Pall Corporation

# Make Water Anywhere with Pall Integrated Membrane Systems

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- Fundamentals of membrane desalination
- Membranes – functions and properties
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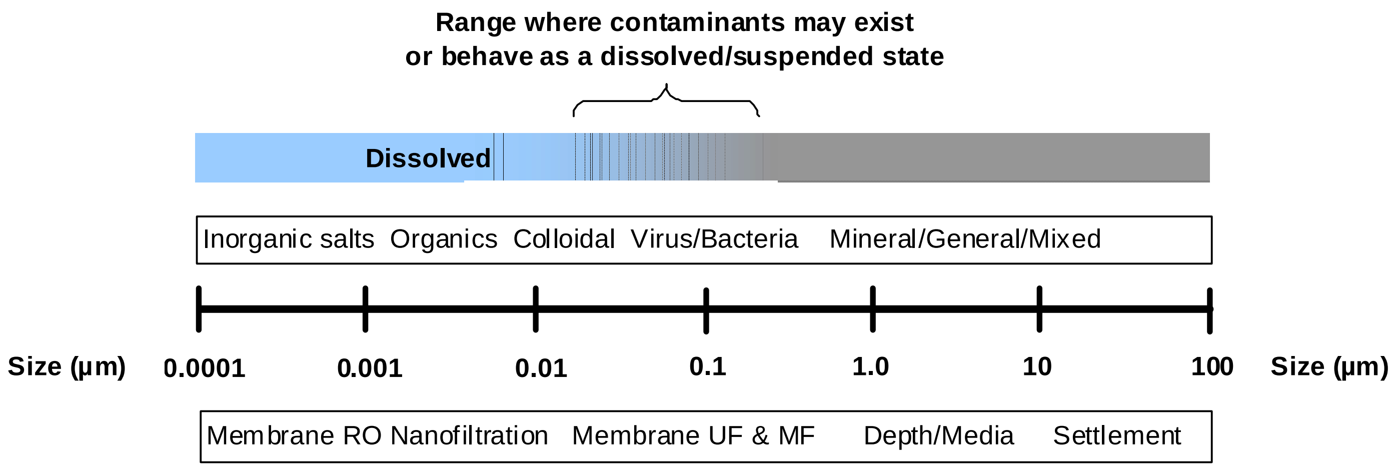
# Constituents of source water

Water contaminants will include dissolved solids and suspended solids




Seawater contains between 30 and 50 g/l of dissolved salts. Depending on the water source, other contaminants will be present across the entire range with huge problems associated with the suspended components

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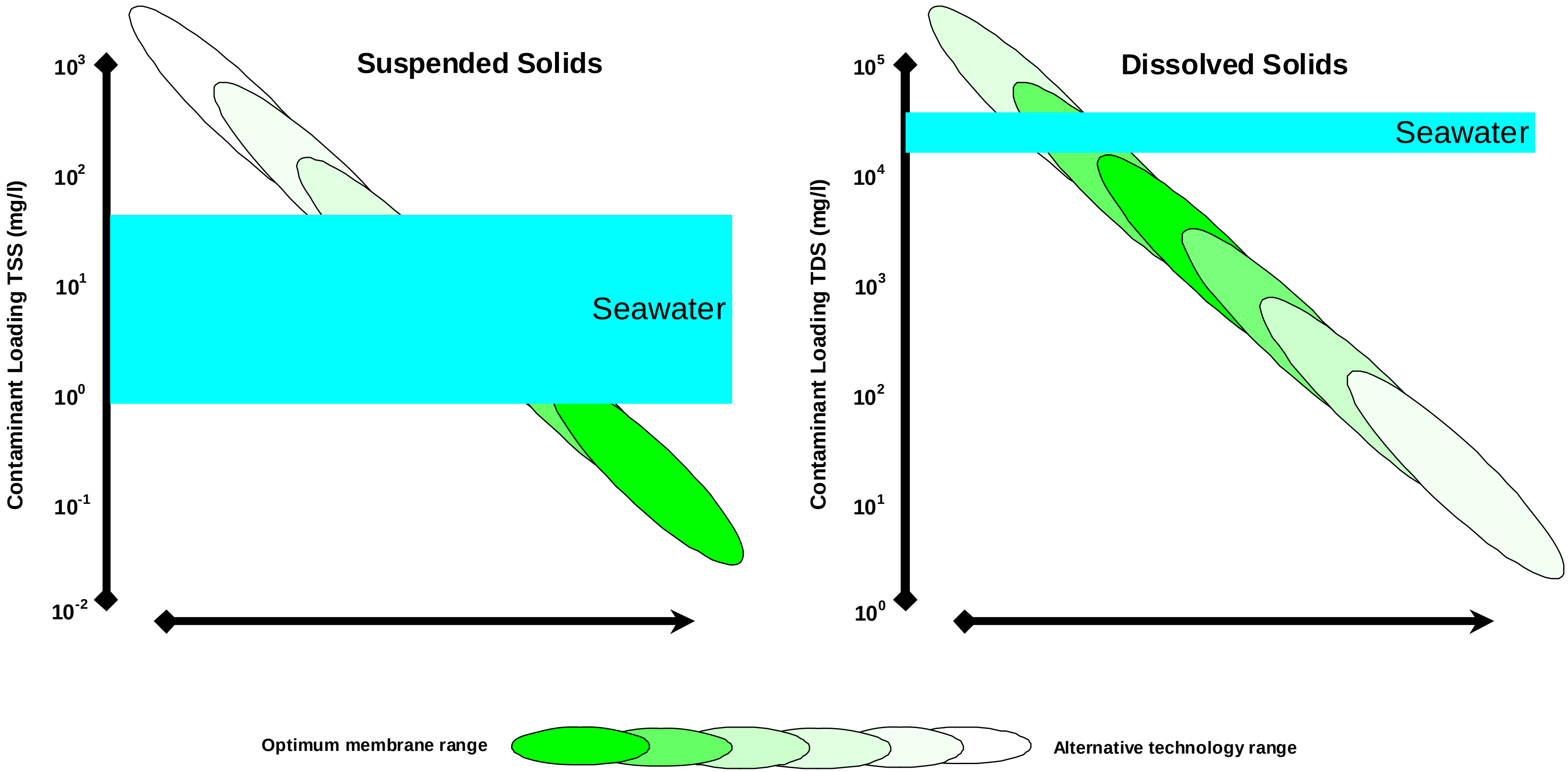
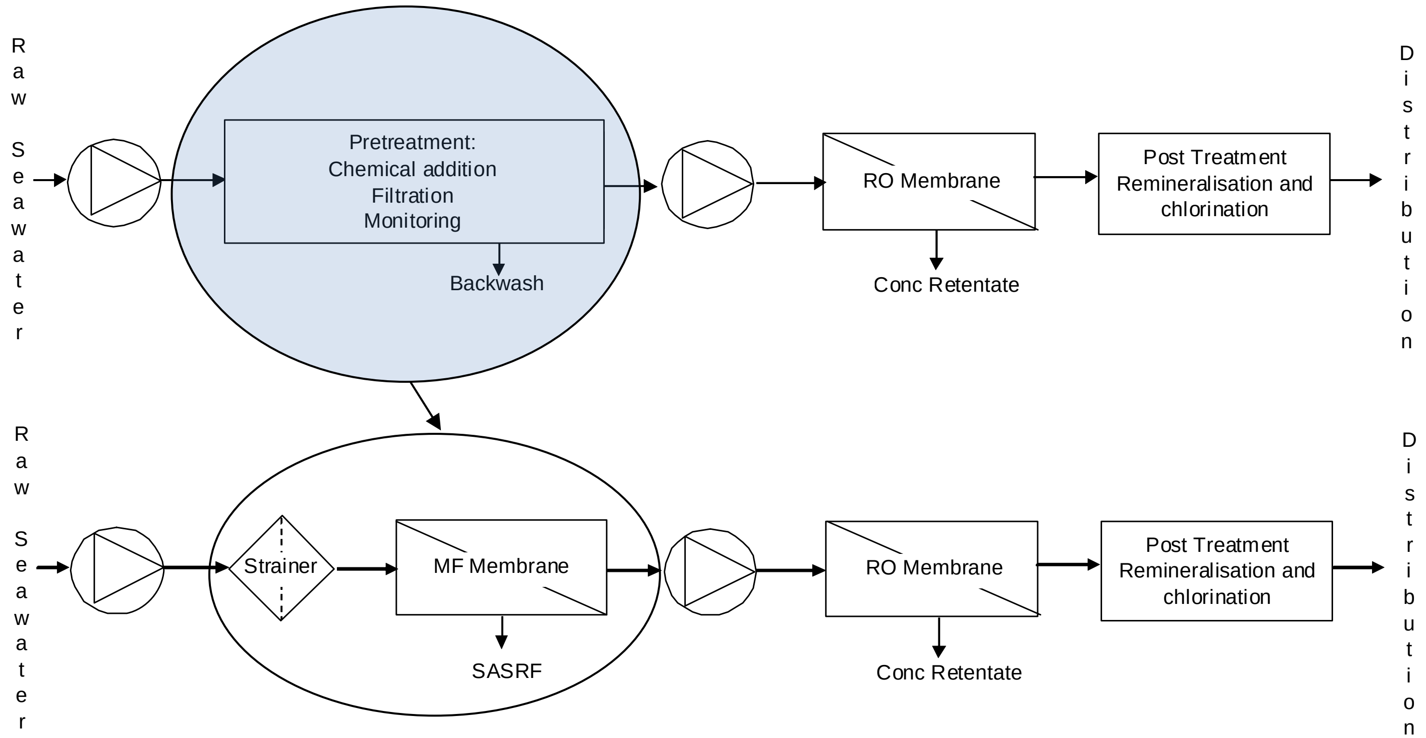
# Constituents of water



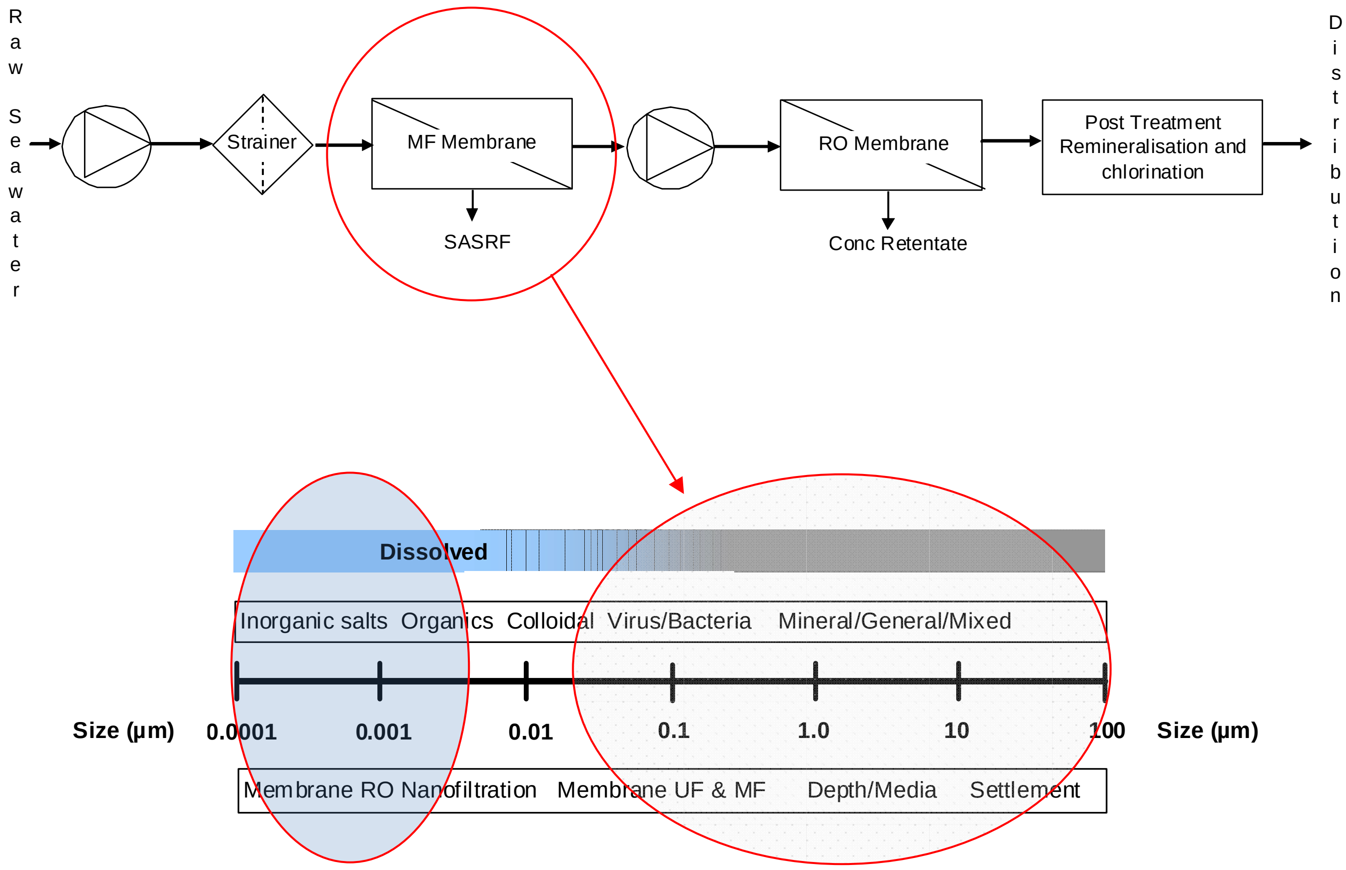
# Constituents of water

Suspended solids - Removed by a filtration media or membrane processes

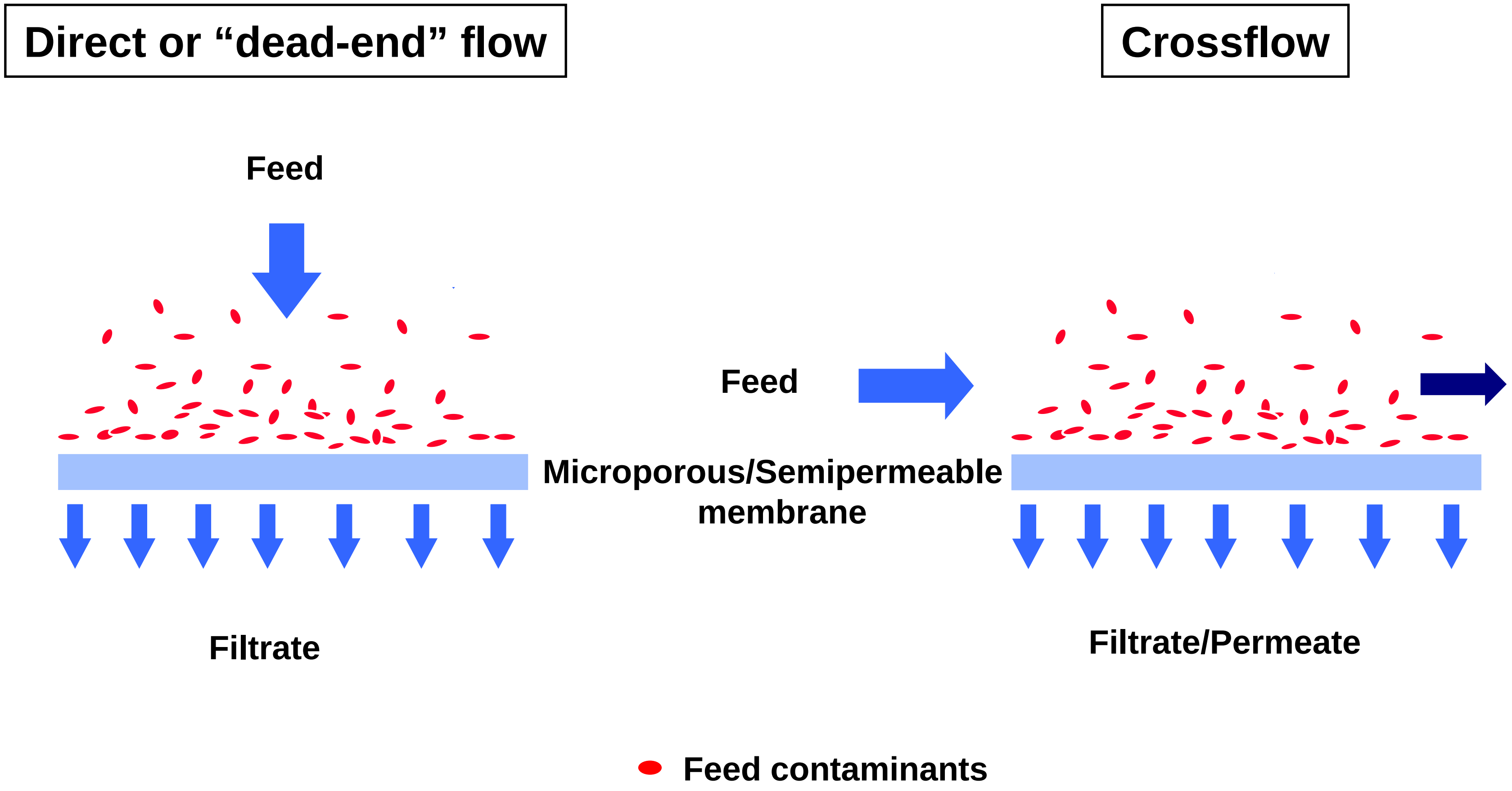
Dissolved contaminants - Removed by Reverse Osmosis (RO)



# Contaminants in Water

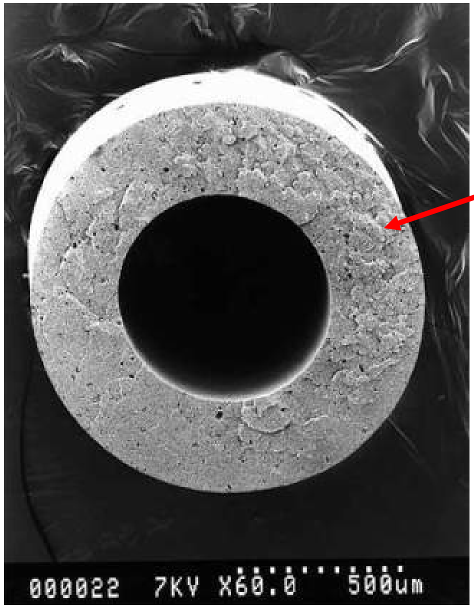


# Membrane separation



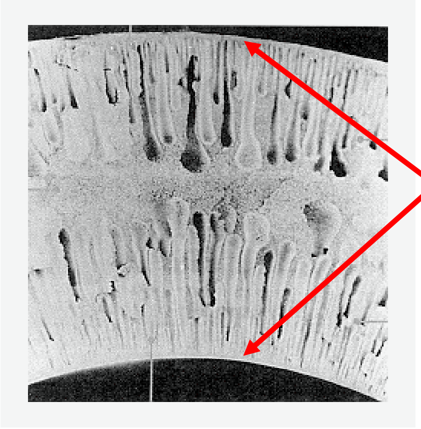
# Membrane configurations

## Microfiltration




Complete uniform pore structure through the thickness **(no skin)** polyvinylidene fluoride (PVDF) membrane construction

## Ultrafiltration



Uniform inner and outer skinned UF membrane with narrow pore range ensures highly efficient rejection characteristics

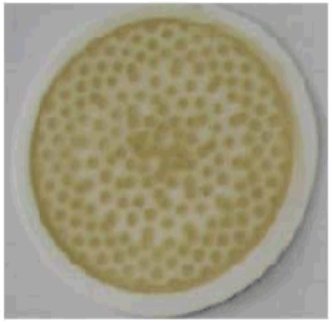
# Membrane vs conventional filtration

| Features / Performance Evaluation | Sand Filter / MMF/DMF | Membrane MF | Benefit of Pall MF |
|---|---|---|---|
| Protection of potential RO | + | ++++ | 0.1 µm rating removes particulate fines (colloids and oxidized metals eg. Fe, Mn, As) & micro organisms |
| Silt Density Index (SDI) | + | ++++ | Filtrate with SDI <3 |
| Turbidity | ++ | ++++ | Filtrate with turbidity < 0.1 NTU |
| Microbial removal | + | ++++ | 6 log removal of microorganism and pathogens |
| Consistency in performance | + | ++++ | Continuous |
| Integrity testable | - | ++++ | Assurance of safe potable water supply |
| Flexibility to cope with variable feeds and hydraulic loads | ++ | ++++ | Broad operation range, handles upsets |
| Reliability & longevity | ++ | ++++ | Superior strength of HC-PVDF membranes |
| Modular & expandable | + | ++++ | Future needs, by modules or banks |
| Waste minimization | + | +++ | Unique Air-scrub-feature for high recovery |
| Footprint and weight | + | +++ | Compact design, small footprint |
| Response to oil in feed | ++ | +++ | CIP will clean membranes while SF blocks |

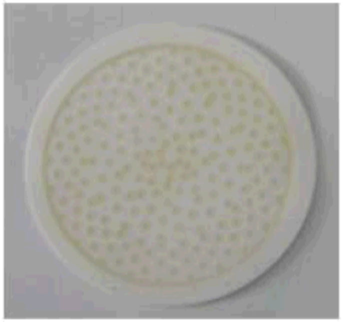
**++++ : excellent** **+++ : good** **++ : fair** **+ : poor** **- : not available**

# Membrane filtration  vs conventional

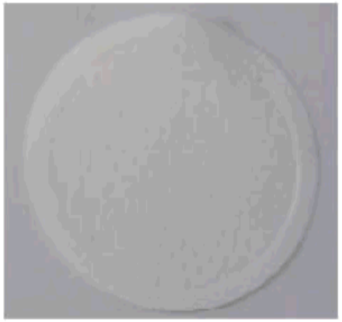
Differences of filtrate qualities between traditional prefiltration and Microza® prefiltration (Deposits during SDI measurements)



Feedwater

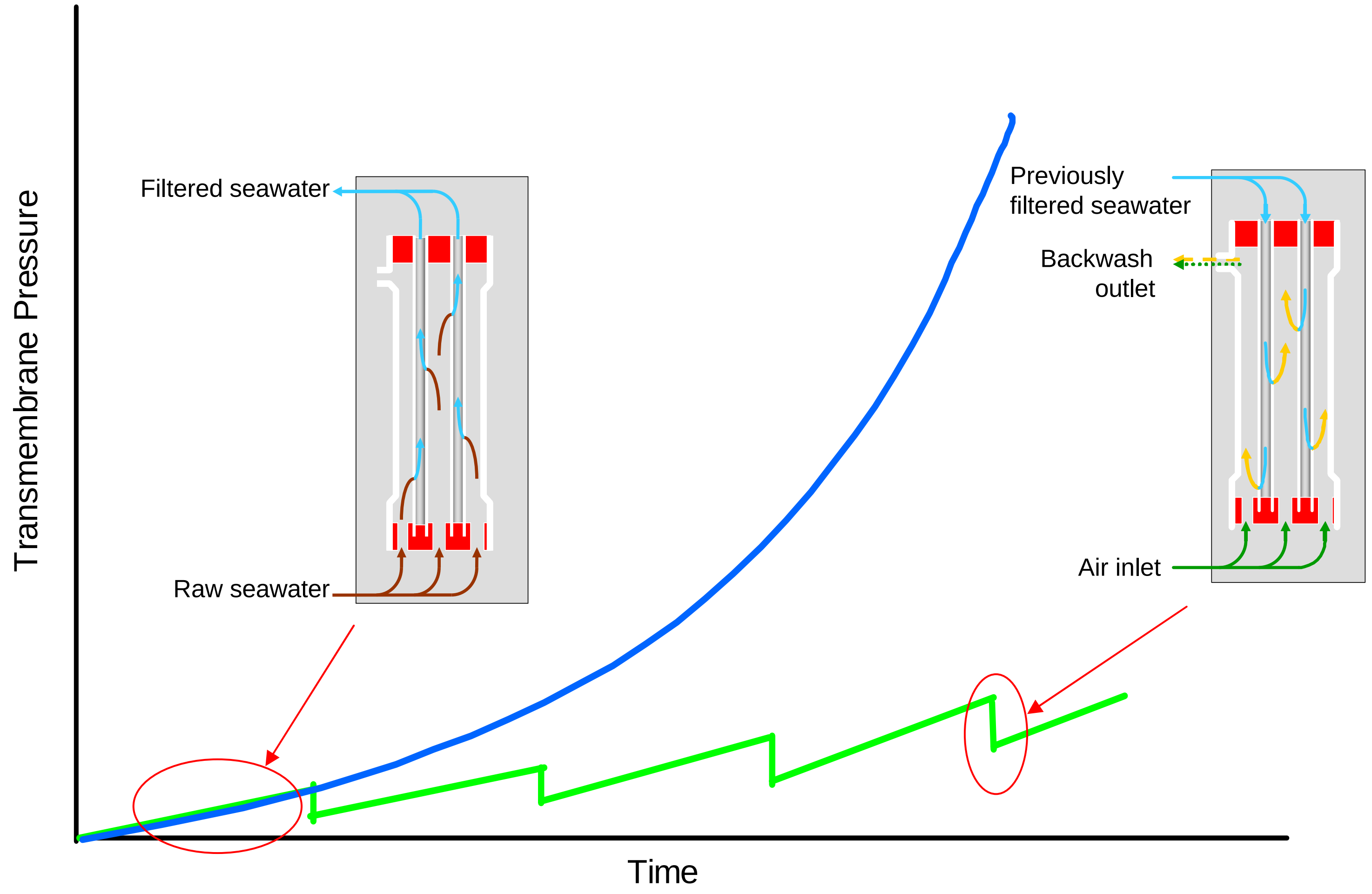


After traditional pre-filtration

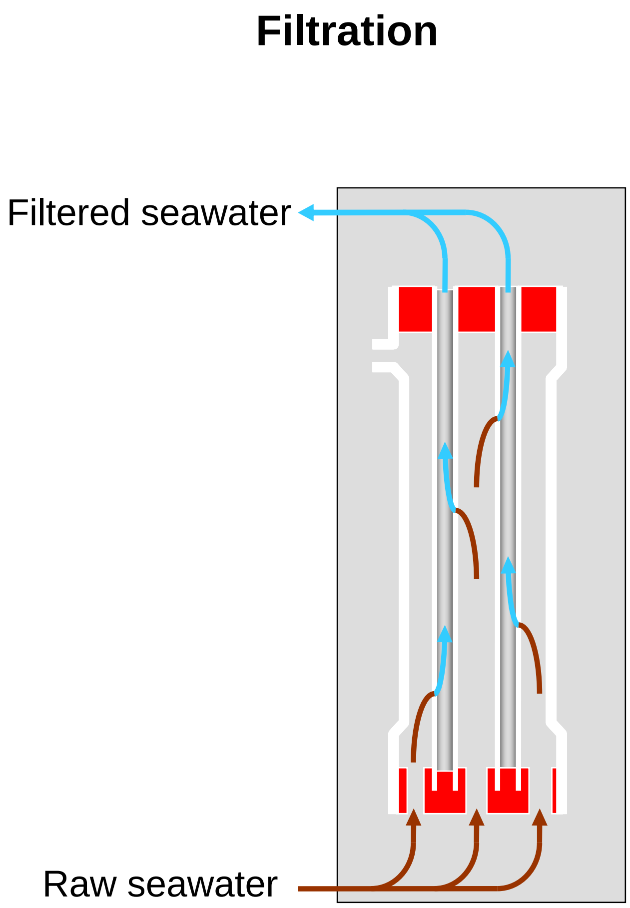


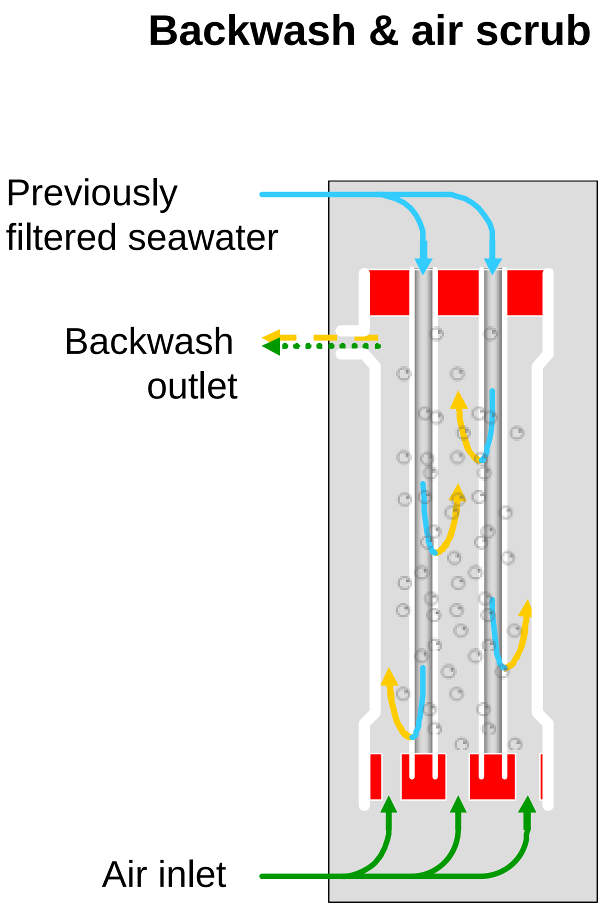
After MF

# Pre-treatment membrane operation



# Pre-treatment membrane operation



# Pre-treatment performance imperatives

Performance metrics

- Particulate (RO pre-treatment)
  - Turbidity < 0.1 NTU
  - SDI < 2 (RO feed requires SDI <3)
  - Total suspended solids - background
- Microbiologicals (RO pretreatemnt and drinking water production)
  - *Giardia, Crypstosporidium* > 6 log removal (99.9999%)
  - Virus 0.5-3 log
  - Animal Parasites

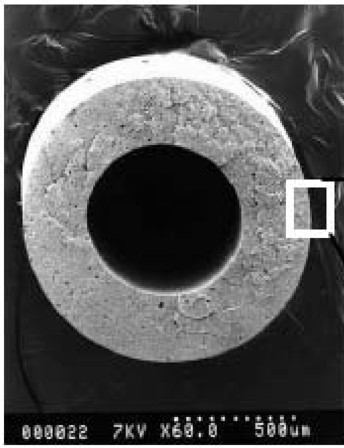

Given the broad range of inlet solids and the life expectancy
It is vital to use a physically robust and chemically resistant
Membrane:

- Homogenous construction
- Chemically inert PVDF
- High degree of crystallinity

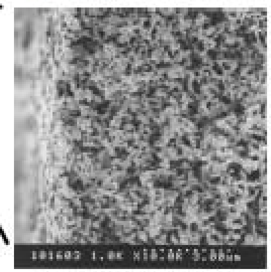
Skinned ultrafiltration membranes will not withstand the rigours of repeated backwashing and air scrub. Resulting in deterioration of performance with time

# Membrane integration

0.1µm rated membrane fibre 1.2mm OD, 0.8mm ID

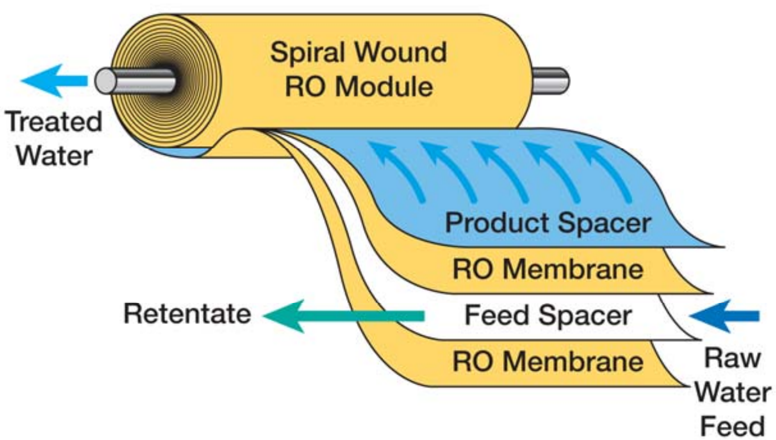



Homogenous fibre material imparting high mechanical strength



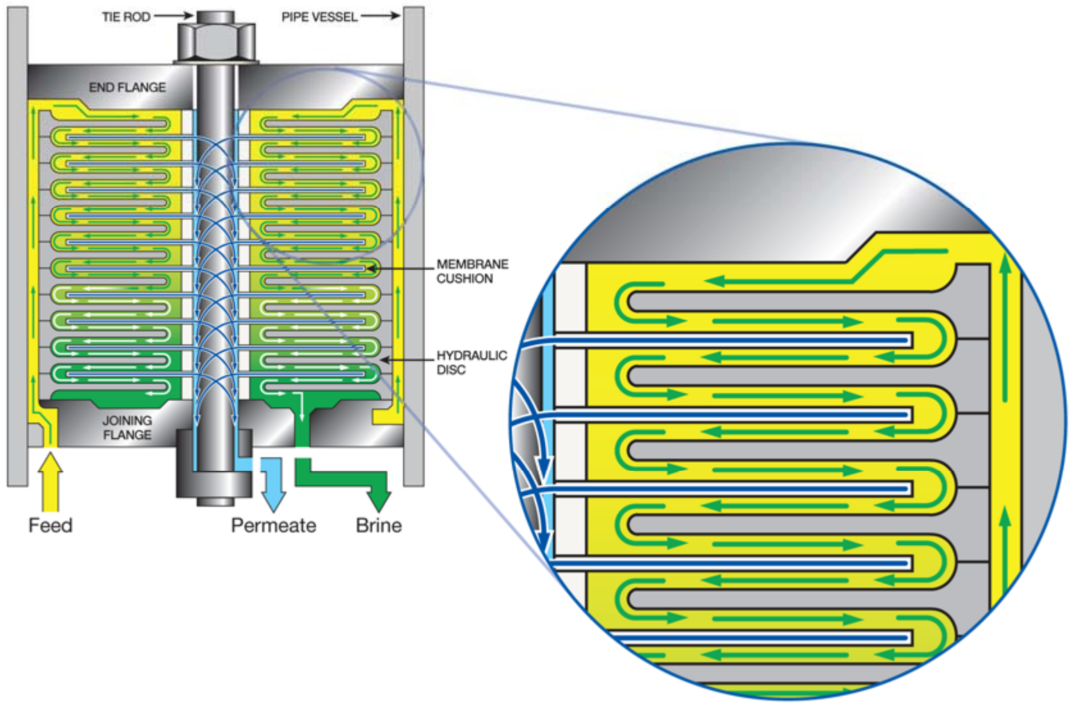
Highly crystalline PVDF pre-treatment membrane

Conventional spiral wound composite polyamide RO membrane configuration



# DTRO configuration

Disc Tube RO (DTRO) membrane alternative configuration



# Membrane properties & considerations

**Pre-treatment**

- Protection of downstream equipment, processes & functions
  - Control of inlet suspended solids (SDI >3 for RO/NF)
  - Microbial barrier
- Integrity assurance
  - Sensitive, automated test to confirm performance
- Sustainable operation
  - Ability to reverse pore occlusion (filtration process)
  - Withstand aggressive cleaning procedures
  - Chemical resistance

**RO**

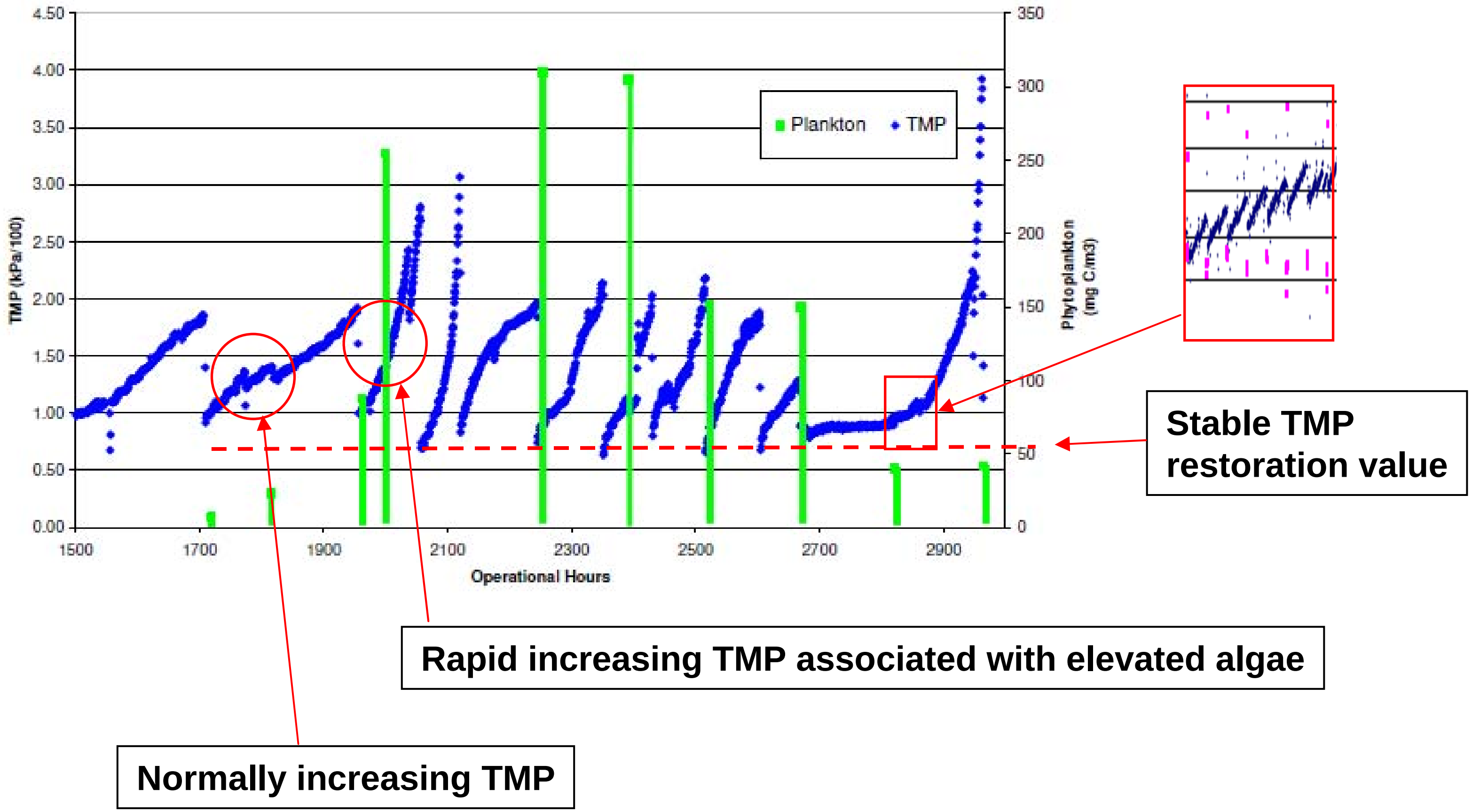
- Desired rejection rates for ionic species
- Minimal loss of production through flow channel and membrane fouling

# Operational considerations - sustainability

- The pre-treatment stage can face extremely challenging and sometimes often variable feed water conditions
- As the filtration membrane retains solids, it exhibits an increase in transmembrane pressure (TMP) as previously demonstrated
- The increase in TMP must be completely recoverable, this is achieved with physical and chemical cleaning regimes
  - Reverse filtration with previously filtered water in combination with air scour
  - Regular (24 hr – infinite) flux maintenance clean ($ClO^-$)
  - CIP (~monthly – infinite) Chemical clean ($ClO^-$ + NaOH)
  - Chemical cleaning can be eliminated with low flux operation
- Membrane prefiltration dramatically reduced cleaning burden of downstream RO
- Membrane prefiltration reduces scale formation in RO by reduced precipitation nucleation

# Sustainable operation

MF TMP trends in heavily contaminated feed water



# Sustainable operation

Robust and chemically resistant membranes are required to withstand the rigours of feed water duty and the associated aggressive cleaning procedures over the years of their service life

Highly crystalline PVDF exhibit greater mechanical and chemical resistance (Liu, C. 2007). Factors affecting stability..

- Morphology of polymers: crystalline vs. amorphous polymers
- Chemical composition, inc structure of monomers
- Molecular architecture - average mol wt & distribution, branching, cross linking.
- Chain orientation with respect to the major stresses during operation
- Structure and geometry of membranes
- The presence of catalysts and inhibitors for chemical reactions relevant to chemical degradation of polymeric membranes

# Shipboard Series

**AT25 - 20m³/day**

**AT32 - 40m³/day**

**MF pre-treatment upgrade**

**DTRO special Submarine**

# Conclusions

- Membrane technology has a long history in water treatment but recent developments in construction and polymer chemistry have enabled significant broadening of this scope – particularly as a conventional media filter replacement option
- Robust polymeric prefiltration membranes remove virtually all suspended solids and produce a high quality filtrate with background levels of TSS and SDI
- Membranes provide dependable barriers to microorganisms in drinking water supply and as such enable treatment of freshwater sources (Bunker feed)
- Combining MF membranes as pre-treatment to RO enables the latter to function under optimum conditions and produce a treated water quality that is reliably within demanding target limits
- The control of TSS and microbial burden reduces bio fouling of RO membranes and delays scale formation enabling optimum RO production and extended life
- The robust MF membranes can continuously maintain throughput when challenged with a wide range of inlet solids and algae conditions with effective TMP regeneration