Oil related microbiology

Terje Torsvik

UNI - CIPR

CENTRE FOR INTEGRATED PETROLEUM RESEARCH

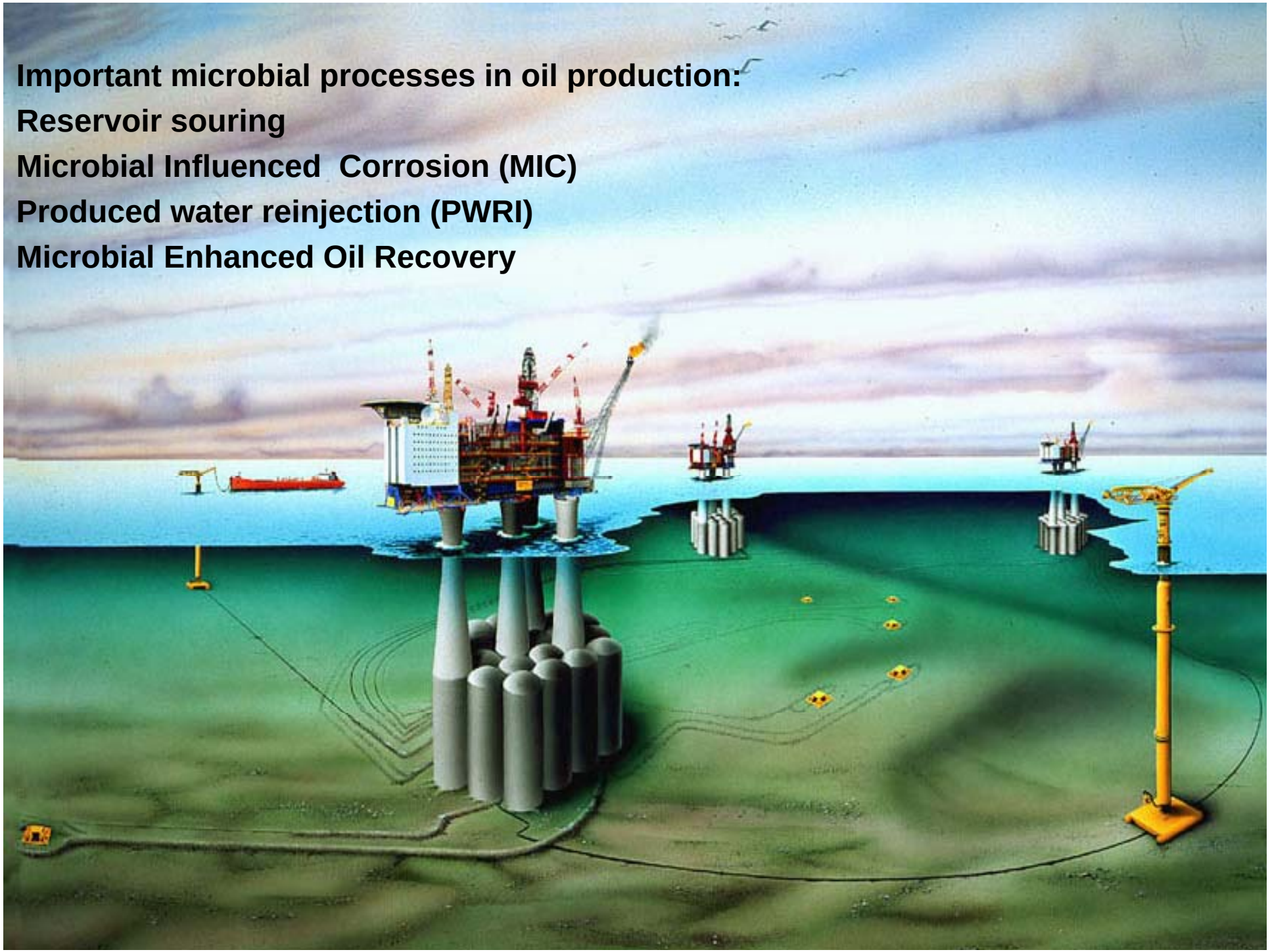
Important microbial processes in oil production:

Reservoir souring

Microbial Influenced Corrosion (MIC)

Produced water reinjection (PWRI)

Microbial Enhanced Oil Recovery



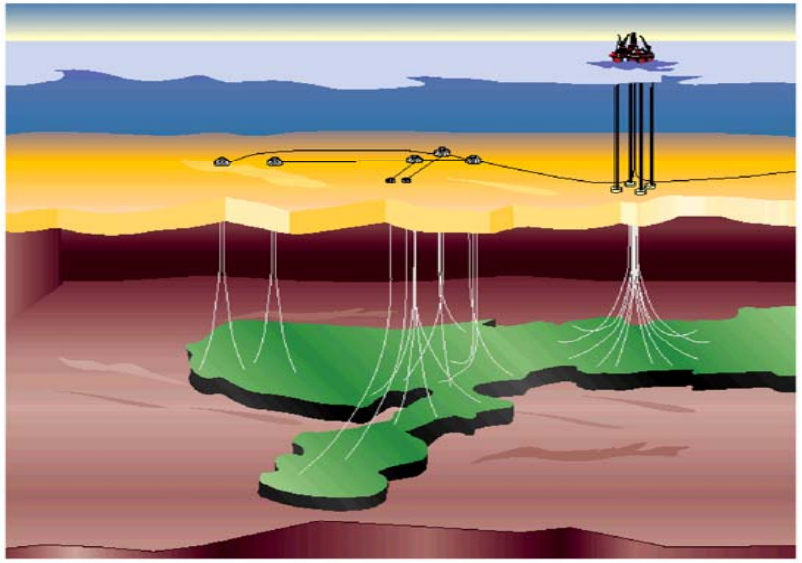
Reservoir souring in offshore oil production

Sea water is injected into the reservoir as pressure support

Oxygen is removed to reduce corrosion

Sea water contains 28 mM sulphate

Sea water injection promotes growth of SRB in the water injection system and in the reservoir



SRB use sulphate for respiration:

$$SO_4^{2-} \rightarrow H_2S$$

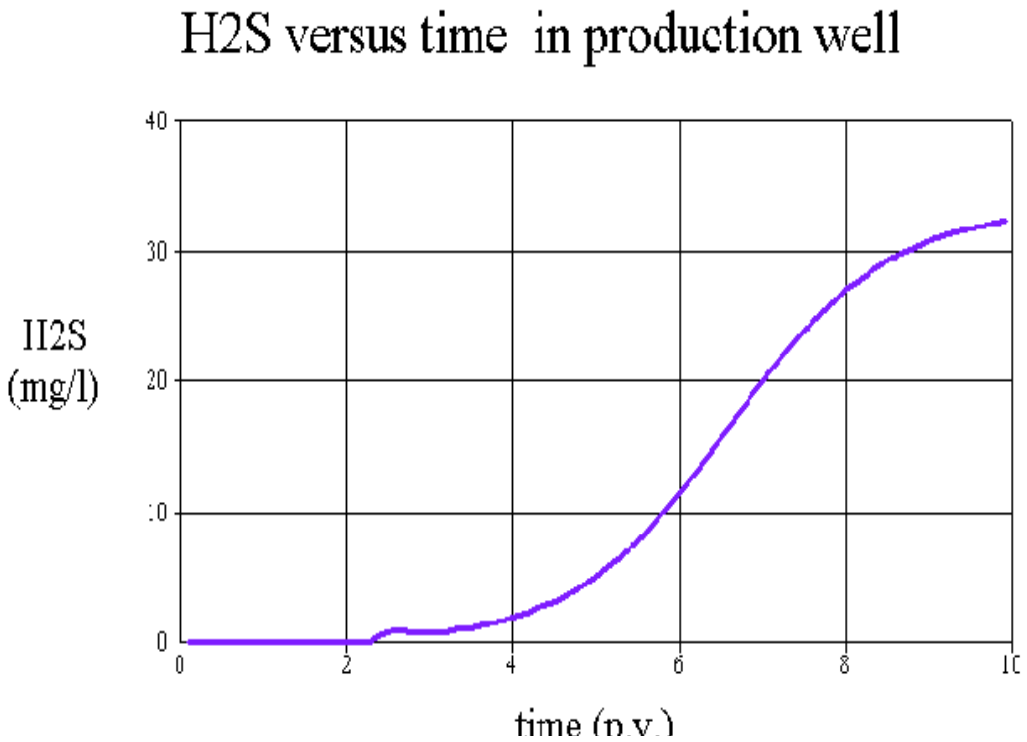
H_2S cause problems because it is toxic and corrosive

Traditionally biocides have been used to inhibit SRB

An alternative method based on nitrate injection have been developed in collaboration with Statoil and Hydro

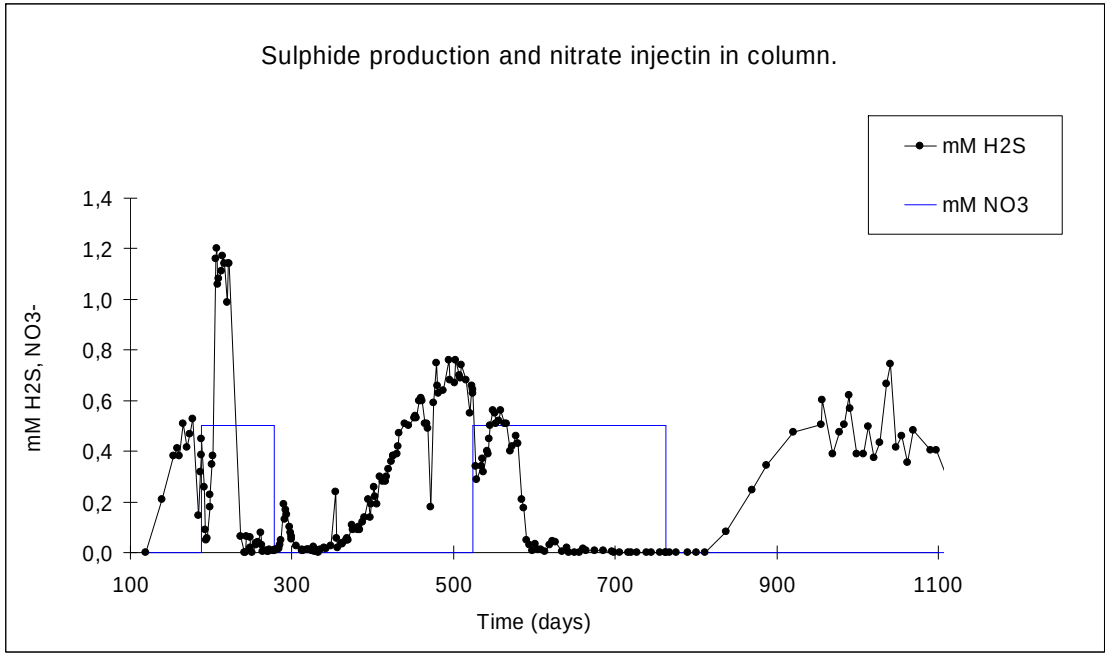
Microbial production of H_2S in the oil reservoir

- H_2S production increases dramatically over the lifetime of a production well.
- High H_2S levels may result in shut down of the well and reduced oil and gas production.
- H_2S is toxic and corrosive
- Strong restrictions on H_2S concentration in export gas



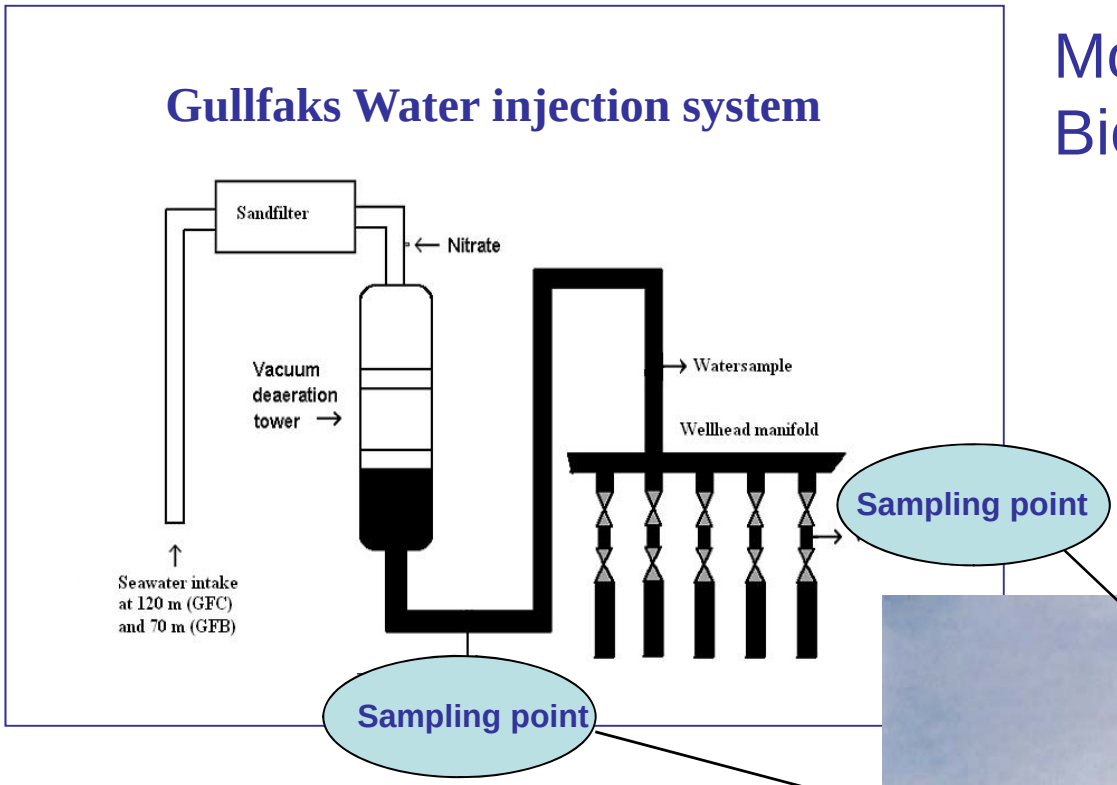
Ref. : Sunde et al. (1993). Field related mathematical model to predict and reduce reservoir souring. SPE 25197 (1993)

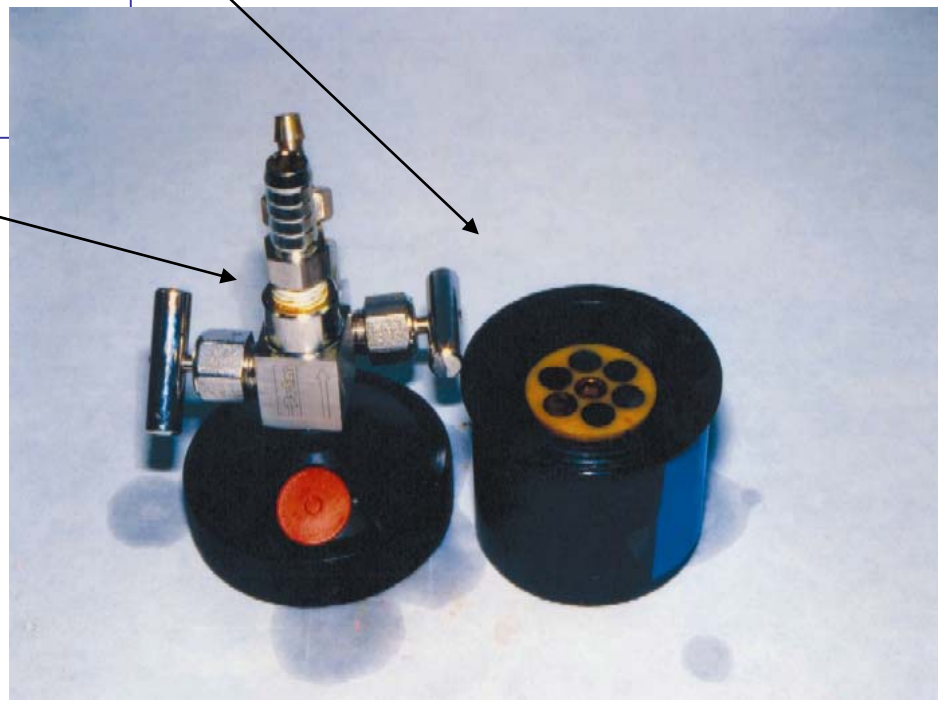
Laboratory experiments:
Effect of nitrate injection on H_2S production



Ref.: **Myhr et al. (2002).** Inhibition of microbial H_2S production in an oil reservoir model column. Appl. Microbiol Biotechnol 58: 400-408.

Monitoring SRB in the field: Biofilm sampling



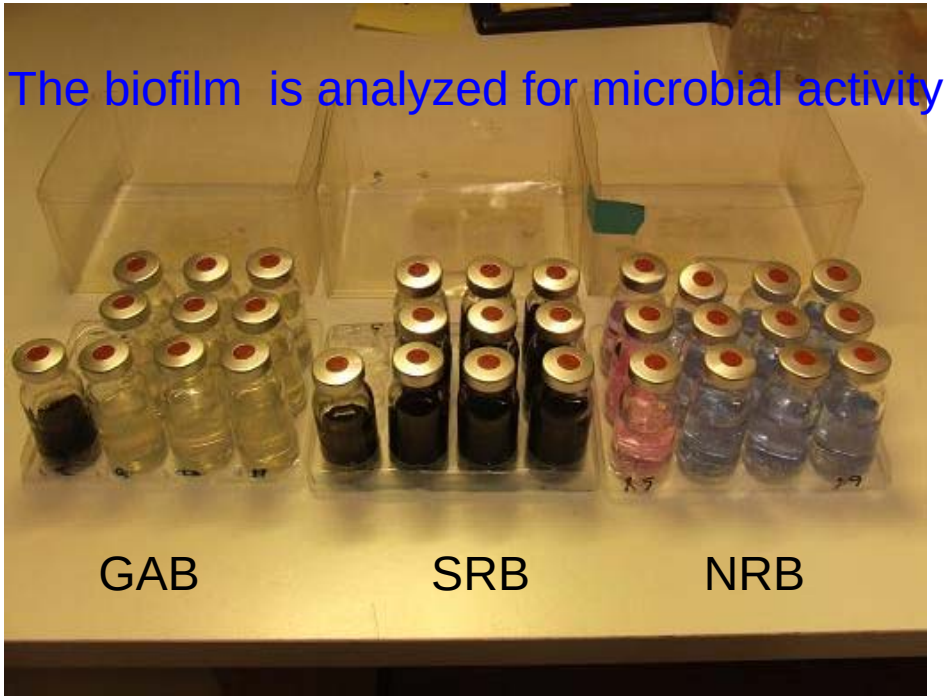


Biocoupons collected from pipiline

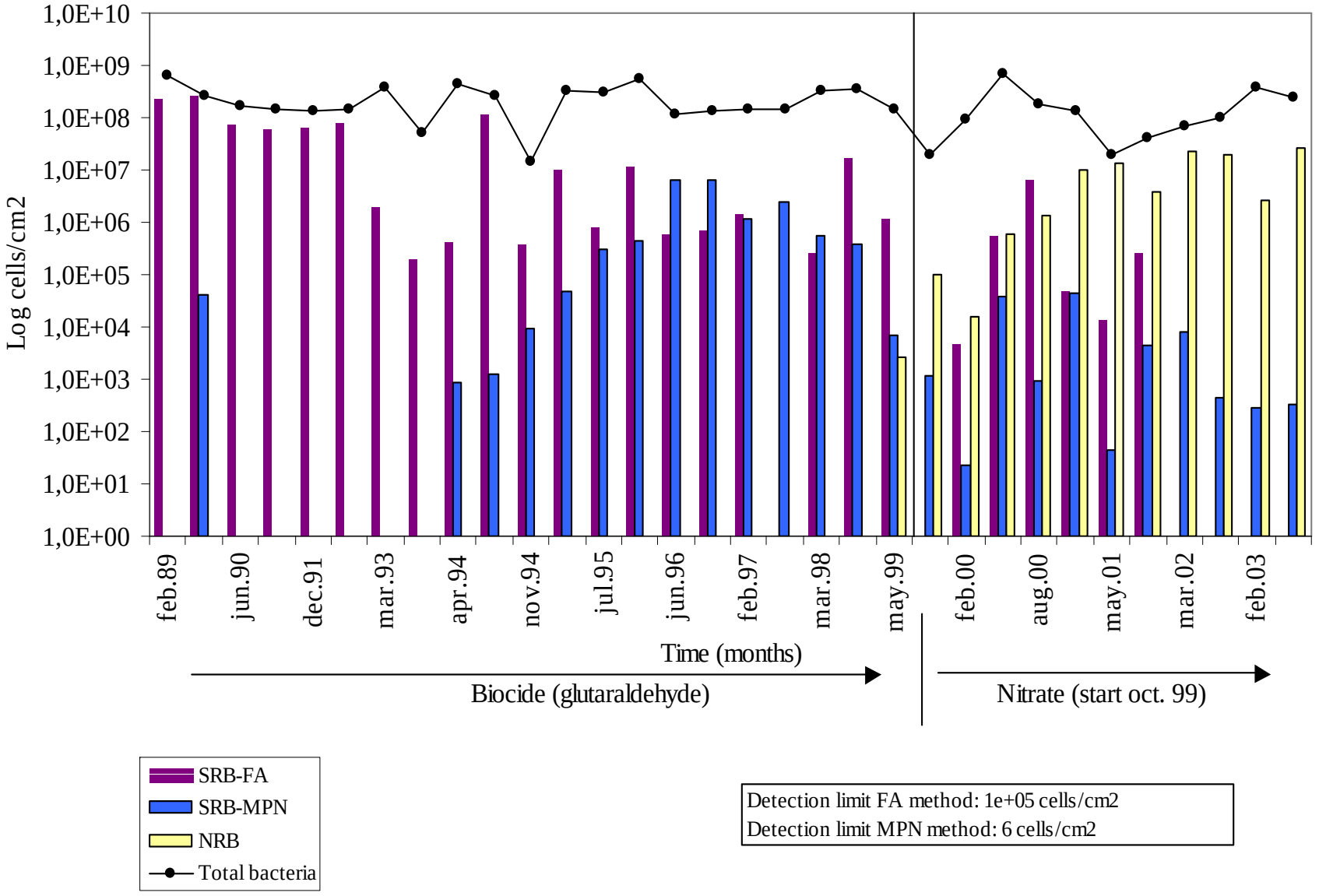
Placed in box for anaerobic transportation

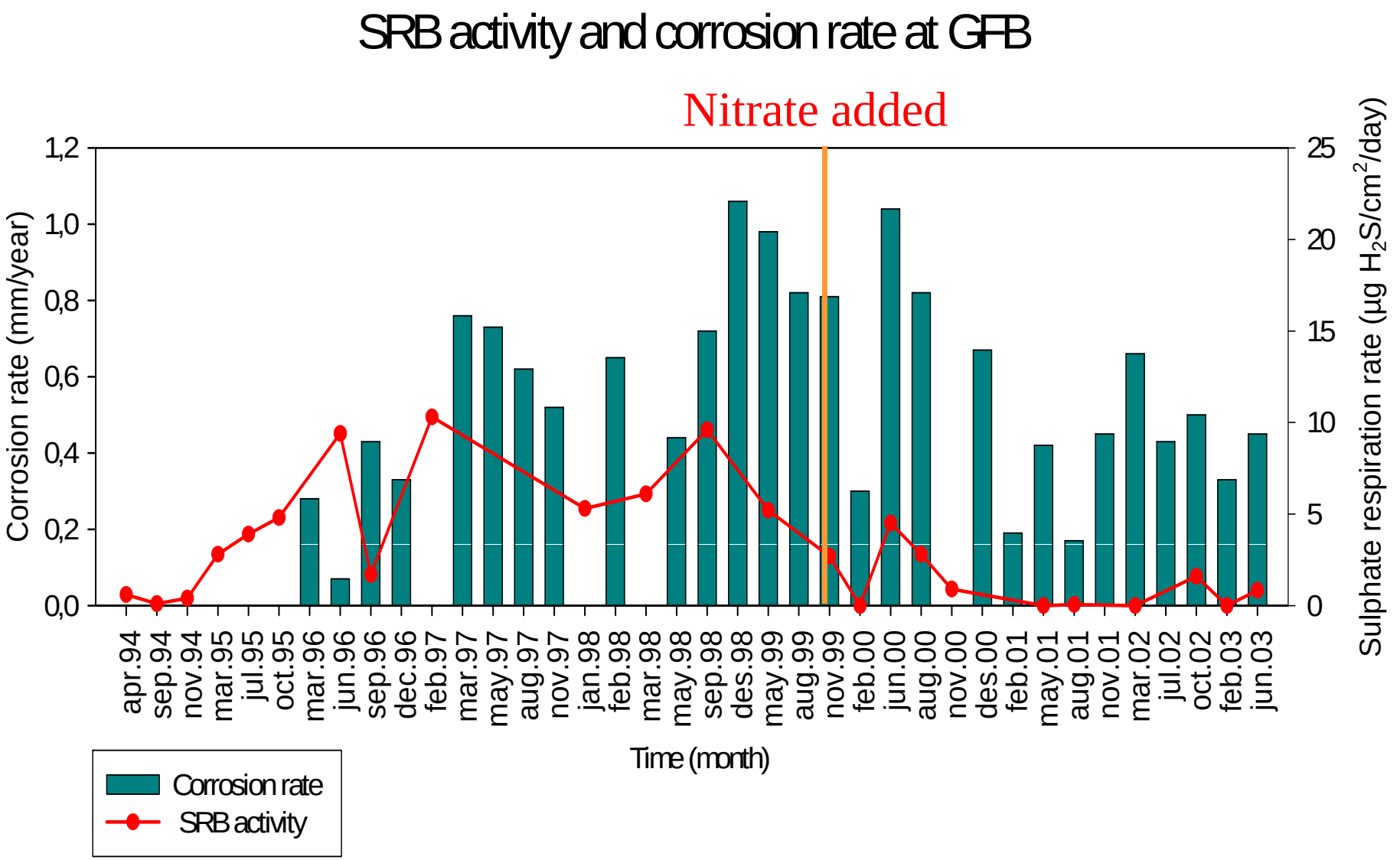
Filled up with anaerobic injection sea water

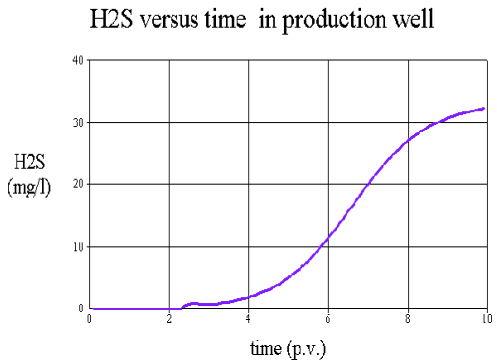
Measuring microbial activity
in the water injection system

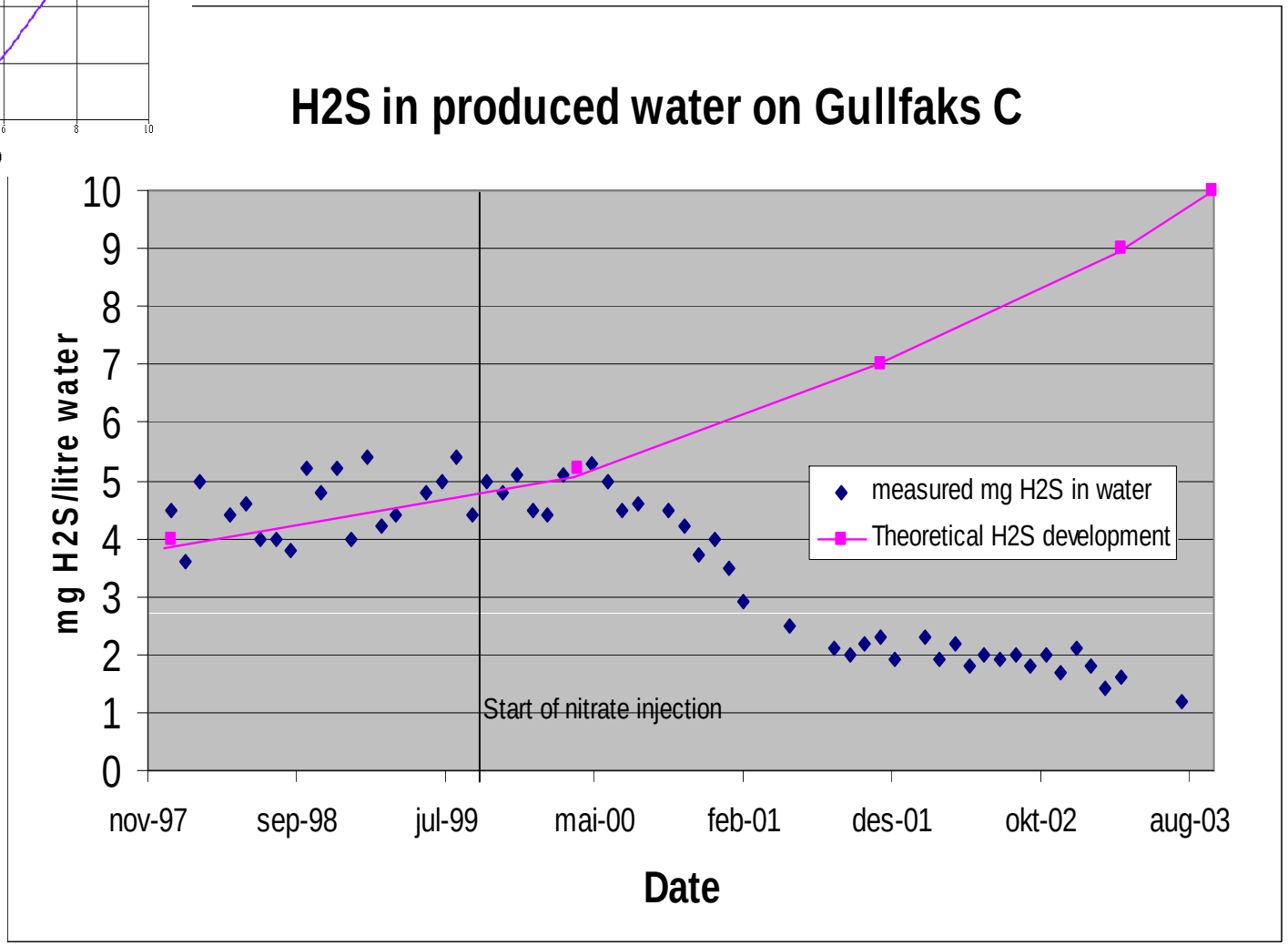


Water injection system at Gullfaks.
Bacteria in biofilm before and after nitrate treatment




SRB activity and corrosion rate at GFB
Nitrate added
Corrosion rate (mm/year)
Sulphate respiration rate (µg H2S/cm2/day)
1,2
1,0
0,8
0,6
0,4
0,2
0,0
25
20
15
10
5
0
apr.94
sep.94
nov.94
mar.95
jul.95
oct.95
mar.96
jun.96
sep.96
dec.96
feb.97
mar.97
may.97
aug.97
nov.97
jan.98
feb.98
mar.98
may.98
sep.98
des.98
may.99
aug.99
nov.99
feb.00
jun.00
aug.00
nov.00
des.00
feb.01
may.01
aug.01
nov.01
mar.02
jul.02
oct.02
feb.03
jun.03
Time (month)
Corrosion rate
SRB activity





Sunde, Egil; Lillebø, Bente-Lise Polden; Bødtker, Gunhild; Torsvik, Terje; Thorstenson, Tore. H2S inhibition by nitrate injection on the Gullfaks field. *NACE Corrosion 2004, Paper No 04760*; 2004

Produced Water Reinjection (PWRI)

Produced Water Reinjection (PWRI) has been used on platforms, mainly due to requirements from the Norwegian Pollution Agency regulating release of hydrocarbons to the sea.

In the event of permission to produce oil in the Barents Sea, there must be zero release of hydrocarbons to the environment.

Challenges:
High temperature stimulate growth of thermophilic SRB
Increased supply of VFA in the injected water stimulate reservoir souring

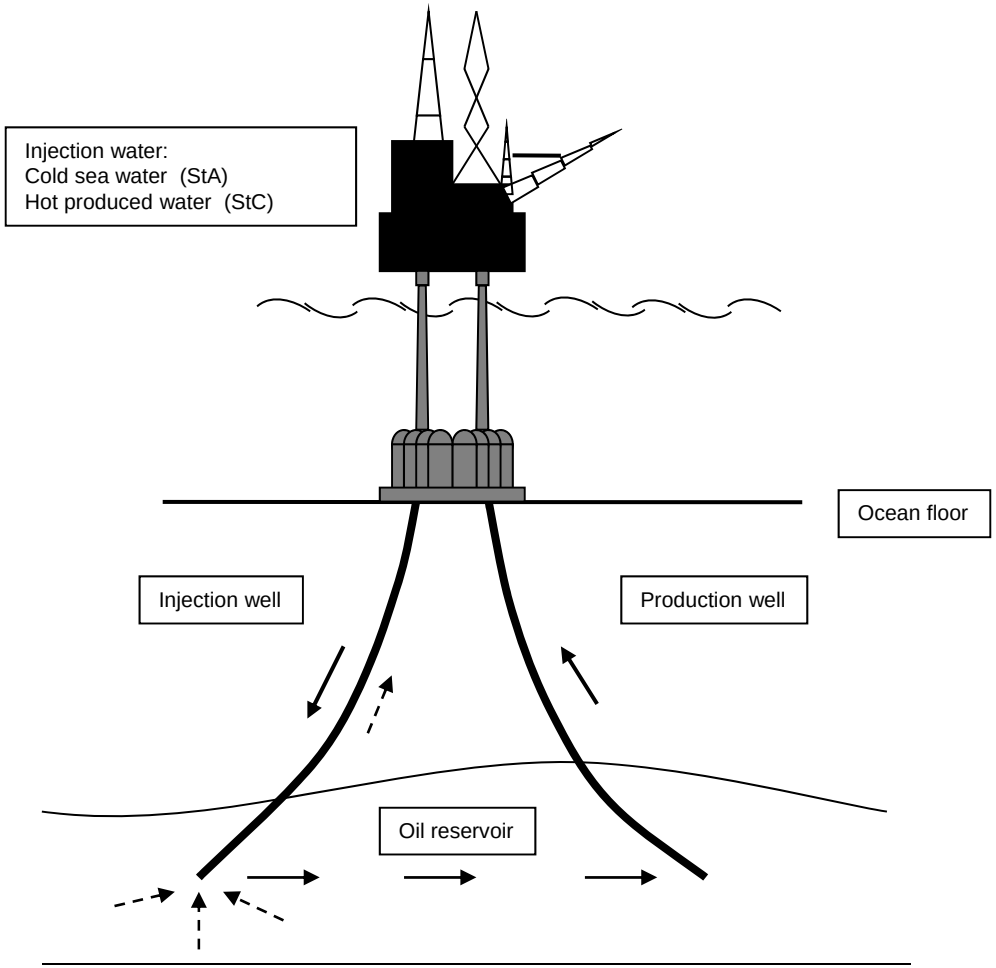
PWRI at Statfjord

Microboal analysis of back flooded injection water

Injection water

St A and B: Sea water

St C: Produced water

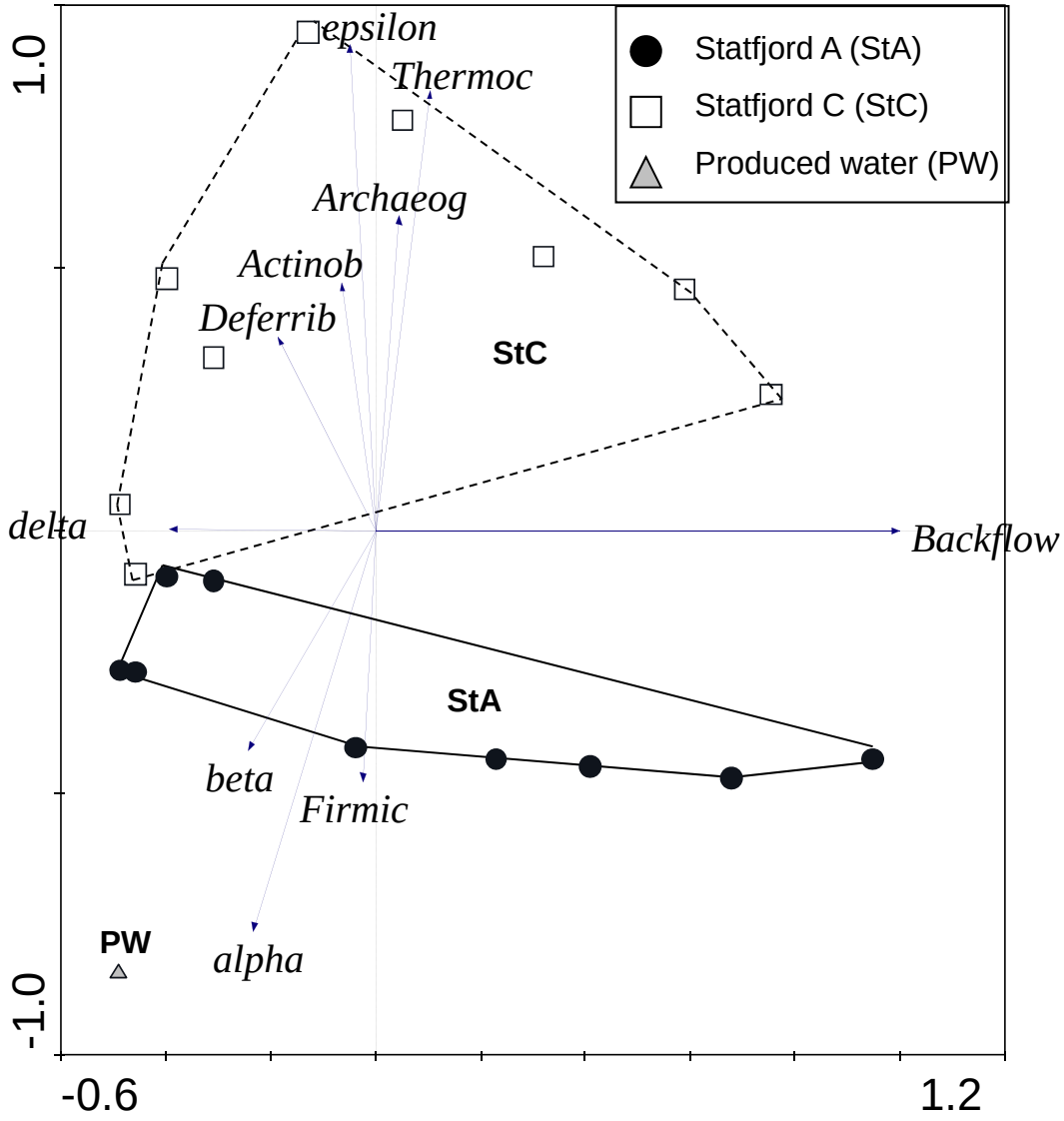


Samples

- Back-flooded injection water from wells 3000 meters below sea floor.
- From each injector: 9 samples taken at different times (0 – 96 hours) of back-flooding.

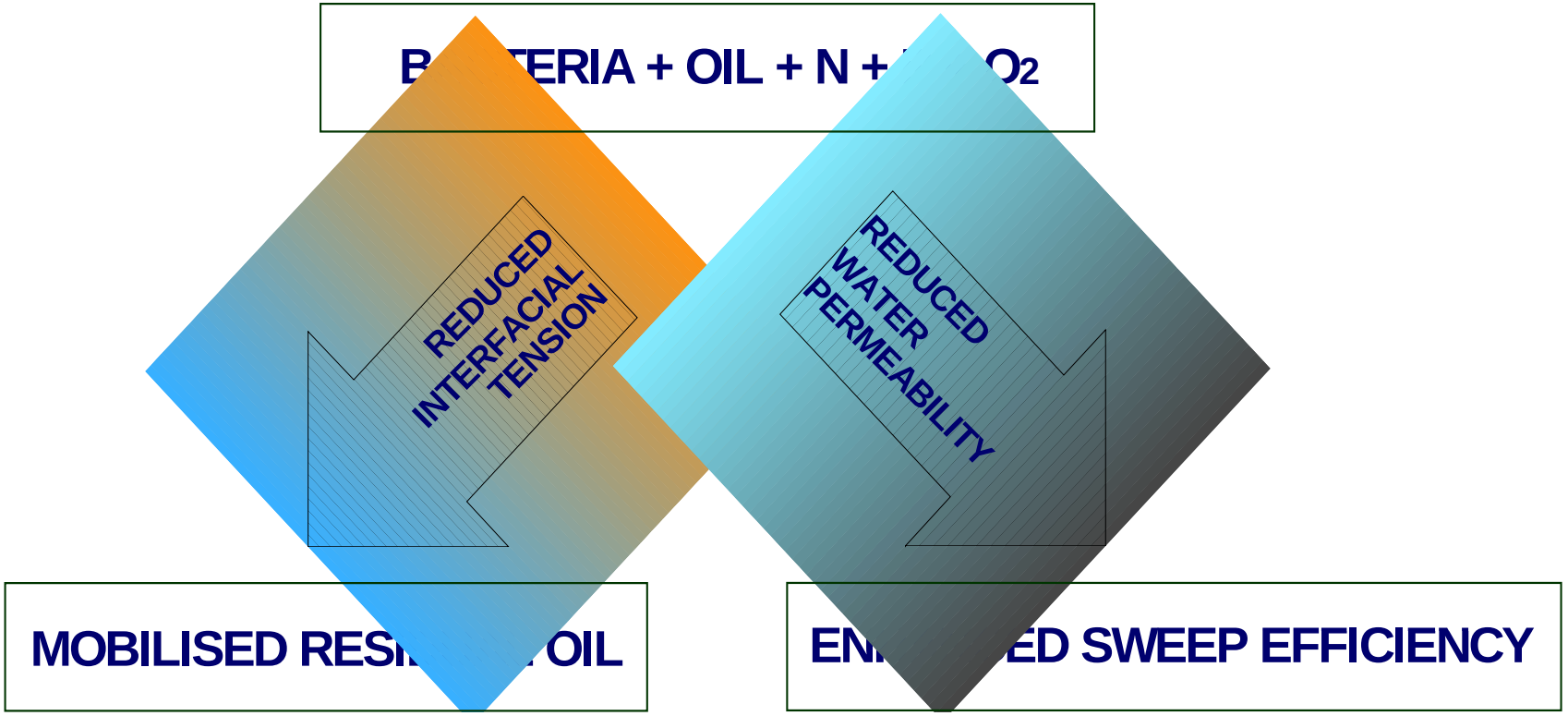
Sample	**Statfjord A**	**Statfjord B**	**Statfjord C**
Injected with	Sea water	Sea water	Produced water
Temperature	30 °C	30 °C	60 °C
Treatment	Deoxygenated, biocide treatment	Deoxygenated, nitrate treatment	Deoxygenated, 75 % produced water 25 % seawater
Souring potential H_2S mg/liter (calculated by Statoil)	30	<1	200-400

Principal component analysis of native populations at St A and C



K. Lysnes, G. Bødtker, T. Torsvik, E. Ø. Bjørnestad & Egil Sunde: Appl Microbiol Biotechnol (2009) 83:1143–1157

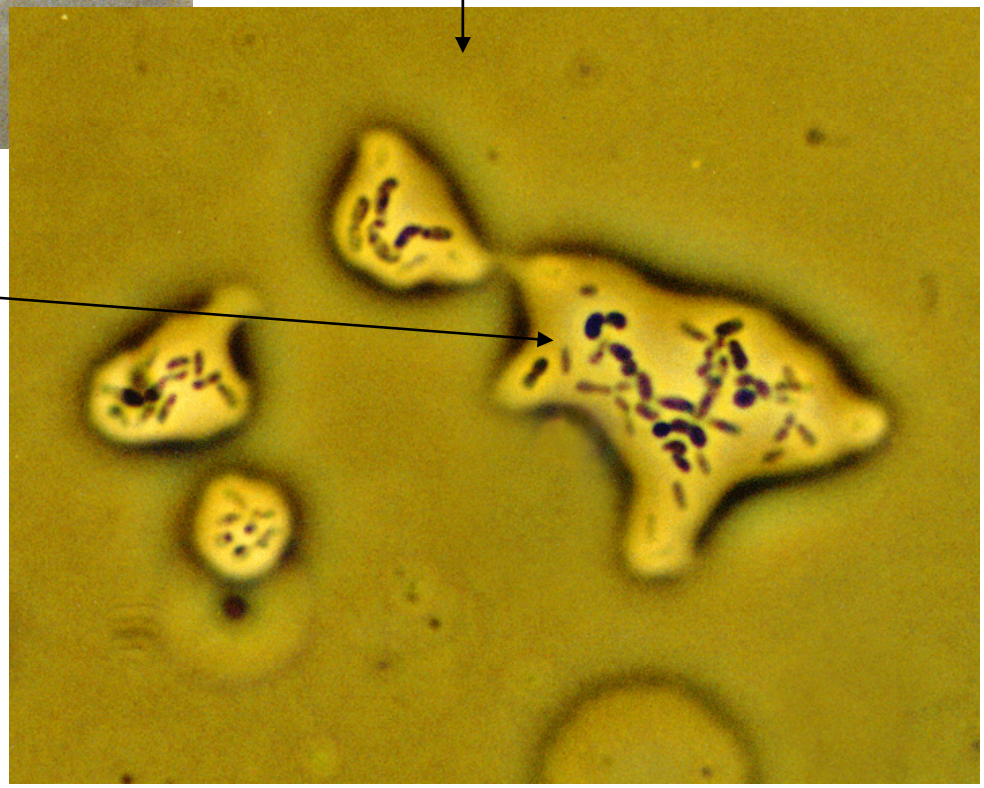
MEOR
Principles – reservoir effects



Microbial biofilm on oil

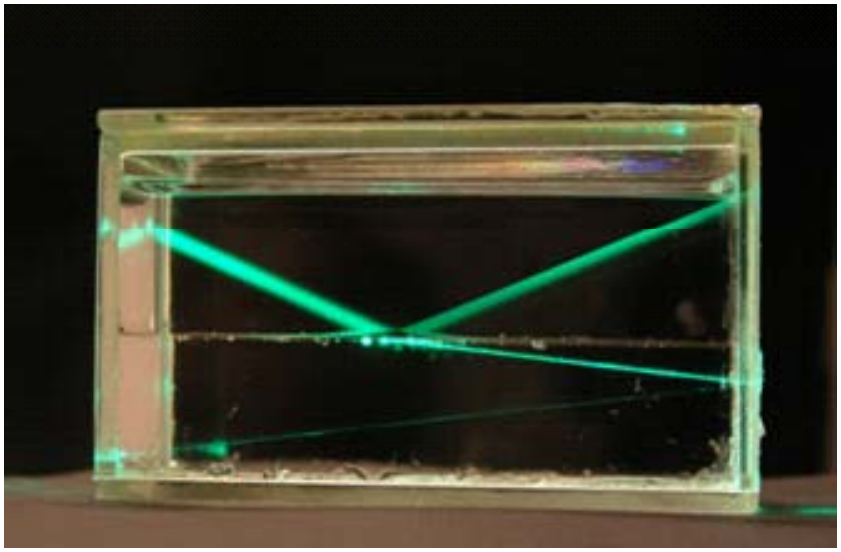
crude oil

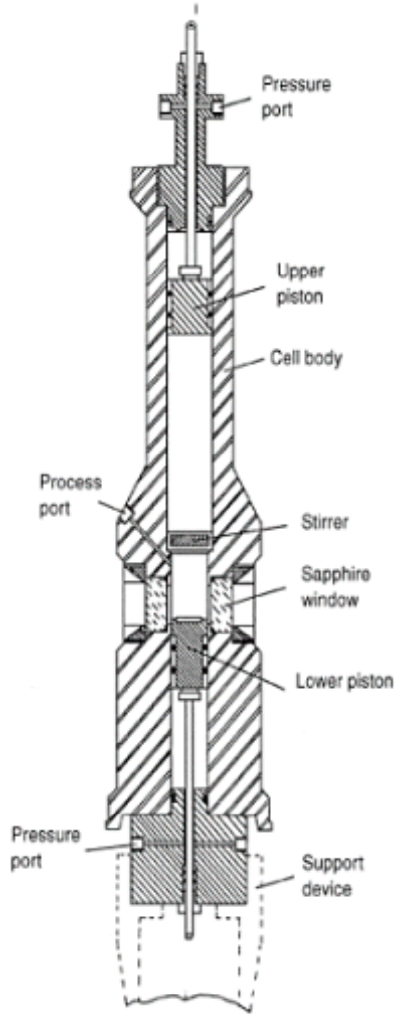
Bacterial colony
surrounded by water



IFT laser-light scattering

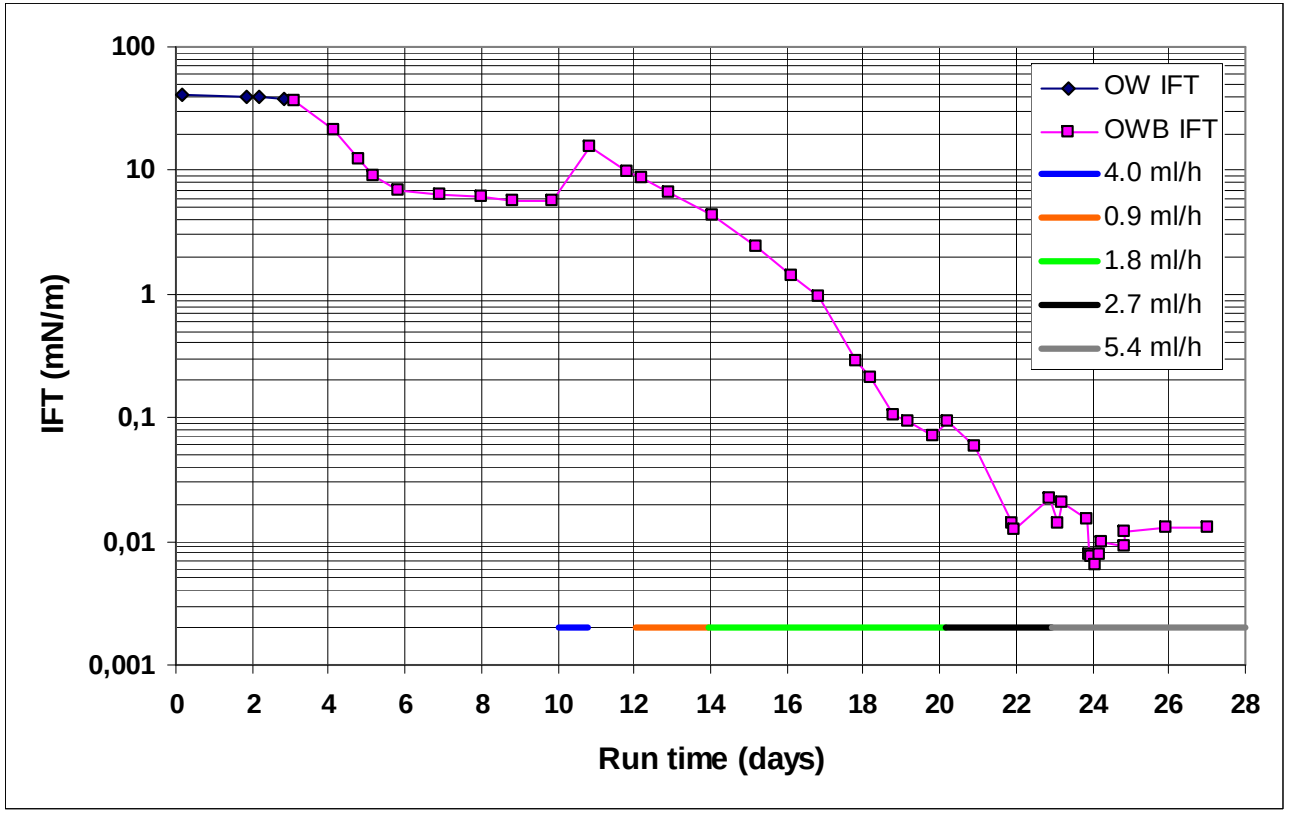
- Best suited for low values (< 30 mN/m)
- Measurement range is 10^{2} – 10^{-5} mN/m
- Method has been successfully applied down to 10^{-4} mN





Bacterum: *Dietsia maris*

Dodekan, aerobic synthetic sea water



Kowalewski, E., Rueslåtten, I., Gilje, E., Sunde, E., Bødtker, G., Lillebø, B.L.P., Torsvik, T., Stensen, J.Å., Bjørkvik, B. and Strand, K.A., 2005, "Interpretation of Microbial Oil Recovery from Laboratory Experiments", Paper presented at the 13th European Symposium on Improved Oil Recovery, Budapest, Hungary, Apr 25-27

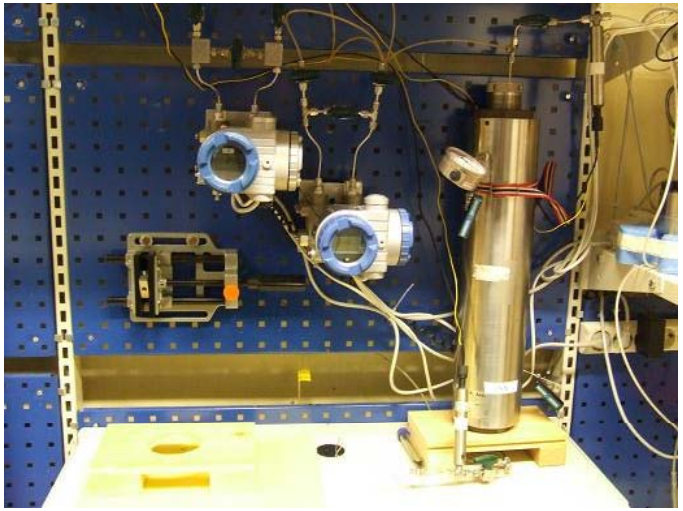
Laboratory experiments

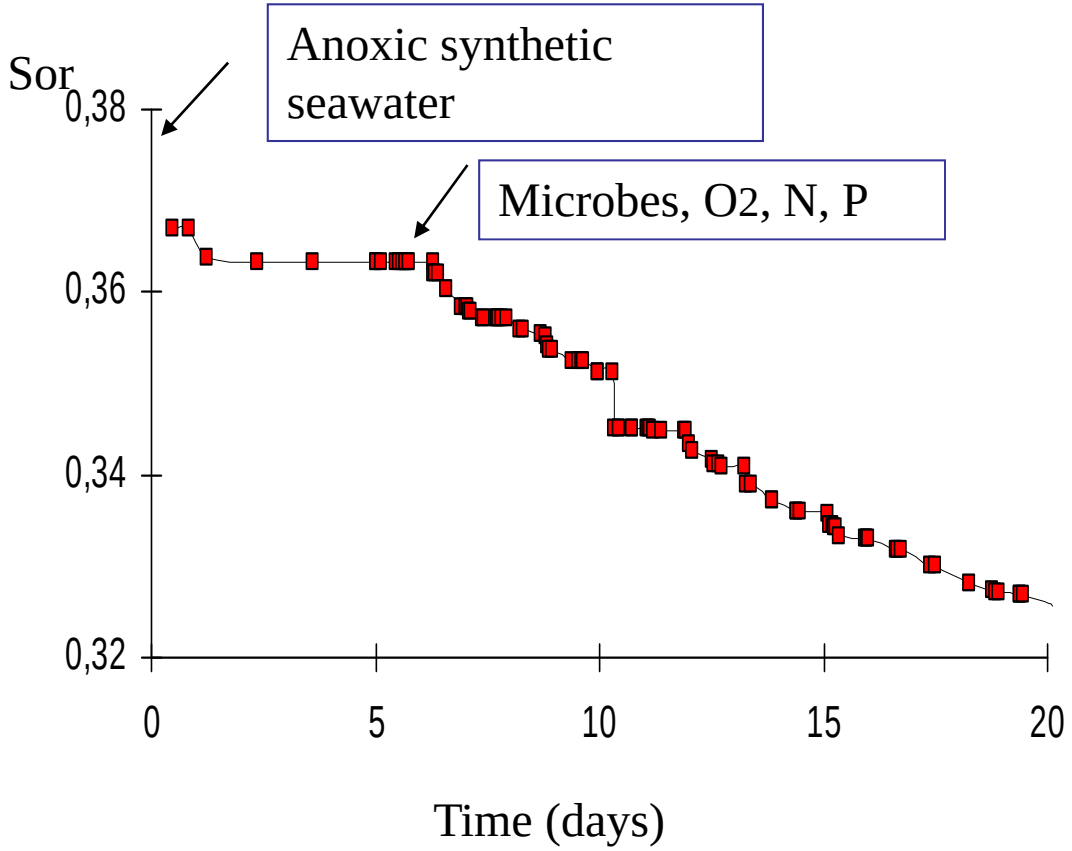
Hopeman sandstone core

45 cm long, 5 cm diameter

Statfjord model oil

Flow rate: 0,1 ml/min = 1 PV/d



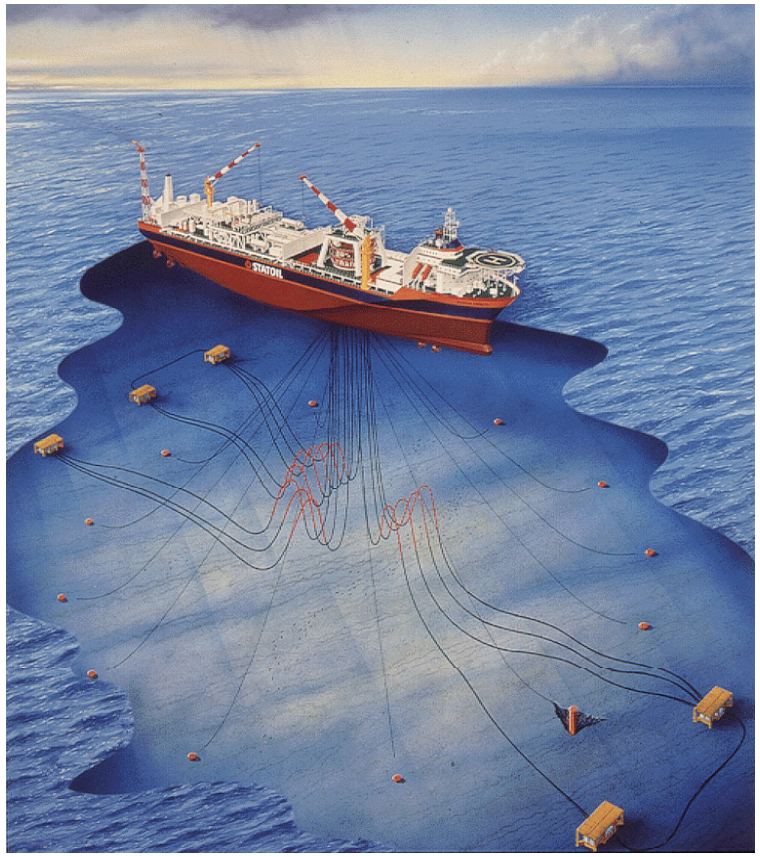


MEOR at Norne

Injection of aerobic seawater from start in 1997

MEOR implemented in January 2001 by adding N and P to the injection water to stimulate bacterial growth in the reservoir

Nitrate is also added in order to inhibit reservoir souring



MEOR at Norne

2002: Increased oil production from MEOR at Norne

- **900 000 m^3**
- **1 % of producible oil**
- **At an oil price 20 $ per barrel and 1$= 5 NOK this amounts to approximately 750 000 000 NOK.**

(Reported from Norne to OD in 2002)