

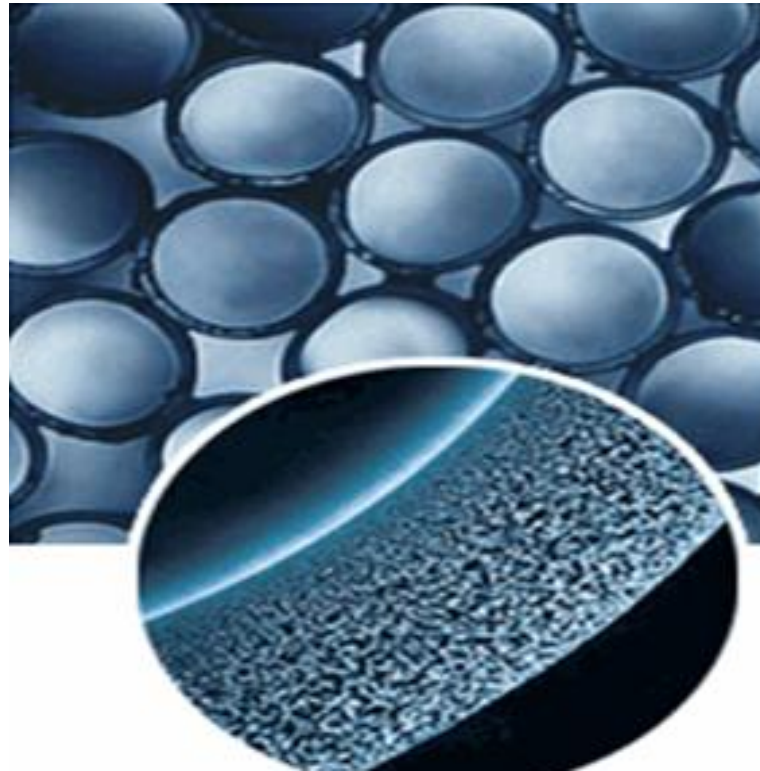
DESIGNER WATER

Dr. Torleiv Bilstad

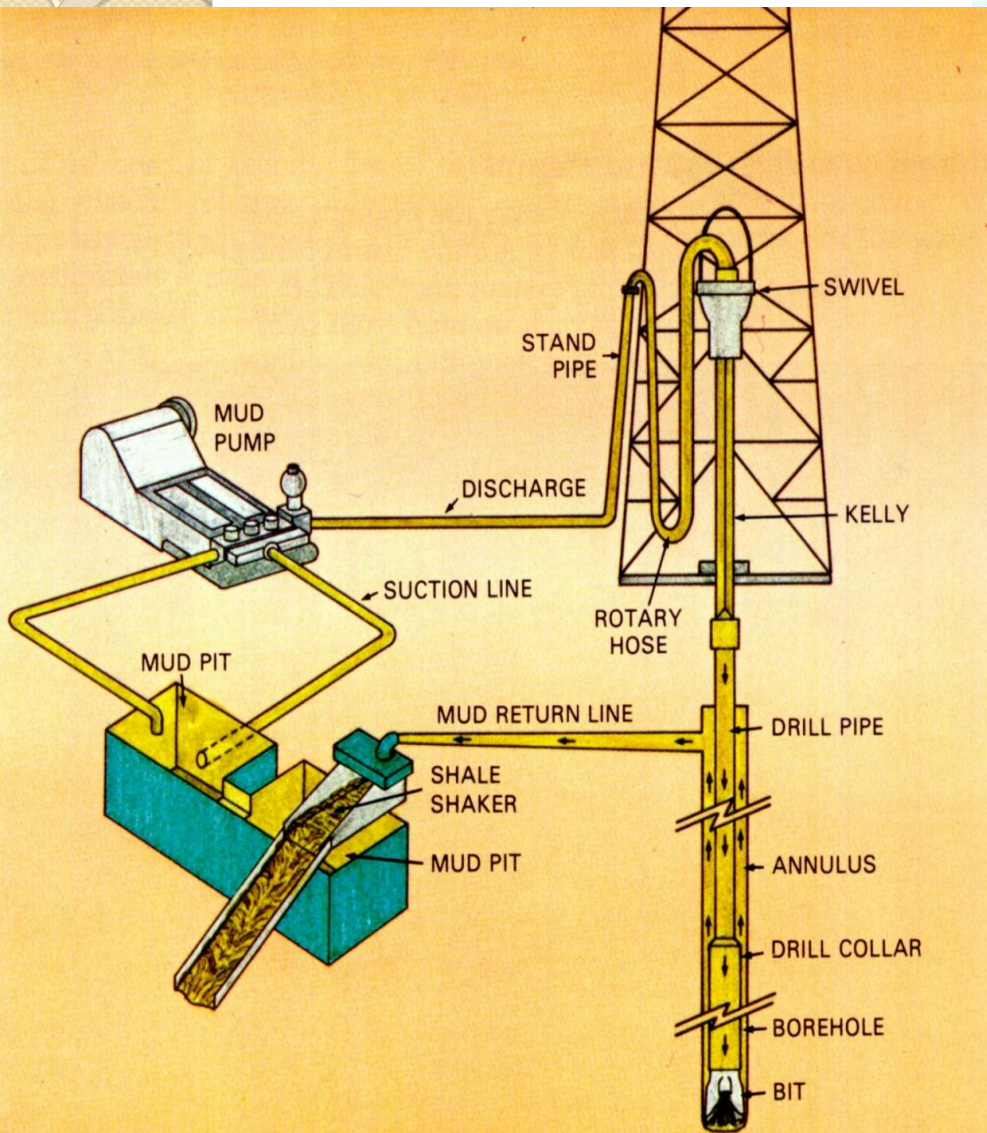
*Professor of Environmental Engineering,
University of Stavanger, Norway*



University of
Stavanger



Drilling ≠ Production of oil and gas

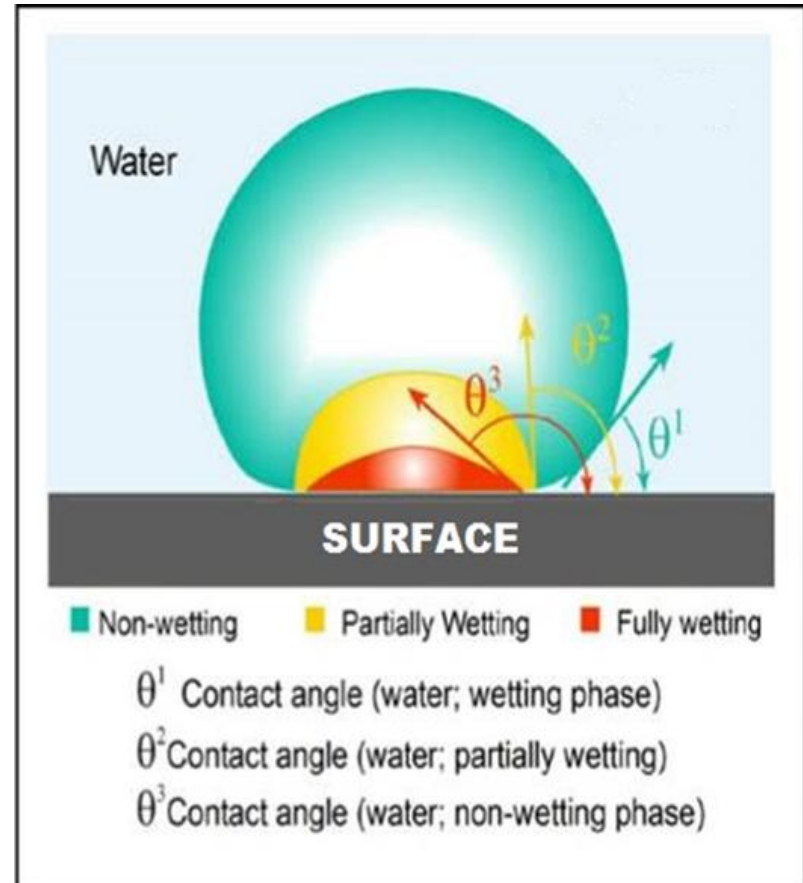
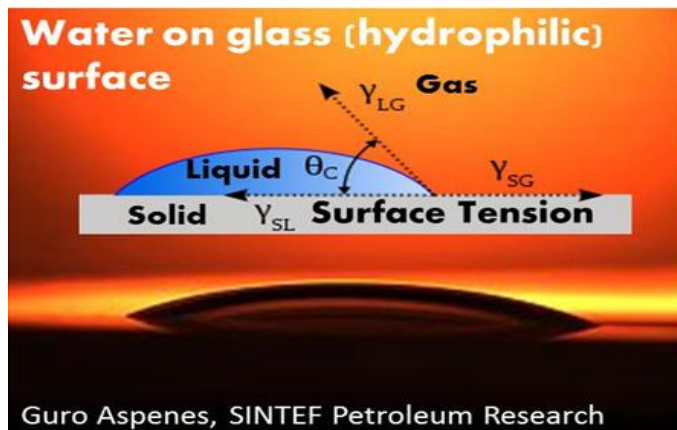


Flow of crude oil from well



WETTABILITY

- Tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids
- Reservoir wettability determines the flow of oil and water in the reservoir



DESIGNER WATER

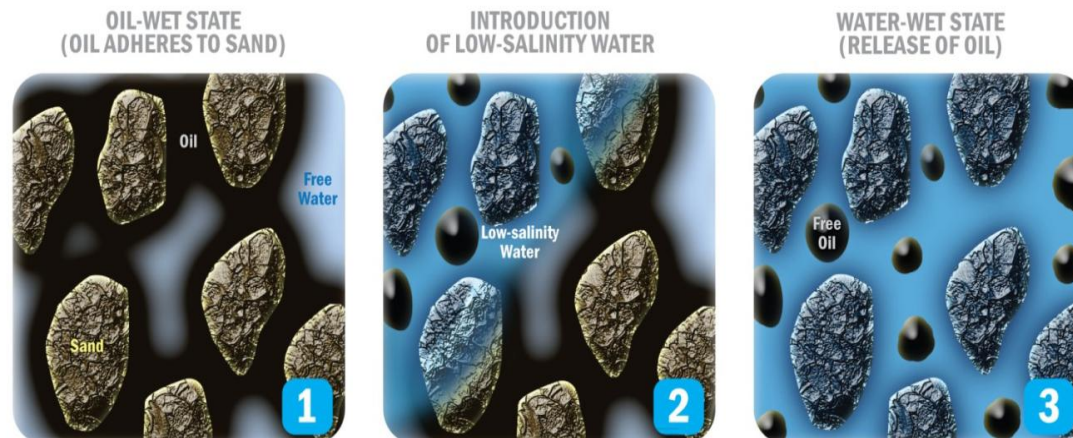
Designer water - Produced by adjusting the ionic composition of the injected seawater thereby modifying the initial wetting conditions of the reservoir.

Desirable characteristics

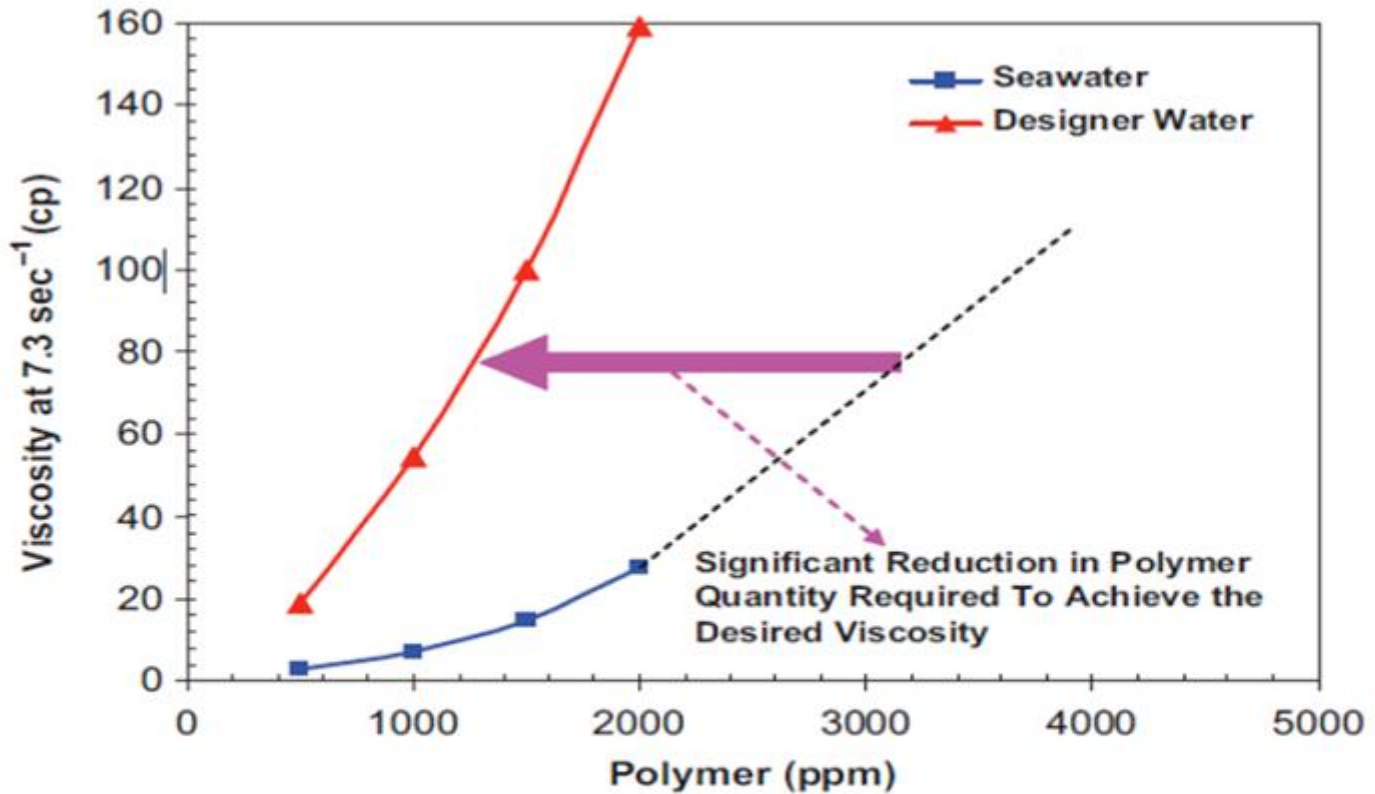
- Divalent ions (SO_4^{2-} , Mg^{2+} and Ca^{2+})
- Low salinity or low NaCl concentrations

Advantages of Designer water

- Higher ultimate oil recovery with minimal investment in current operations
- Cheap, environmentally friendly and no expensive chemicals are used compared to many other EOR methods



DESIGNER WATER



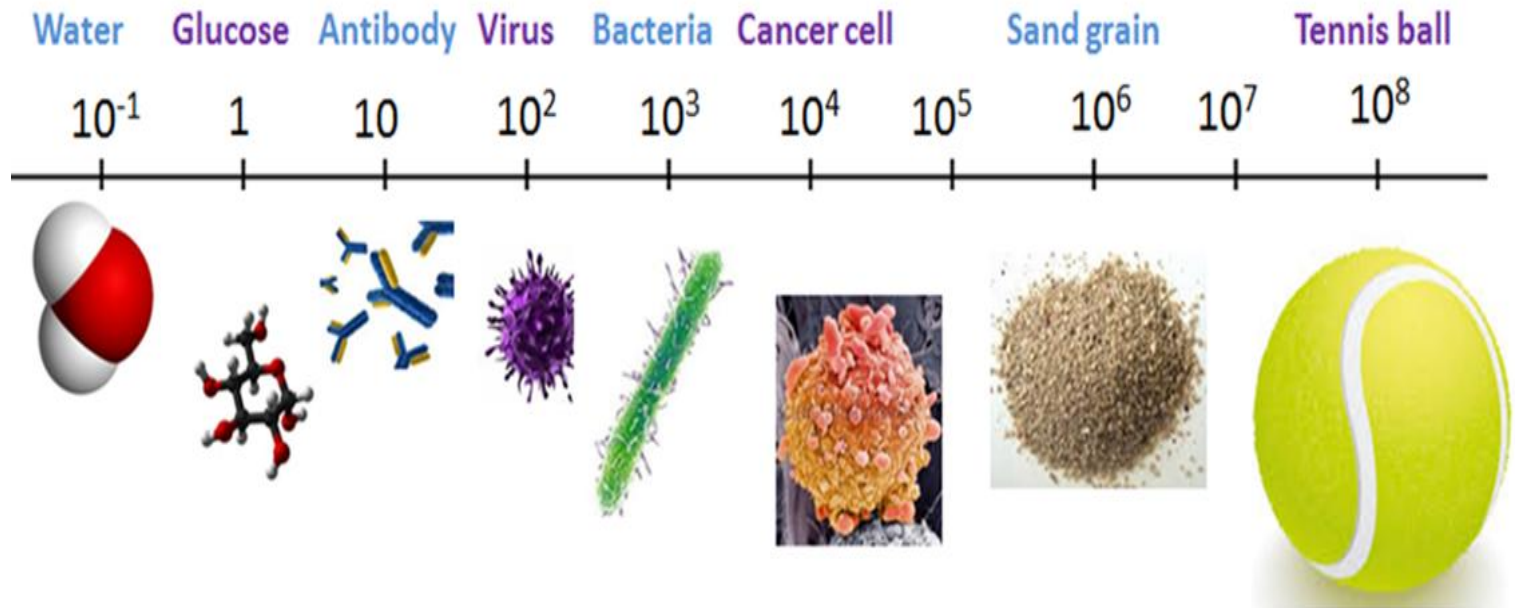
Polymer Requirements for Seawater versus Low Salinity SmartWater⁴⁸

(Figure Source: Ayirala et al., 2008; SPE; Ref. 48)

Nanofiltration membranes

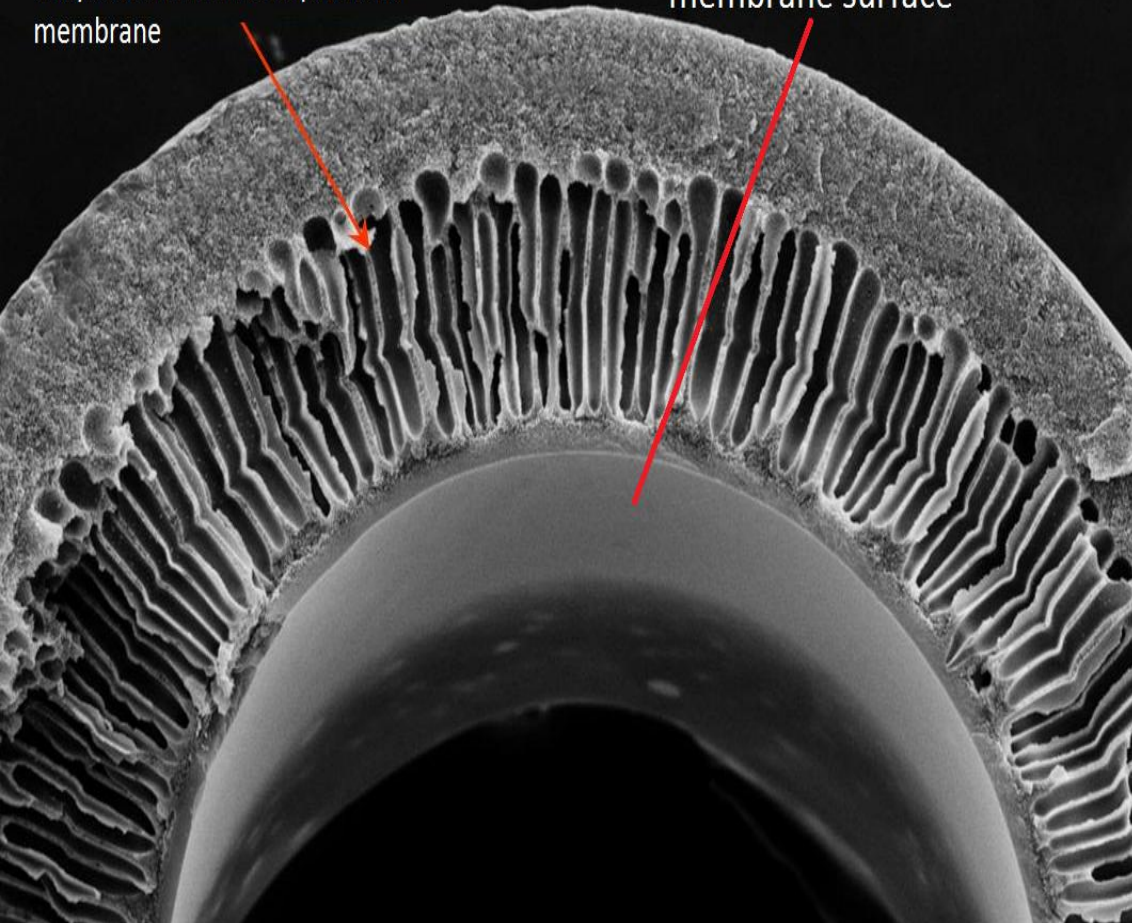
Objective : **Designer water by membrane process**

Method : **Nanofiltration membrane- Negatively charged (pore size from 10 - 1 nm)**

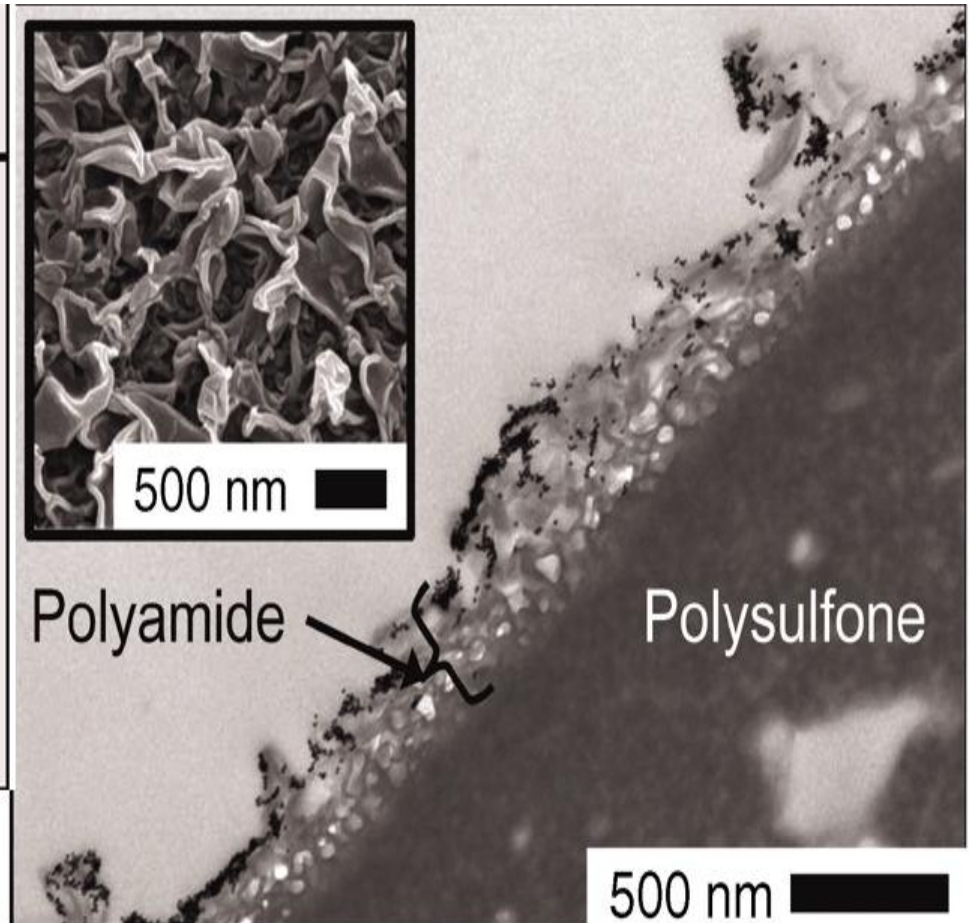


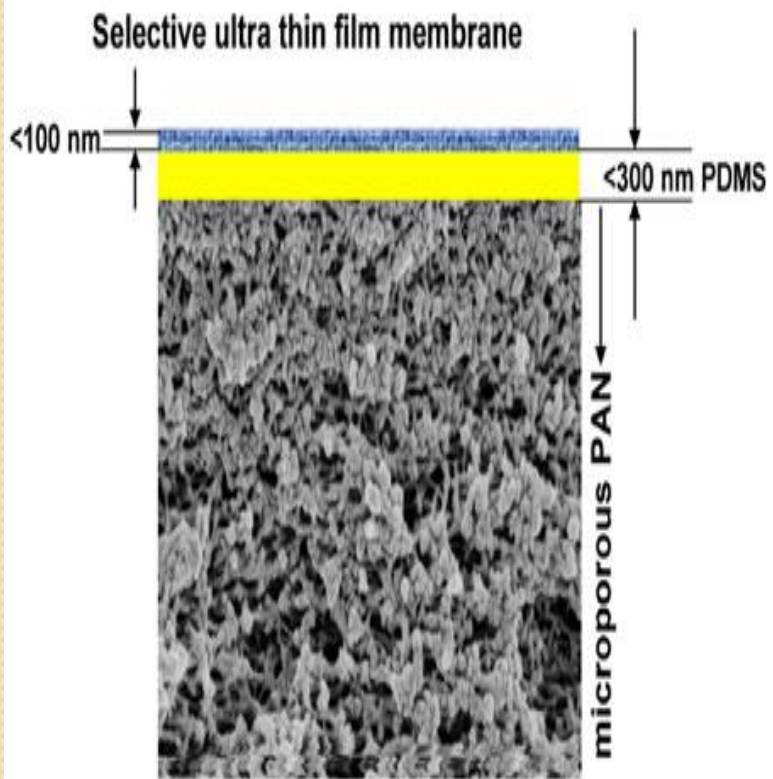
3 layered thin film composite NF membrane

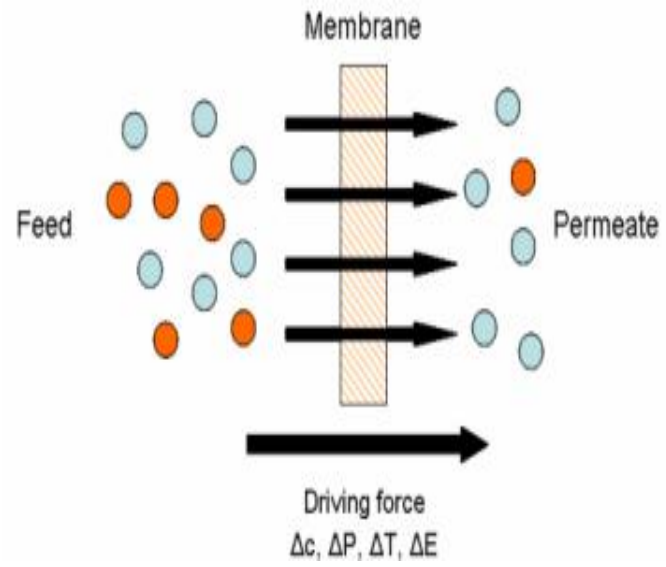
Negatively charged membrane surface



Surface property	TFC membrane
Contact angle	50 – 60°
Surface charge	Negative
-COO ⁻ /nm ²	20 – 30
RMS roughness	100 – 200 nm







SEPARATION OF IONS

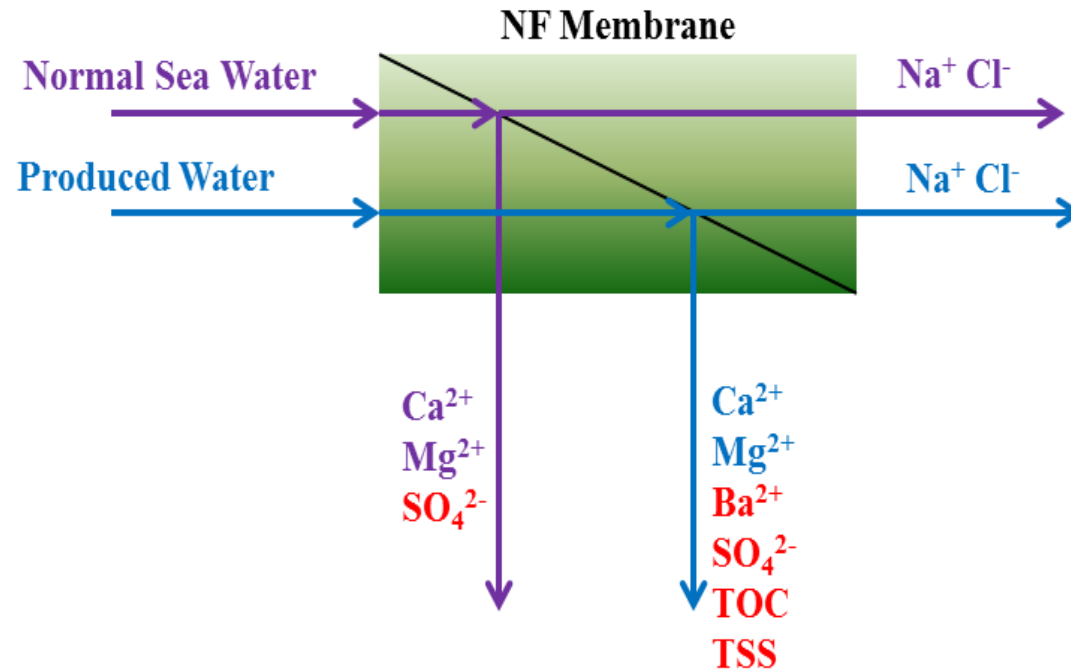
Feed

F1. Filtered normal sea water with TDS = 34500 ppm

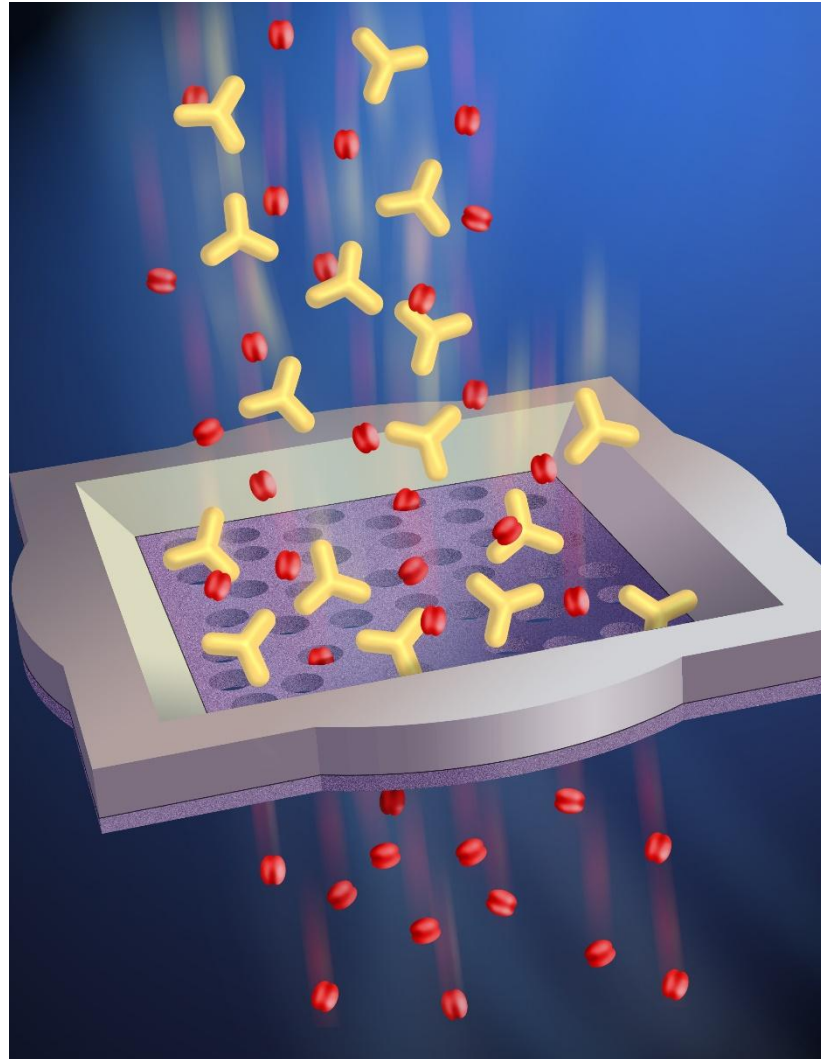
F2. Produced Water with very high TDS as feed

Type

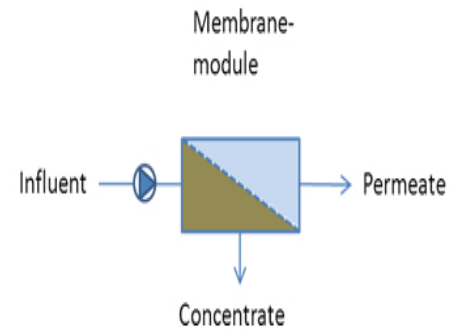
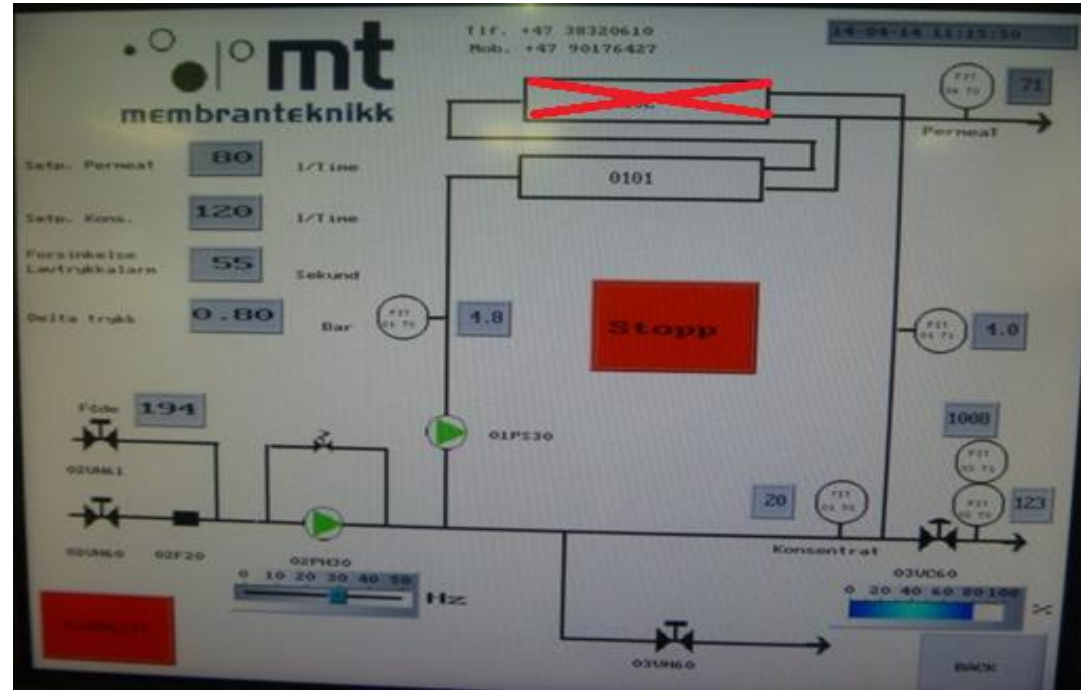
NF membrane – NANO - BW 4040



Pictures

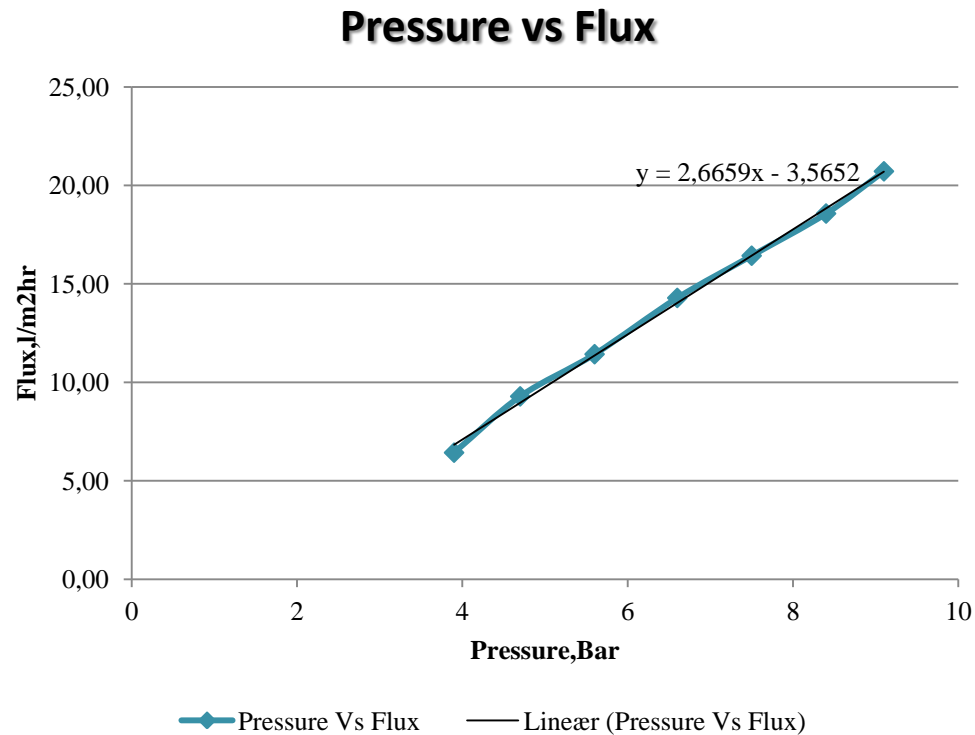


Experiments



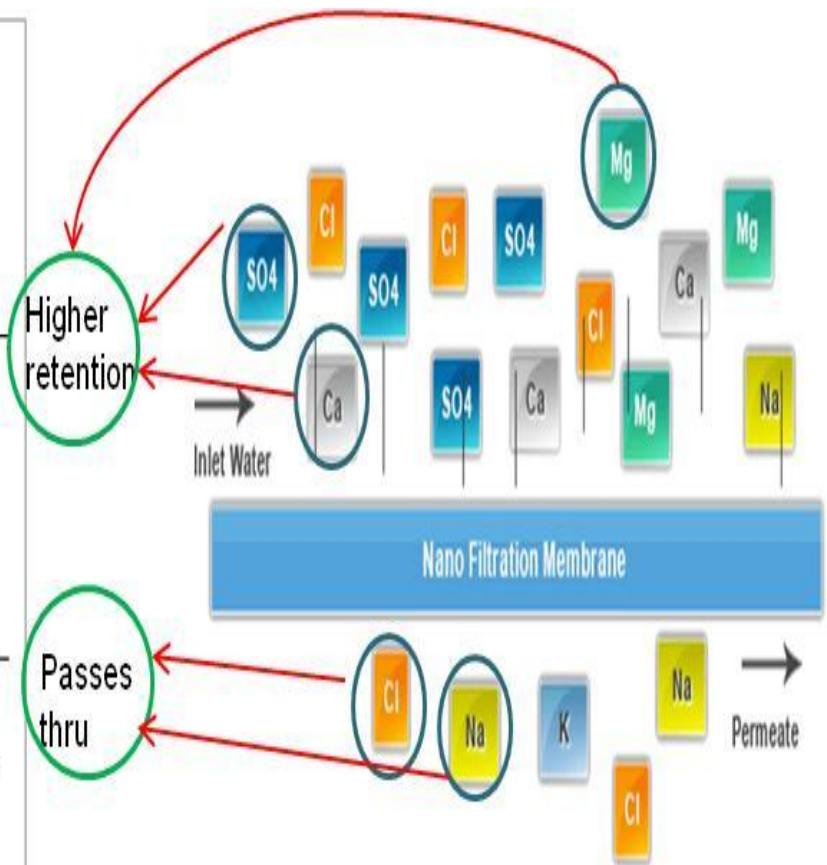
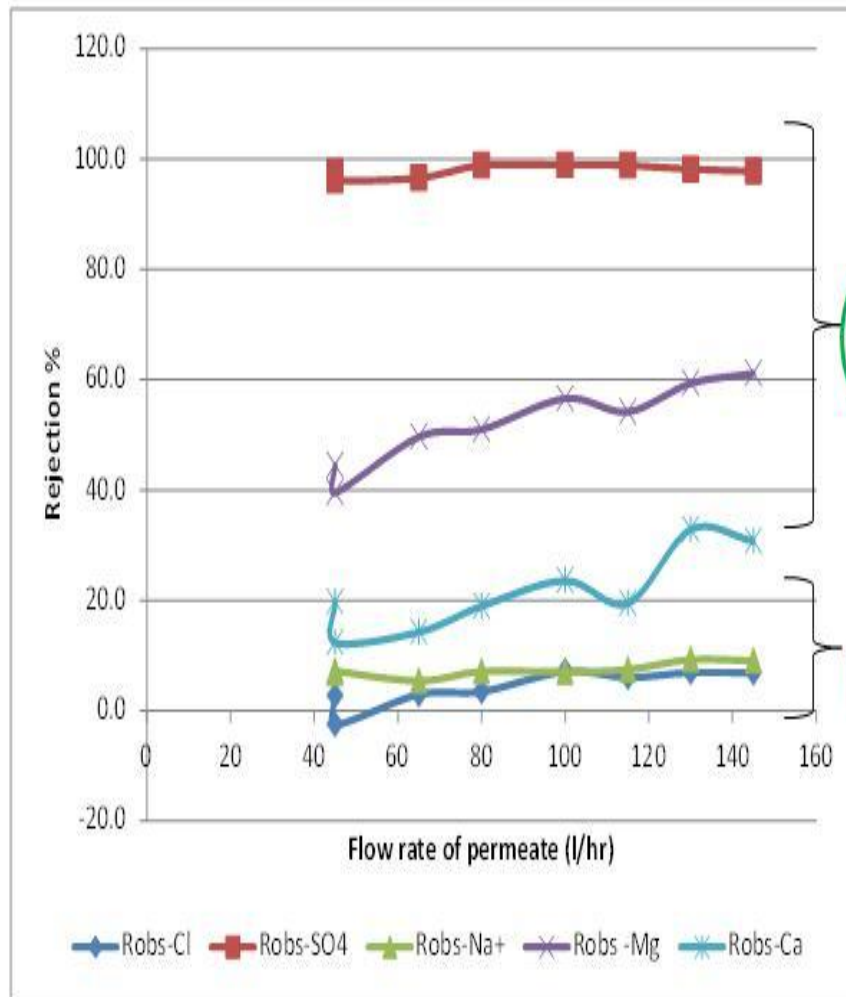
Results of Nano Filtration Experiments

Flow rate is varied: Flux increases linearly with flow rate and pressure. Retentate flow is almost constant.



NF -Results

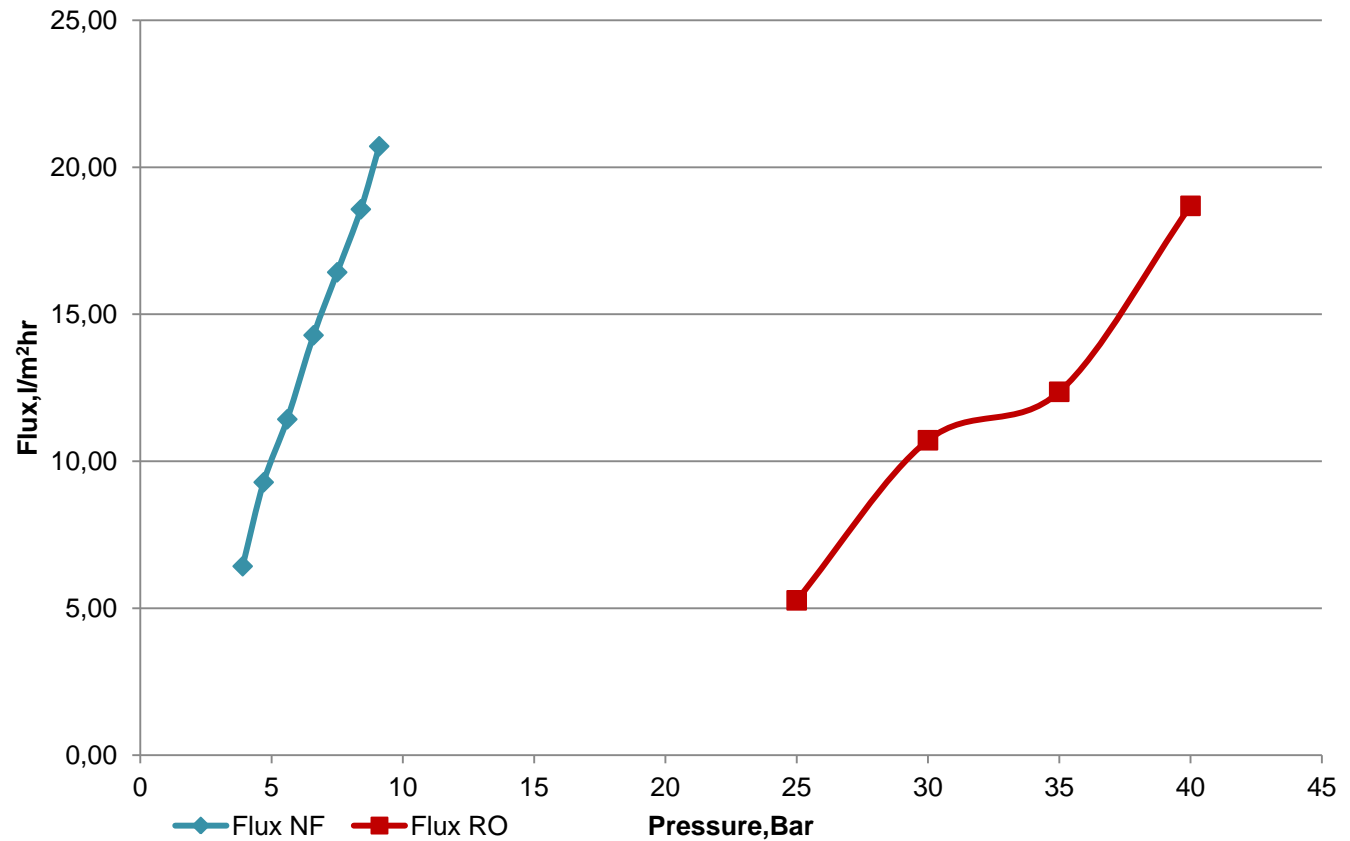
- ❖ The retentate is dominated by divalent ions SO_4^{2-} , Mg^{2+} and Ca^{2+}
- ❖ Higher size of SO_4^{2-} and the repulsive force from the negatively charged NF membrane helps the higher retention of sulphate.
- ❖ Small sized chloride passes through the membrane pores and it maintains the charge balance.



Comparison between NF and RO

Effect on Flux- Recovery from the RO membrane is very low (i.e. from 6-19 %) and needs higher pressure ,making the process less economical.

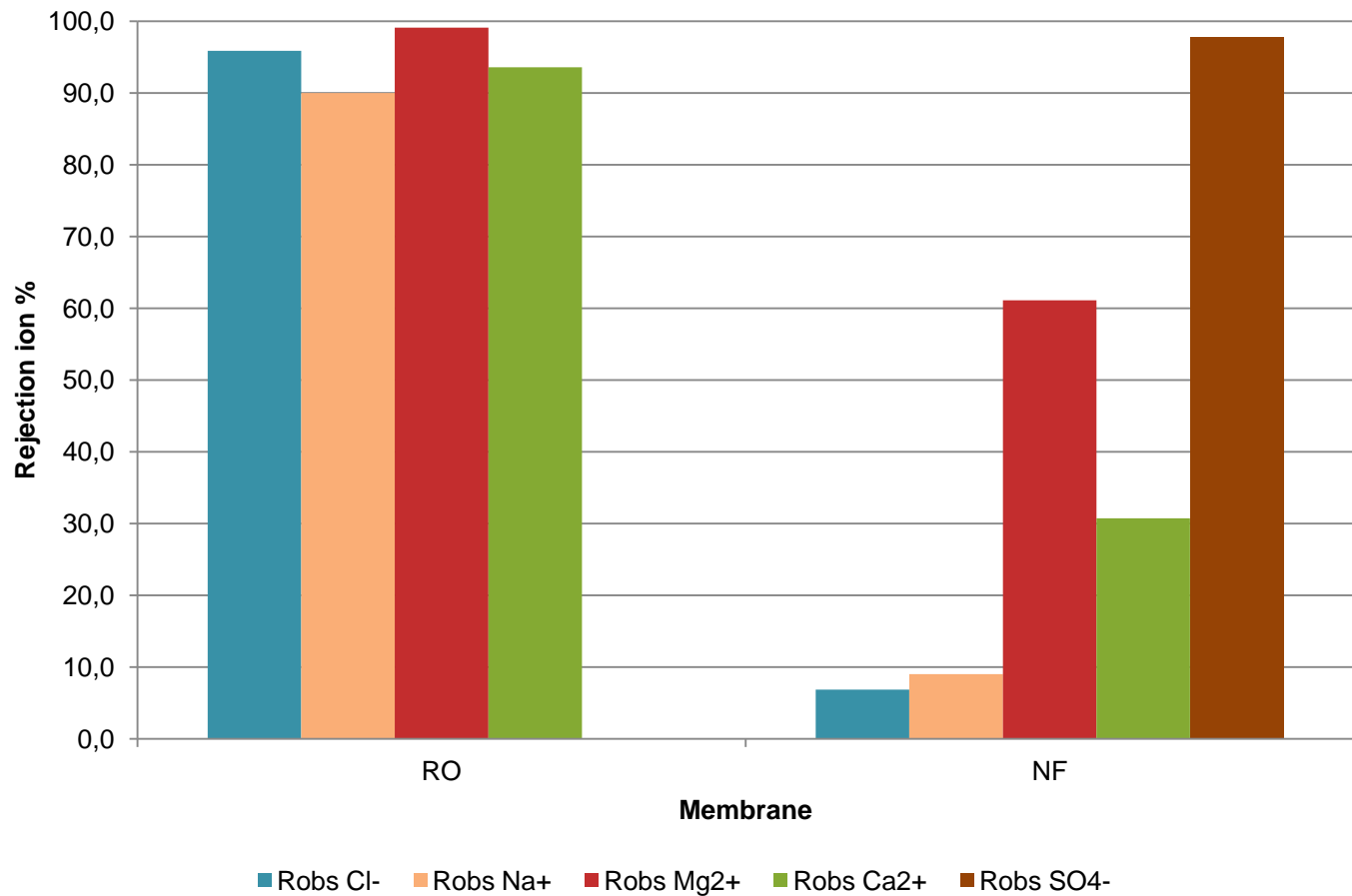
Flux vs Pressure for NF and RO



Comparison between NF and RO

-Selectivity of NF

- **NF rejects ions based on the size and charge**
- **The predominant retention of divalent ions in NF retentate makes it a desirable constituent for designer water.**

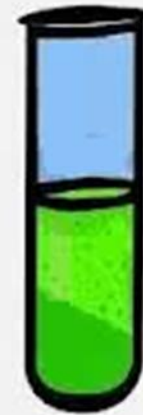


Produced Water as Feed

- High level of TDS (Few thousands to 460,000 ppm)

Challenges:

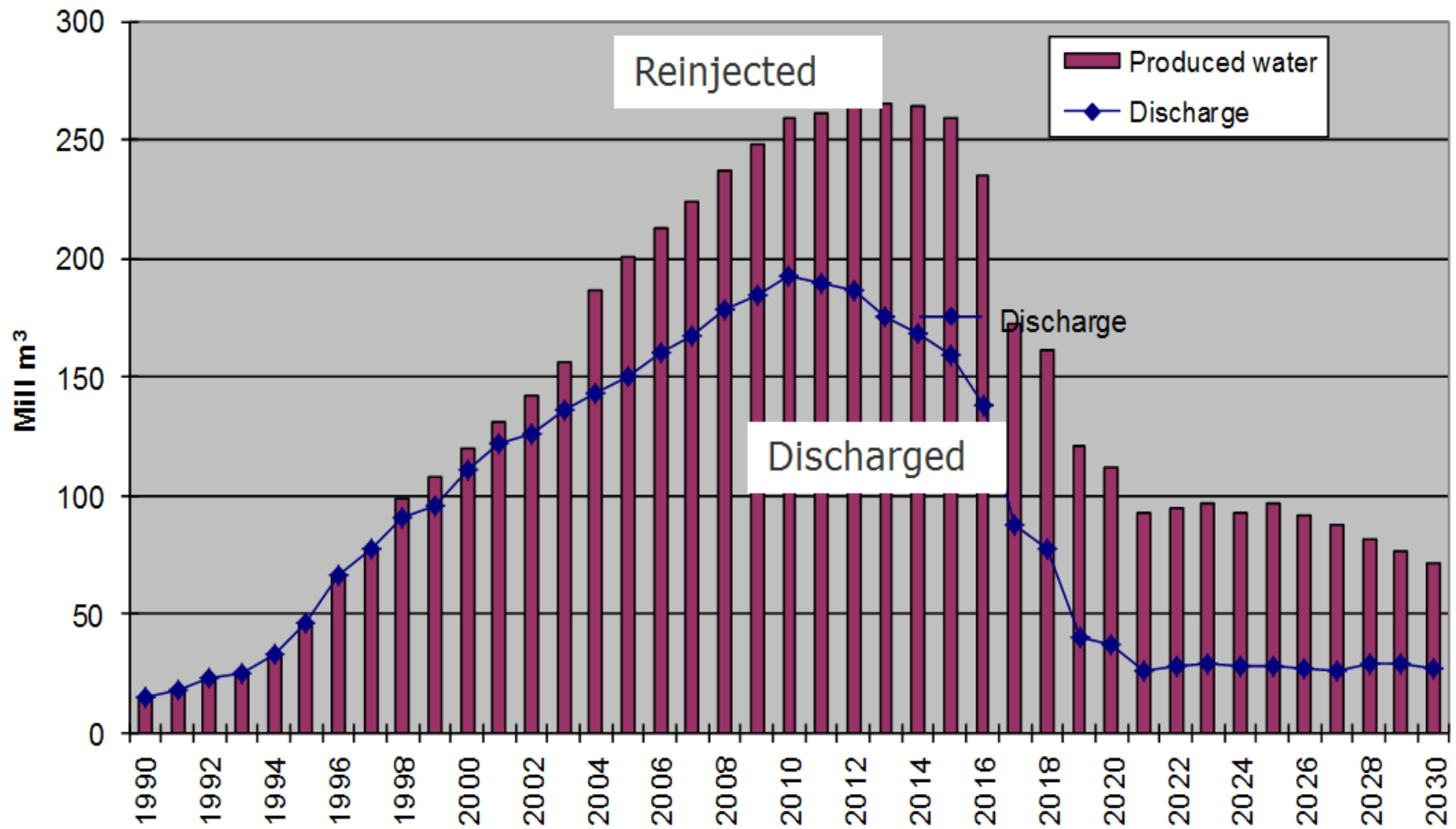
- *Dispersed Oil*
- *High TDS*
- *High TOC*
- *Chemical additives*
- *TSS*
- *Heavy metals*
- *NORM and microbes*



If you're not
part of the
SOLUTION,

You're part of
PRECIPITATE

Water Production and Discharge from Norwegian Continental Shelf



Produced Water Injection in the USA

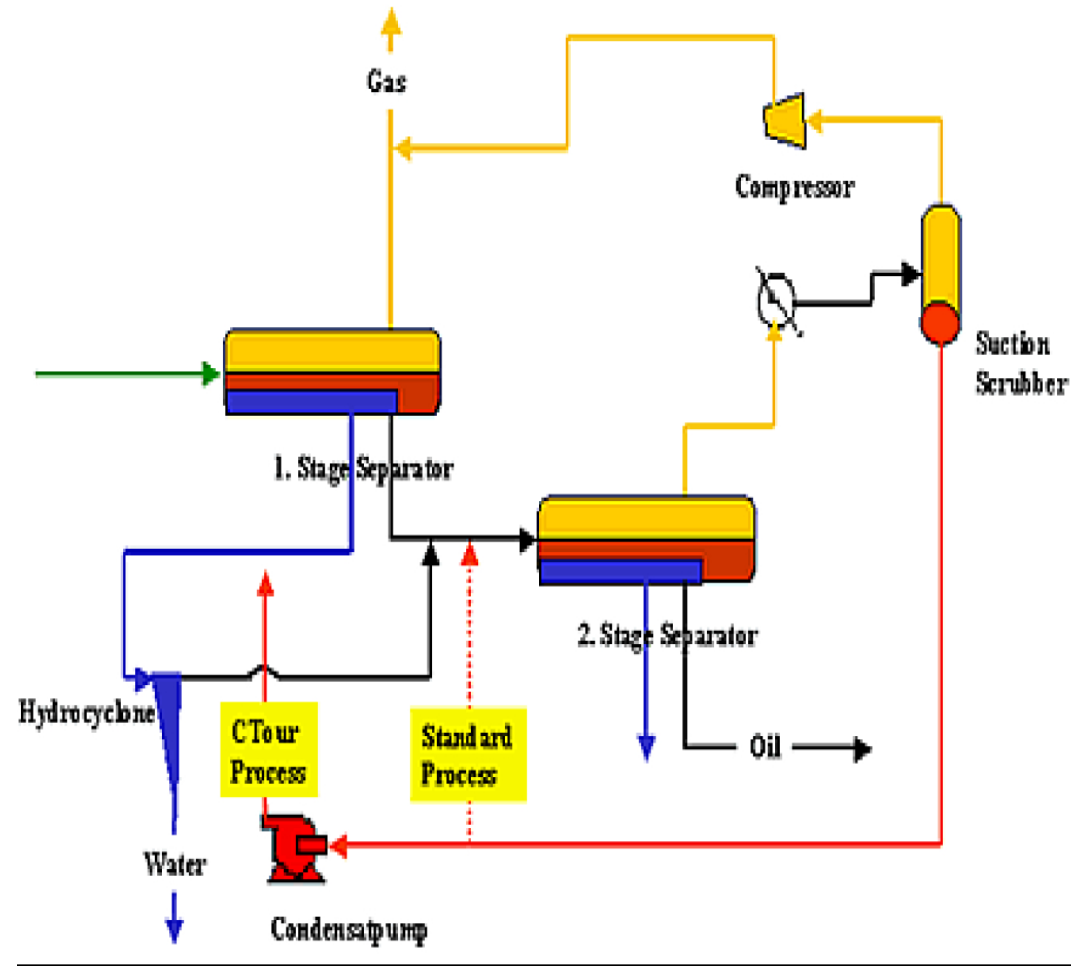
Place	Injection for EOR	Injection for Disposal	Total injected volume
California	232.12 million m ³ /year	54.05 million m ³ /year	286.17 million m ³ /year
In 2013, over \$11 billion was spent on trucking produced water across the major shale plays in the US			
New Mexico	55.65 million m ³ /year	30.21 million m ³ /year	85.86 million m ³ /year
Texas	842.63 million m ³ /year	190.78 million m ³ /year	1033.41 million m ³ /year
Total	1130.4 million m ³ /year	275.04 million m ³ /year	44. million m ³ /year

Separation Technology Produced Water Treatment



Produced Water: Separation and polishing

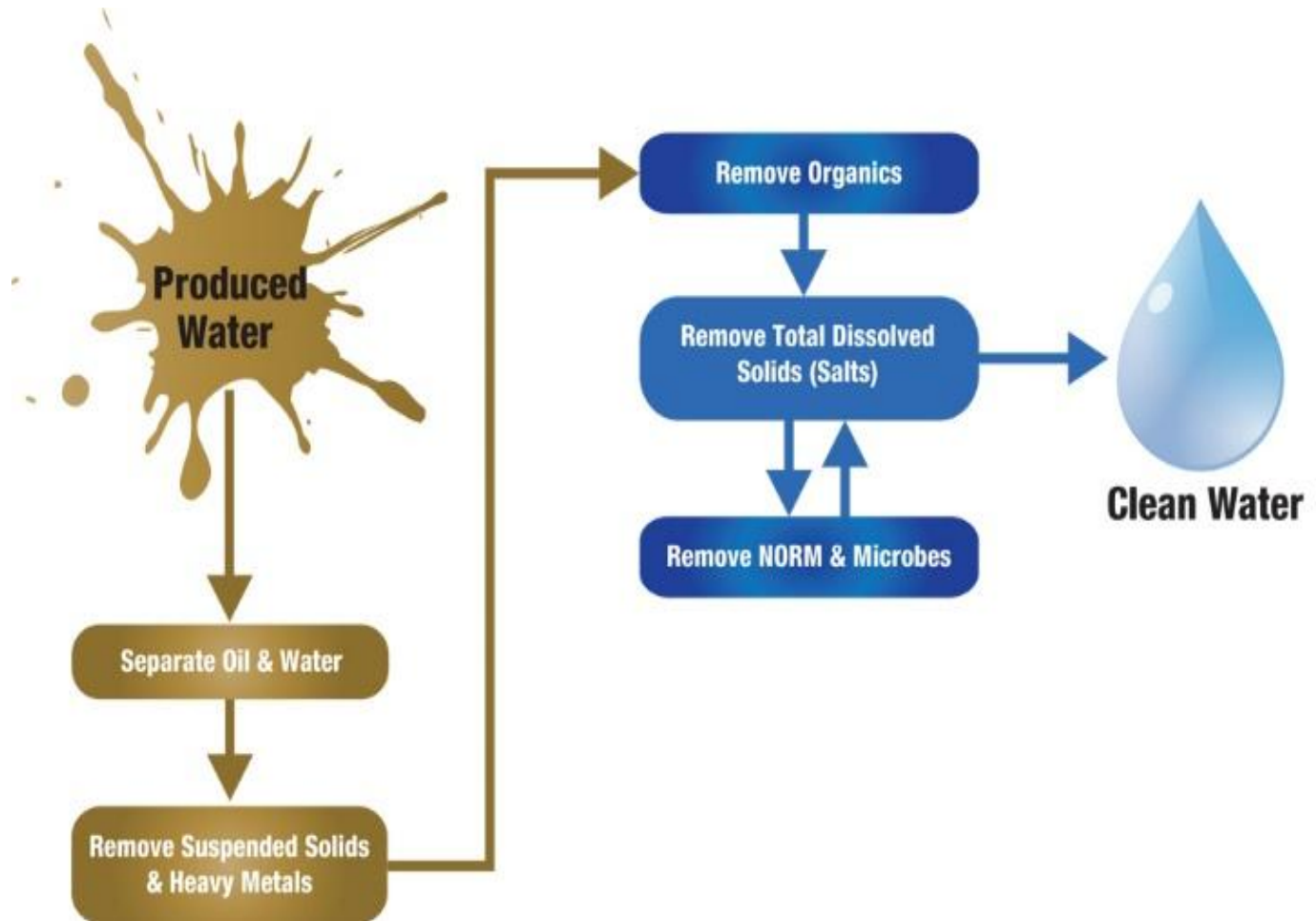
- Choke technology
- Separator technology
- Oil Droplet separation
- Chemical Injection Points
- Sand/Particle Handling
- OnLine OiW monitoring



Ceramic membranes



Pictures





OIL – GAS - WATER - SOLIDS MANAGEMENT

All produced water discharge problems solved...?



**Job
done**