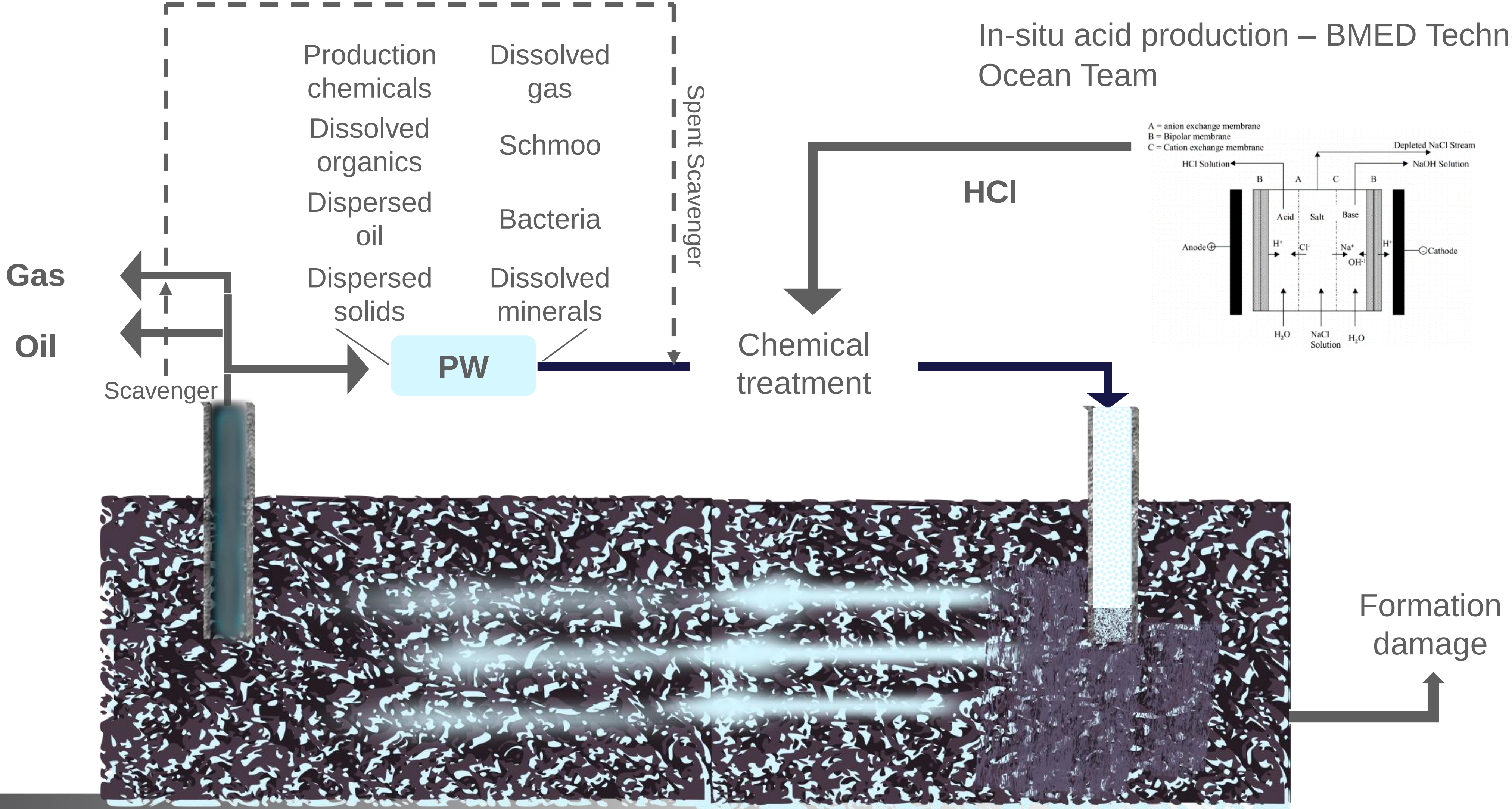


Produced water reinjection

A sustainable alternative to offshore discharge

Produced water reinjection
Challenges

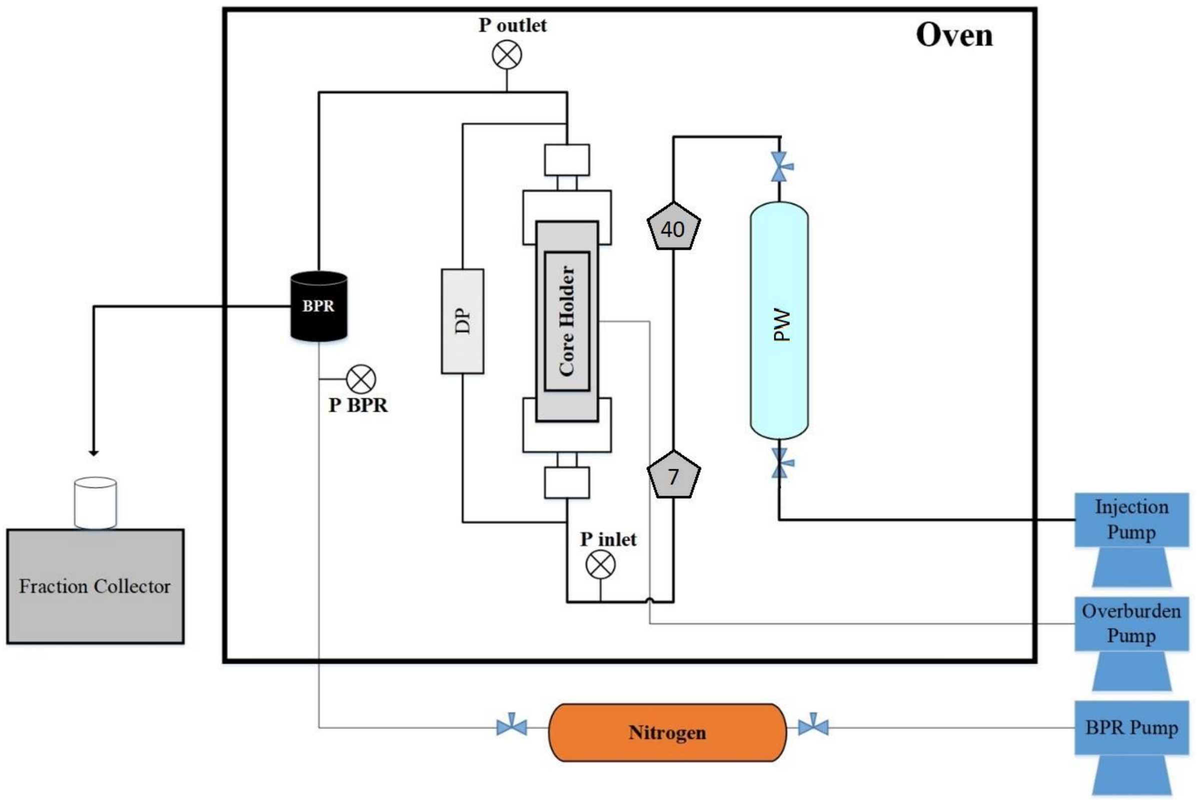
In-situ acid production – BMED Technology
Ocean Team



Injectivity impairment

Assessment of the formation damage – Experimental protocol

Core flooding setup



C [ppm]	SW	PW
Na^{+}	10692	18330
K^{+}	390	425
Mg^{2+}	1282	691
Ca^{2+}	396	915
Cl^{-}	20125	39626
SO_4^{2-}	3182	1460
pH	7.99	7.82

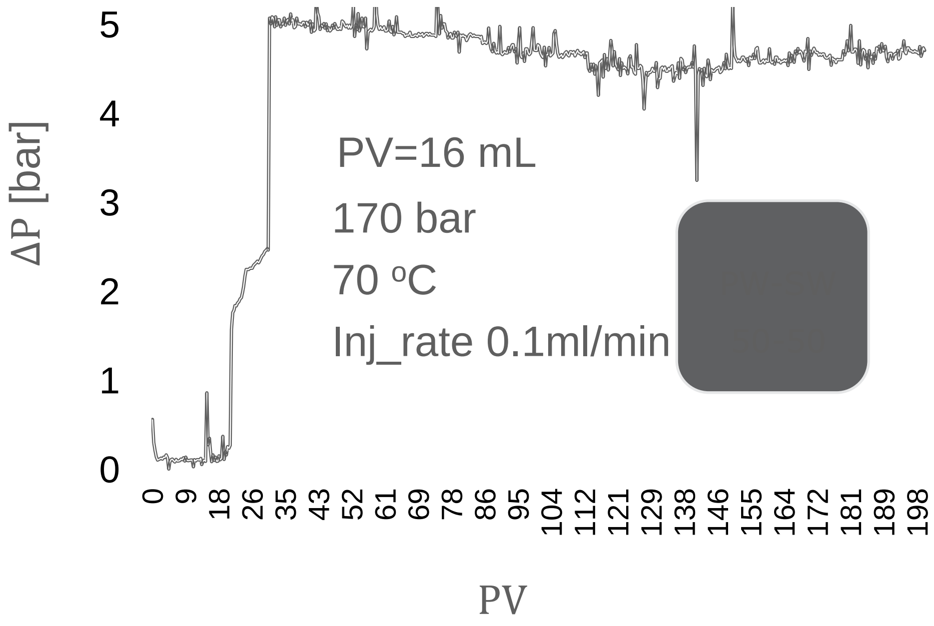
PW may also contain fines, oil particles, and production/processing chemicals

Core flooding experiments are performed at different ratios of produced water (PW) and sea water (SW) to reveal the formation damage.

Injectivity impairment
Assessment of the formation damage – Experimental results

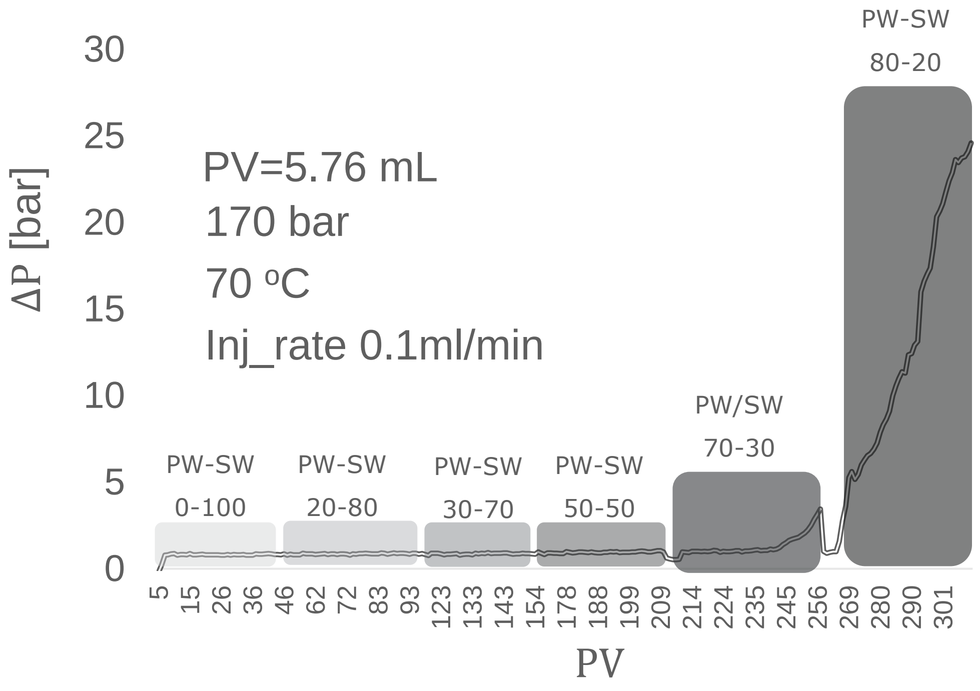
- Experiment #1 – Core flood

  Filtered PW (particle size < 7 μm)
  PW samples after degasser



- Experiment #2 –Mini core flood

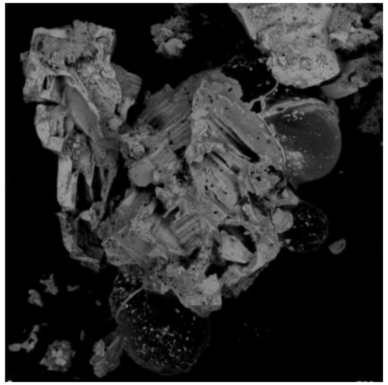
  Filtered PW (particle size < 7 μm)
  PW samples after degasser

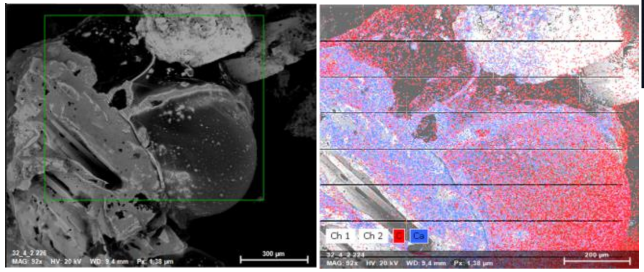


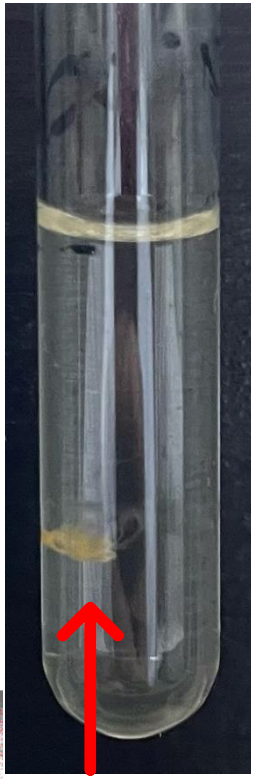
Injectivity impairment
Assessment of the formation damage – Experimental results

Organics

Fines and oil particles impair injectivity



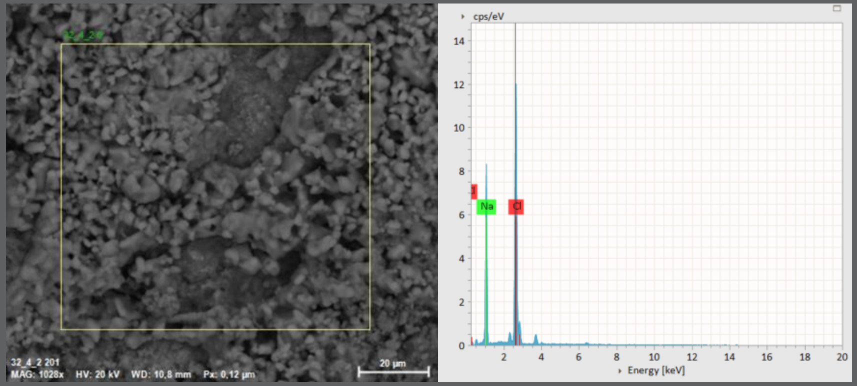




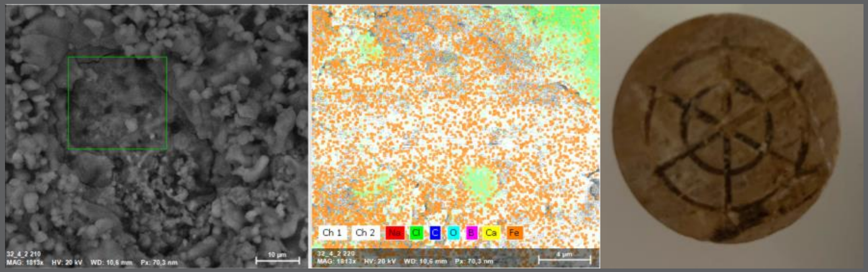
Oil in PW/SW effluent after injection

Inorganics

NaCl layer on core surface



Iron (hydr)oxides layer on core surface



Restoring the injectivity

Screening inorganic precipitates

- Thermodynamic modelling
- Different PW/SW ratios and H_2S spent scavenger concentrations

Chemical solution

- Scale inhibitor
- Scale inhibitor + acid
- Chelating agents

Performance of chemical treatment

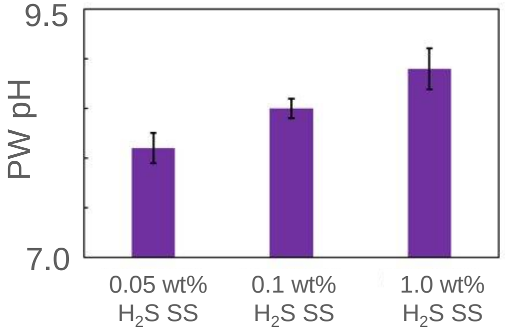
- Experimental assessment of scale inhibitor efficiency
- Theoretical assessment of acid treatment
- Theoretical assessment of chelating agents efficiency

Restoring the injectivity

Screening of inorganic precipitates

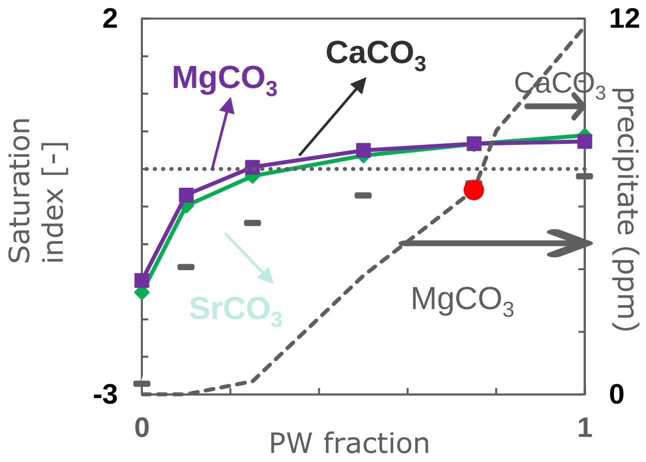
- Spent H_2S scavenger:
  - has a high environmental footprint
  - can be mixed with PW and re-injected
  - increases the pH of PW, promoting scaling
  - Only the effect of pH variation induced by the scavenger is investiga

pH increase with H_2S spent scavenger concentration

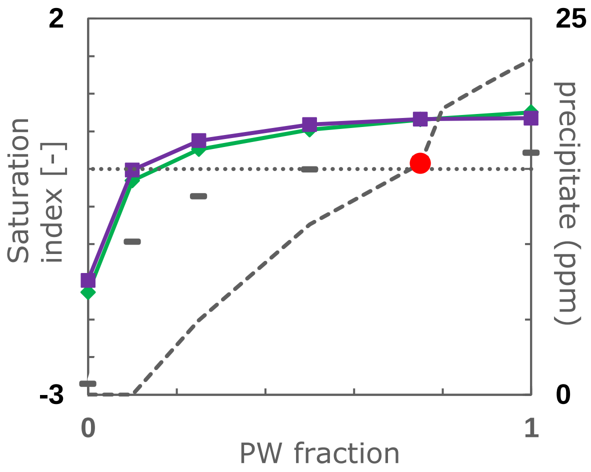


Carbonate scales

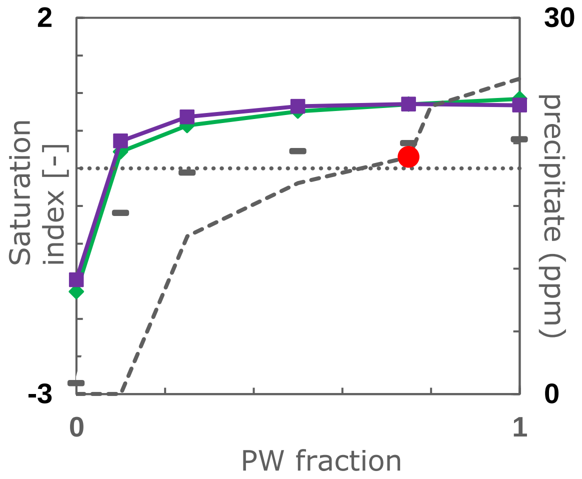
0.05 wt % spent H_2S scavenger



0.5 wt % spent H_2S scavenger



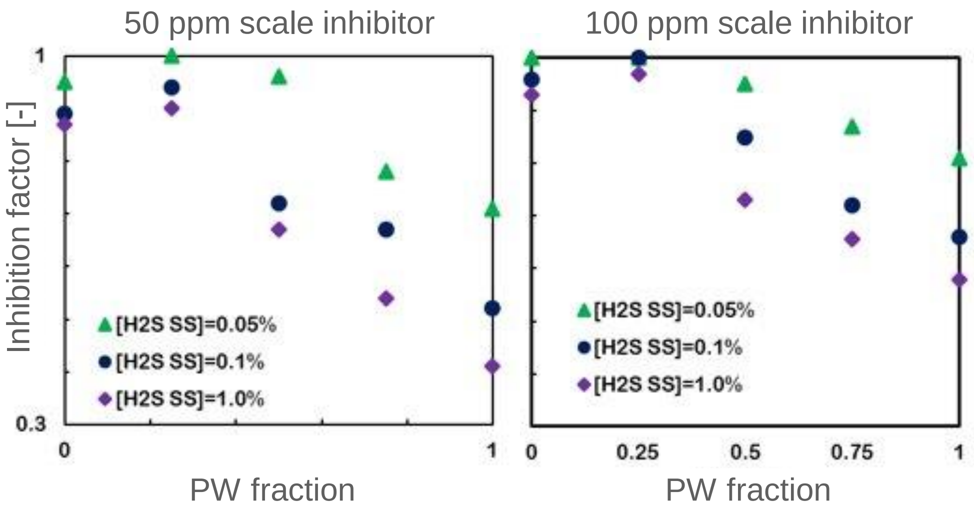
1 wt % spent H_2S scavenger



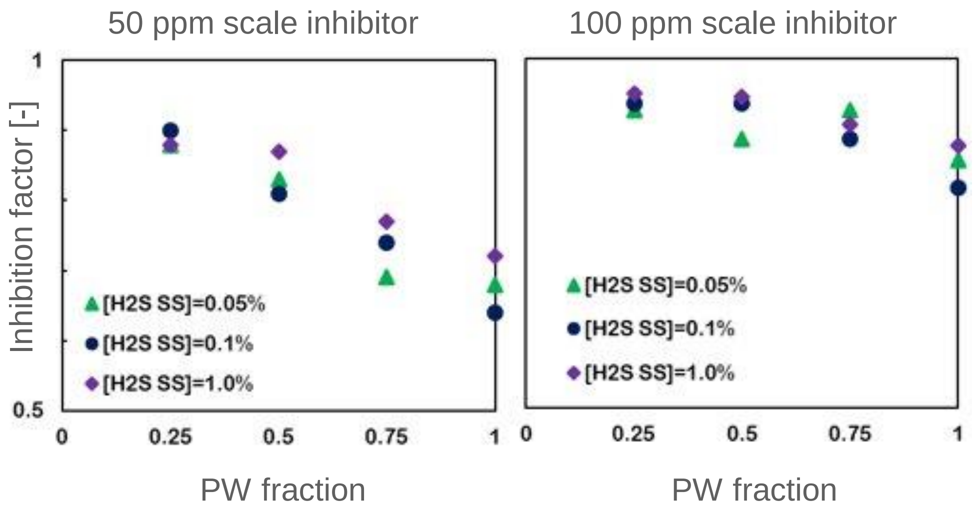
Other scales identified: $BaSO_4$, $SrSO_4$, FeS, FeS_2, Fe_2O_3, FeOOH

Restoring the injectivity
Chemical solution – Commercial scale inhibitor

- $CaCO_3$



- $BaSO_4$

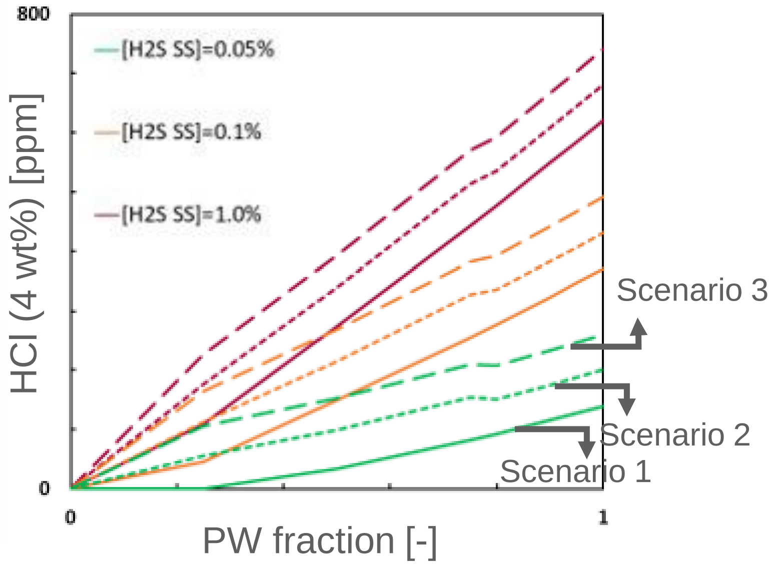


- The efficiency of the scale inhibitor increases is improved by mixing PW with SW
- The efficiency of the scale inhibitor decreases at increasing H_2S spent scavenger concentrations
- The scale inhibitor is not as efficient against Fe-based scales
- The chemistry of H_2S spent scavenger once introduced to the aqueous phase is not considered

Restoring the injectivity
Chemical solution – Scale inhibitor + acid

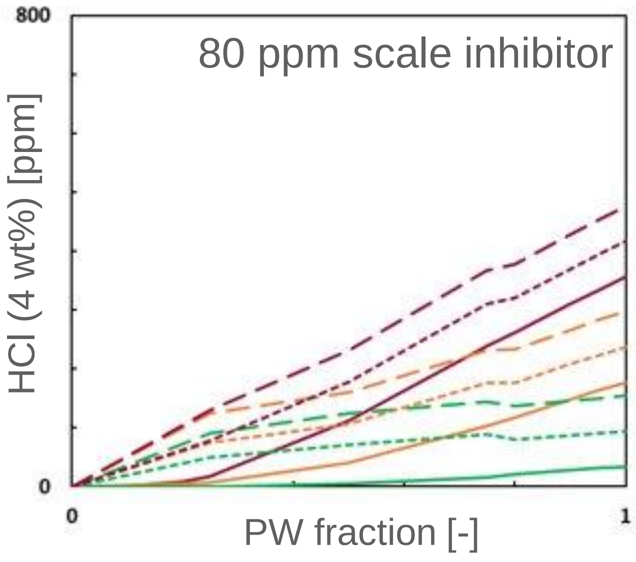
Scenario 1: $CaCO_3$ removal
Scenario 2: CO_3-based scales
Scenario 3: CO_3-based scales + $CaCO_3$ particles

- HCl



0.5 PW-0.5 SW
0.1wt% H_2S SS
159 L
+
4 wt% HCl
~23.85 mL

- HCl + Scale inhibitor



0.5 PW-0.5 SW
0.1wt% H_2S SS
159 L
+
4 wt% HCl
~6.4 mL

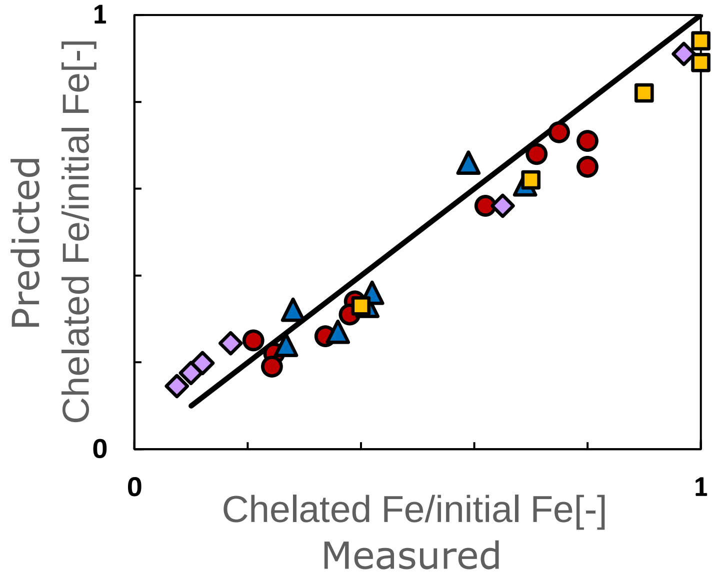
Scale inhibitor reduces the amount of HCl (~ 25%) required to avoid carbonate scales and $CaCO_3$ particles

Restoring the injectivity

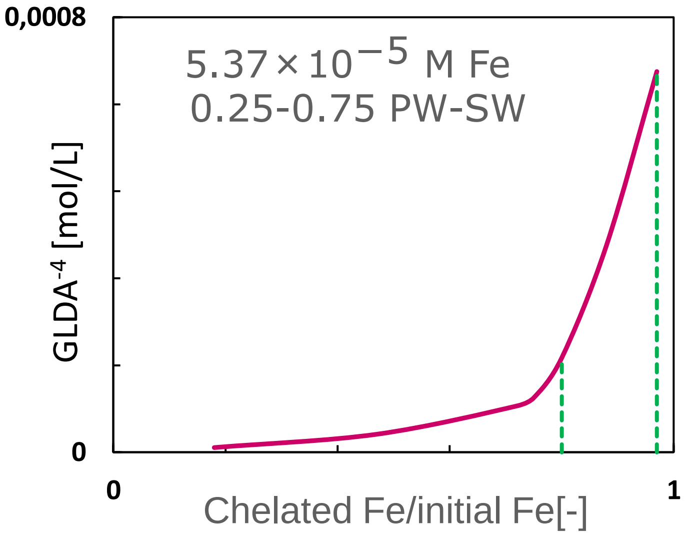
Chemical solution – Chelating agents for Fe-based scales

- Chelating agents prevent the formation of iron (hydr)oxides by binding iron
- Effect of different chelating agents modelled and tested against experimental data
- GLDA is used further because of its biodegradability

Predicted vs measured performance of several chelating agents



GLDA concentration required for removing Fe



Conclusions

- PWRI can reduce the environmental footprint of O&G operations
- Oil particles and inorganic precipitates impaired injectivity during PWRI
- Mixing and reinjecting the H_2S spent scavenger with the PW has environmental benefits but promotes additional scaling
- A combination of acid, scale inhibitor, and chelates is proposed to address the different inorganic precipitates
- A chemical model is under development to assist in designing PWRI operations

Thanks to the presenters
Thank you all for listening!

Simon Ivar Andersen and Charlotte Lassen

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