Impact of well intake systems on bacterial, algae and organic carbon reduction in SWRO desalination systems, SAWACO, Jeddah, Saudi Arabia

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Seawater Intake Issues

Significance of intake systems:

- **Control feed water quality**
- **Controls the design, operation and performance of downstream process components**
- **Influences the use of chemicals in the treatment processes**
- **Influences the environmental impacts (impingement and entrainment)**
- **Influences the energy consumption of the pretreatment processes**
- **Influences overall cost of desalination**

Seawater Intake Types

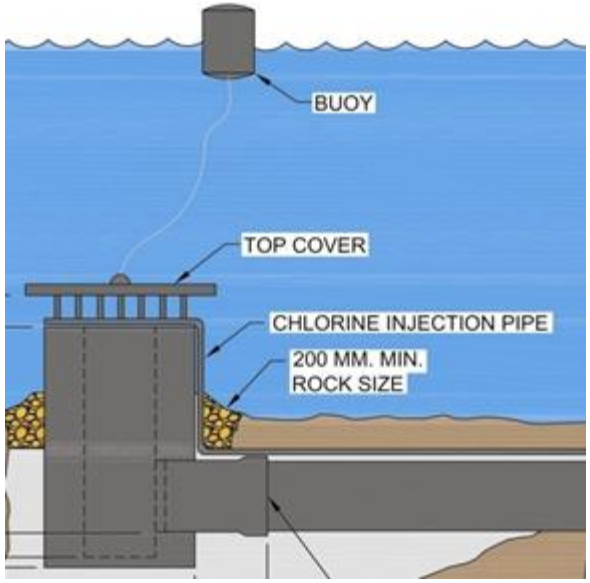
- **Open-ocean intake**

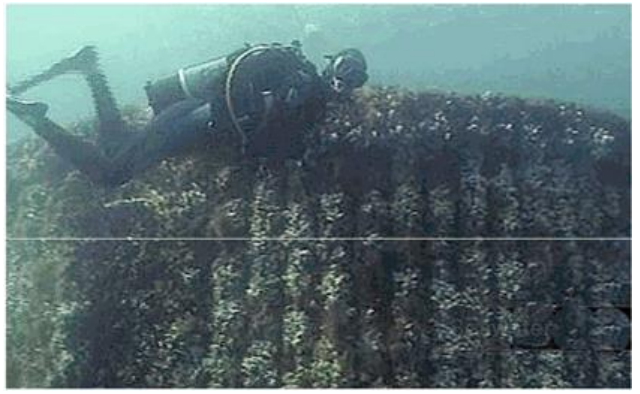
Positives:

- **Supplies unlimited quantities of raw seawater**
- **Well-known design and construction methods**
- **Independent of coastal and ocean floor geology**

Negatives:

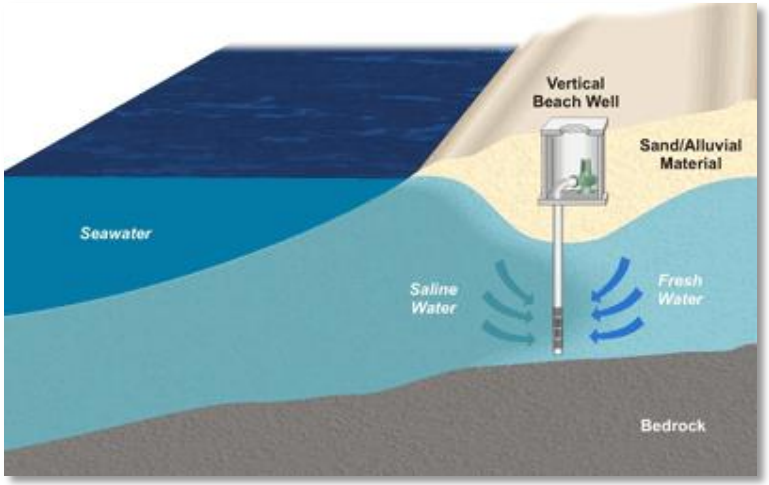
- **Environmental impacts associated with the intake operations (e.g. entrainment and impingement)**
- **Use of chemicals**
- **Fluctuation in the raw water quality based on the seasonal changes, special events (algal blooms)**
- **Extensive pretreatment processes required**

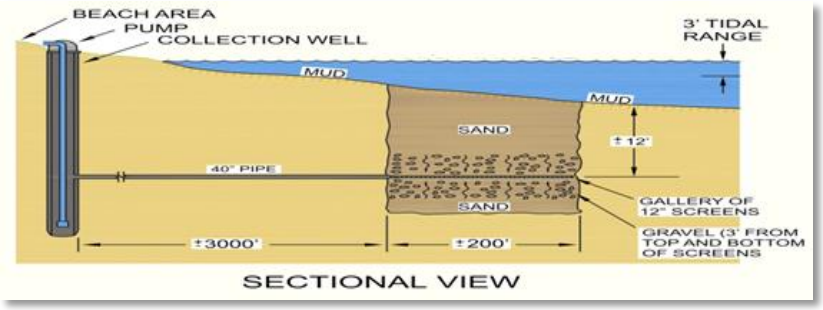




Subsurface Intakes

- **Positives:**
  - Acts as part of the pretreatment system
  - Provides better quality feed water for desalination
  - Reduces environmental impacts
  - Reduces the need for chemicals
  - Reduces the facility footprint
  - Operates during algal blooms (red tide) or oil spill events
- **Negatives:**
  - Dependent on the local geological conditions (Limited capacity)
  - Not enough documentation available about the operation of these type of intakes

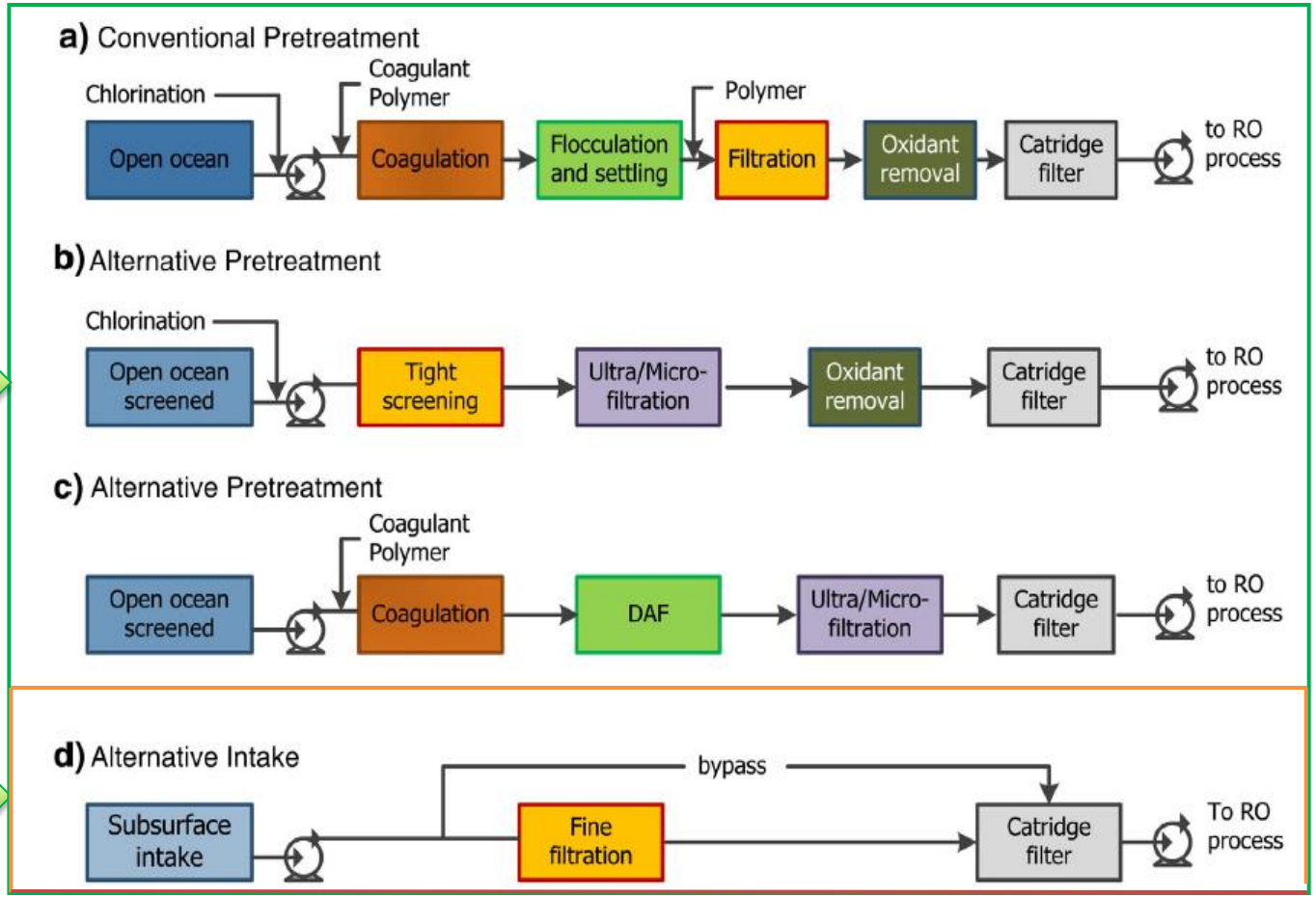




Pre-treatment Requirements for the Different Intakes

Open-ocean

Subsurface

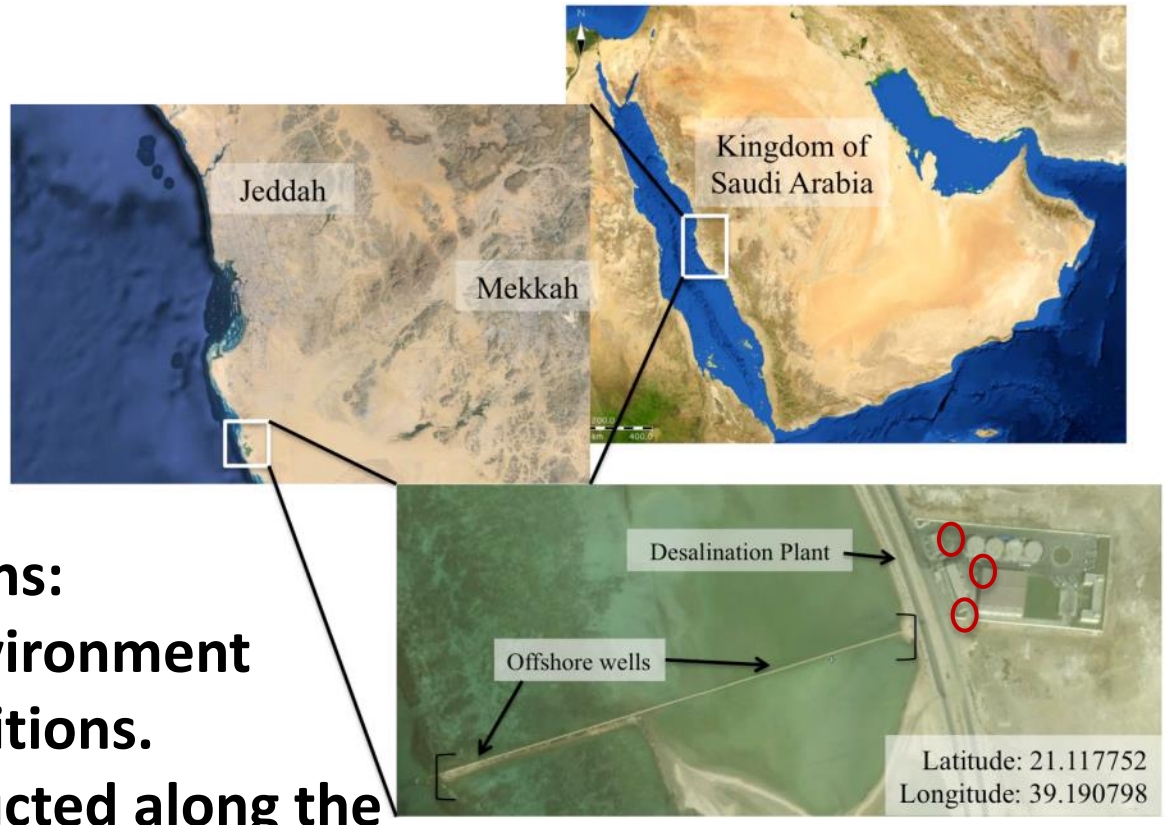


The Need for This Research

- The intake system can play a significant role in improving the feed water quality and ultimately influences the performance of downstream components of desalination processes.

- It is necessary to understand the role of subsurface intake (well system) in minimizing potential risk of membrane bio-fouling.

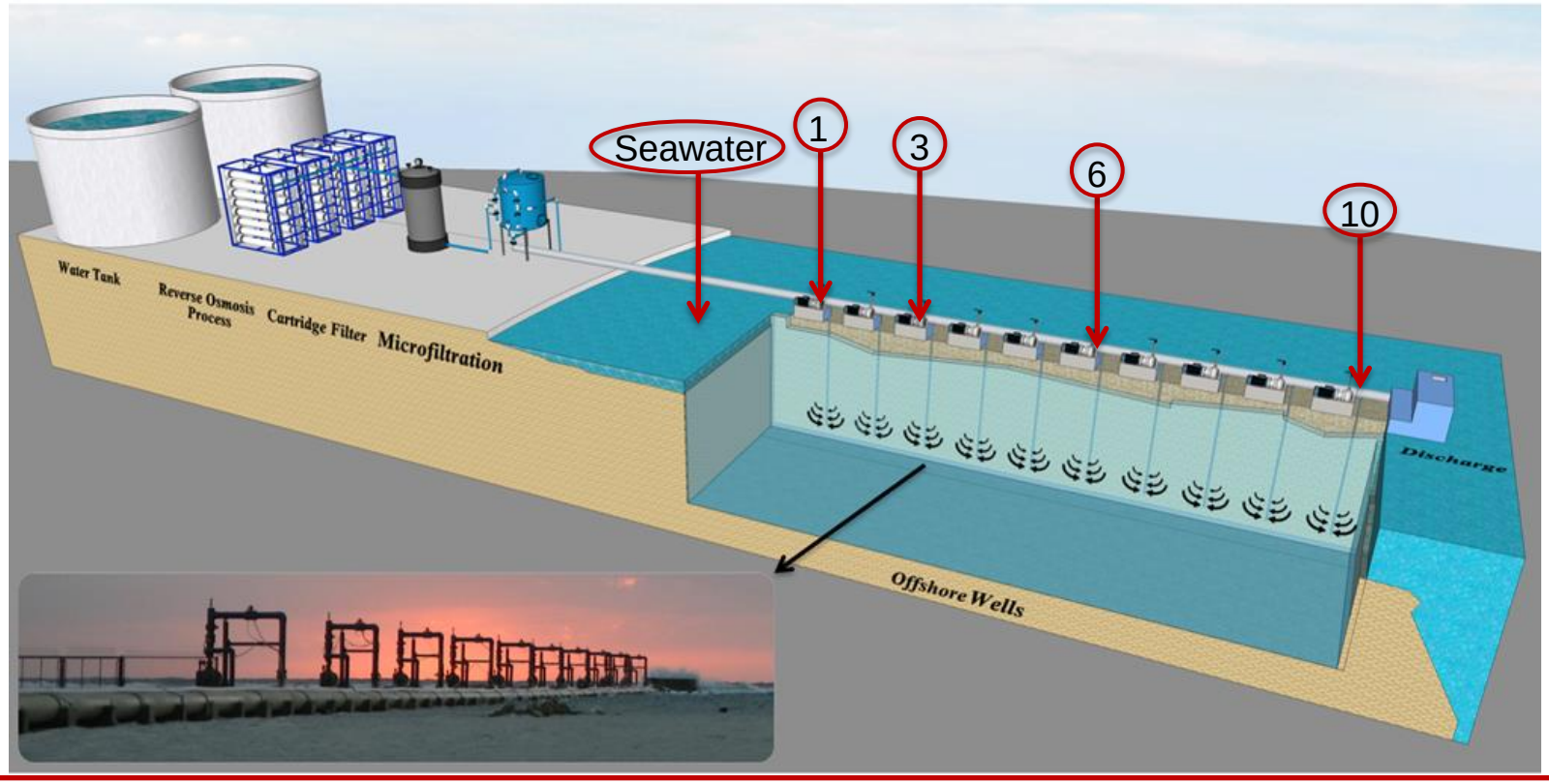
Studied Site



Location of the studied SWRO facility

Geological conditions:
-Coastal sabkha environment (hyper-saline) conditions.
-Wells were constructed along the shoreline.
(limited yield, TDS ≈90,000mg/L)
- Unlithified carbonate sediments and limestone (seabed).

Offshore Well System



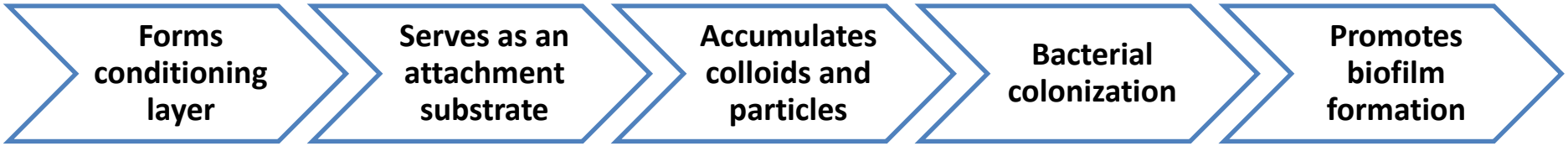
Offshore wells intake used to supply feed water to the studied SWRO facility

- **A series of 10 wells were drilled on an artificial-fill peninsula constructed from the shoreline into the nearshore area of the Red sea**
- **Well Depths: 40-50 m**
- **Distance: 20m between each well, furthest well 800m from the desalination plant**
- **Pretreatment stages: Microfiltration(0.02 µm), Cartridge filter (5 µm)**

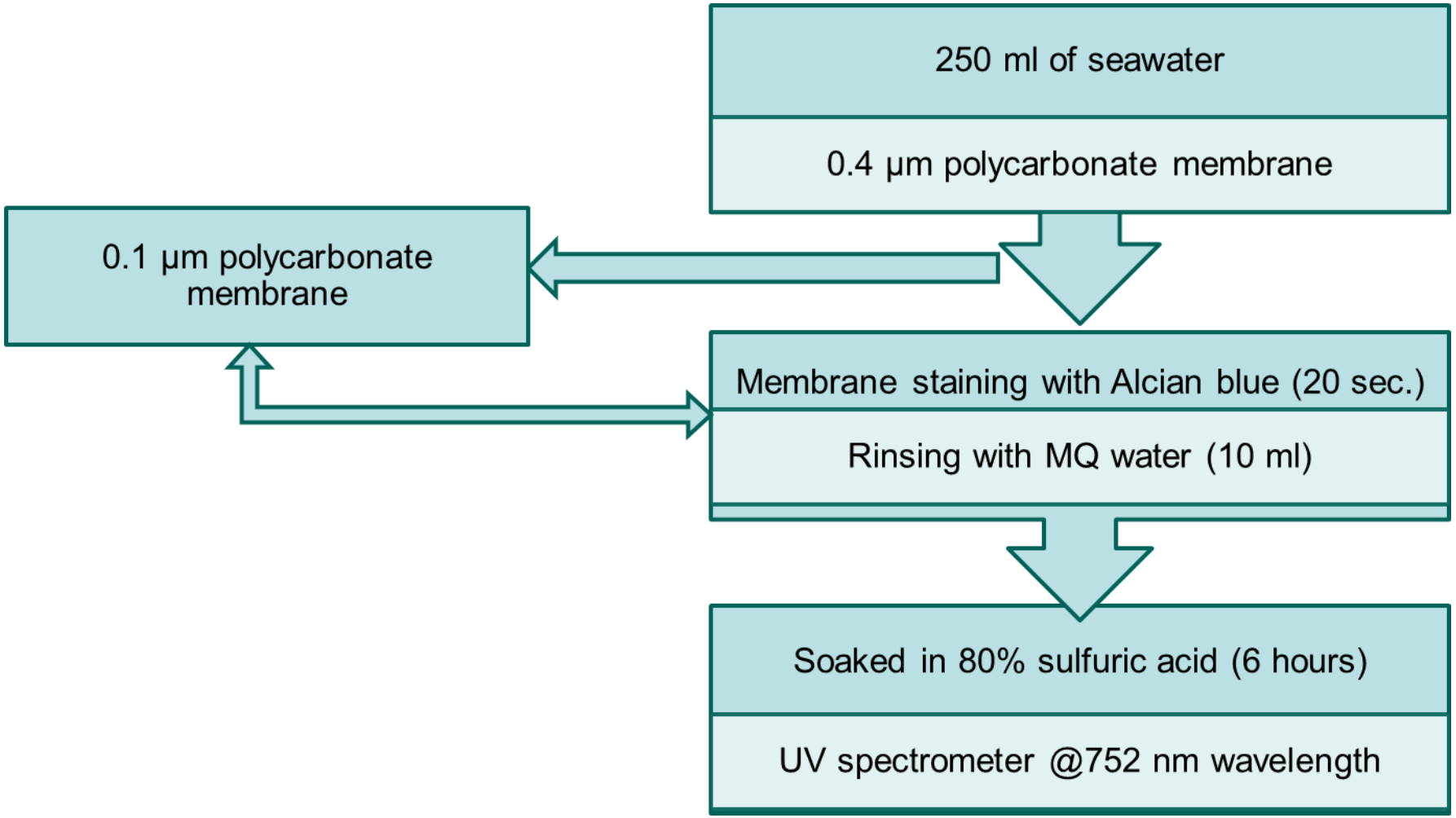
Measurements (Natural Organic Matter)

Transparent Exopolymer Particles (TEP):

- One of the main compounds leading to membrane biofouling
- It has sticky nature and high surface reactivity
- Composed of acidic polysaccharides
- Two types of TEP:
  - ✓ Particulate TEP (size > 0.4 µm)
  - ✓ Colloidal TEP (0.40 µm < size> 0.05 µm)



TEP Measurement (Passow and Alldredge Method)



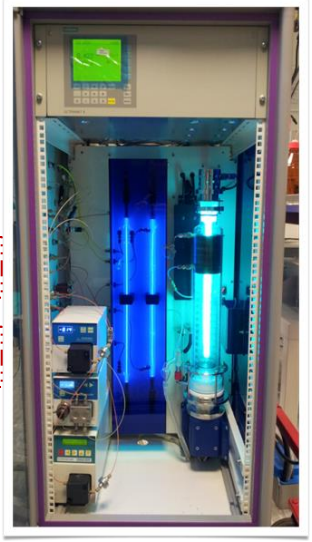
Measurments(continued..)

Natural organic fractions measurement :

- Liquid Chromatography-Organic Carbon Detection (LC-OCD)

Biopolymers | Humic substances | Building blocks

Low molecular weight (LMW) acids | LMW neuturals



Microorganism quantification:

Algae | Bacteria

- Flow cytometer was used for algae and bacterial counts
- Cell counting based on particle relative size and fluorescence through cell excitation

BD FACSVerse Model

Physical parameters:

Turbidity | Total dissolved solids (TDS) | pH

Physical Parameters (Results)

Parameter	Seawater	Well #1	Well #3	Well #6	Well #10
TDS [g/l]	48.4	50.5	49.4	54.5	49.5
Turbidity [NTU]	3.67	0.55	1.58	1.07	1.09
Conductivity [ms/cm]	61.4	66.6	59.8	62.3	59.8
PH	8.24	7.49	7.7	7.63	7.71

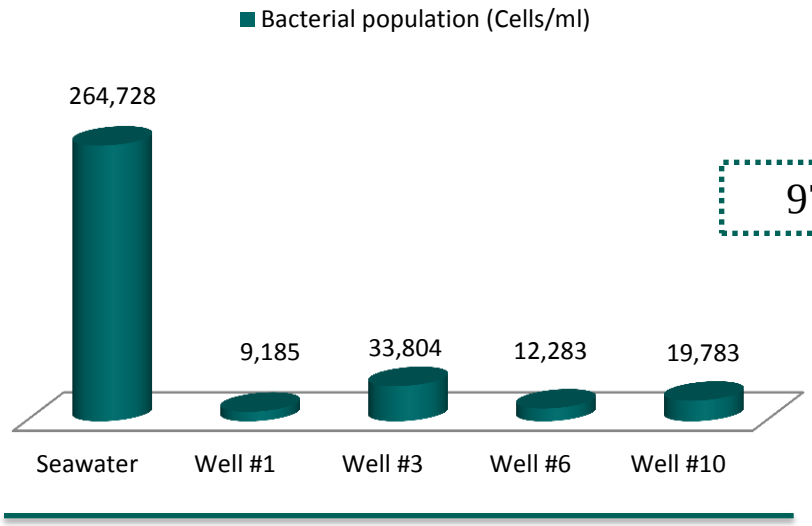
55 to 85% lower turbidity in the well system → Shows the straining effect of the aquifer system underlying the seabed

Higher TDS in the well system → Hydraulic connection with the shoreline

Lower pH in the well system → Active cementation of the sea floor is ongoing, pH reduction is expected when the water enters the underlying sediments

Bacterial and Algae Quantification

Bacterial concentration



97 % removal

Algae concentration (cells/ml)

Sampling Point	Cyanobacteria	Prochlorococcus	Pico/nanoplankton
Seawater	1507	140	30
Well #1	<5	<5	<5
Well #3	<5	<5	<5
Well #6	<5	<5	<5
Well #10	<5	<5	<5

≈100 % removal

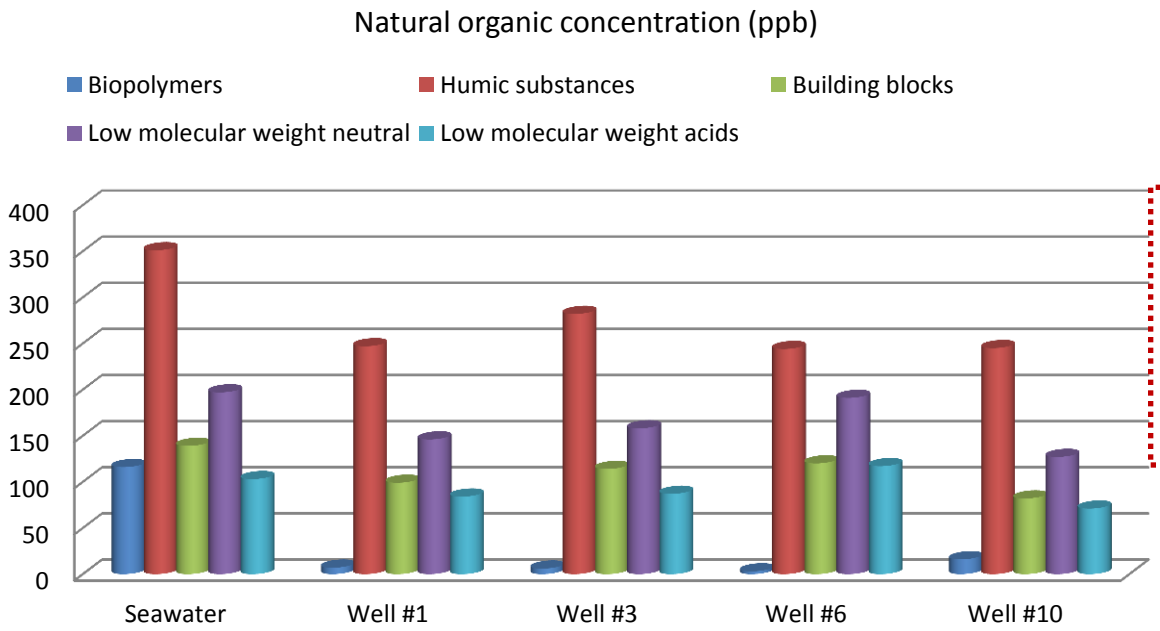
Natural Organic Matter

Total organic carbon

Parameter	Seawater	Well #1	Well #3	Well #6	Well #10
TOC [mg/l]	1.02	0.69	0.75	0.71	0.59

up to 40 % removal

Natural Organic Matter (fraction)

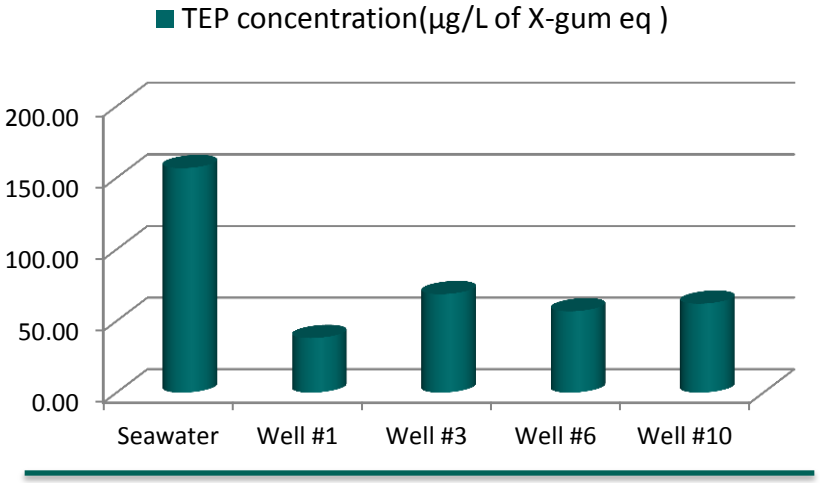


93 % removal of biopolymers
27% removal of humic substances
25% removal of building blocks
21% removal of LMWN
13% removal of LMWA

- Size exclusion
- Adsorption
- Some biodegradation

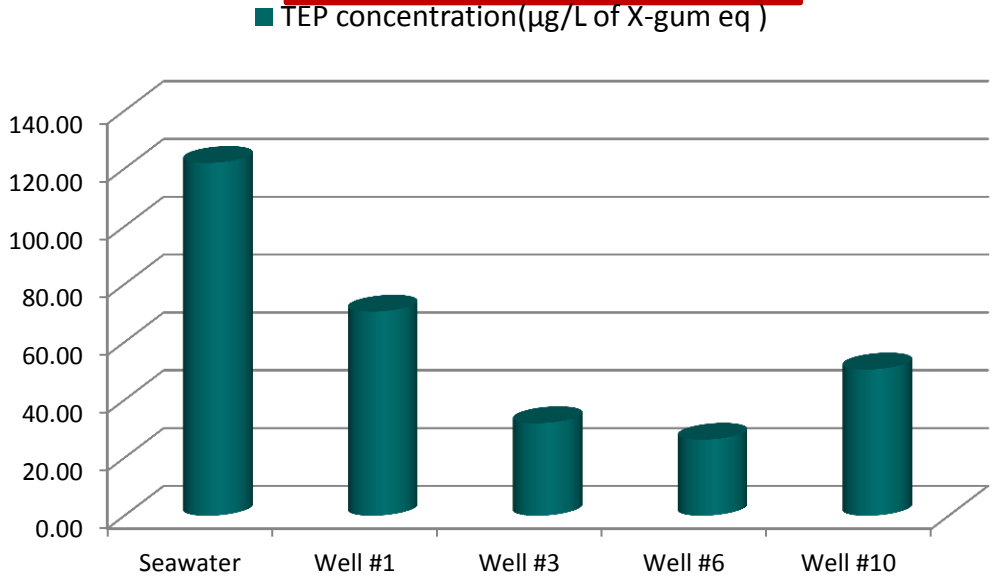
Transparent Exopolymer Particles (TEP)

Particulate TEP (>0.4 µm)



(55-75) % removal of TEP by the aquifer system

Colloidal TEP



(42-87) % removal of colloidal TEP by the aquifer system

Conclusions

- An uniquely-designed offshore well intake system is effective at removing TEP (75%), bacteria (97%) & algae (100%) and natural organic compounds (up to 97% of biopolymers)
- Offshore wells help to overcome the geological condition of hypersaline environments occurring at the shoreline (sabkhas)
- The high quality feed water produced from the offshore well system demonstrates that less pretreatment will be needed, reduces the frequency of membrane cleanings and reduces operating costs.

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Q & A

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