Reducing the environmental impact of oil and gas production

Simon Ivar Andersen, DHRTC TC 2021
Overview getting to Zero Harmful Discharge

• Emission vs Discharge

• Optimization by fundamental insight

• Focus on limiting discharge
  – Reduce discharge volumes – by reinjection
  – Reduce impact by cleaning water
Increasing water production....

Danish North Sea Production

- water produced
- oil production

volume 1000 m³

year


1 : 4

PW worldwide more than 60 Billion cubic meters/Year
Produced Water Management towards zero harmful discharge

Discharge to Sea

Reinjection

EIF: Environmental Impact Factor; OiW: Oil-in-Water
Produced Water Compounds

• A complex cocktail

Interface between oil/water
Densely populated
OSPAR compliance IF OiW < 30 mg/L

Discharge OiW Concentration vs years

Have we reach some physical limit?

What can we do to further reduce this?
1) Optimize present system
2) Find new production chemicals
3) Introduce Polishing techniques
4) New treatment processes
Environmental Impact Factor (EIF) Contribution

"Anthropogenic" Prod. chem

Geochemical

Oil-in-Water droplets 1% of EIF

And only a few chemicals dominate EIF e.g. H2S scavengers
Produced Water ReInjection (PWRI)

1:1 effect on EIF

- Reduce volume of discharged PW
- No present regulations on what is injected?

BUT for DUC

- Rock is supertight!!!!
- Water is still dirty!!!
- And it can easily become "a filtration exercise in the reservoir"
PW Reinjection – add the injectivity concerns

✓ PWRI decreases or eliminates surface disposal of produced water

To minimize injectivity loss (skin formation) some requirements are important:
– to avoid solids in the produced water system,
– to maintain injectivity whenever possible,
– to use compatible chemical products for oil-water separation
– avoid the formation solids-oil agglomerates (Schmoo... oil+solids = gunk)
– avoid corrosion
– avoid incompatibility with production chemicals

We work on understanding injectivity enhancement in carbonate reservoirs
And what treatment is needed to avoid issues
Deep bed filtration in the porous matrix

Injection of particles

Oil and chemicals may act as a glue!

Scaramento et al, JPSE 2015
The task of removing oil drops and chemicals

\[ P_{\text{oil-water}} = \frac{C_{\text{oil}}}{C_{\text{water}}} = \frac{V_{\text{water}}}{V_{\text{oil}}} \frac{m_{o,o}}{m_{o,w}} \]

Dissolved Species: Where they end (in Oil or Water) is determined by the partition coefficients.
Oil Field and Production Chemicals

<table>
<thead>
<tr>
<th>Production chemistry purpose</th>
<th>Chemical class</th>
<th>Primary solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion inhibitor</td>
<td>Amine imidazolines</td>
<td>Oil</td>
</tr>
<tr>
<td></td>
<td>Amines</td>
<td>Oil</td>
</tr>
<tr>
<td></td>
<td>Amine salts</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Nitrogen heterocycles</td>
<td>Oil</td>
</tr>
<tr>
<td>Biocides</td>
<td>Quat. Ammonium salts</td>
<td>Water</td>
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<tr>
<td></td>
<td>Amine acetate</td>
<td>Water</td>
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<tr>
<td></td>
<td>Gluteraldehyde</td>
<td>Water</td>
</tr>
<tr>
<td>Scale inhibitors</td>
<td>Phosphate ester</td>
<td>Water</td>
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<tr>
<td></td>
<td>Phosphonates</td>
<td>Water</td>
</tr>
<tr>
<td>Demulsifier</td>
<td>Oxyalkylated resins</td>
<td>Oil</td>
</tr>
<tr>
<td></td>
<td>Polyglycols</td>
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<tr>
<td></td>
<td>Sulfonates</td>
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</tr>
<tr>
<td>Antifoamer</td>
<td>Silicone polymers</td>
<td>Oil</td>
</tr>
<tr>
<td></td>
<td>Polymeric surfactants</td>
<td>Oil</td>
</tr>
<tr>
<td>H2S scavenger</td>
<td>Triazines</td>
<td>Water</td>
</tr>
</tbody>
</table>

We need chemicals to reduce problems during production
Interface is different from bulk – fundamental to oil removal.....

Composition
Tension
Elasticity
Rheology
Dynamic

Complex composite interface

Dispersed – solubilized – dissolved
Partitioning across interface

Skin formed on oil drop

Energy barrier
Simplified process with average oil-in-water concentrations

Well stream → separators

500-1000 mg/l → hydrocyclones

50 mg/L → Gas flotation

5-10 mg/L → Oil export

Water Zero harmful discharge
Reduced environmental impact
Improve injectability

Polishing
Or
Filters for PWRI preparation
To reduce further we need monitoring and control

1. Process Slops with chemicals
2. 3-phase separator efficiency
3. Primary OiW treatment
   - E.g. hydrocyclones
4. Signal Control process
5. Monitoring OiW
   - Chemicals?
6. Polishing by new tech
7. Zero discharge Vision

- Currently simple OiW monitoring
- No on-line monitoring device for “oil field chemicals”
- Only removes droplets of oil
- Removing dissolved species
- Monitoring needed

- Oil/Water/Chem
- Inversion
How do we optimize the current treatment system

- Understand the right mechanisms
- Monitor the important properties
- Control the system correctly based on insight – not necessarily on output

Amongst others We need to understand
“dilute emulsions”
“surfactancy”
“Oil chemistry”
“Partitioning between phases/solubility”
“Particle effects”
“Fluid dynamics”

And we need to actively use this....
Fluid Dynamics and "re-emulsification" by drop break-up

\[ d_{\text{max}} = \frac{W e^{3/5}}{\rho} \left( \frac{\gamma}{\rho} \right)^{3/5} \varepsilon^{-2/5} \]

If \( d > d_{\text{max}} \) the droplet will break

\[ \varepsilon = \frac{\Delta P \cdot Q}{\rho \cdot V_{\text{diss}}} \]

Relative Area/Mass of drop increases
Polishing….. Size, footprint and cost!

Alternatives

Zero Harmful Discharge comes at a price!
Combining fundamental insight to optimize the discharge quality

- Reduce droplet stability and break-up eg. by avoiding antagonistic surface activity
- What are the main reason for high EIF? How do we attack that?
- What geochemical substances are active?
- What chemicals can and shall we substitute?
- What methodologies can be applied to treat large (30 mill m3/yr) volumes with low concentrations?
- How do we monitor the right things for monitoring and control?
- Can we remove causes at root of problem?
DHRTC Produced water management programme

Current PW Partners
- KU
- AAU
- DTU
- DHRTC
- AU
- NTNU

Numbers
- 50 Million DKK
- 20 Projects
- 60 Researchers
- 10 Companies
- 1 EUDP project
We work on

• Optimization based on fundamentals to decrease load on polishing.
• New monitoring and control approaches.
• New chemicals to substitute more toxic ones.
• Better analysis of toxicity and what to remove from the cocktail.
• Remove and convert compounds with high EIF contribution (e.g. H2S scavengers).
• New technologies for discharge water treatment.
• New technologies for injection water treatment.
• Improved understanding of reinjection in carbonate fields.
Acknowledgement

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• Thank you!