Seawater Desalination Plant Operations, Maintenance and Trouble shooting.

By
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What are we going to learn today?

1. A Brief Introduction about Sea water, acceptable quality for drinking water and theory of Desalination.

2. Reverse osmosis technology.

3. Usage of Chemicals in Reverse osmosis Plant.

4. General Operation & Maintenance of Reverse osmosis Plant.

5. Trouble shooting of Reverse osmosis Plant.

Introduction

Characteristics of Seawater

- Seawater is generally very high in salinity and typical seawater has the following characteristics.
- Total dissolved solids - 30,000 mg/l to 45,000 mg/l.
- Total suspended solids - 50 mg/l to 250 mg/l.
- Total hardness - 500 mg/l to 2000 mg/l.
- Biodegradable oxygen demand - 50 mg/l to 75 mg/l
- pH - 7 to 8
- Presence of Micro organisms
- Small amount of Heavy metals.

Acceptable Potable Water quality

- Drinking water should be free from color, odor and turbidity.
- Total dissolved solids - <500 mg/l.
- Total suspended solids - Nil
- Total hardness - <200 mg/l.
- Biodegradable oxygen demand - Nil
- pH - 7 to 7.5
- Presence of Micro organisms should be Nil.
- Heavy metals should be Nil.

How do you convert seawater to drinking water?

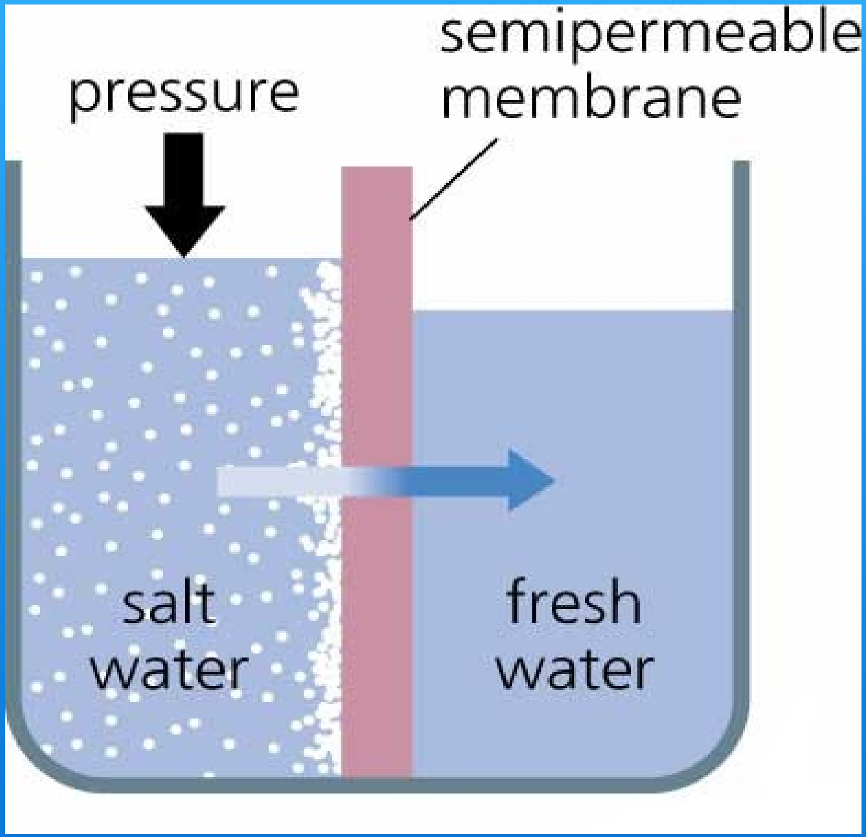
The answer is **DESALINATION**

Desalination refers to any of the several processes that remove the salt and other minerals from the water.

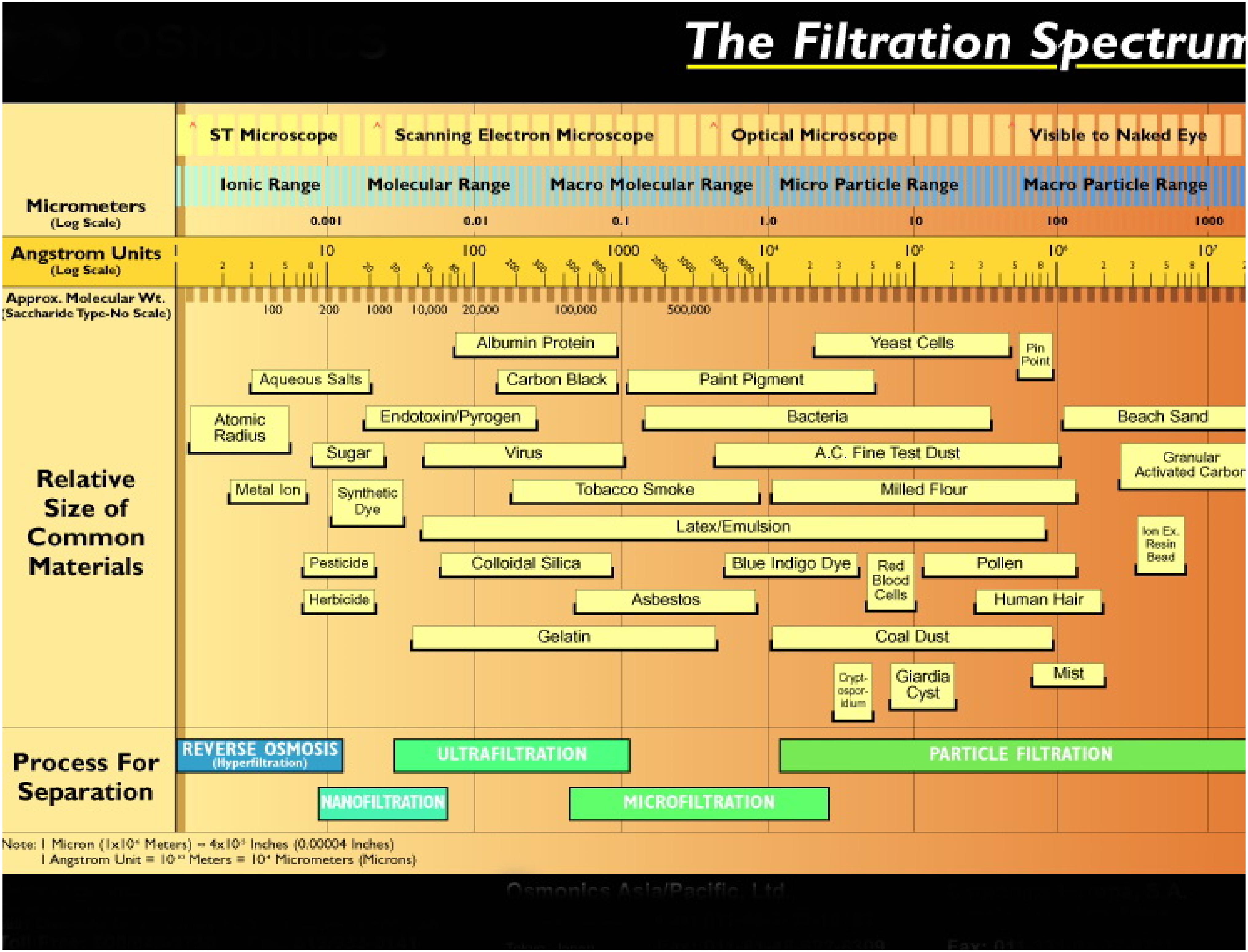
One of the best methods for desalination is Reverse osmosis and It is a widely used technology to desalinate seawater in many countries.

Reverse Osmosis

Theory of Reverse osmosis



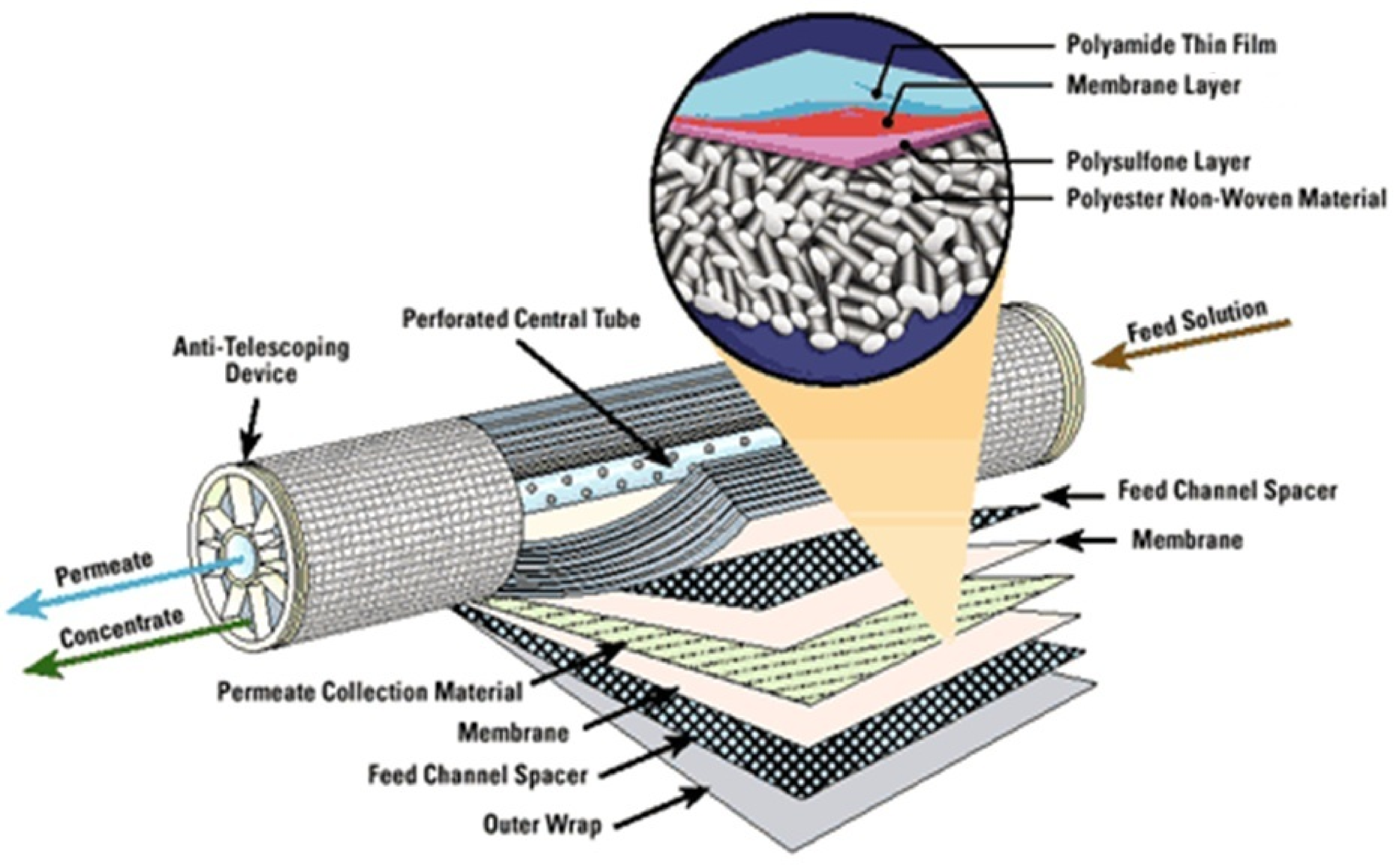
everse osmosis is a membrane filtration method that removes many types of larg olecules and ions from solution by applying pressure to the solution when it is or e one side of a selective membrane. The result is that the solute is retained on e pressurized side of the membrane and the pure solvent is allowed to pass rough the membrane.


The Filtration Spectrum
ST Microscope
Scanning Electron Microscope
Optical Microscope
Visible to Naked Eye
Micrometers
(Log Scale)
Ionic Range
Molecular Range
Macro Molecular Range
Micro Particle Range
Macro Particle Range
0.001
0.01
0.1
1.0
10
100
1000
Angstrom Units
(Log Scale)
10
100
1000
10^4
10^5
10^6
10^7
Approx. Molecular Wt.
(Saccharide Type-No Scale)
100
200
1000
10,000
20,000
100,000
500,000
Relative Size of Common Materials
Albumin Protein
Yeast Cells
Pin Point
Aqueous Salts
Carbon Black
Paint Pigment
Atomic Radius
Endotoxin/Pyrogen
Bacteria
Beach Sand
Sugar
Virus
A.C. Fine Test Dust
Granular Activated Carbon
Metal Ion
Synthetic Dye
Tobacco Smoke
Milled Flour
Latex/Emulsion
Ion Ex. Resin Bead
Pesticide
Colloidal Silica
Blue Indigo Dye
Red Blood Cells
Pollen
Herbicide
Asbestos
Human Hair
Gelatin
Coal Dust
Cryptosporidium
Giardia Cyst
Mist
Process For Separation
REVERSE OSMOSIS
(Hyperfiltration)
ULTRAFILTRATION
PARTICLE FILTRATION
NANOFILTRATION
MICROFILTRATION
Note: 1 Micron (1×10^{-6} Meters) = 4×10^{-5} Inches (0.00004 Inches)
1 Angstrom Unit = 10^{-10} Meters = 10^{-4} Micrometers (Microns)

Thin Film Composite Membrane

Thin film composite membranes are semipermeable membranes manufactured principally for use in water desalination systems. TFC material is a molecular sieve constructed in the form of film from two or more layered materials. TFC membranes are typically made out polyamide, chosen primarily for its permeability to water and relative impermeability to various dissolved impurities including salt ions and other small, unfilterable molecules.

Thin Film Composite Membrane



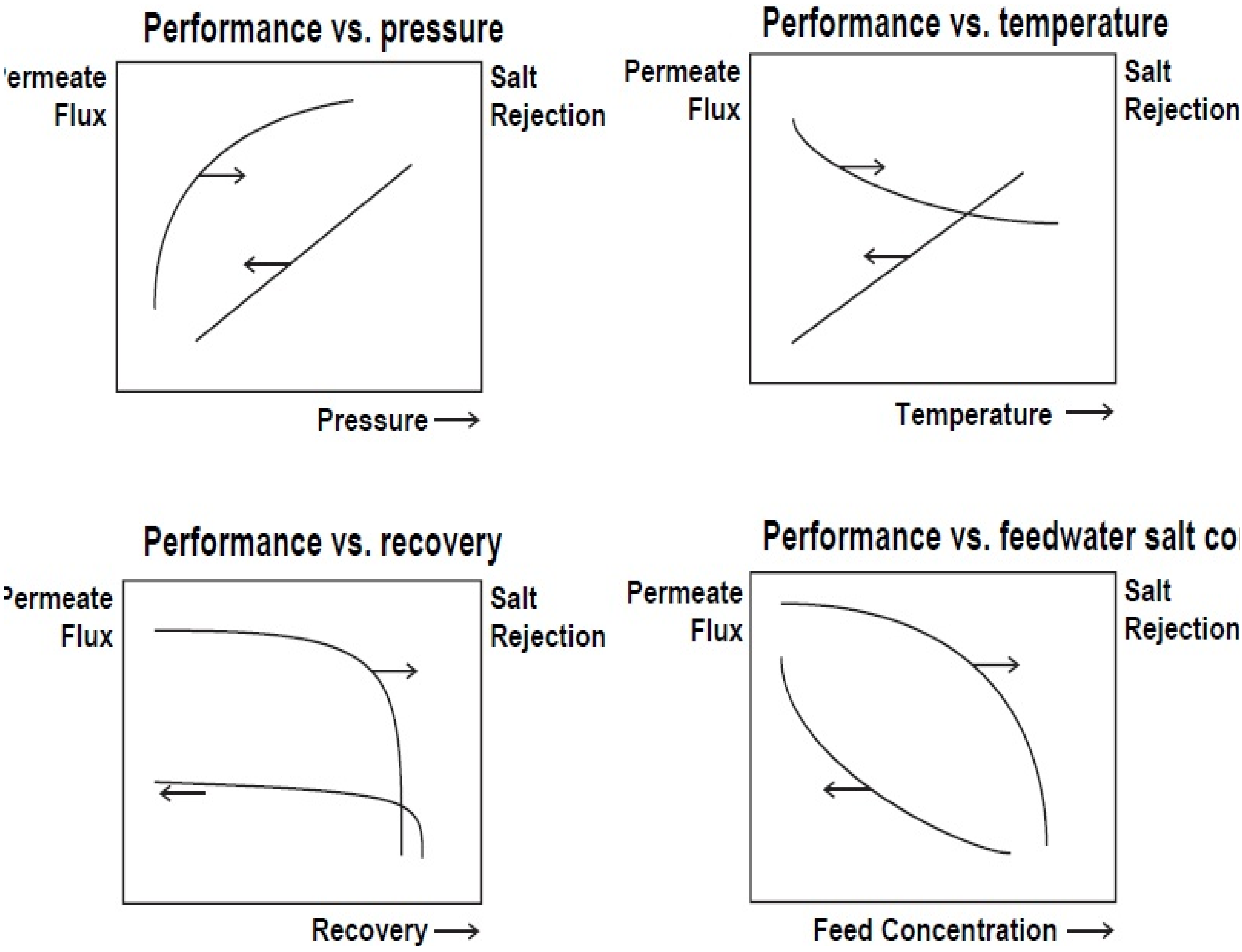
Key Terms in Reverse Osmosis system

- Permeate - The purified product water exiting the system.
- Concentrate - The concentrated salt solution existing the system.
- Feed flow - The total flow rate of source water pumped in the system.
- Recovery - The percentage of permeate achieved in a system, % Recovery = permeate flow/feed flow x 100.
- Rejection - The percentage of dissolved solids removed from the source water by the membrane.
- Passage - Opposite of "Rejection", passage is percentage of dissolved constituents in the feed water allowed to pass through the membrane.
- Flux - The rate of permeate transported per unit of membrane area, usually measured in gallons per square foot per day (gfd) or liters per square meter and hour (lmh).

Factors influencing Reverse Osmosis

Permeate Flux and salt rejection are the key performance parameters of a reverse osmosis. Under specific reference conditions, flux and rejection are intrinsic properties of membrane performance. The flux and rejection of a membrane system are mainly influenced by variable parameter including:

- Pressure - With increasing effective feed pressure, the permeate TDS will decrease while the permeate flux will increase.
- Temperature - If the temperature increases and all other parameters are kept constant, the permeate flux and the salt passage will increase.
- Recovery - In the case of increasing recovery, the permeate flux will decrease and stop if the salt concentration reaches a value where the osmotic pressure of the concentrate is as high as the applied feed pressure. The salt rejection will drop with increasing recovery.
- Feed water salt concentration - If the feed water salt concentration increases, permeate flux will decrease and the salt rejection will increase.


Performance vs. pressure
ermeate
Flux
Salt
Rejection
Pressure
Performance vs. temperature
Permeate
Flux
Salt
Rejection
Temperature
Performance vs. recovery
ermeate
Flux
Salt
Rejection
Recovery
Performance vs. feedwater salt co
Permeate
Flux
Salt
Rejection
Feed Concentration

Typical Seawater RO Design by using ROSA software for a 100m3/day plant

System Details projection

System Details

Feed Flow to Stage 1	11.91 m^3/h	Pass 1 Permeate Flow	4.17 m^3/h	Osmotic Pressure:	
Raw Water Flow to System	11.91 m^3/h	Pass 1 Recovery	35.00 %	Feed	32.15 bar
Feed Pressure	64.88 bar	Feed Temperature	25.0 C	Concentrate	50.76 bar
Flow Factor	0.85	Feed TDS	45089.51 mg/l	Average	41.45 bar
Chem. Dose (100% H2SO4)	0.00 mg/l	Number of Elements	6	Average NDP	22.31 bar
Total Active Area	245.26 M^2	Average Pass 1 Flux	17.00 lmh	Power	26.85 kW
Water Classification: Seawater (Open Intake) SDI < 5				Specific Energy	6.44 kWh/m^3

Stage	Element	#PV	#Ele	Feed Flow (m^3/h)	Feed Press (bar)	Recirc Flow (m^3/h)	Conc Flow (m^3/h)	Conc Press (bar)	Perm Flow (m^3/h)	Avg Flux (lmh)	Perm Press (bar)	Boost Press (bar)	Perm TDS (mg/l)
1	SW30HRLE-440i	1	6	11.91	64.54	0.00	7.74	62.71	4.17	17.00	0.00	0.00	166.54

Typical Seawater RO Design by using ROSA software for a 100m3/day plant

Feed/Reject/Permeate quality projection

Pass Streams (mg/l as Ion)					
Name	Feed	Adjusted Feed	Concentrate	Permeate	
			Stage 1	Stage 1	Total
NH4	0.00	0.00	0.00	0.00	0.00
K	496.00	496.00	761.74	2.46	2.46
Na	13812.00	13840.03	21259.51	60.19	60.19
Mg	1657.00	1657.00	2548.29	1.65	1.65
Ca	539.00	539.00	828.93	0.53	0.53
Sr	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00
CO3	34.26	34.26	53.62	0.00	0.00
HCO3	182.00	182.00	277.58	1.15	1.15
NO3	0.00	0.00	0.00	0.00	0.00
Cl	24868.00	24868.00	38204.30	99.18	99.18
F	0.00	0.00	0.00	0.00	0.00
SO4	3472.00	3472.00	5340.69	1.37	1.37
SiO2	1.20	1.20	1.84	0.01	0.01
Boron	0.00	0.00	0.00	0.00	0.00
CO2	0.71	0.71	1.29	0.80	0.80
TDS	45061.48	45089.51	69276.52	166.54	166.54
pH	8.10	8.10	8.11	6.31	6.31

Typical Seawater RO Design by using ROSA software for a 100m3/day plant

Design Warnings & Stage wise recovery projection

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element	Recovery	Perm Flow (m^3/h)	Perm TDS (mg/l)	Feed Flow (m^3/h)	Feed TDS (mg/l)	Feed Press (bar)
1	0.09	1.05	94.50	11.91	45089.51	64.54
2	0.08	0.89	119.19	10.87	49424.09	64.14
3	0.07	0.75	152.23	9.97	53835.99	63.80
4	0.07	0.61	196.76	9.23	58170.36	63.49
5	0.06	0.49	256.63	8.62	62267.41	63.21
6	0.05	0.39	336.83	8.13	65997.07	62.95

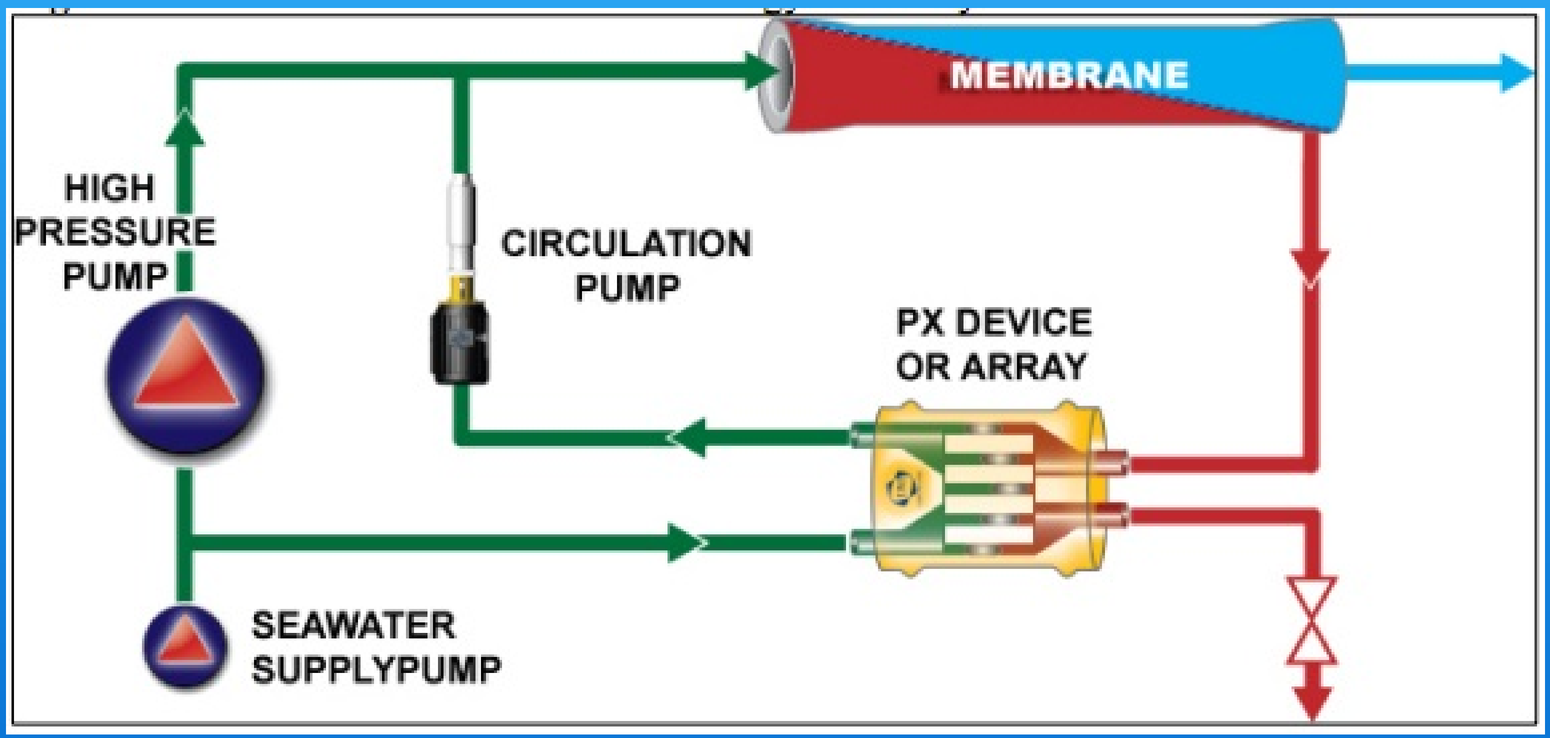
Energy Recovery System

In the previous slides, we have learnt that, for a 100m3/day of SWRO, the required feed pressure is 64.88 bar and power consumption is 26.85 Kw which are quite high.

Energy recovery /Pressure exchanger technology is designed to address the need for affordable desalination of water.

Energy recovery devices reduce the amount of energy required in membrane desalination by up to 60%, resulting in more economical production of drinking water and reduced carbon foot print.

Energy Recovery System



nergy recovery system transfers the RO reject pressure to
O feed which reduces RO high pressure pump capacity and
aves power consumption.

Chemical Usage in RO Plant

List of Chemicals used in Reverse Osmosis.

1. Pre-chlorination - NaOCl
2. pH correction - HCl
3. Dechlorination - SMBS
4. Antisclant - Specialty chemical
5. Post chlorination - NaOCl
6. pH correction - $NaHCO_3$

Pre Chlorination

Chlorination for pretreatment has been applied usually where biological fouling prevention is required.

Chlorine is added continuously at the intake, and a reaction time of 20 - 30 min should be allowed.

A free residual chlorine concentration of 0.5 - 1.0 mg/l should be maintained through the whole pretreatment line. Hence Chlorine dosage of 2.0 - 3.0 mg/l is recommended.

Chlorine is most commonly available as the chlorine gas and hypochlorites of sodium and calcium.

pH Correction by Acid

Adding acid to feed solutions changes Total alkalinity, CO_2 content and pH in the feed water which will result in decreasing the LSI value (Indicator of scaling potential for calcium carbonate over membrane).

Acid dosing ensures the heavy metals present in the feed water are in soluble condition and increases its solubility level during reverse osmosis process which will reduce the risk of heavy metal scaling over the membrane.

Most commonly used acids are Hydrochloric acid and Sulphuric acid. pH of feed water is recommended to be maintained around 6.5

Dechlorination

When TFC membrane is used in RO process, the feed must be dechlorinated to prevent oxidation of the membrane.

Sodium metabisulfite is commonly used for removal of free chlorine and as a biostatic.

In theory, 1.34 mg of sodium metabisulfite will remove 1.0 mg of free chlorine. In practice, however, 3.0 mg of sodium metabisulfite is normally used to remove 1.0 mg of free chlorine.

Anti scalant

Antiscalants/Scale Inhibitors can be used to control carbonate scaling, sulfate scaling and calcium fluoride scaling. There are generally three different types of scale inhibitors : sodium hexametaphosphate, organophosphonates and polyacrylates.

Polymeric organic scale inhibitors are more effective than other scale inhibitors.

In SWRO plant, scaling is not a major problem as in brackish water plants due to its lesser recovery. However, for safety reasons, Antiscalant is recommended at a dosage level of 1.0 - 2.0mg/l.

Post chlorination

Chlorination for post treatment has been applied when the treated water is used for drinking and it is done to avoid bacterial growth in the treated water storage.

A free residual chlorine concentration of 0.5 - 1.0 mg/l should be maintained in the treated water. Hence Chlorine dosage of 0.5 - 1.0 mg/l is recommended.

Chlorine is most commonly available as the chlorine gas and hypochlorites of sodium and calcium.

pH Correction by Alkali

The treated water pH will always be in acidic condition due to the removal of hydroxyl ions during reverse osmosis process.

A neutral pH has to be maintained in the treated water when the treated water is used for drinking purpose.

pH correction can be done by Sodium Bicarbonate as it is safe for human consumption.

General Operation & Maintenance of Reverse Osmosis Plant

Importance of Proper Operation & Maintenance

- Successful long term performance of the membrane system depends on proper operation and maintenance of the system. This includes the initial plant start up and operational start-ups and shut-downs.
- Preventing fouling, scaling, plugging and degradation, e.g. by oxidation, of the membranes is not only a matter of system design, but also a matter of proper commissioning and operation.
- Record keeping and data normalization is required in order to know the actual plant performance and to enable corrective measures when necessary. Complete and accurate records are also required in case of a system performance warranty claim.

Operation Start up

- *Once a membrane system has been started up, ideally it should be kept running at constant conditions. In reality, membrane plants have to be shut down and restarted frequently.*
- *Start/stop cycles result in pressure and flow changes, causing mechanica stress to the membrane elements. Therefore, the start/stop frequency should be minimized, and the regular operation start-up sequence shoul be as smooth as possible.*
- *In principle, the same sequence is recommended as for the initial start-up. Most important is a slow feed pressure increase, especially for seawater plants.*
- *The normal start-up sequence is typically automated through the use of programmable controllers and remotely operated valves. The calibration of instruments, the function of alarms and safety devices, corrosion prevention and leak-free operation have to be checked and maintained o a regular basis.*

Operation Shutdown

- *When the membrane system is shutdown, the system must be flushed preferentially with permeate water, to remove the high salt concentration from the pressure vessels until concentrate conductivity matches flushing feed water conductivity.*
- *Flushing is done at low pressure (about 40 psi/3 bar). A high feed flow rate is sometimes beneficial for a cleaning effect; however, the maximum pressure drop per element and per multi-element vessel as stated on the membranes product information sheet must not be exceeded.*
- *The water used for flushing shall contain no chemicals used for the pretreatment, especially no scale inhibitors. Therefore, any chemical injection is stopped before flushing. After flushing the system, the feed valves are closed completely. If the concentrate line ends into a drain below the level of the pressure vessels, then an air break should be employed in the concentrate line at a position higher than the highest pressure vessel.*

During Shutdown

When the system must be shut down for longer than 48 hours, take care that:

- *The elements do not dry out. Dry elements will irreversibly lose flux.*
- *The system is adequately protected against micro-biological growth, or regular flushing is carried out every 24 hours.*
- *When applicable, the system is protected against temperature extremes.*

The membrane plant can be stopped for 24 hours without preservation and precautions for microbiological fouling. If feedwater for flushing every 24 hours is not available, preservation with chemicals is necessary for longer stops than 48 hours.

Adjustment of Operation parameters

- *The normal way of operating RO plants is to keep the flows and thus the recovery constant at the design values. Any change in the membrane flux, e.g. by temperature or fouling, are compensated by adjusting the feed pressure. However, the maximum allowed feed pressure as specified on the product information sheet, and the permeate TDS are often the limiting factors.*
- *Decreasing feed water temperature can be compensated by increasing the feed pressure up to the maximum. Once the maximum pressure is reached, a further decreasing temperature causes the permeate flow to decrease.*
- *Increasing temperature is compensated by lowering the feed pressure. This is only possible, however, as far as the tolerated permeate TDS is not exceeded.*

Record Keeping

- *In order to be able to follow the performance of the RO unit, it is necessary that all relevant data are collected, recorded and kept on file. Apart from keeping track of the performance, the log sheets are also valuable tools for troubleshooting, and are needed in the cases of warranty claims.*

RO Operating Data - 1

he following data must be recorded and logged into an appropriate logsheet t least once per shift.

- Date, time and hours of operation.
- Pressure drop per filter cartridge and per stage.
- Feed, permeate and concentrate pressure of each stage.
- Permeate and concentrate flows of each stage.
- Conductivity of the feed, permeate and concentrate streams for each stage.
- ermeate conductivity of each pressure vessel weekly.
- TDS of feed, permeate and concentrate streams for each stage.
- pH of the feed, permeate and concentrate streams.
- Silt Density Index (SDI) or turbidity of the RO feed stream, or both.
- Water temperature of the feed stream.
- Stiff and Davis Stability Index (S&DSI) of the concentrate stream from the ast stage.

RO Operating Data - 2

The following data must be recorded and logged into an appropriate logsheet at least once per shift.

- *Calibration of all gauges and meters based on manufacturer's recommendations as to method and frequency but no less frequent than once every three months.*
- *Any unusual incidents, for example, upsets in SDI, pH and pressure and shutdowns.*
- *Complete water analysis of the feed, permeate and concentrate streams and the raw water at start-up and every week thereafter.*

Typical Logsheet

		Design					
	Date						
	Time						
	Operating hours						
Pressure (psig)	Feed Array 1						
	Feed Array 2						
	Permeate						
	Concentrate						
Δ p (psid)	Cartridge						
	Array 1						
	Array 2						
Flow (gpm)	Feed						
	Permeate						
	Concentrate						
	Recovery (%)						
Conduc-tivity (mS/m)	Feed						
	Permeate						
	Concentrate						
TDS (mg/l)	Feed						
	Permeate						
	Concentrate						
	Salt Passage (%)						
pH	Raw Water						
	Feed						
	Concentrate						
	Permeate						
Feed	Cl_2 (mg/l)						
	SDI						
	Turbidity (NTU)						
	Temperature (°C)						
Acid	Level						
	Refill (l)						
	Consumption (g/m³)						
Inhibitor	Level						
	Refill (l)						
	Consumption (g/m³)						
Normal-ized	Permeate flow (gpm)						
	Salt Passage (%)						
	Remarks						

Pre Treatment operating Data

Since the RO system performance depends largely on the proper operation of the pretreatment, the operating characteristics of the pretreatment equipment should be recorded. Typically, the following items must be recorded:

- *Total residual chlorine concentration in the RO feed (daily - unless known to be completely absent).*
- *Discharge pressure of any well or booster pumps (twice a day).*
- *Pressure drop of all filters (twice a day).*
- *Consumption of acid and any other chemicals (daily - if used).*
- *Calibration of all gauges and meters based on manufacturers recommendations as to method and frequency but no less frequent than once every 3 months.*
- *Any unusual incidents, for example, upsets and shutdowns as they occur.*

Maintenance Log

- Record routine maintenance.
- Record mechanical failures and replacements.
- Record any change of membrane element locations with element serial umbers.
- Record replacements or additions of RO devices.
- Record calibration of all gauges and meters.
- Record replacement or additions of pretreatment equipment, for example artridge filters and include date, brand name and nominal rating.
- Record all cleanings of RO membranes. Include date, duration of cleaning, leaning agent(s) and concentration, solution pH, temperature during leaning, flow rate and pressure.

Membrane Fouling & Scaling

The surface of a reverse osmosis (RO) membrane is subject to fouling by foreign materials that may be present in the feed water, such as hydrates of metal oxides, calcium precipitates, organics and biological matter. The term "fouling" includes the build-up of all kinds of layers on the membrane surface, including scaling.

Pretreatment of the feed water prior to the RO process is basically designed to reduce contamination of the membrane surfaces as much as possible. This is accomplished by installing an adequate pretreatment system and selecting optimum operating conditions, such as permeate flow rate, pressure and permeate water recovery ratio.

Reasons for Membrane Fouling & Scaling

Fouling & Scaling of the membrane surfaces is caused by:

- *Inadequate pretreatment system*
- *Pretreatment upset conditions*
- *Improper materials selection (pumps, piping, etc.)*
- *Failure of chemical dosing systems*
- *Inadequate flushing following shutdown*
- *Improper operational control*
- *Slow build-up of precipitates over extended periods (barium, silica)*
- *Change in feed water composition*
- *Biological contamination of feed water*

The fouling of membrane surfaces manifests itself in performance decline, lower permeate flow rate and/or higher solute passage. Increased pressure drop between the feed and concentrate side can be a side effect of fouling.

When to Clean?

In normal operation, the membrane in reverse osmosis elements can become fouled by mineral scale, biological matter, colloidal particles and insoluble organic constituents. Deposits build up on the membrane surfaces during operation until they cause loss in normalized permeate flow, loss of normalized salt rejection, or both.
Elements should be cleaned when one or more of the below mentioned parameters are applicable:

- *The normalized permeate flow drops 10%*
- *The normalized salt passage increases 5 - 10%*
- *The normalized pressure drop (feed pressure minus concentrate pressure) increases 10 - 15%*

If you wait too long, cleaning may not restore the membrane element performance successfully. In addition, the time between cleanings becomes shorter as the membrane elements will foul or scale more rapidly.

Cleaning chemicals for various Floulant/Scalant

- *Acid cleaners and alkaline cleaners are the standard cleaning chemicals. Acid cleaners are used to remove inorganic precipitates/scaling (including iron), while alkaline cleaners are used to remove organic fouling (including biological matter).*
- *Sulfuric acid should not be used for cleaning because of the risk of calcium sulfate precipitation.*
- *Specialty cleaning chemicals may be used in cases of severe fouling or unique cleaning requirements. Preferably, RO permeate should be used for the preparation cleaning solutions, however, prefiltered raw water may be used.*
- *The feed water can be highly buffered, so more acid or hydroxide may be needed with feed water to reach the desired pH level, which is about 2 for acid cleaning and about 12 for alkaline cleaning.*

Cleaning Solution composition for various floulant/scalant

Simple cleaning solutions

Cleaner ulant	0.1% (W) NaOH and pH 12, 35°C max. or 1.0% (W) Na_4EDTA and pH 12, 35°C max.	0.1% (W) NaOH and pH 12, 35°C max. or 0.025% (W) Na-DSS and pH 12, 35°C max.	0.2% (W) HCl, 25°C and pH 1 - 2	1.0% (W) $Na_2S_2O_4$, 25°C and pH 5	0.5% (W) H_3PO_4, 25 °C and pH 1 - 2	1.0% (W) NH_2SO_3H , 2 and pH 3 -
rganic Salts (for example, $CaCO_3$)			Preferred	Alternative	Alternative	
lfate Scales ($CaSO_4$, $BaSO_4$)	OK					
tal Oxides (for example, iron)				Preferred	Alternative	Alternative
rganic Colloids (silt)		Preferred				
ica	Alternative	Preferred				
ofilms	Alternative	Preferred				
ganic	Alternative	Preferred				

Cleaning Procedure

here are six steps in the cleaning of elements:

Make up cleaning solution as mentioned in chemical composition table.

Low-flow pumping. Pump mixed, preheated cleaning solution to the vessel at onditions of low flow rate and low pressure to displace the process water. Use nly enough pressure to compensate for the pressure drop from feed to oncentrate. The pressure should be low enough that essentially no or little ermeate is a. A low pressure minimizes redeposition of dirt on the membrane. ump the concentrate, as necessary, to prevent dilution of the cleaning solution.

Recycle. After the process water is displaced, cleaning solution will be present the concentrate stream. Then recycle the concentrate and permeate to the eaning solution tank and allow the temperature to stabilize. Measure the pH of ne solution and adjust the pH if needed.

Cleaning Procedure

4. Soak. Turn the pump off and allow the elements to soak. Sometimes a soak period of about 1 hour is sufficient. For difficult fouling an extended soak period is beneficial; soak the elements overnight for 10-15 hours. To maintain a high temperature during an extended soak period, use a slow recirculation rate.

5.High-flow pumping. Feed the cleaning solution for 30-60 minutes. The high flow rate flushes out the foulants removed from the membrane surface by the cleaning. If the elements are heavily fouled, a flow rate which is 50 percent higher than shown in Chemical solution composition Table may aid cleaning. At higher flow rates, excessive pressure drop may be a problem. The maximum recommended pressure drops are 15 psi per element or 50 psi per multi-element vessel, whichever value is more limiting. Cleaning is recommended when the pressure drop increases 15%. Pressure drop above 50 psi in a single stage may cause significant membrane damage.

Cleaning Procedure

6. Flush out. RO permeate or deionized water is recommended for flushing out the cleaning solution. Prefiltered raw water or feed water should be avoided as its components may react with the cleaning solution: precipitation of foulants may occur in the membrane elements. The minimum flush out temperature is 20°C.

Membrane Preservation & Storage

Long Storage

Any membrane that has been used and removed from the pressure vessel for storage must be preserved in a preservation solution as follows:

- *Use the standard storage solution of 1% food-grade SMBS (not cobalt-activated) in good-quality water (preferably reverse osmosis permeate).*

- *Soak the element for 1 h in the solution; keep it in a vertical position so that the entrapped air can escape. Allow it to drip out, and seal it into an oxygen barrier plastic bag. Do not fill the plastic bag with the preservation solution, the moisture in the element is sufficient, and leaking bags might create a problem during transport.*

- *Identify the element and the preservation solution on the outside of the bag.*

Membrane Preservation & Storage

Long Storage

• Re-preserved elements should be visually inspected for biological growth every three months. If the preservation solution appears to be not clear the element should be re-preserved and repacked as mentioned in the previous slide.

• The pH of the preservation solution must never drop below pH 3. In the absence of a buffer such as is used in the original preservative for wet elements, a pH decrease can occur when bisulfite is oxidized to sulfuric acid. Therefore, the pH of the bisulfite preservation solution should be spot checked at least every 3 months. Re-preservation is mandatory when the pH is 3 or lower.

Membrane Preservation & Storage

Short Storage

(It is already explained in the previous slide under the topic "During Shutdown")

When the system must be shut down for longer than 48 hours, take care that:

- *The elements do not dry out. Dry elements will irreversibly lose flux.*
- *The system is adequately protected against micro-biological growth, or regular flushing is carried out every 24 hours.*
- *When applicable, the system is protected against temperature extremes.*

The membrane plant can be stopped for 24 hours without preservation and precautions for microbiological fouling. If feedwater for flushing every 24 hours is not available, preservation with chemicals is necessary for longer stops than 48 hours.

Troubleshooting of Reverse Osmosis Plant

List of Typical Problems

Trouble with the performance of an RO system normally means at least one of the following:

• Loss of normalized permeate flow rate; in practice this is normally seen as a feed pressure increase in order to maintain the permeate output.

• Increase in normalized solute passage; in RO this is typically associated with an increase in permeate conductivity.

• Increase in pressure drop: the difference between feed pressure and concentrate pressure at constant flow rate becomes larger.

From such symptoms, their location and kind of occurrence, the causes of the trouble can often be determined. In the following slide, the mentioned three main troubles are discussed systematically.

Troubleshooting Grid

hanges of the permeate flow, the salt passage and the differential pressure are ymptoms which can be attached to specific causes in many cases.

though, the symptoms of different causes may over-lap in reality, and the ymptoms are more or less pronounced in specific cases.

n overview of symptoms, their possible causes and corrective measures are ven in the troubleshooting grid of the following table.

Troubleshooting Grid

Symptoms, causes and corrective measures

Permeate flow	Salt passage	Differential pressure	Direct cause	Indirect cause	Corrective measure
↑	⇑	→	Oxidation damage	Free chlorine, ozone, $KMnO_4$	Replace element
↑	⇑	→	Membrane leak	Permeate backpressure; abrasion	Replace element, improve cartridge filtration
↑	⇑	→	O-ring leak	Improper installation	Replace o-ring
↑	⇑	→	Leaking product tube	Damaged during element loading	Replace element
⇓	↑	↑	Scaling	Insufficient scale control	Cleaning, scale control
⇓	↑	↑	Colloidal fouling	Insufficient pretreatment	Cleaning, improve pretreatment
↓	→	⇑	Biofouling	Contaminated raw water, insufficient pretreatment	Cleaning, disinfection, improve pretreatment
⇓	→	→	Organic fouling	Oil; cationic polyelectrolytes water hammer	Cleaning, improve pretreatment
⇓	↓	→	Compaction	Water hammer	Replace element or add elements

` Increasing ↓ Decreasing → Not changing ⇑ Main symptom

The End

Thank You.