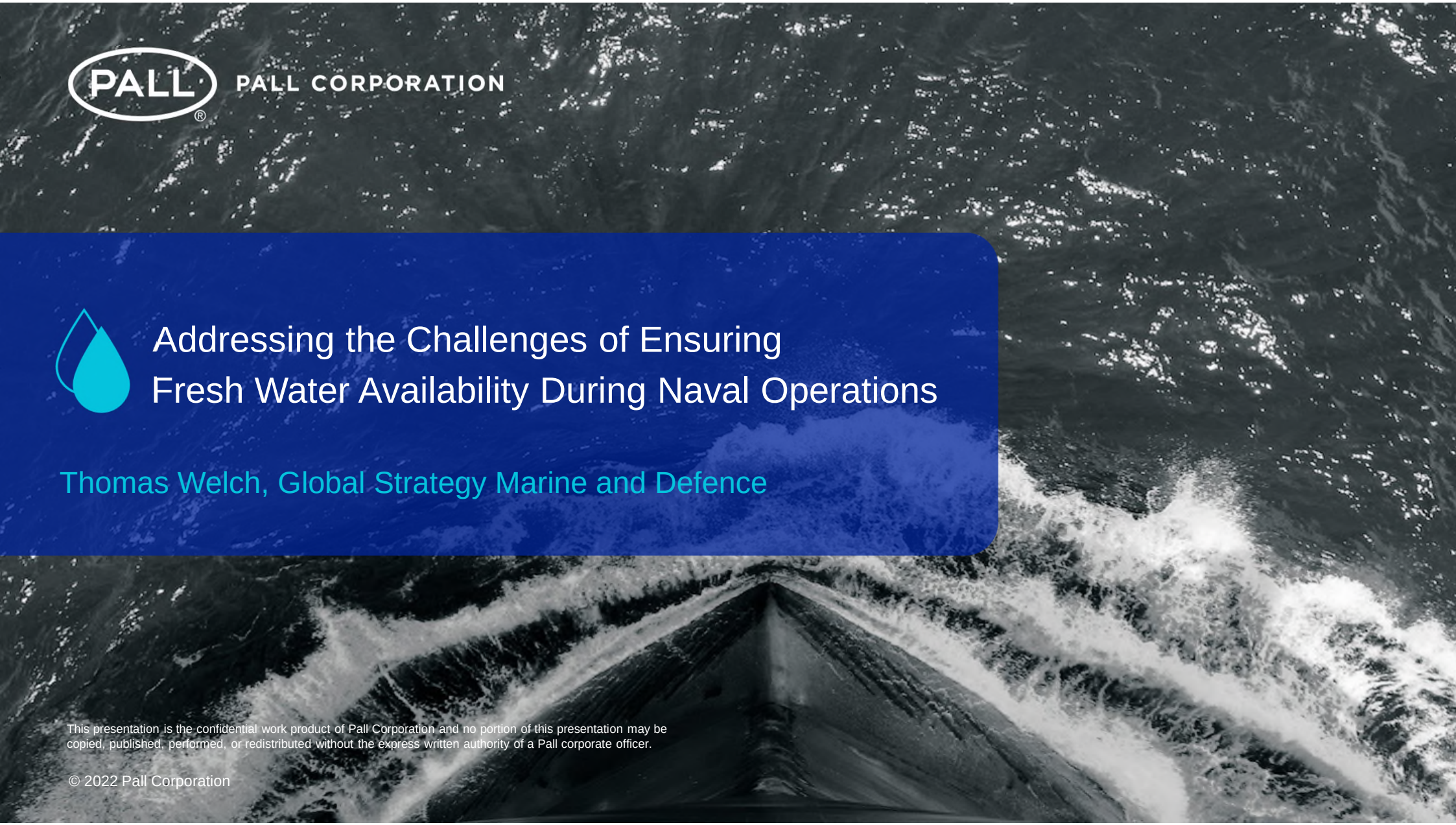

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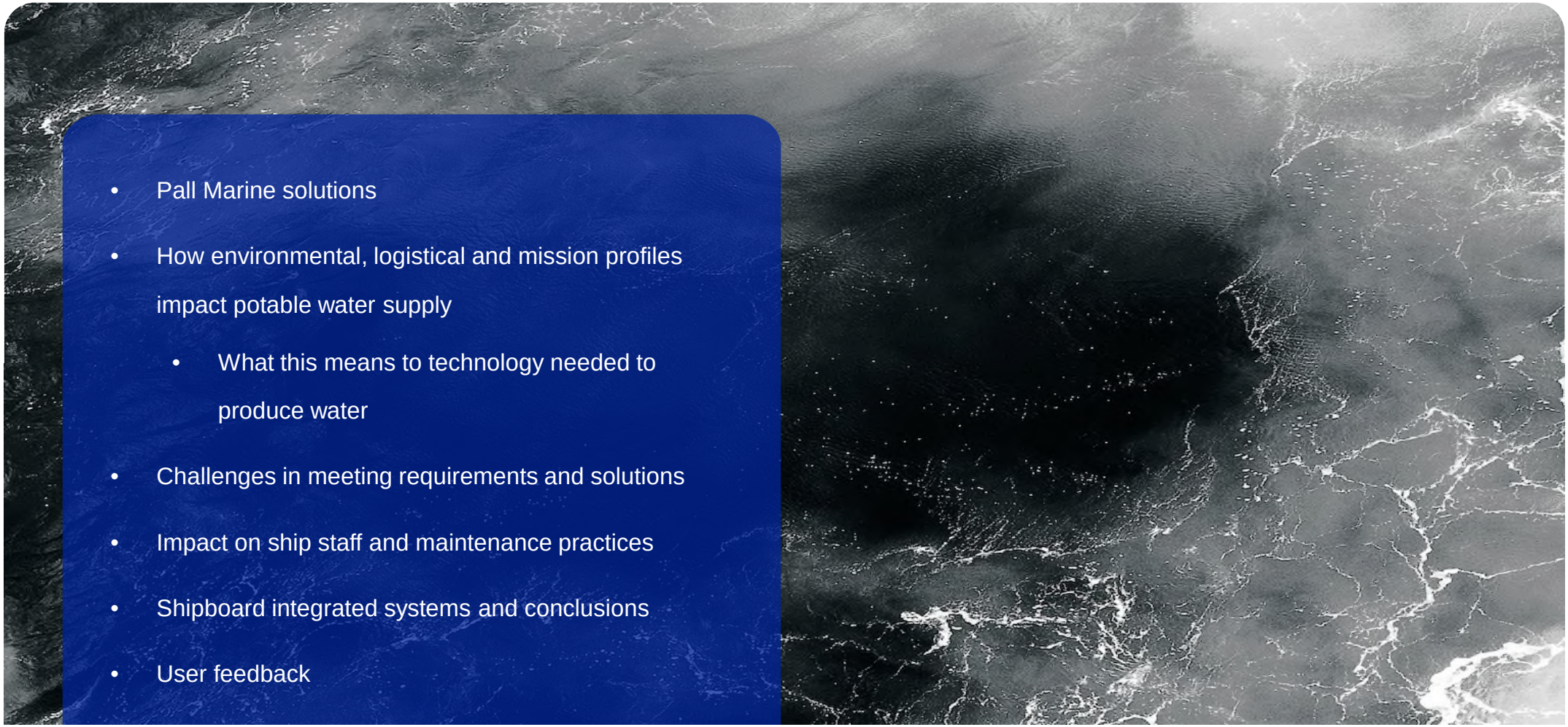
Addressing the Challenges of Ensuring Fresh Water Availability During Naval Operations

Thomas Welch, Global Strategy Marine and Defence

Agenda



- Pall Marine solutions
- How environmental, logistical and mission profiles impact potable water supply
    - What this means to technology needed to produce water
- Challenges in meeting requirements and solutions
- Impact on ship staff and maintenance practices
- Shipboard integrated systems and conclusions
- User feedback

Marine Solutions

Hydraulic System Filtration Manifolds and Assemblies Help remove damaging particulate contaminants from hydraulic fluid ensuring effective protection for hydraulic system flight control components.

Reverse Osmosis Water Filtration Systems Fully automated Micro Filtration Reverse Osmosis and Disc Tube Reverse Osmosis systems reduce reliance on Port Authority or bunker water by allowing commercial and military vessels to remain 'on-station' and make water anywhere from water sources with high levels of contamination.

Engine and Drive Transmission Assemblies Protect the engine and drive transmission system components from damaging contaminants.

Bulk Fuel Filter Assemblies and Manifolds Offer contamination control solutions for bulk fuel.

Diagnostic and Monitoring Systems Are a breakthrough in preventive maintenance saving operators money and time by ensuring operations without down time caused by fluid contamination.

Engine Lube Filter Elements and Assemblies Offer optimum particulate removal efficiency and protection for lube system components.

Fuel System Filter Elements and Assemblies Offer optimum protection for the fuel system controls by providing high-efficiency particulate removal from fuel.

Challenges and changes in mission profiles:

- Difficulty in managing RO systems
- Environmental concerns
- System downtime
    - Frequency of service
- Training and manpower demands

- Inability to make water in harbour
- Variability of bunkered water globally
- Security of harbour

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Guest Speaker: Tim Lilley, Industry SME and Pall Marine Consultant

How environmental, logistical and mission profiles impact the production and supply of potable water

- Constituents of source water
- Treated water quality requirements

What this means to the technology needed to produce water

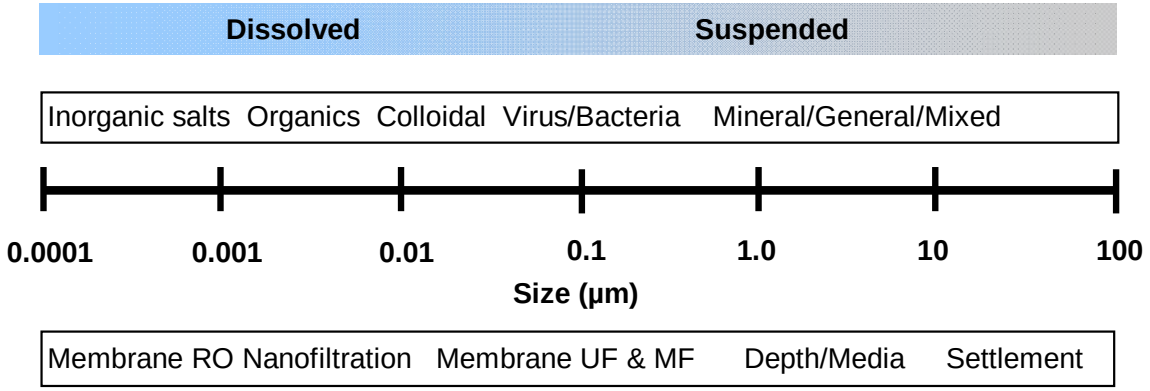
- Fundamentals of desalination
- Membranes – functions and properties
- Control of contaminants

Challenges in meeting requirements, how they can be overcome and impact on maintenance practices

- Membrane configurations
- Sustainable operation

How environmental, logistical and mission profiles impact the production and supply of potable water 1/2

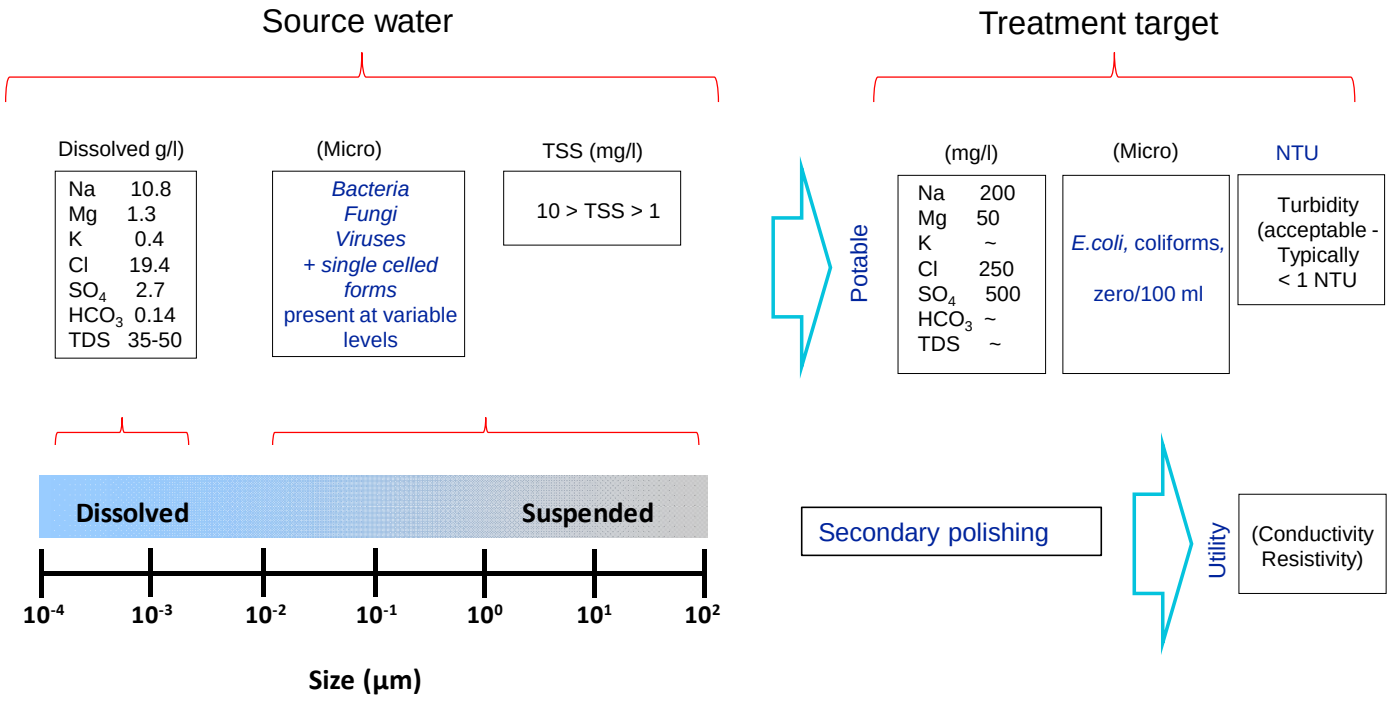
Producing potable water from seawater involves the removal and control of both suspended and dissolved constituents



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

How environmental, logistical and mission profiles impact the production and supply of potable water 2/2

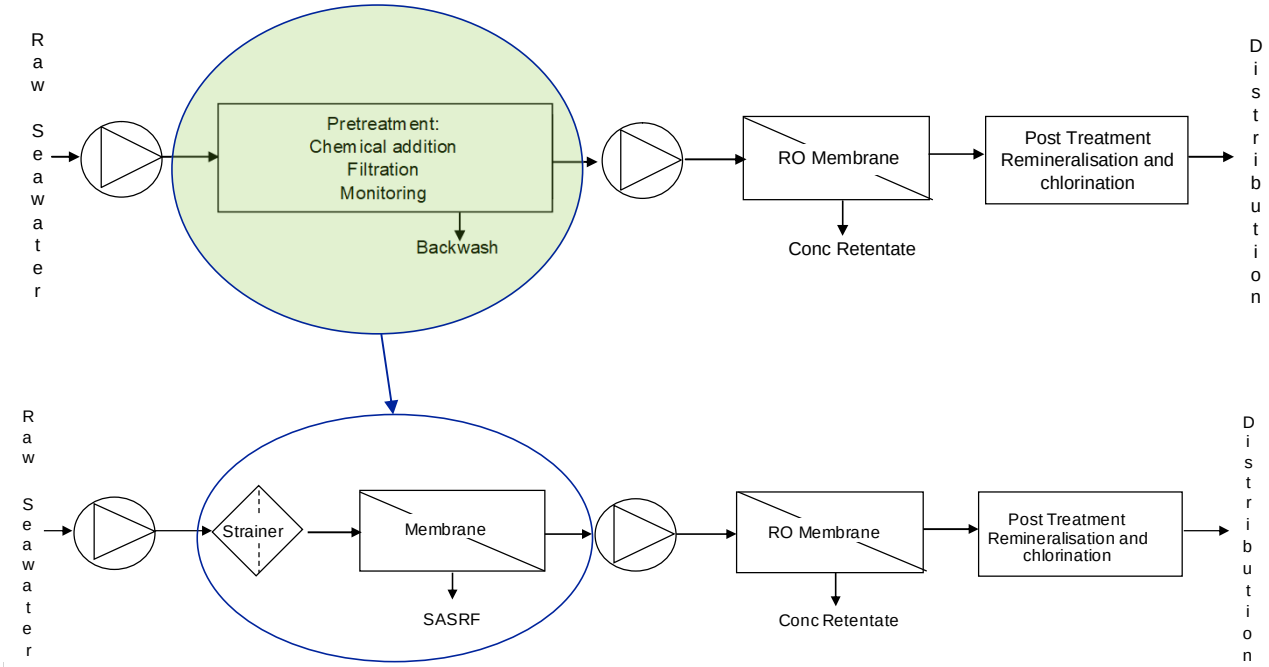
- FWG's have to be able to address these specific contaminants to meet both water regulations and also ensure reliable operation.



What this means to the technology needed to produce water 1/5

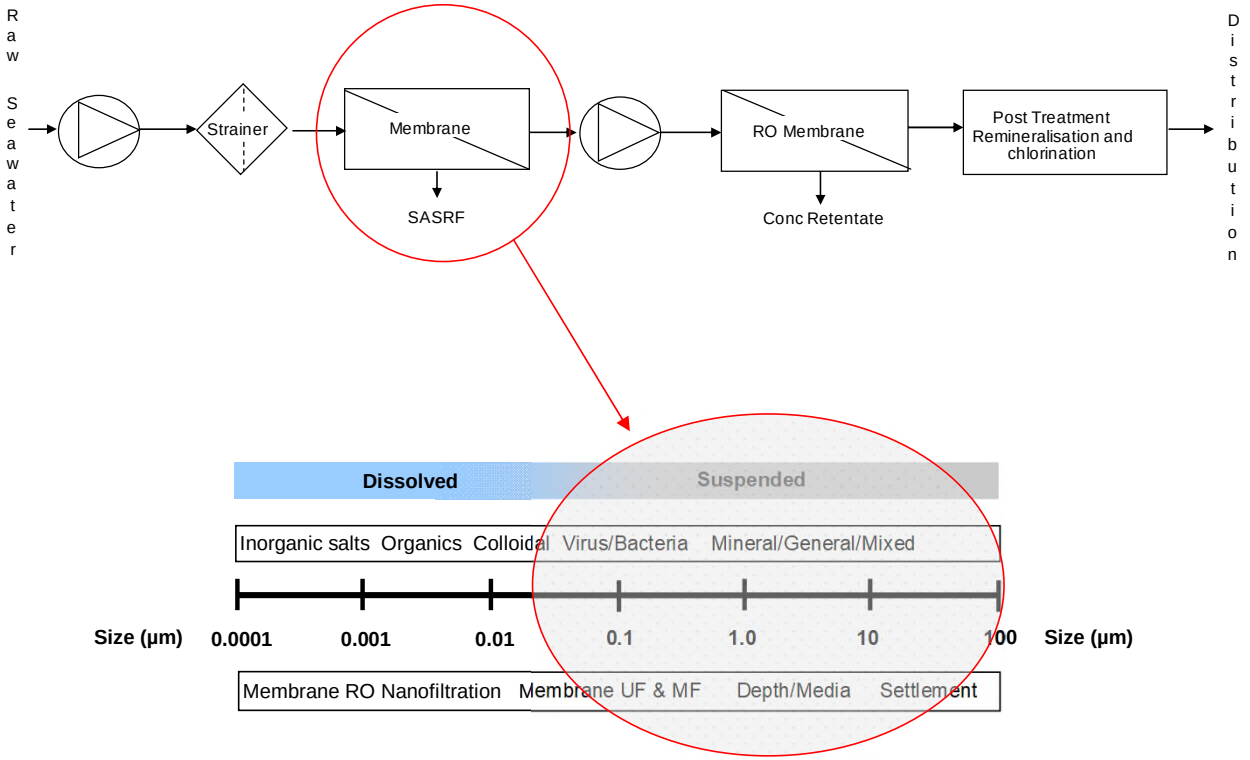
- To achieve these requirements, 2 stages of treatment is needed

1. Suspended solids:
   Removed by a filtration media or membrane processes
2. Dissolved contaminants:
   Removed by
   Reverse Osmosis (RO)



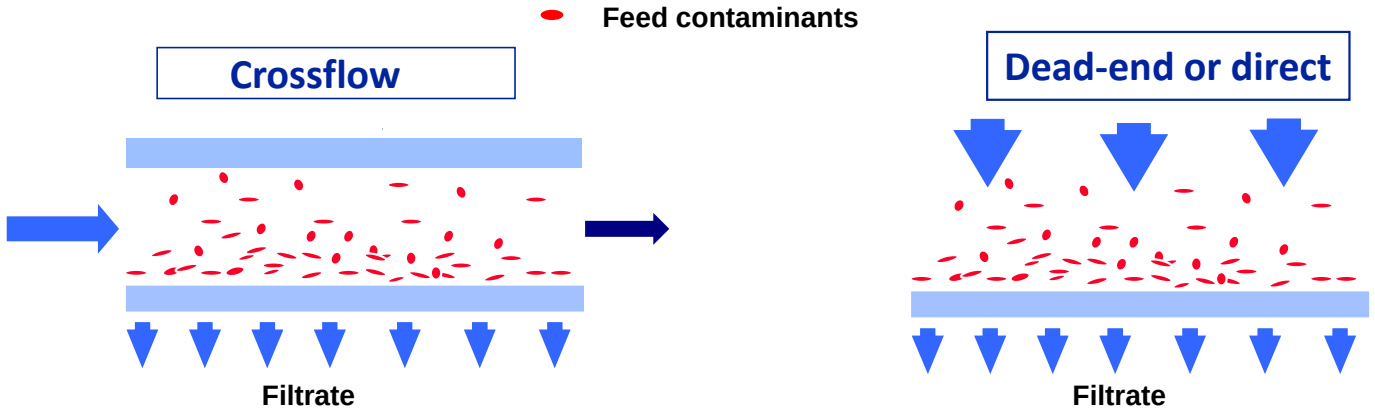
What this means to the technology needed to produce water 2/5

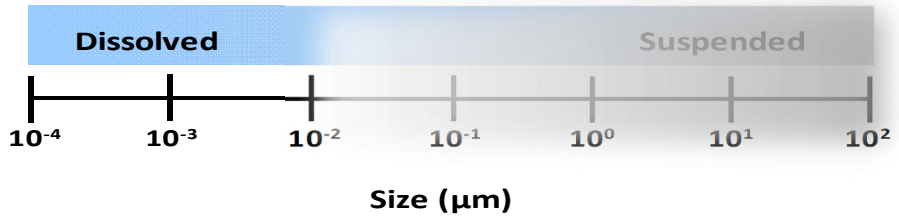
- Fundamentals of desalination



What this means to the technology needed to produce water 3/5

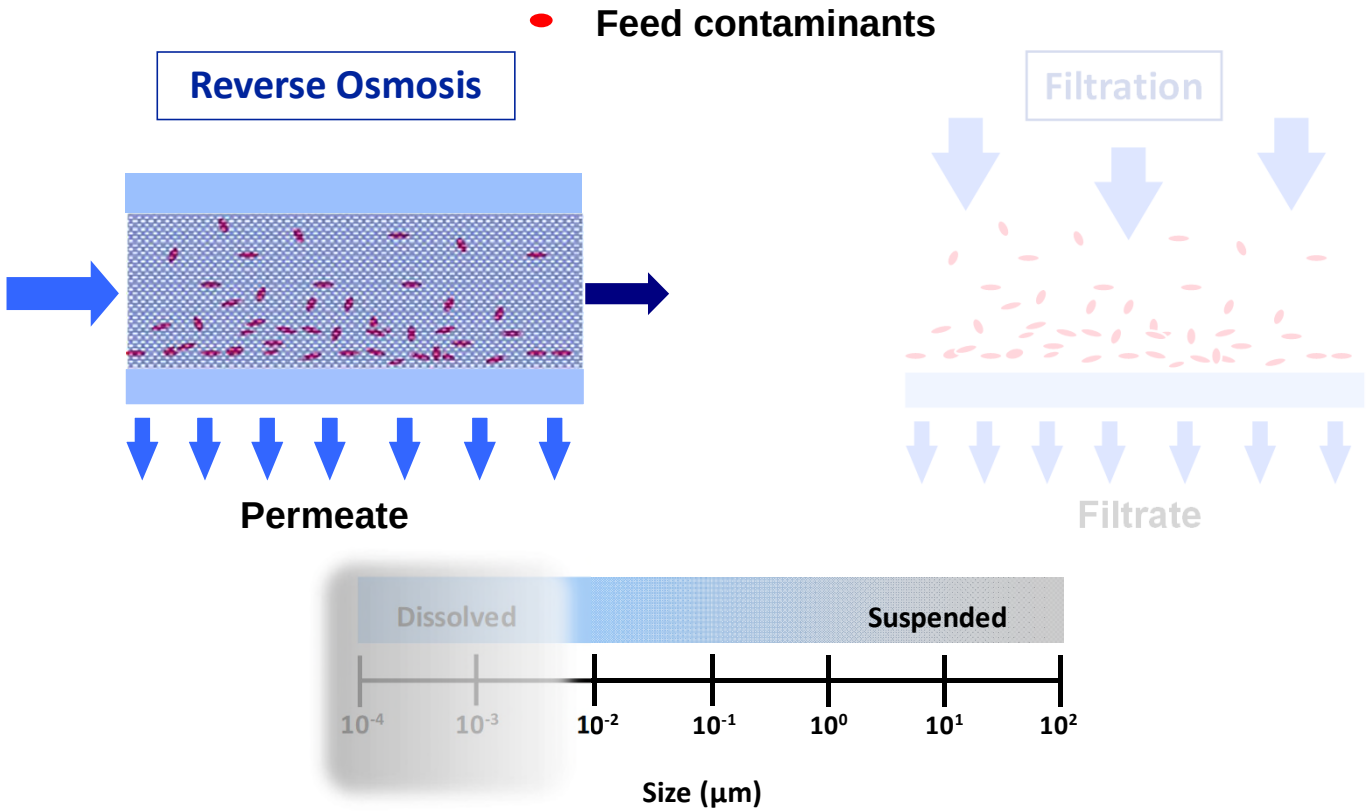
- Removal of suspended contaminants with membrane technology is critical to system reliability.





What this means to the technology needed to produce water 4/5

- Control of contaminants with membrane technology.



What this means to the technology needed to produce water 5/5

- Control of contaminants with membrane technology.

Pre-treatment

- Protection of downstream equipment, processes & functions
  - Control of inlet suspended solids (SDI >3 for RO/NF)
  - Microbial barrier
- 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

Challenges in meeting the requirements and how they can be overcome

Membrane classification

Microfiltration
- ‘Rating’: 0.05 to 1 micron
- Control of suspended solids, bacteria, plankton, algae etc

Ultrafiltration
- ‘Rating’: <0.01 – 0.05 micron
- Molecular weight cut-off (MWCO) – 5kD to 100kD
- Macromolecules (proteins, polysaccharides etc) & viruses

Nanofiltration
- Polyvalent ions & small molecules

Reveres Osmosis
- Monovalent ions

Challenges in meeting requirements and how they can be overcome 1/7

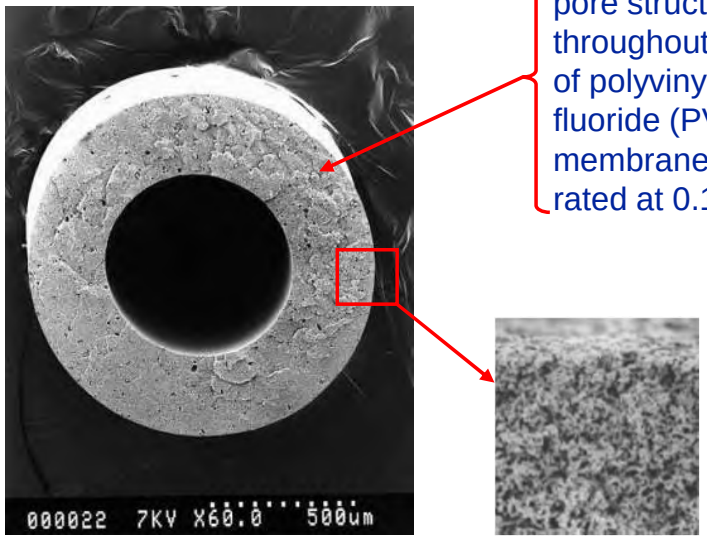
- Membrane Requirements

	PALL MEMBRANE	
Critical RO Pre treatment Parameters	MF	UF
Giardia Cysts	4.5-7 log	5-7 log
Cryptosporidium	4.5-7 log	5-7 log
MS-2 Virus	0.5-3.0 log	4.5-6 log
Particle Counts		
<2 micron	<10/ml	<10/ml
2-5 micron	<10/ml	<10/ml
5-15 micron	<1/ml	<1/ml
Filtrate Turbidity	0.01-0.03 NTU	0.01-0.03 NTU
Silt Density Index	<1	<1

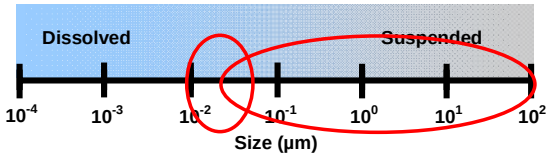
Challenges in meeting requirements and how they can be overcome 2/7

- Filtration membrane configurations

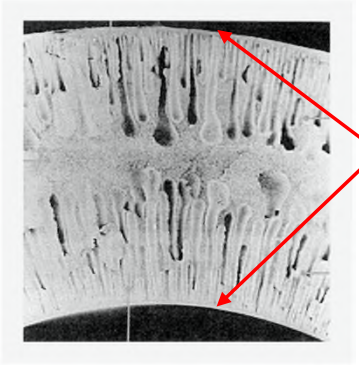
Hollow fibre microfiltration



Completely uniform pore structure throughout the thickness of polyvinylidene fluoride (PVDF) membrane construction rated at 0.1um



Hollow fibre ultrafiltration

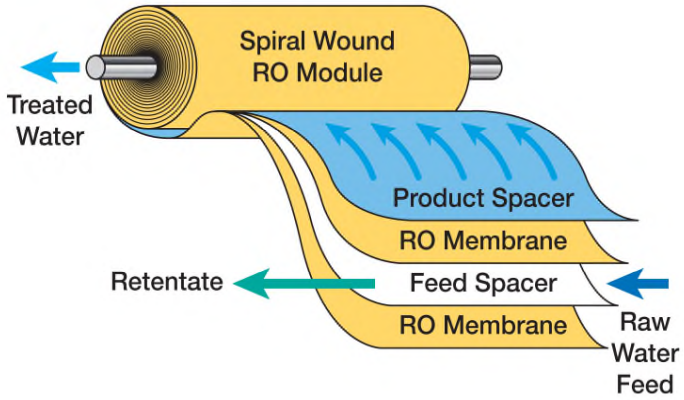


Uniform inner and outer skinned membrane with narrow pore range ensures highly efficient rejection characteristics

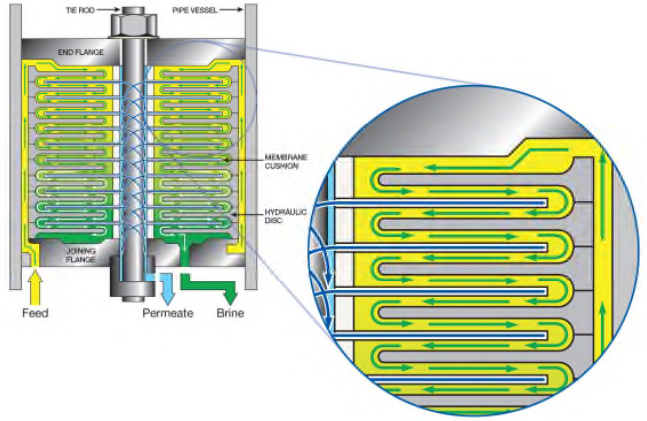
Challenges in meeting the requirements and how they can be overcome

RO membrane configurations

Conventional spiral wound composite polyamide configuration

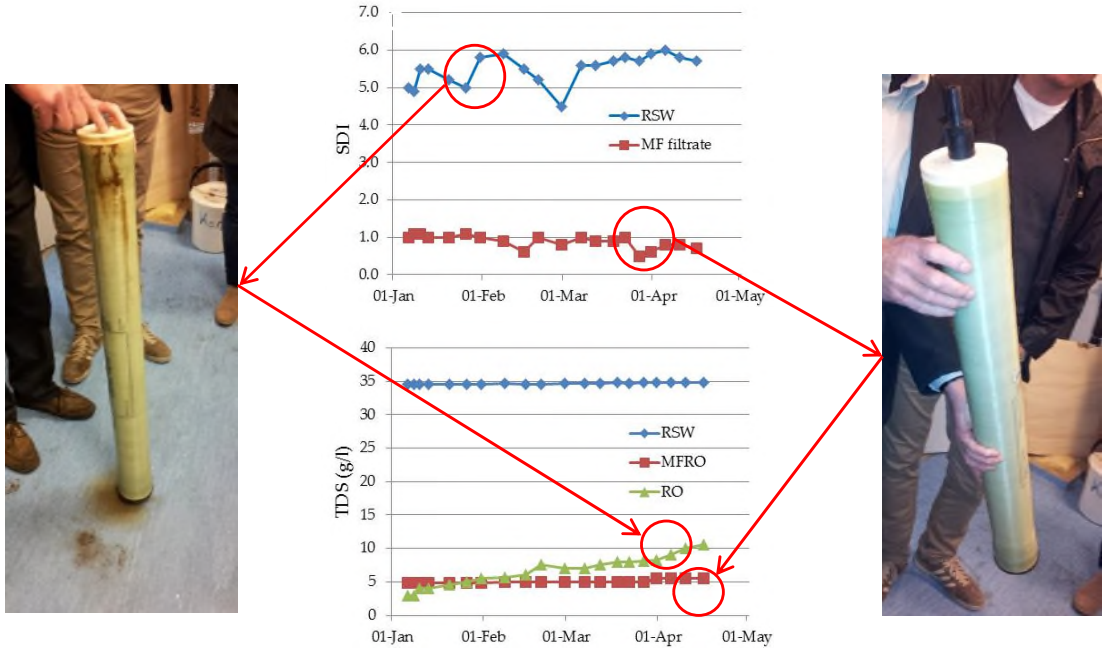


Disc Tube RO (DTRO) open channel configuration



Challenges in meeting requirements and how they can be overcome 3/7

- Sustainable operation - Consequence of inadequate pre treatment



Challenges in meeting requirements and how they can be overcome 4/7

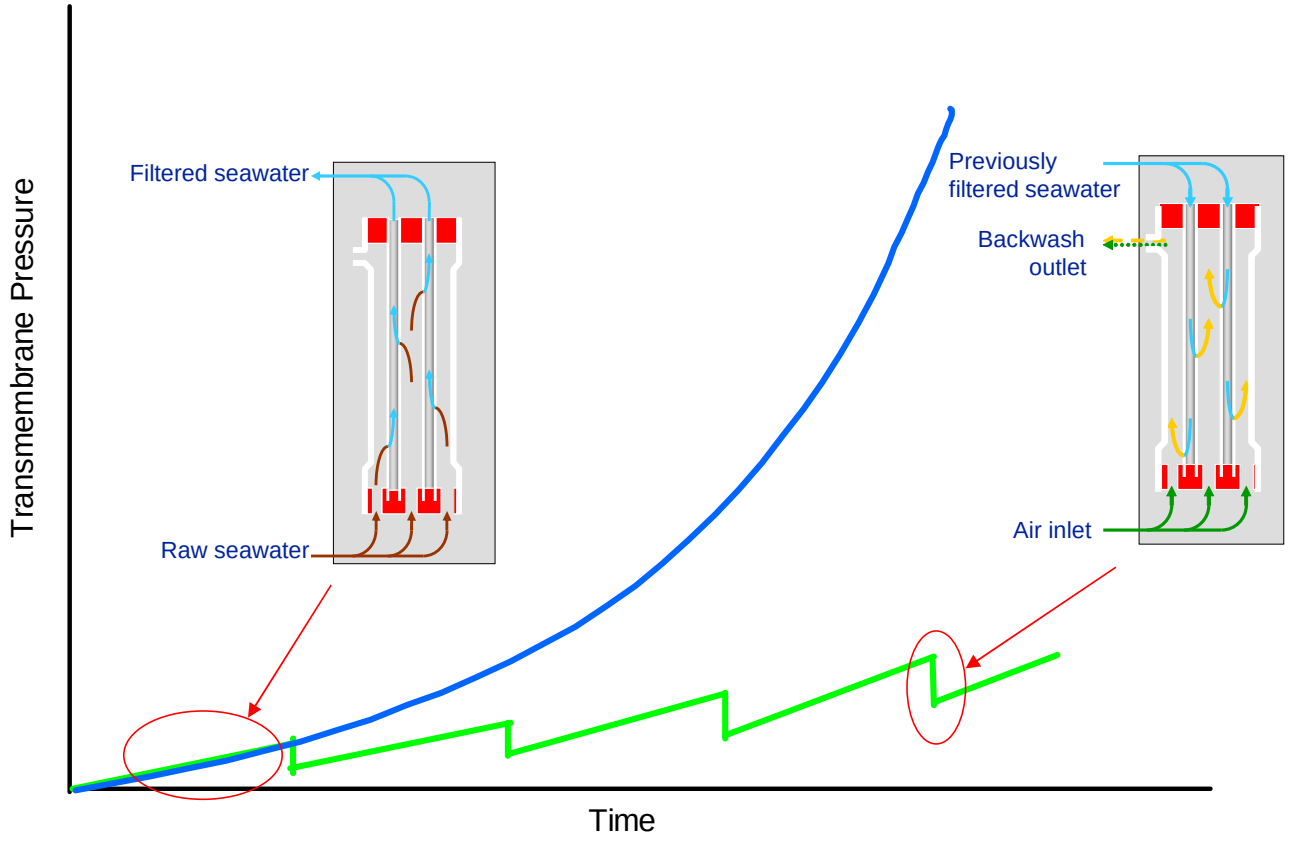
- Sustainable operation

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

Feedwater | After traditional pre-filtration | After MF

Challenges in meeting requirements and how they can be overcome 5/7

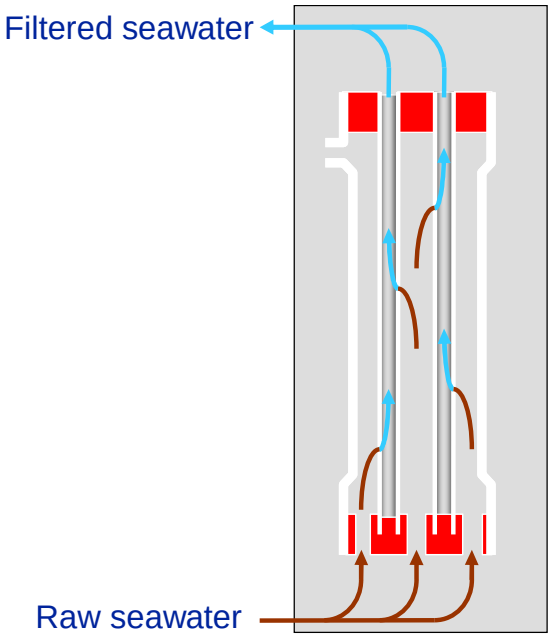
- Sustainable operation – operation and regeneration of the MF membranes.



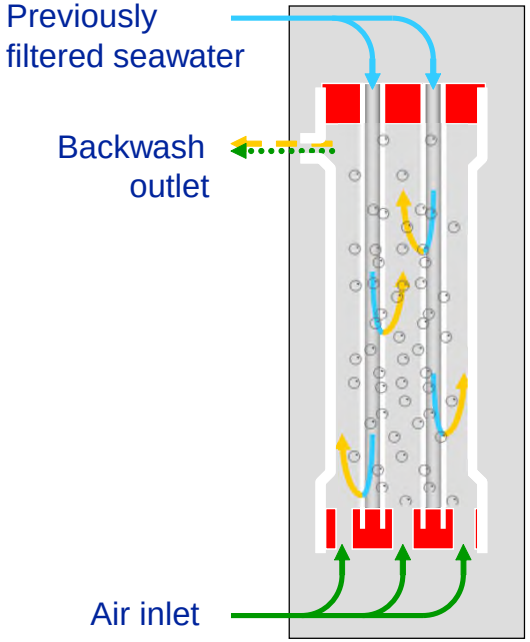
Challenges in meeting requirements and how they can be overcome 6/7

- Sustainable operation – operation and regeneration of the MF membranes.

Filtration



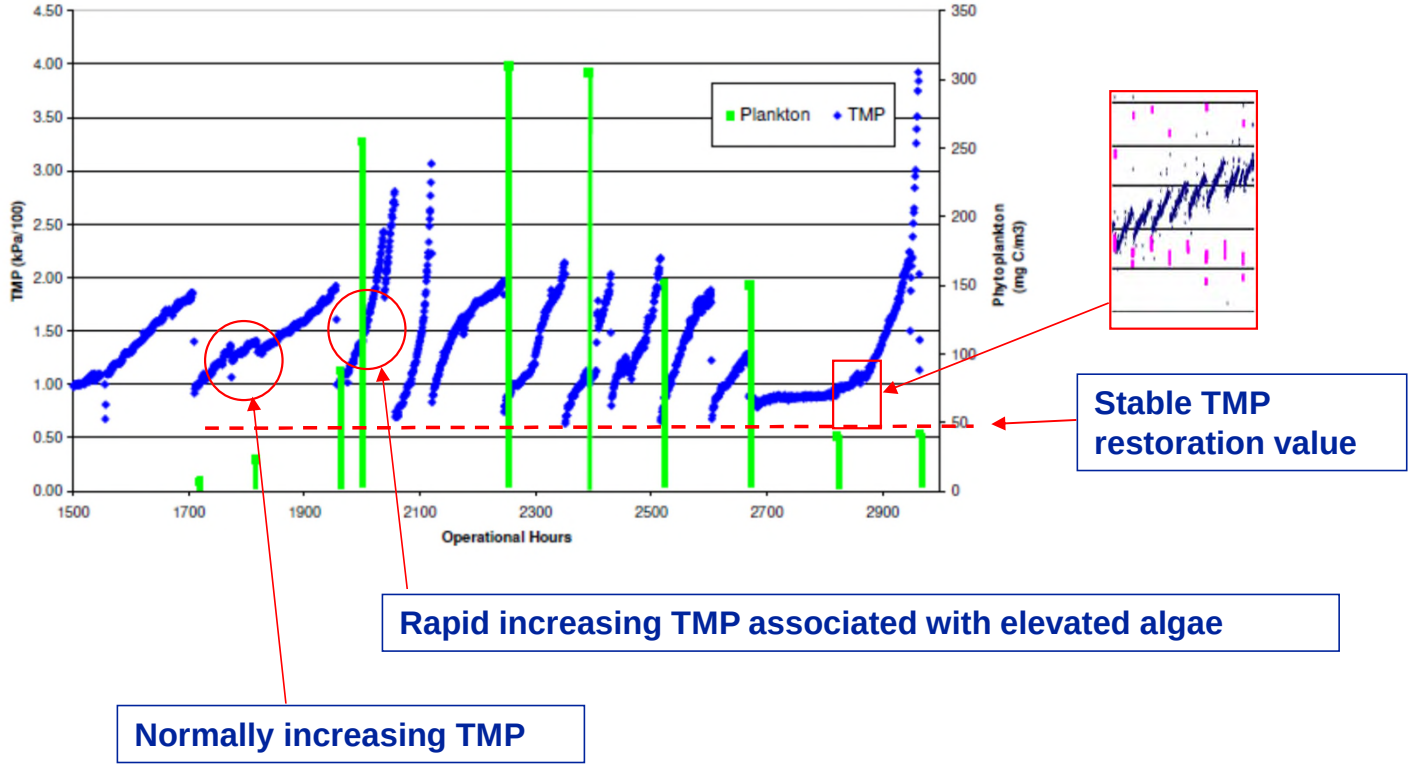
Backwash & air scrub



Challenges in meeting requirements and how they can be overcome 7/7

- Sustainable operation – Continued performance after heavy contamination

Transmembrane pressure (TMP) trends in heavily contaminated feed water



Challenges in meeting the requirements and how they can be overcome

Sustainable operation

Performance metrics

- Particulate (RO pre-treatment)
  - Turbidity < 0.1 NTU
  - SDI < 2 (RO feed requires SDI <5)
  - Total suspended solids - background
- Microbiologicals (RO pretreatment and drinking water production)
  - Bacteria > 6 log removal (99.9999%)

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

Conclusions:

- 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
  - 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

Pall Shipboard Integrated Systems

MFRO1014

MFRO1530

MFRO3560

- Make water anywhere immediately in situ
- Independence of vessel location - stay on station
- Cost saving of not pulling bunkered water
- Disaster and humanitarian relief mission benefits

- Reduced system downtime
  - Maintenance intervals lower
  - MTBF Higher
  - Reduced Manpower needs
- More balanced consistency and output of an MF system
- Potential to build lighter vessels with smaller bunker tanks

Pre-treatment upgrade

- Any existing RO system can be upgraded with a stand alone pre-filtration stage

Conclusions

- Seawater desalination is a multistage process and each stage must operate reliably and sustainably
- Pre-treatment is the most demanding process stage but is the key to sustainable operation of the overall process
- Established robust PVDF filtration membranes provide optimum protection for spiral RO modules with a wide variety of inlet solids
- Recovery of TMP in seawater with heavy concentrations of mineral, organic and microbial feed conditions
- Integration of pre-treatment and RO membranes offer reliable desalination packages with minimum footprint and weight

Customers about the Pall MFRO system:

- *"…Pall's significant contribution made to implementing this innovative solution on Type 45 destroyer before the ship was deployed to the Gulf, and the noticeable difference the MFRO has made to the ship's fresh water supplies in that challenging area, and during transit through the Suez Canal"*

- *"The additional capabilities provided by the MFRO unit is a fantastic evolution in fresh water production technology. As shown by the humanitarian assistance provided following a hurricane in the Philippines, it is a true 'make water anywhere' solution, and should set the standard for all future water generating installations.*

- *[…] if I had my way we would have this unit fitted to every ship in the fleet!"* Gareth Pritchard - Type 45 ADTA Warship Technical Authority

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Thank you.

Find me and the Pall SMEs team at stand 24.