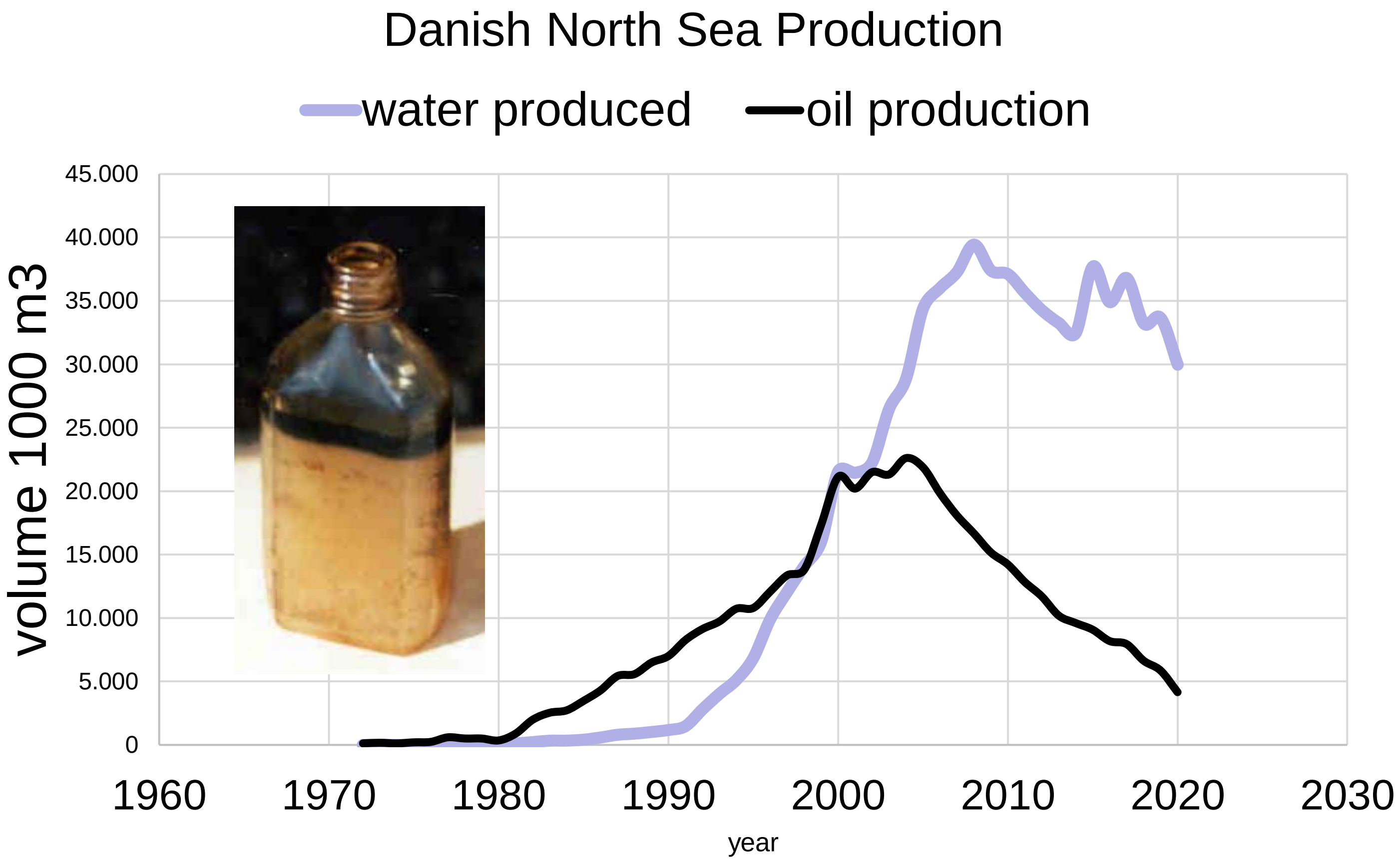
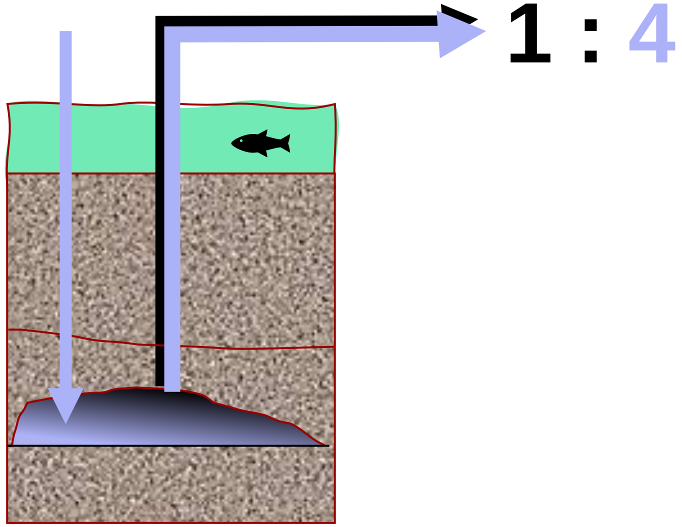
Simon Ivar Andersen, DTU Offshore

Water Management in the Offshore Environment

Present results – and the future…

What is Produced Water….





PW worldwide more than 60 Billion cubic meters/Year

DOTC Produced water management programme

Current PW Uni Partners

- KU (blue)
- AAU (green)
- DTU (red)
- AU (pink)
- NTNU (yellow)
- DOTC (orange)

Numbers

Ca 50 Million DKK

20 Projects

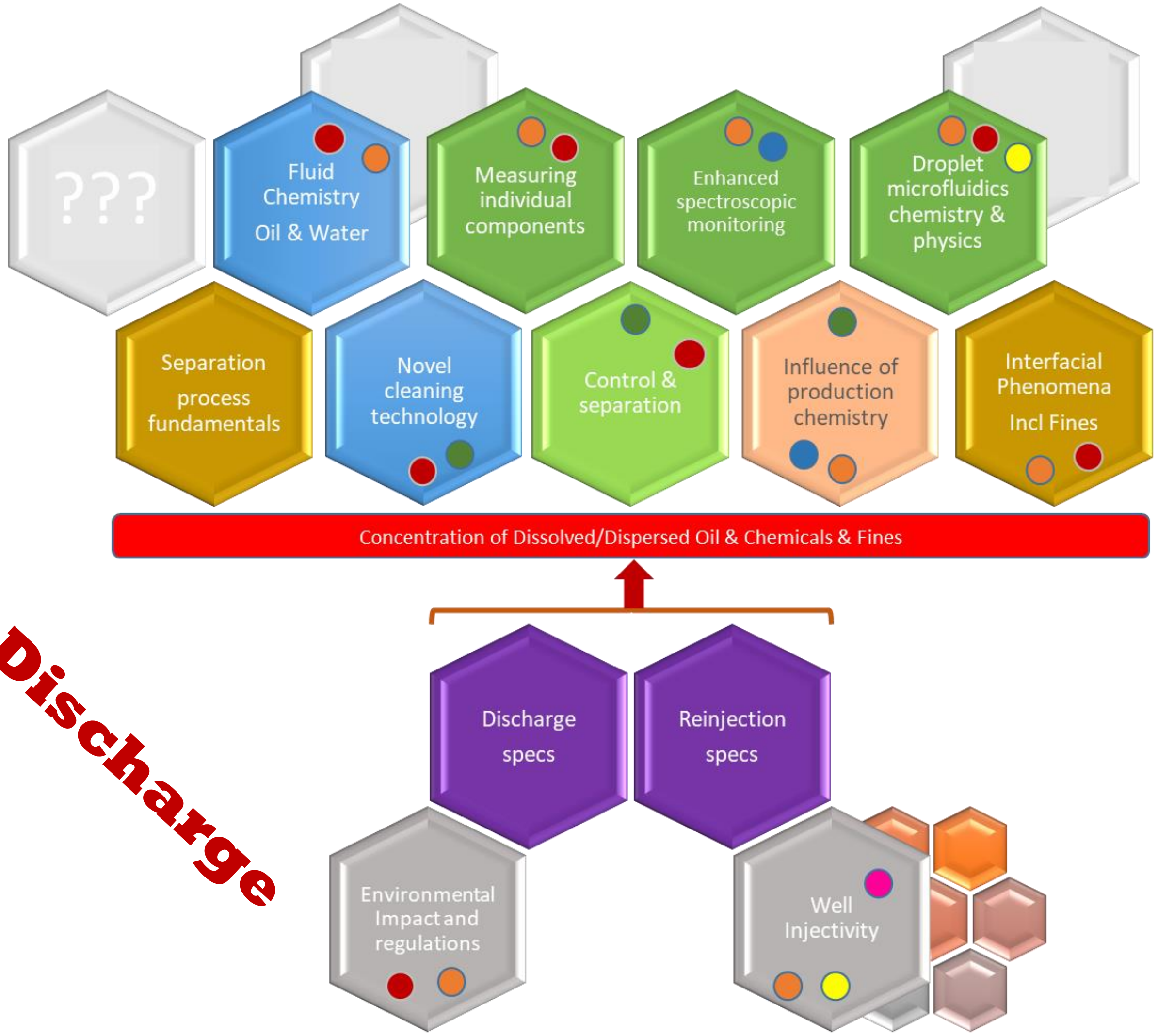
60 Researchers

10 Companies

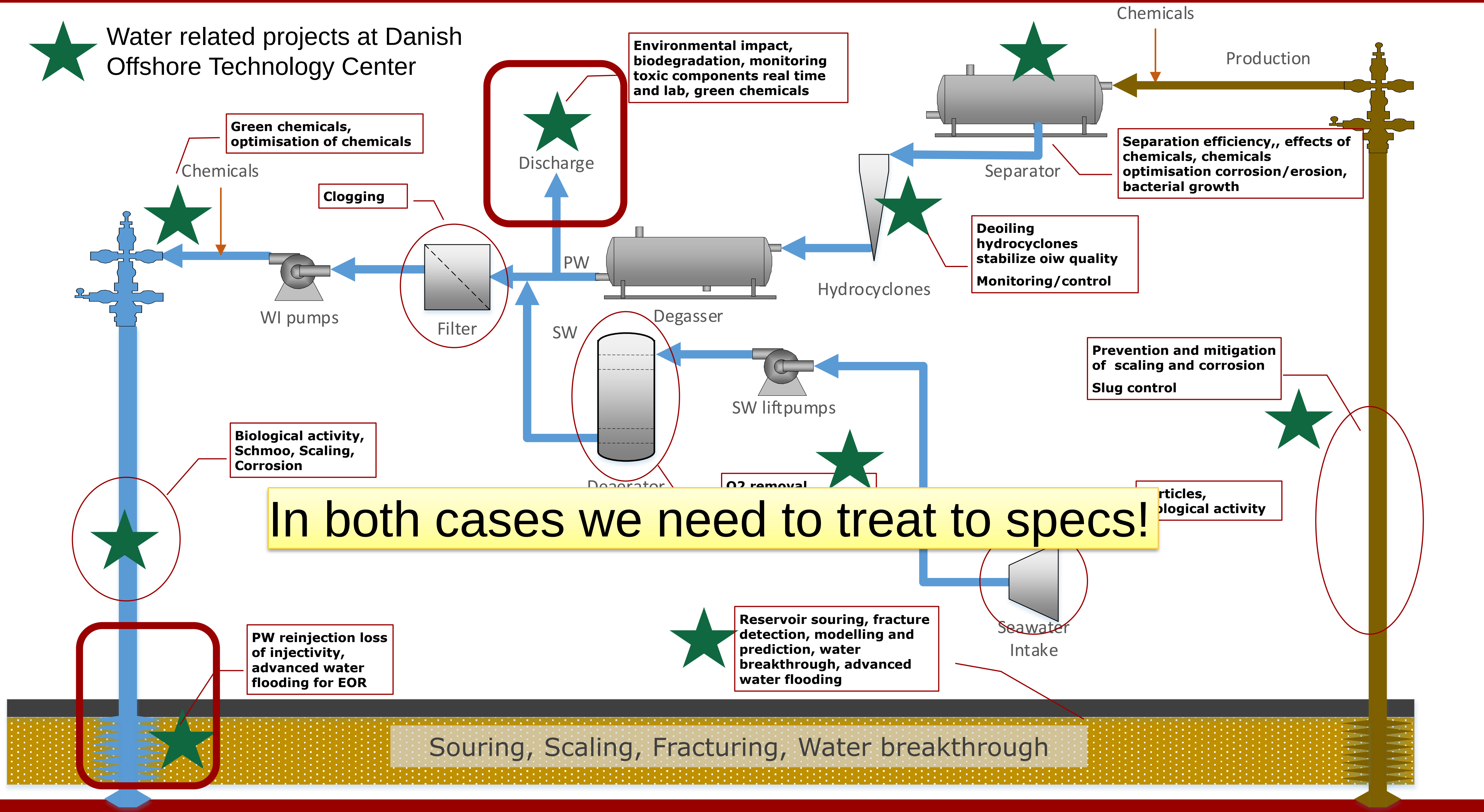
2 EUDP projects

80+ publications/conf.

Zero Harmful Discharge

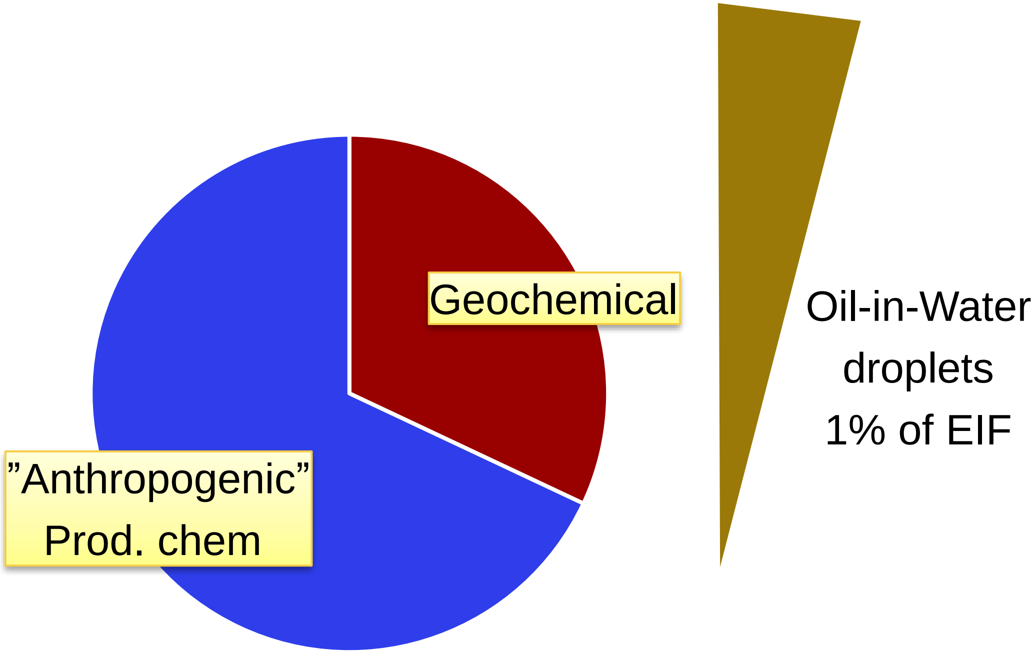


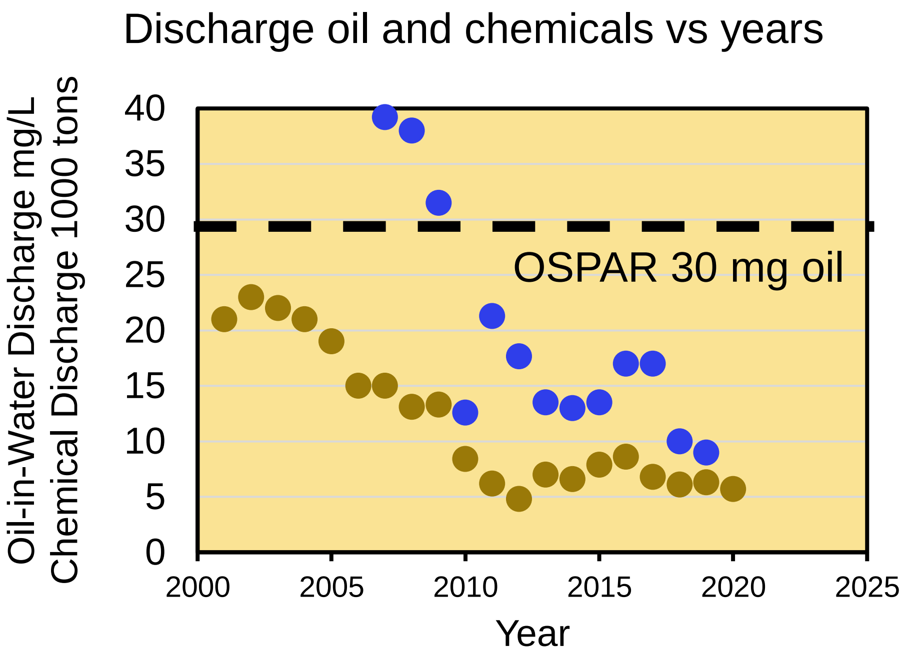
Application call Jan 14, 2020



Water related projects at Danish Offshore Technology Center
Chemicals
Production
Environmental impact, biodegradation, monitoring toxic components real time and lab, green chemicals
Green chemicals, optimisation of chemicals
Chemicals
Discharge
Separator
Separation efficiency,, effects of chemicals, chemicals optimisation corrosion/erosion, bacterial growth
Clogging
PW
Deoiling hydrocyclones stabilize oiw quality
Monitoring/control
Hydrocyclones
WI pumps
Filter
Degasser
SW
Prevention and mitigation of scaling and corrosion
Slug control
SW liftpumps
Biological activity, Schmoo, Scaling, Corrosion
O2 removal
In both cases we need to treat to specs!
Seawater Intake
PW reinjection loss of injectivity, advanced water flooding for EOR
Reservoir souring, fracture detection, modelling and prediction, water breakthrough, advanced water flooding
Souring, Scaling, Fracturing, Water breakthrough

Environmental Impact Factor (EIF) Contribution

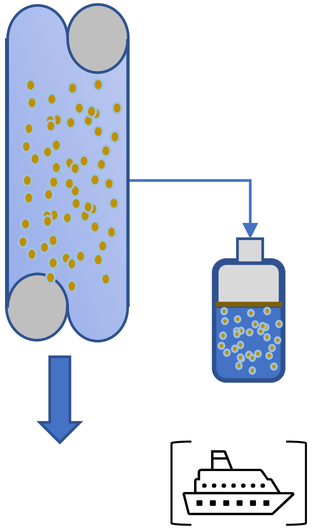




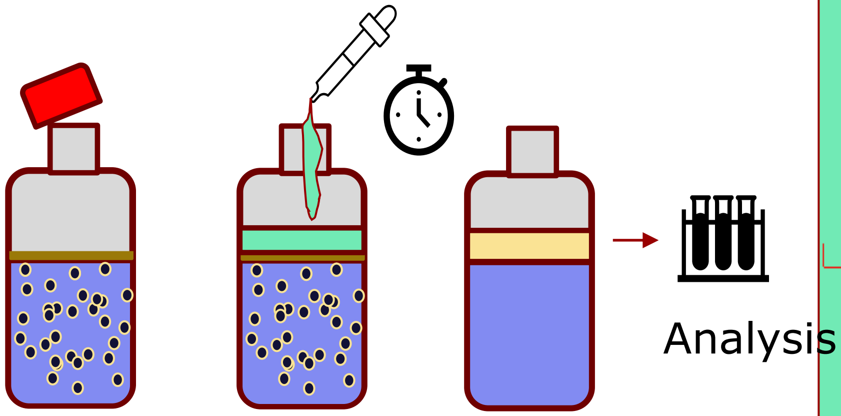
Sometimes a few chemicals dominate EIF e.g. H_2S scavengers

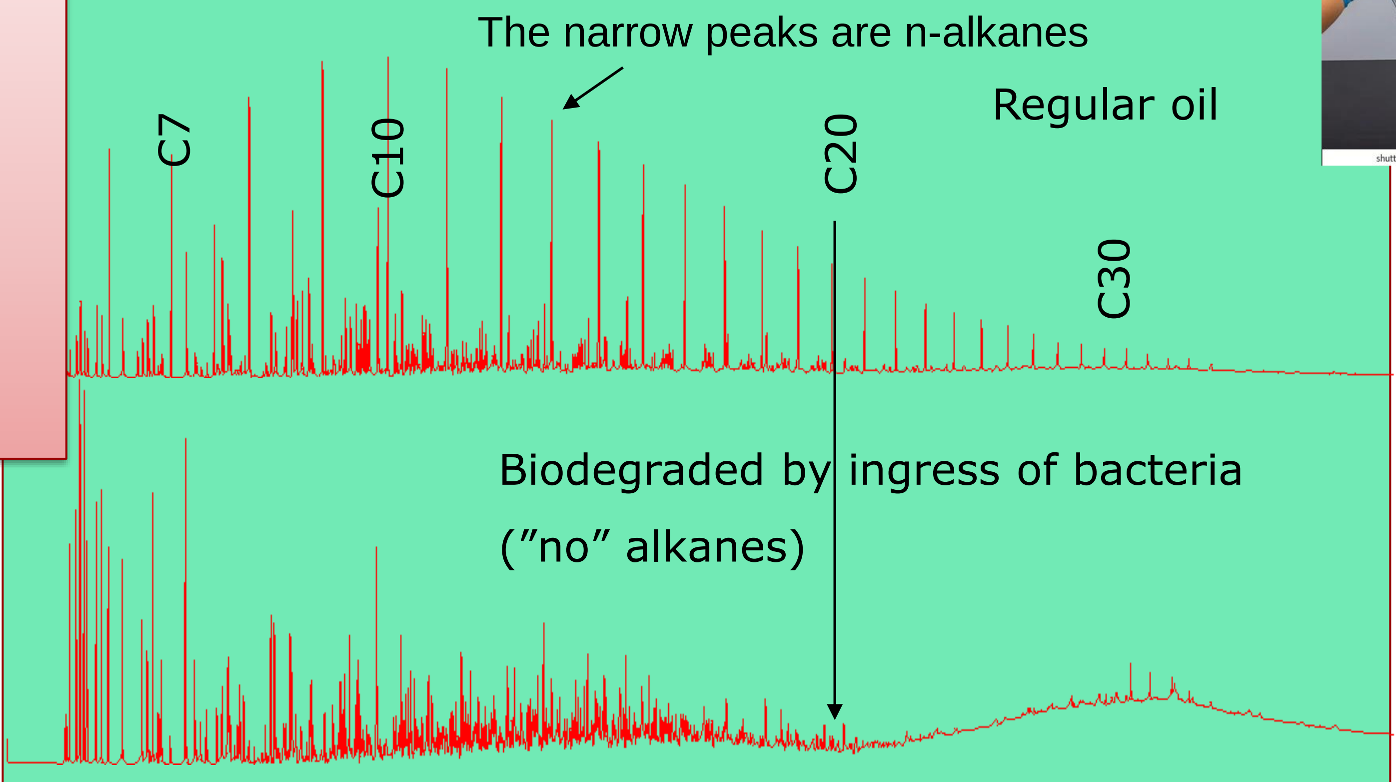
$$\text{Total EIF} = \Sigma \text{ Individual EIF}_i$$

We depend on good sample quality….

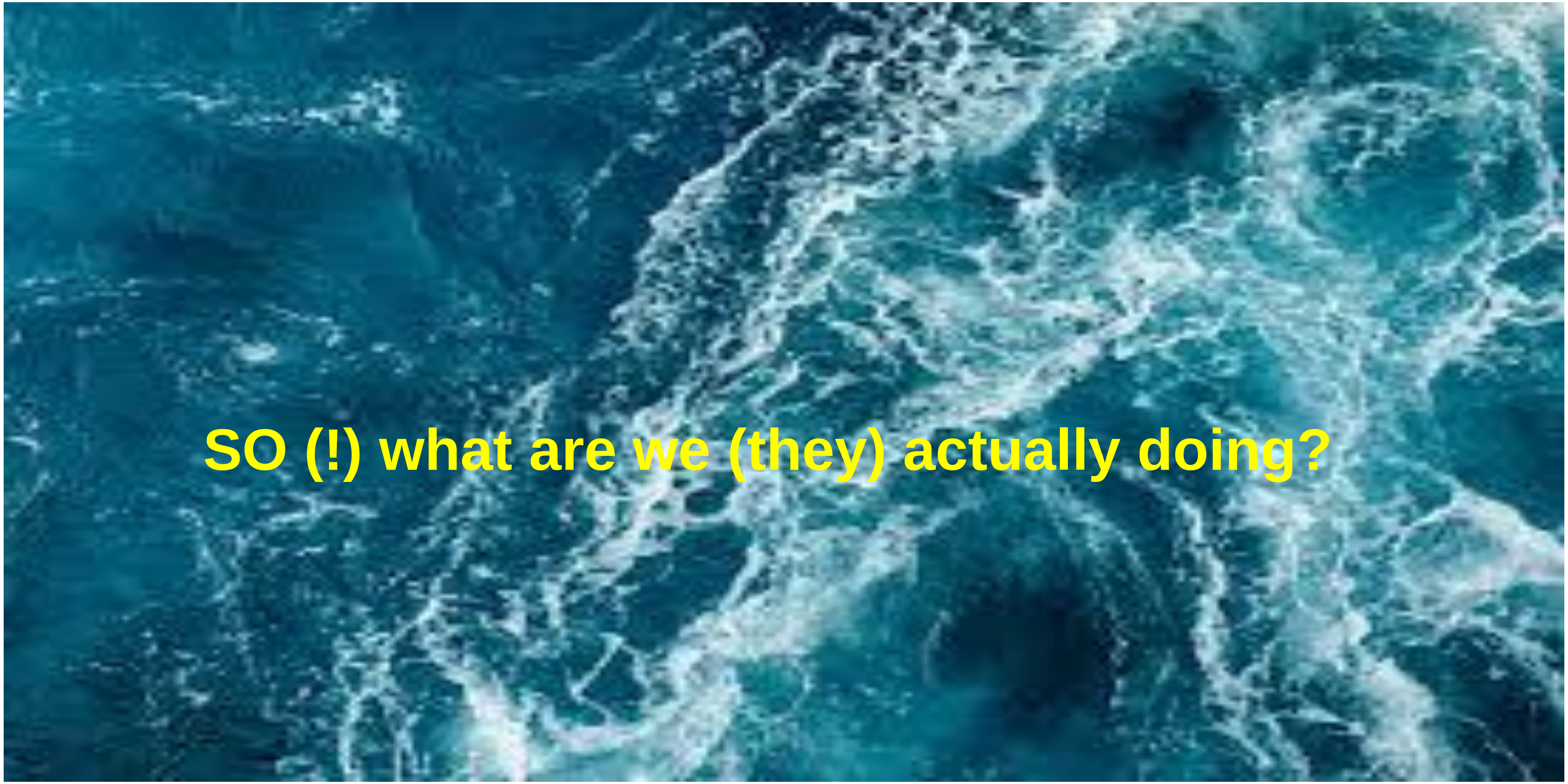


Samples are altered by
Sampling
Solvent selection
Filtration
Pipetting
Time
contamination
Etc.





We need the good samples, please ☺


SO (!) what are we (they) actually doing?

Environmental impact, legislation and ecotoxicity– visit Room B!

Assessing Environmental Impact

Legislation

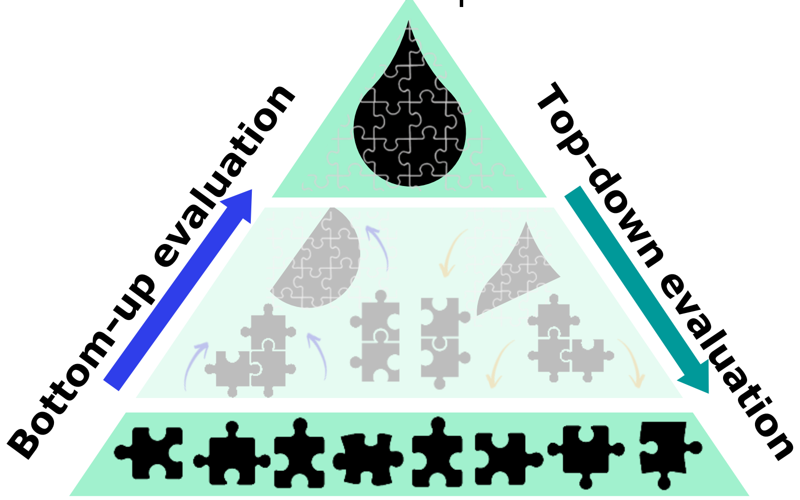
§ Compliance §
???

Natural compounds	ppb
Dispersed oil	[illegible].4
BTEX mono-arom[illegible]	17
Naphthalenes	2.1
PAH 2-3 ri[illegible]thalenes)	0.15
PAH 4[illegible]	0.05
Ph[illegible]3	10
[illegible]4 - C5	0.36
[illegible]s C6 +	0.04
[illegible]nc (Zn)	0.46
Copper (Cu)	0.02
Nickel (Ni)	1.22
Cadmium (Cd)	0.028
Lead (Pb)	0.182
Mercury (Hg)	0.008

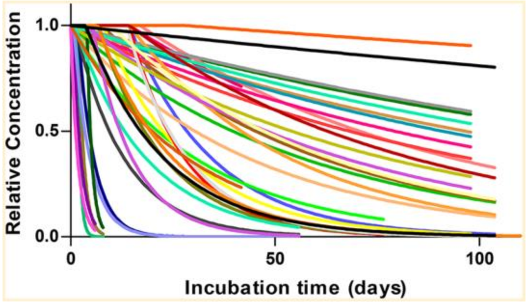
Total EIF = Σ Individual EIF_i

Proposing solutions

PW sample

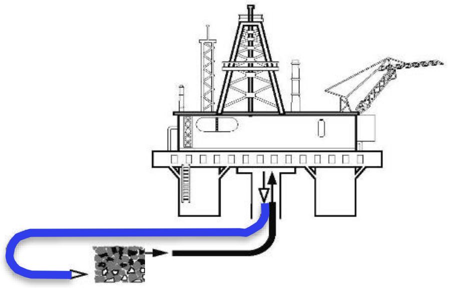


Individual PW constituents

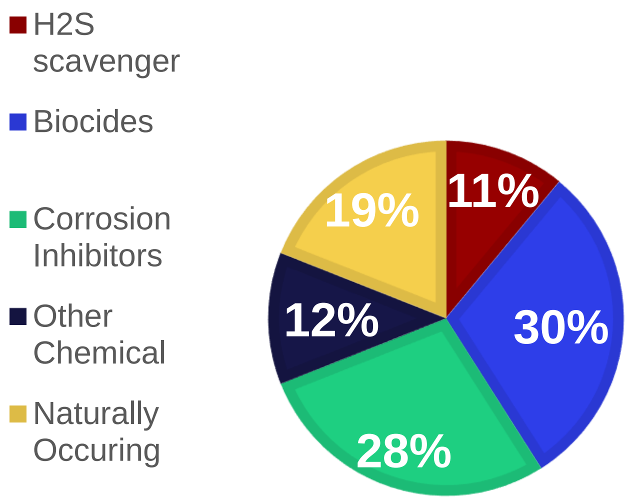


Action

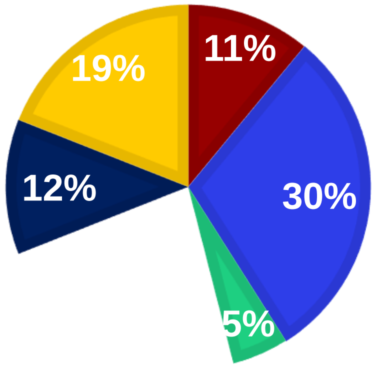
Improve processing?



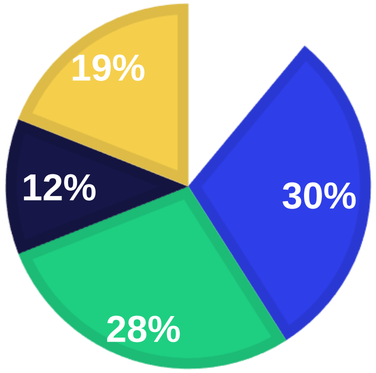
Different Strategies regarding Oil Field Chemistries

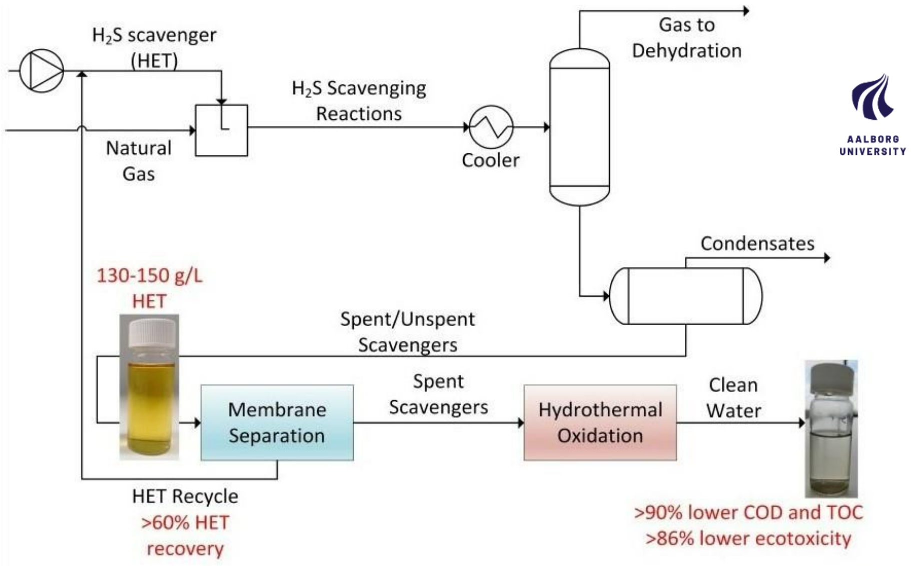


Substitute with new Green chemical

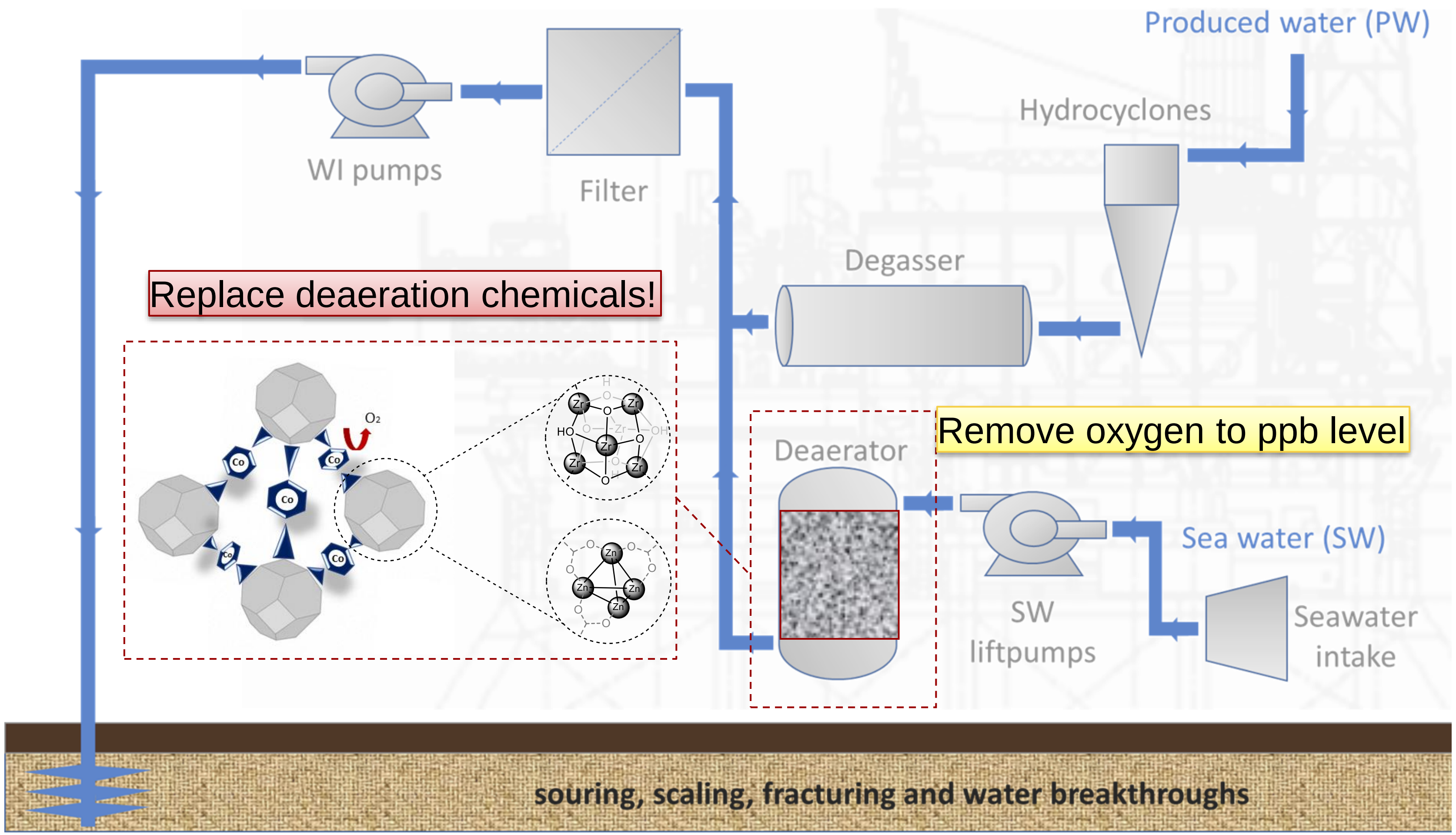


Remove H_2S scavenger stream @ source





Reduce chemical usage in PWRI: Metal-organic frameworks (MOFs) as oxygen scavengers



MOF-abilities

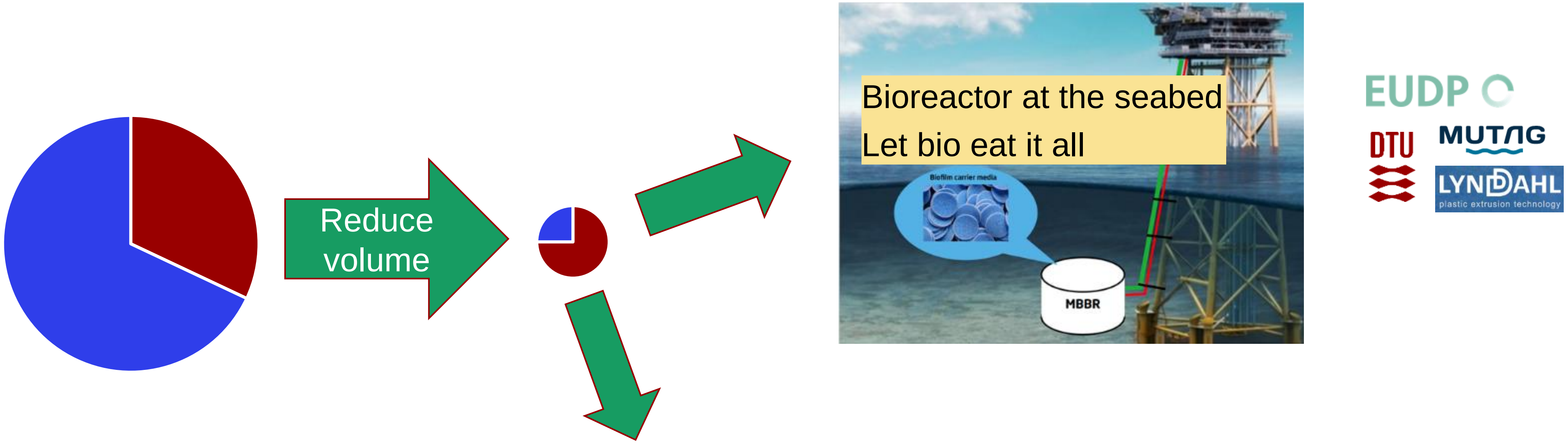
- reusable porous self-assembled coordination polymers.
- demonstrate O_2 absorption up to ppb

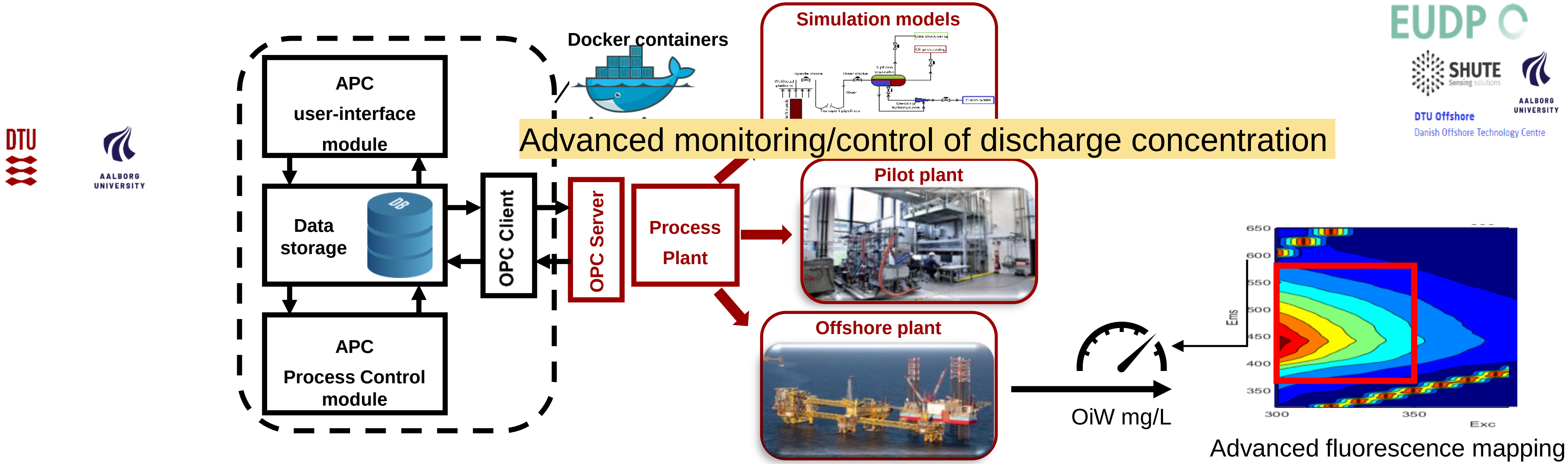
MOF-ortunities

- replacing oxygen scavenging chemicals
- increasing eco-efficiency
- reducing environmental impact factor (EIF)

Per Reichert
Ph.D. Student in Material Chemistry at DTU Offshore

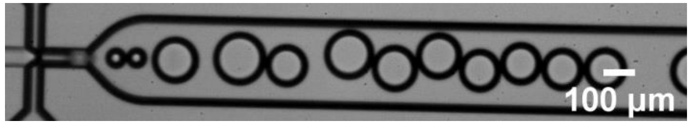
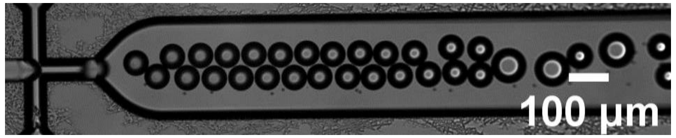
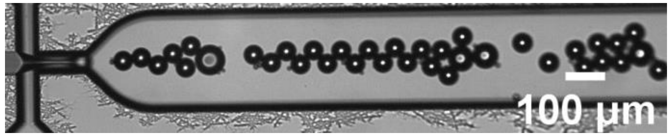
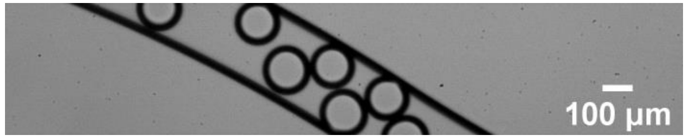
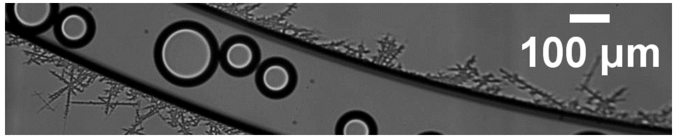
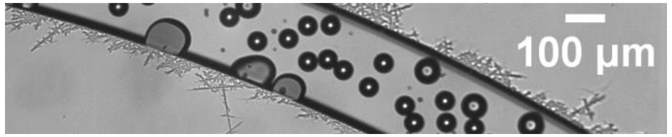
Reduce discharge content of oil and chemicals

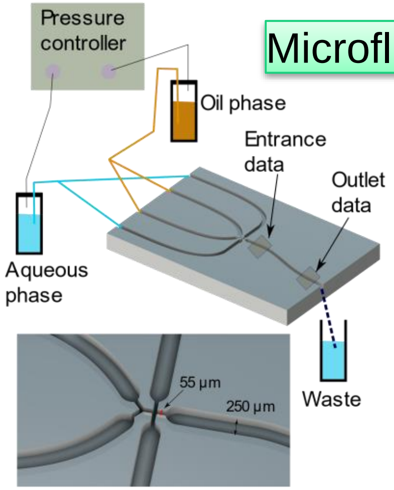




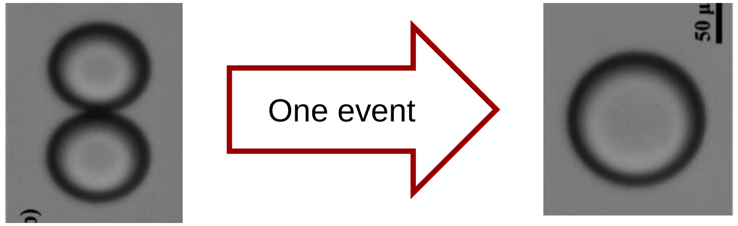
Advanced fluorescence mapping

Produced water can actually stabilize oil drops….

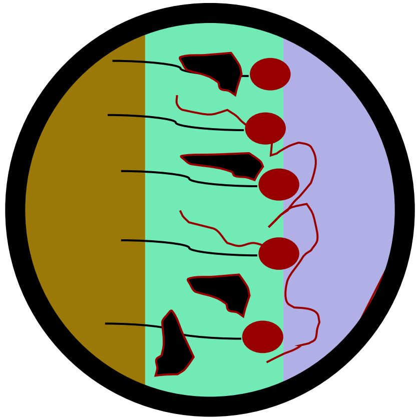
Oil phase	Toluene	Toluene	Crude oil
Water phase	H_2O	Prod.water 3.9 ppm oil-in-water	Prod.water 3.9 ppm oil-in-water
Entrance			
Outlet			



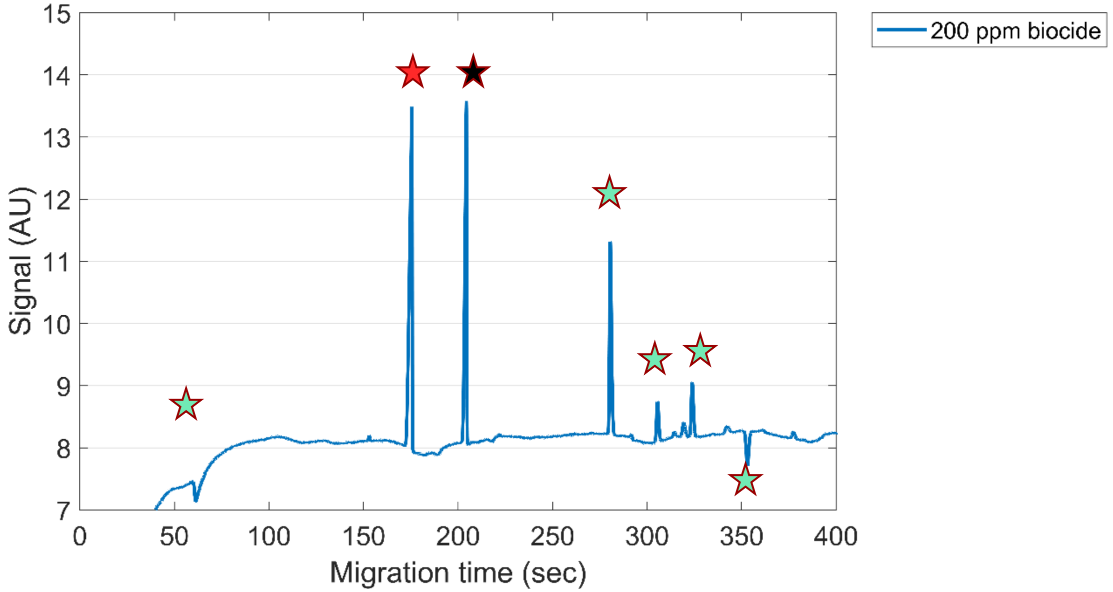
Microfluidics

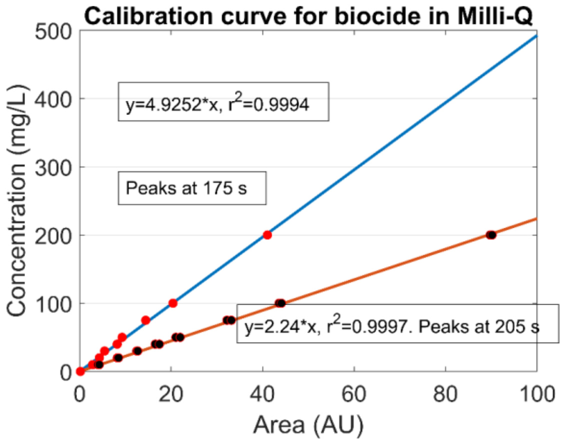


Events are crucial for drop removal
Microfluidics can quantify this



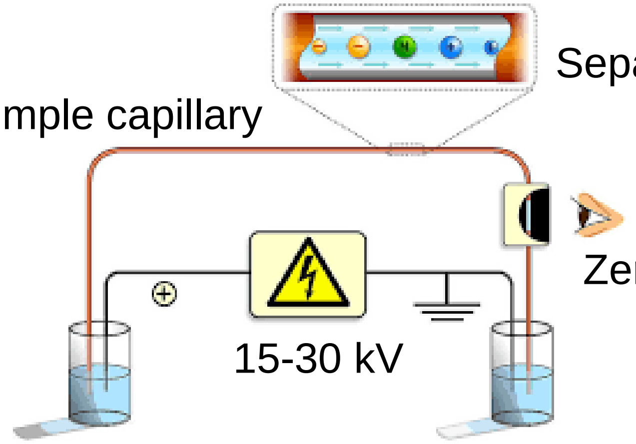
Quantifying Production Chemicals in Water with Capillary Electrophoresis (CE)



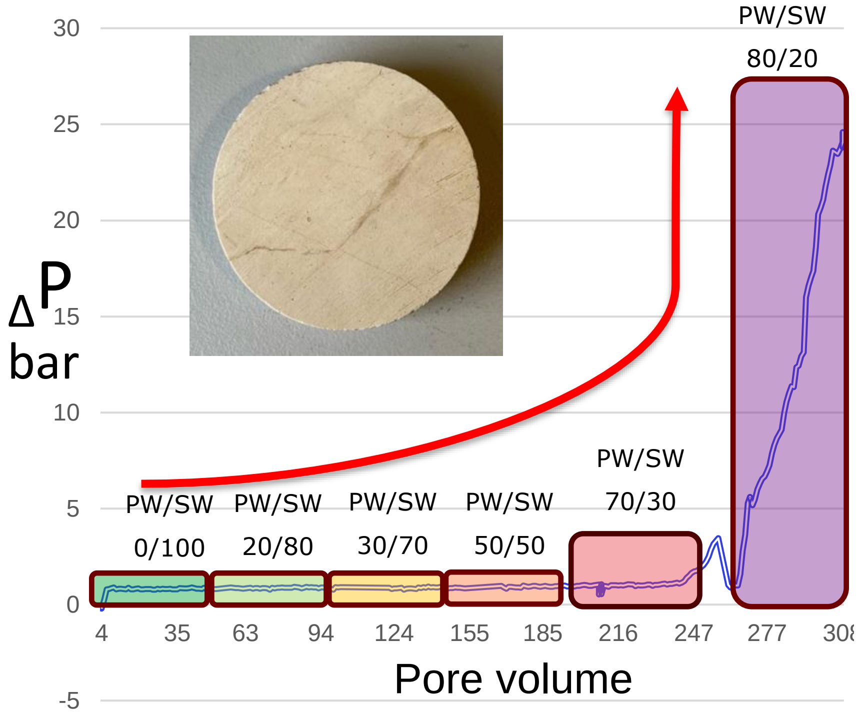


- CE provides an opportunity for fast determination of:
  - Actual concentration of individual components in PW
  - Partition of chemical between oil and water
  - Input to EIF assessment based on actual numbers

$$P_{oil-water} = \frac{C_{oil}}{C_{water}} = \frac{V_{water}}{V_{oil}} \frac{m_{o,o}}{m_{o,w}}$$



Produced Water Reinjection in Chalk



Room B at 10:00

To
Avoid
then

Understand input

- Scale
- Schmoo
- Bacteria
- Particle treat
- Corrosion

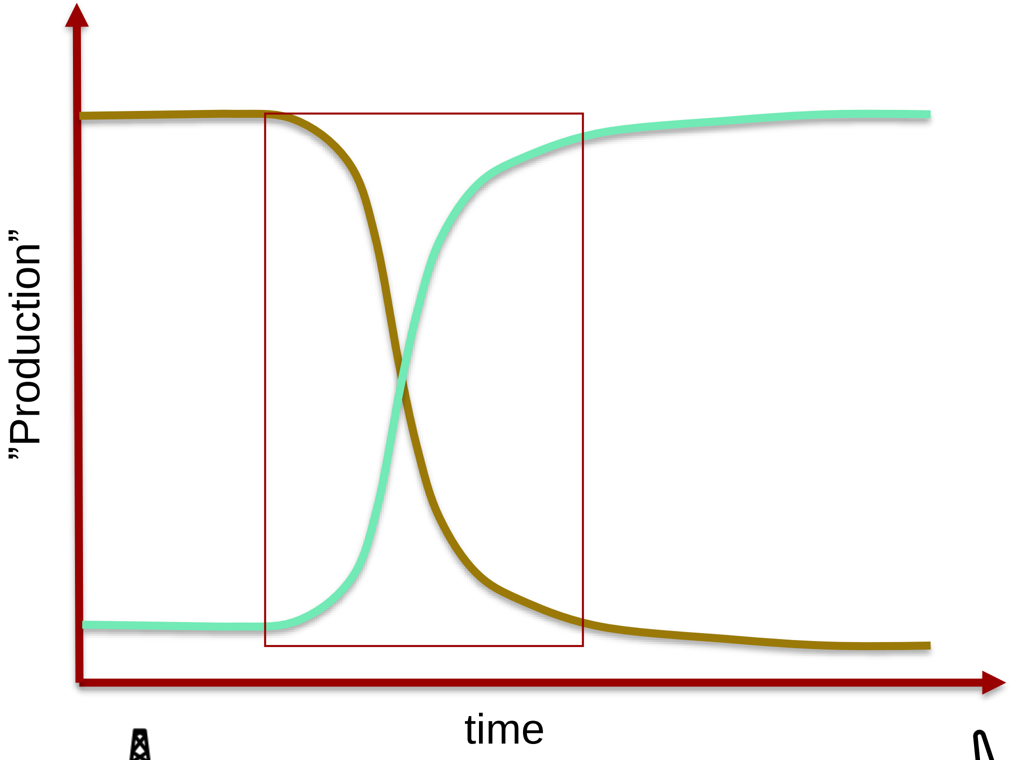
Develop Specification for PWRI in chalk

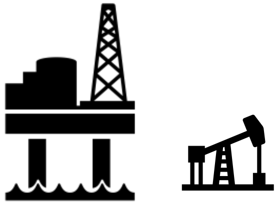
Develop optimal treatment process

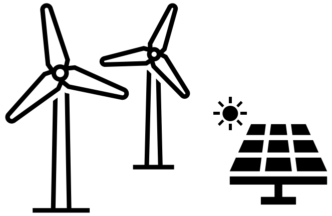
- Low Acid Treatment
- Technology for on-site manufacturing
- Being able to model this to optimize
- All steps in the process need consideration

PWM in a world in transition

Almost every activity humans do has a chemical footprint



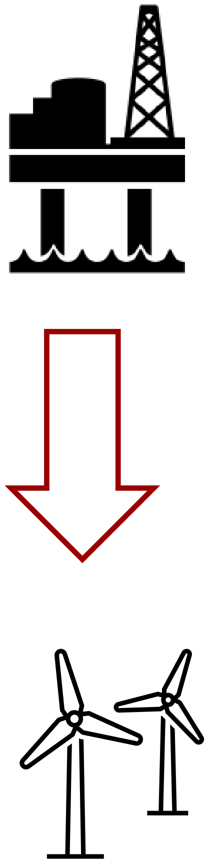




Knowledge and technology transfer to other wastewaters

- Systems with oil (or non-miscible oily phase) and water with varying chemistry
- Workflows for understanding substitution
- New chemicals
- Sensors and detectors
- Wastewater treatment and optimization

Produced Water and Chemical Foot Print Management in Offshore Environment – and transition from O&G to Wind



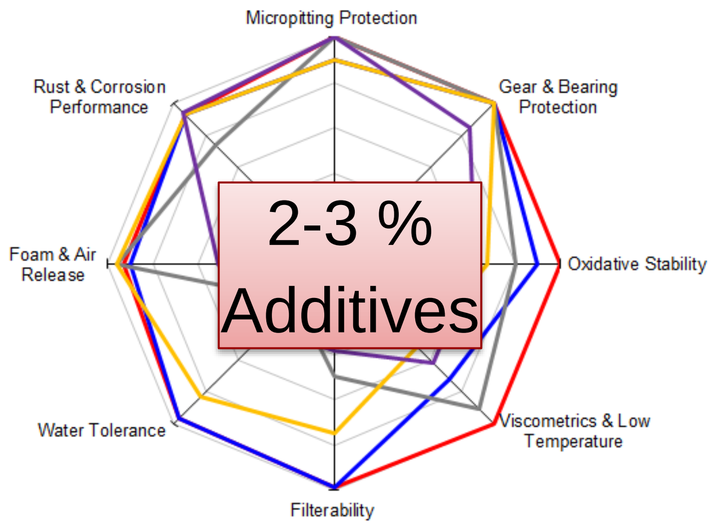
- Discharge to sea: Optimization of existing and new processes though fundamental insights on oil-water behavior, composition, sensors, new product and ecotoxicology.
- PWRI. Provide optimal specs for injection of water reducing scale and bacterial growth – applicable capabilities within geothermal (“1:1”).

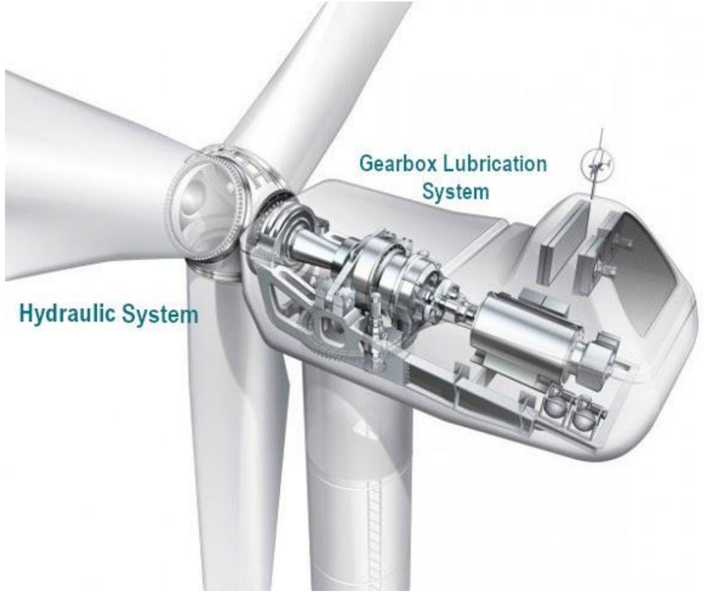
- Other important less developed areas of upcoming Offshore industries:
  - Energy Island P-t-X (assessed to reach 3-5 mill m^3/yr wastewater in Denmark 2030) – concentrated brines and chemical wastewater.
  - Very little literature on impact of e-fuel production on environment (Maria Grahn et al 2022 Prog. Energy 4 032010)
  - Windfarms leaching and degradation products from protection chemicals, coatings, gearbox lubricants, and hydraulics (little attention).

Example: Chemical foot print of wind farms – failure of components may lead to leaks

- Windfarms have similar issue, similar chemistries, but distributed discharge compared to the localized discharge from O&G.

All the known inhibitors and additives but at higher concentrations!



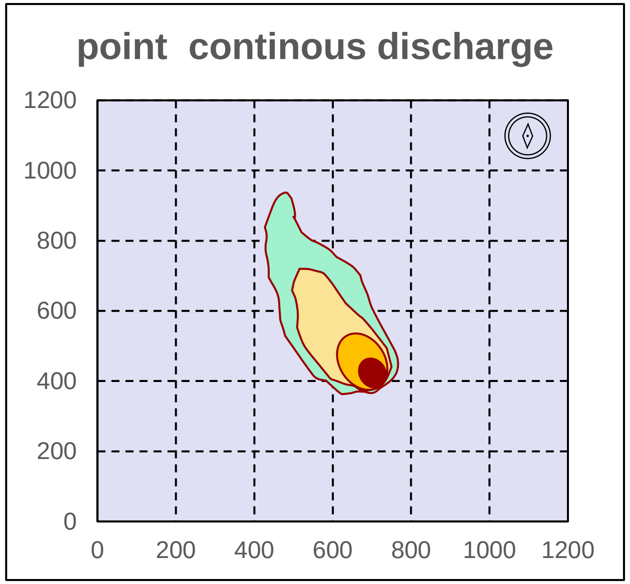


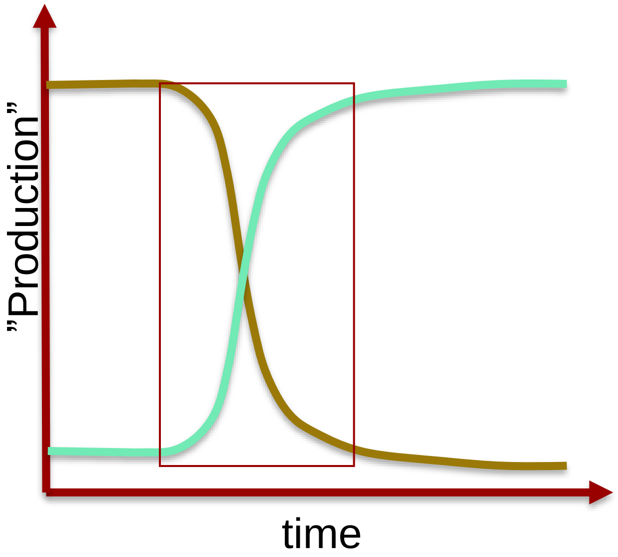
A large turbine contains up to 8000 kg of oily chemicals

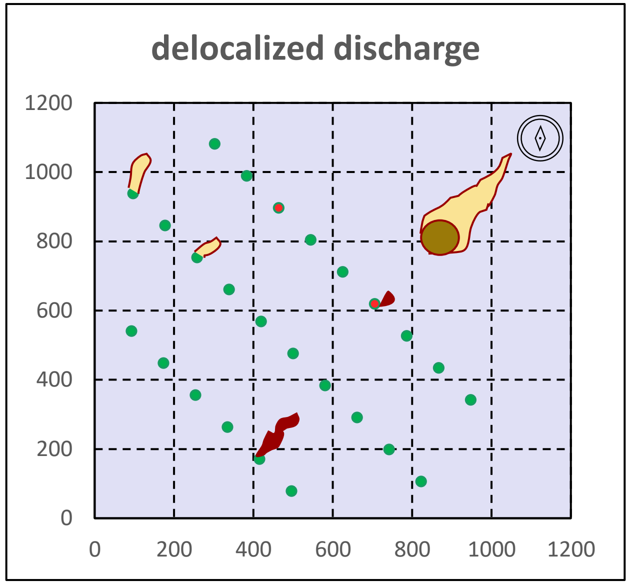
Inventory in 10000 mills: 80.000 tons

From PWM to the future – We can affect both while transitioning

Zero Harmful Discharge & emission







THANK YOU!