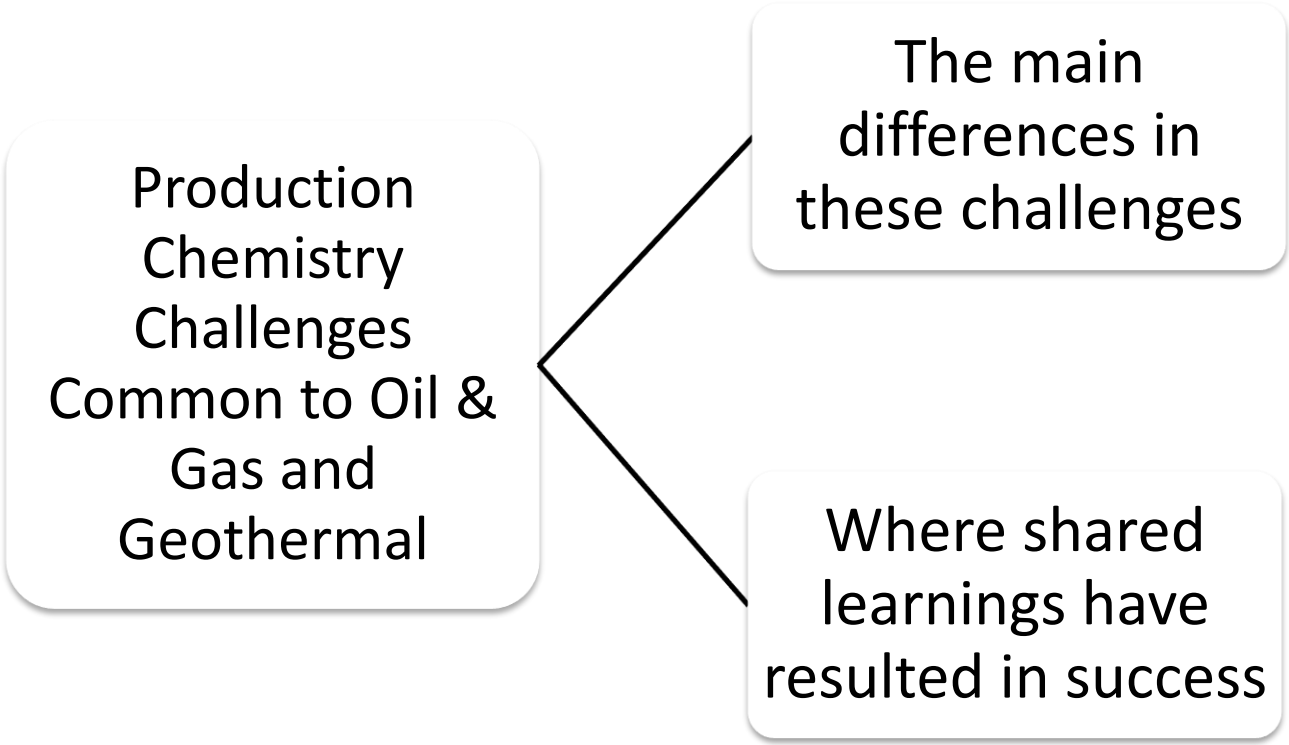
ROEMEX

Production Chemistry Management in Geothermal Assets: Key Learnings & Differences from Oil & Gas Production

Overview


Production Chemistry Challenges Common to Oil & Gas and Geothermal
The main differences in these challenges
Where shared learnings have resulted in success

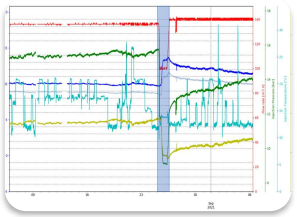
Production Chemistry Challenges

Integrity

Corrosion by CO_2 gas produced with formation water results in corrosion of metal

Flow Assurance

Pressure and temperature change can lead to insolubility of mineral scales resulting in deposition



Injectivity

Solids such as mineral scale, corrosion products and bacterial biofilms can cause problems in injection wells

These challenges are well known and managed in Oil & Gas Industry

Integrity Management

To achieve lifetime design; corrosion rates must be reduced

Similarities to Oil & Gas Industry:

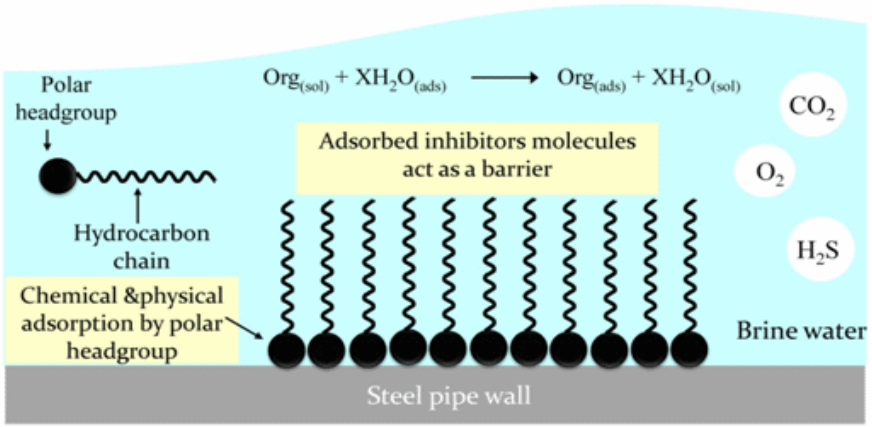
- Metallurgy selection: Corrosion Resistant Alloys can be used or GRE linings
- Injection of corrosion inhibitor chemicals can significantly reduce corrosion rates
- Corrosion rates are monitored by inline coupons and probes and water chemistry monitoring

Key Differences

- Flow rates significantly higher >400 m^3/hr.
- Minimal hydrocarbon phase.
- Geothermal wells cemented casing vs oilfield well tubing - operationally difficult to intervene/replace.
- Casing sizes and lead times can exclude CRAs.

Oilfield Corrosion Inhibitors

- Minimal hydrocarbon phase results in gunking/build up of greasy deposits
- Impacts on injection well pressure
- Remedial treatments can be required to reduce well pressures
- More water-soluble corrosion Inhibitors have been shown to avoid these problems



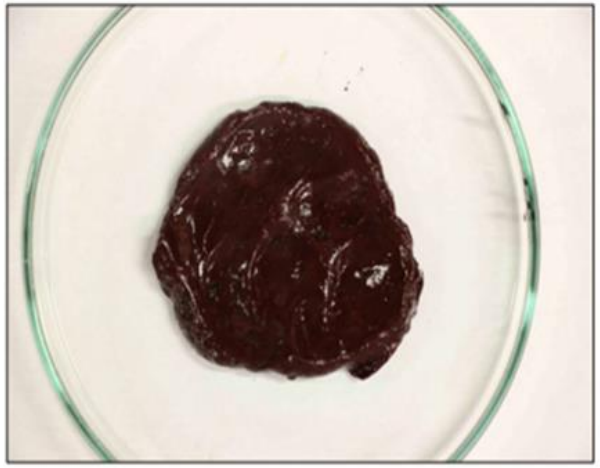


Figure 1: Gunk removed from filter units

Figure 2 Gunk deposition on calliper

Radioactive Deposits

- Radioactive ^{210}Pb deposits widely reported in Slochteren and Delft reservoirs in Netherlands and other regions in Europe
- Pb can cause corrosion and leaves radioactive deposits over metallic structures.
- HSE implications for removal and handling
- Expensive for specialist removal

Oil & Gas experience

- Seawater Injection in Oil and Gas – H_2S causes PbS precipitation held in reservoir as mineral
- Potential in Dutch gas production but not widely reported

$Fe^0 - 2e \rightarrow Fe^{2+}$

$Pb^{2+} + 2e \rightarrow Pb^0$

Mitigation for Lead Deposition

- Use of corrosion inhibitors have been shown to reduce quantities of lead deposits
- GRE linings can prevent Pb contact with iron downhole, but may displace the problem to surface
- Lead deposits can be dissolved by nitric acid
- Very little technology available to prevent/mitigate elemental lead formation which will be key to achieving optimal production rates

Scale

Similarities to Oil & Gas Industry

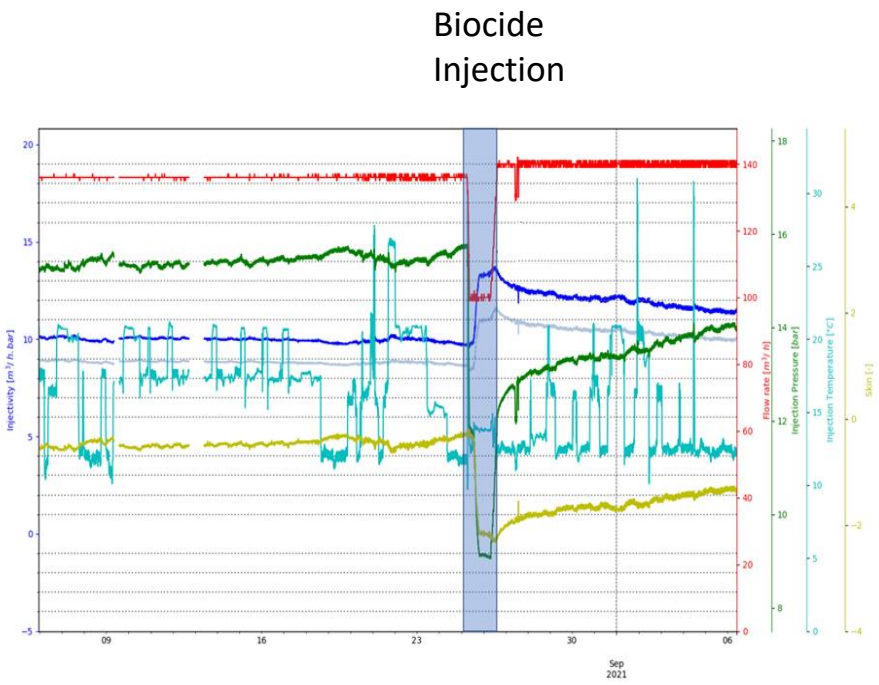
- Pressure and temperature changes from Reservoir to surface cause mineral precipitation
- Silica Scales in HPHT/ASP flood applications

Key differences to Oil & Gas production

- Only formation water is re-injected, no incompatible brine mixing
- Self- Scaling mechanisms dominant
- Temperature decreases rapid cooling effects
- Operational impacts require careful management
- Heat exchanger scaling effects can be observed in real-time
- Lithium extraction systems are sensitive to solids will require scale control

Injectivity

- For reservoir pressure maintenance all produced brine is reinjected
- Unlike offshore Oil & Gas production, no option to reroute fluids
- Capacity to inject at safe injection well pressures is critical to achieve high flow rates
- Bacterial growth / biofilm formation can cause injection well pressure increases
- Periodic biocide treatments can prevent and alleviate pressure increases



Conclusions

- Oil & Gas Industry learnings/best practice valuable
  - Significant production chemistry problems exist
    - Corrosion, scale, microbiology challenges are similar to predict
  - Management strategies required from the Basis of Design
    - Prevention is better than cure
    - Chemical or engineering
- Key differences in Geothermal production require changes to the production chemistry management approach
  - Lack of hydrocarbons
    - Different chemistries
  - Criticality of solids on Injection well pressures, heat exchangers and lithium extraction processes