Training Course on Planning of Desalination plant using R.O system

نقـــابة المهندسيـــن الأردنيين

Jordan Engineers Association

Madaba 18 May – 1 June

تعريف بالمحاضر

- م .محمد زياد الخطيب
  - هندسة المياه والبيئة / جامعة البلقاء التطبيقيه
  - يعمل كمهندس مشاريع في شركة البحر الابيض لمعالجة المياه

- قدم العديد من الدورات التدريبيه في تخطيط وتصميم محطات تحلية المياه :
  - نقابة المهندسين الاردنيين (عمان ، اربد ، معان ، الزرقاء)
  - الجامعـــــة الاردنيــــه

- محاضر في يوم علمي ببحثه عن تحلية المياه في الاردن بين المشاكل والحلول ، الواقع والمستقبل

- عضو جمعية التحلية الاردنيه / لجنة البحث العلمي
- عضو لجنة المياه والبيئة في نقابة المهندسين

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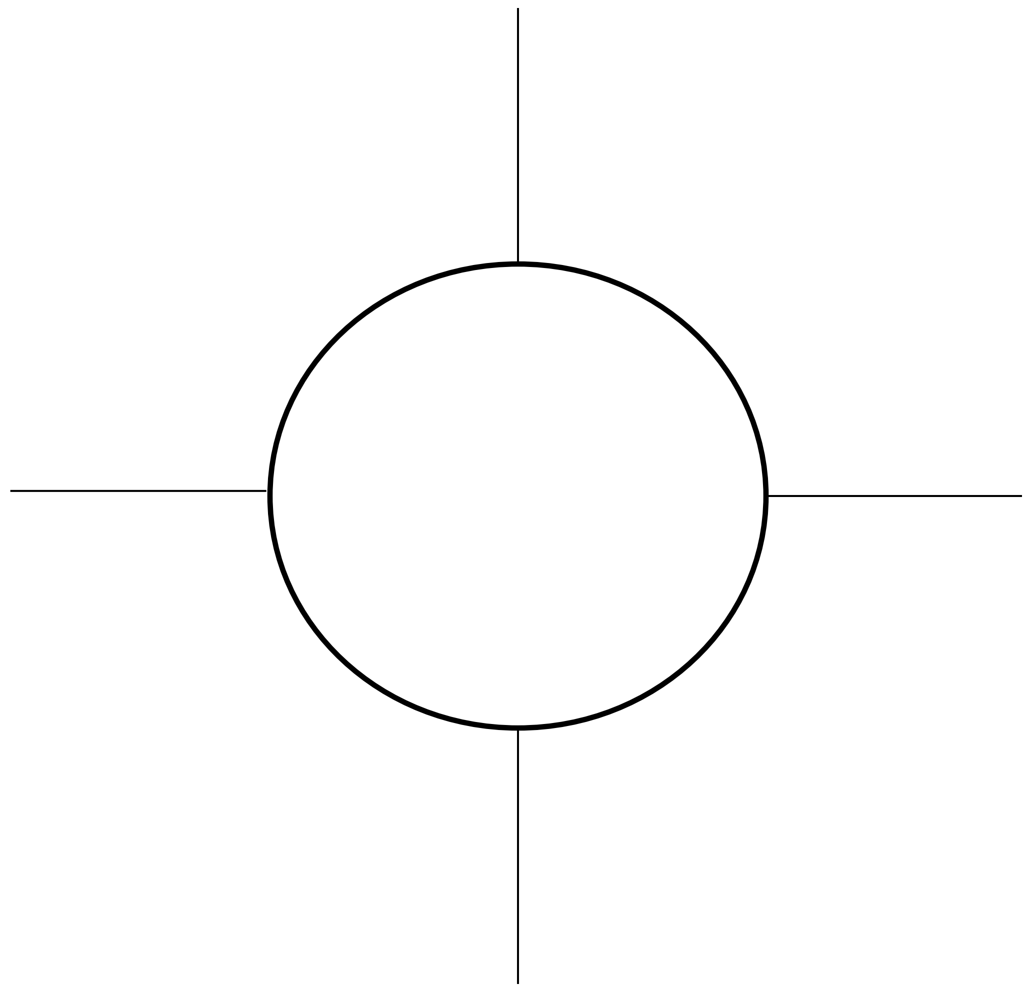
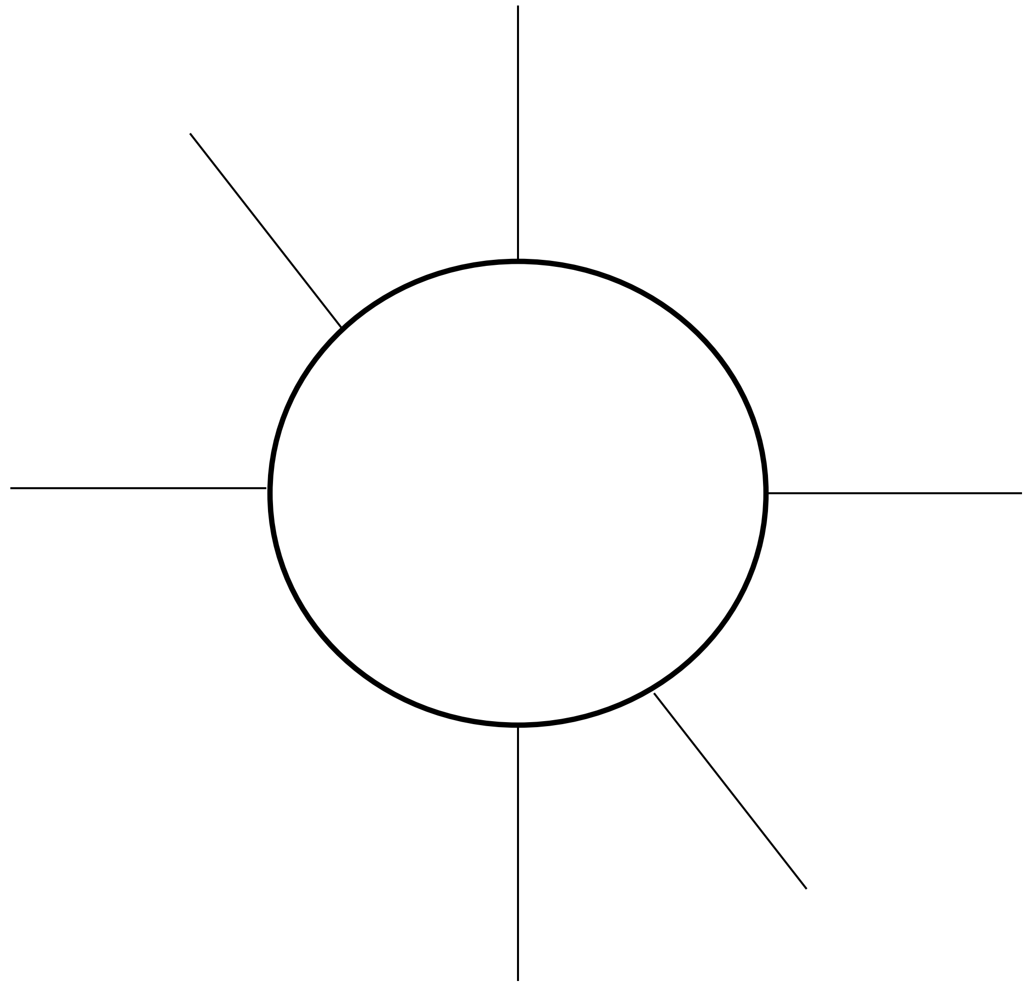
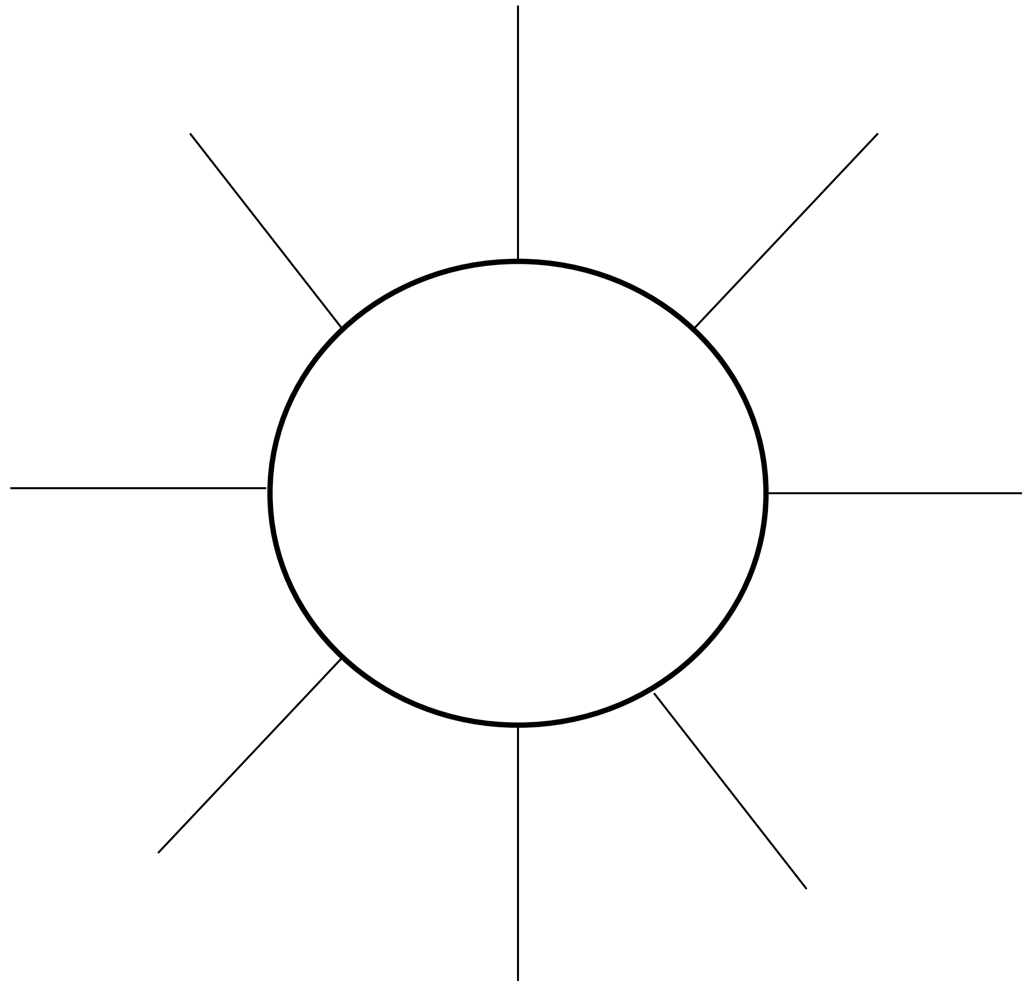
Training Course on Planning of Desalination plant using R.O system

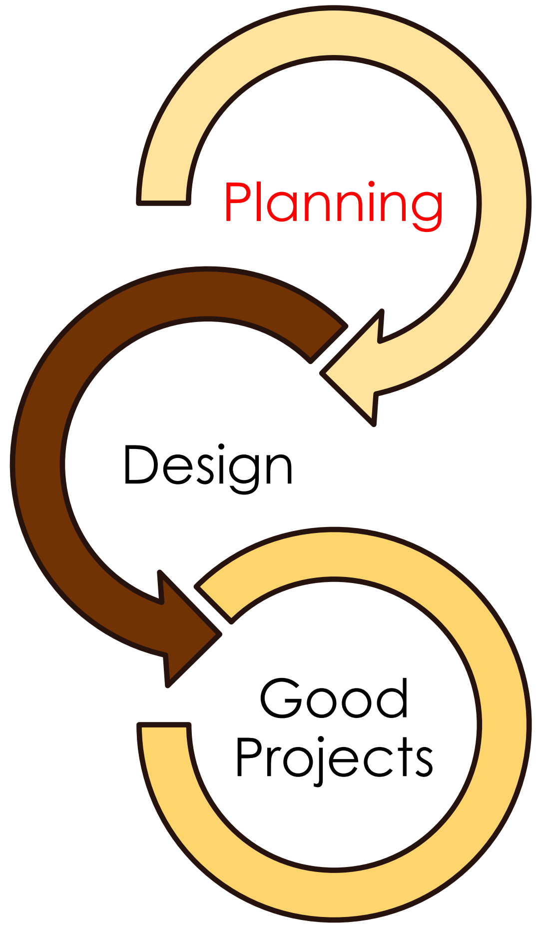
- Introduction to Desalination
- Introduction to Reverse osmosis
- Pretreatment
- R.O
- Post treatment
- Others



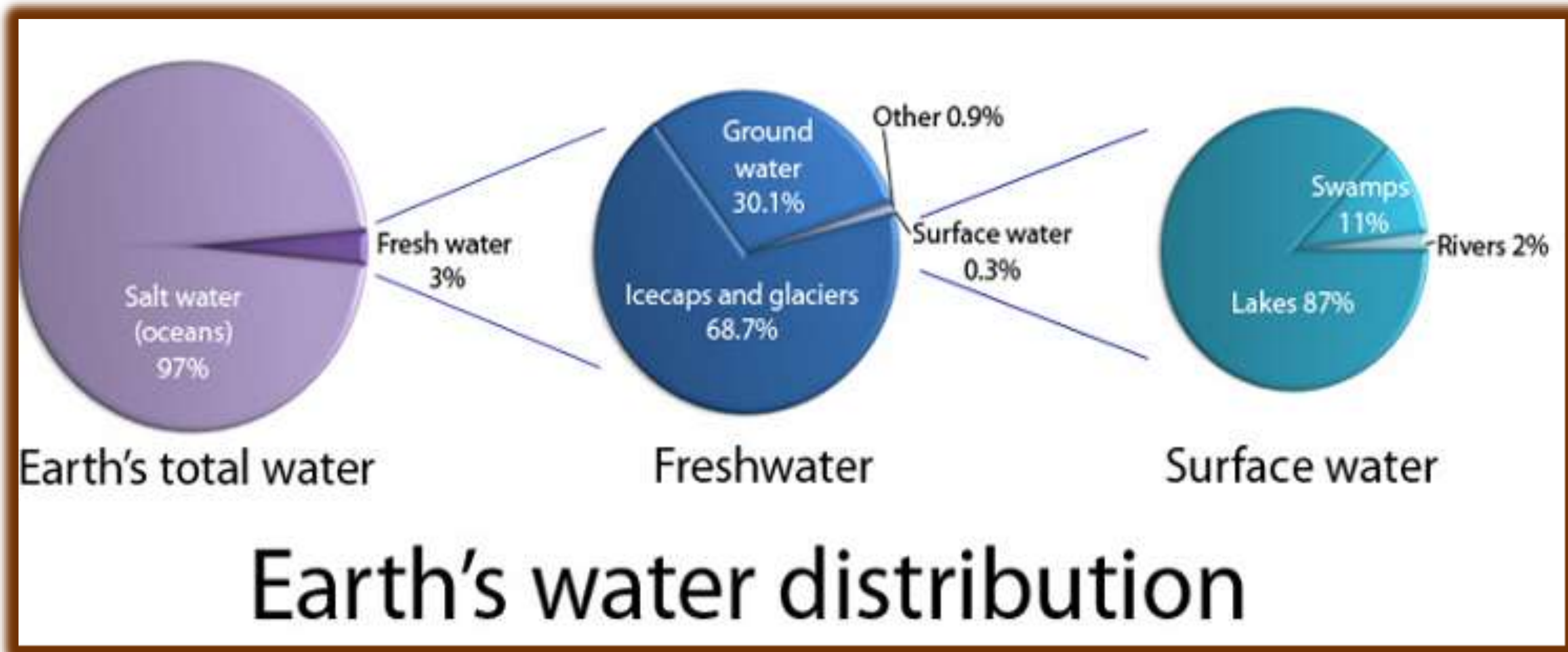


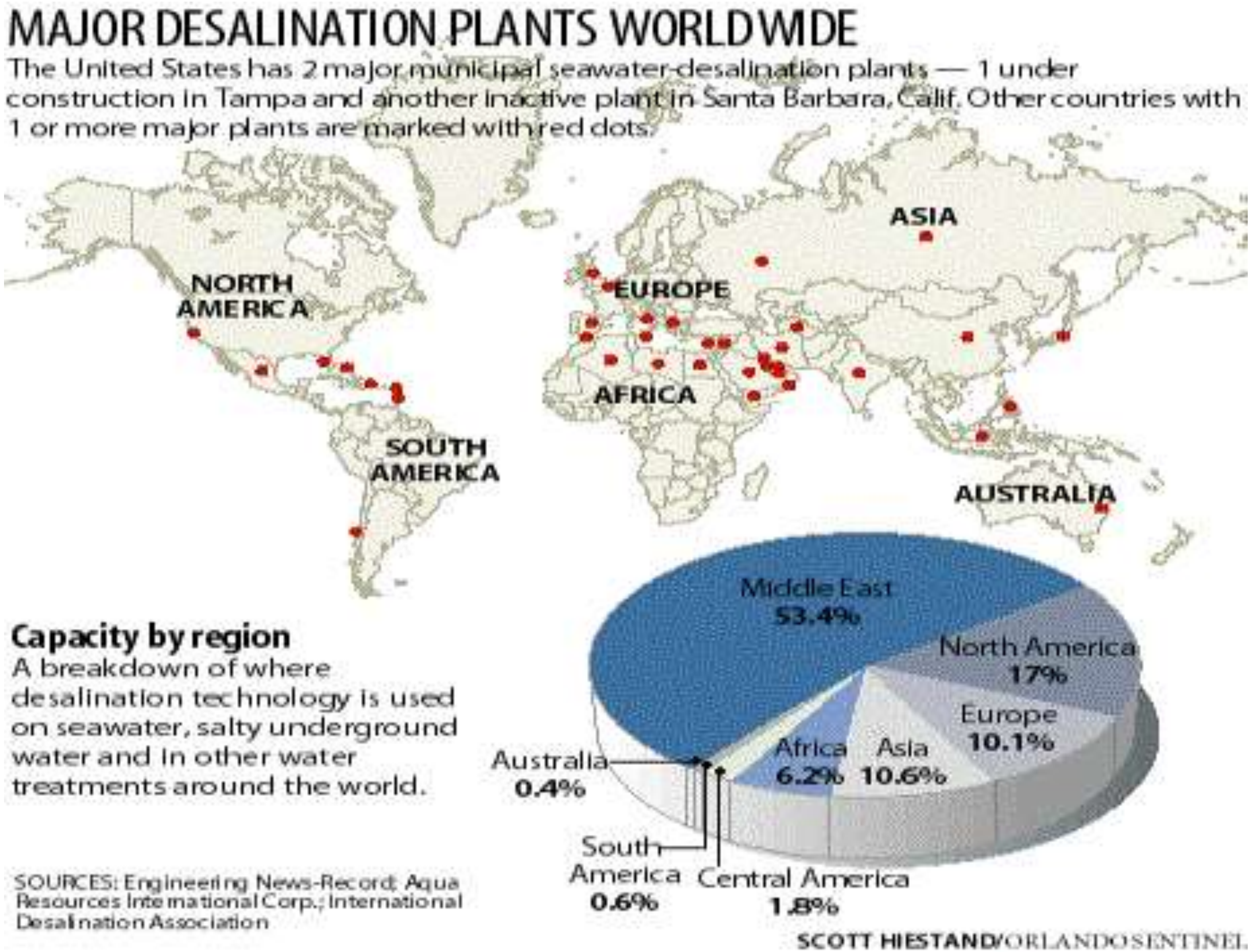


Planning Then Design

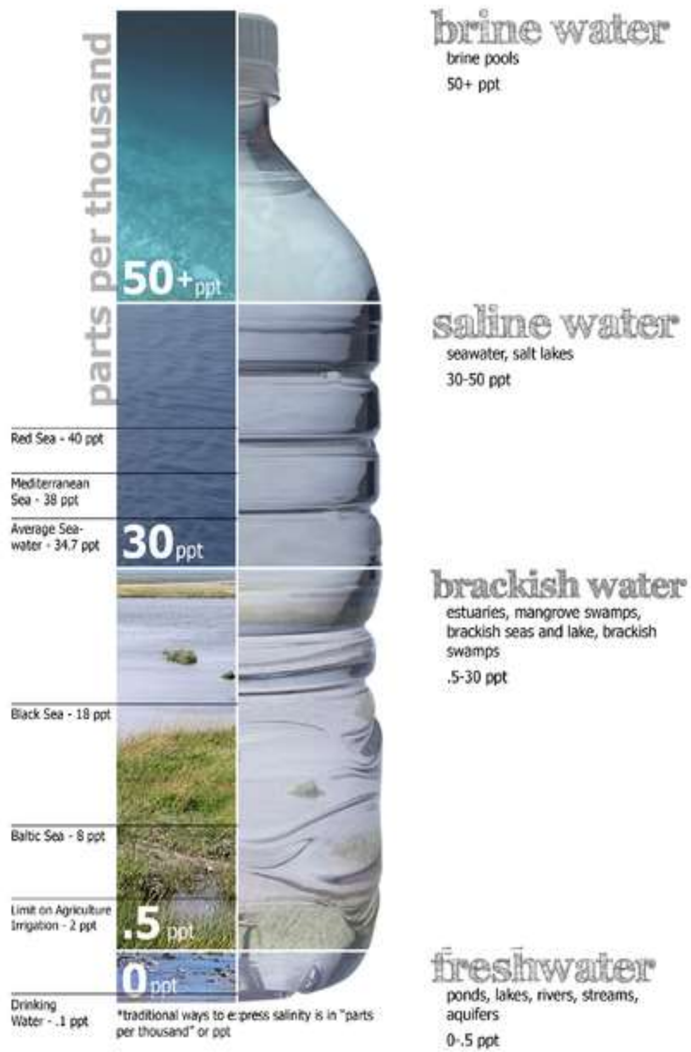


Earth's water distribution




MAJOR DESALINATION PLANTS WORLDWIDE
The United States has 2 major municipal seawater-desalination plants — 1 under construction in Tampa and another inactive plant in Santa Barbara, Calif. Other countries with 1 or more major plants are marked with red dots.
NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
ASIA
AUSTRALIA
Capacity by region
A breakdown of where desalination technology is used on seawater, salty underground water and in other water treatments around the world.
Middle East 53.4%
North America 17%
Europe 10.1%
Asia 10.6%
Africa 6.2%
Australia 0.4%
South America 0.6%
Central America 1.8%
SOURCES: Engineering News-Record; Aqua Resources International Corp.; International Desalination Association
SCOTT HIESTAND/ORLANDO SENTINEL

Classification of water salinity



What we know about Desalination

1. Number of desalination plants in Jordan ?
2. Amount of permeate water come from desalination plants ?
3. TDS of Brackish water and seawater ?
4. Desalination methods ?

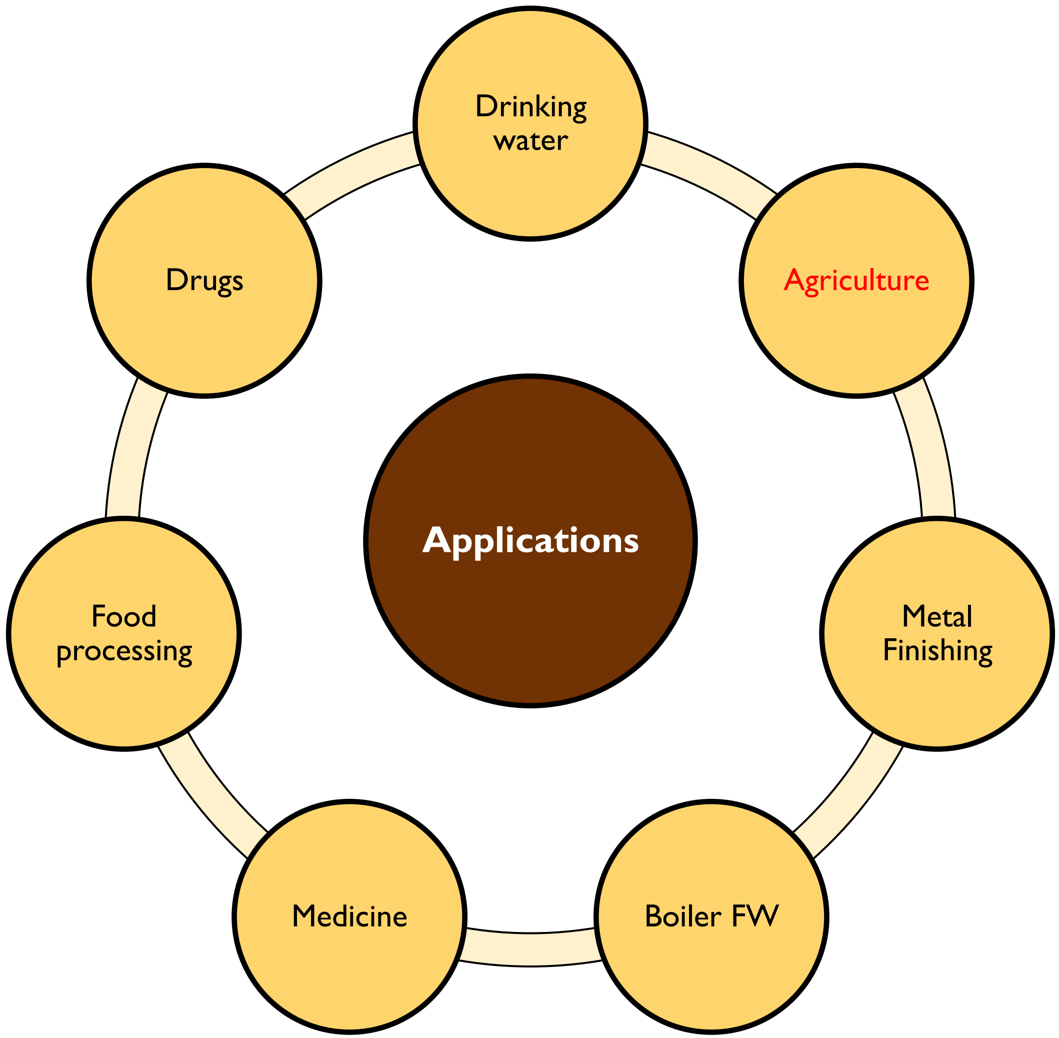
Desalination

In Jordan

Waste water

Waste water reuse	Desalination
118 MCM / Year	90 MCM / Year
More knowledge	Less knowledge
27 plants	24 plants
AlSamra	Zara Ma’in (46 MCM/Yr)
0.08 – 0.55 JD / Cubic meter	0.16 – 0.25 JD / Cubic meter

Applications of Desalination



Desalination Methods

Membrane
- R.O
- ED

Thermal
- MSF
- VC
- MED

Other
- Freezing
- Solar
- MD

Thermal
- 500 BC

Membrane
- 1950

Less Energy
High SR
High Flux

What is Desalination ?

Desalination : is a separation process used to reduce the dissolved salt content of saline water to a usable level.

-All desalination processes involve three liquid streams:

- the saline feedwater (brackish water or seawater).
- low-salinity product water. (permeate)
- very saline concentrate (brine or reject water).

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Introduction to R.O

Advantages

Disadvantages

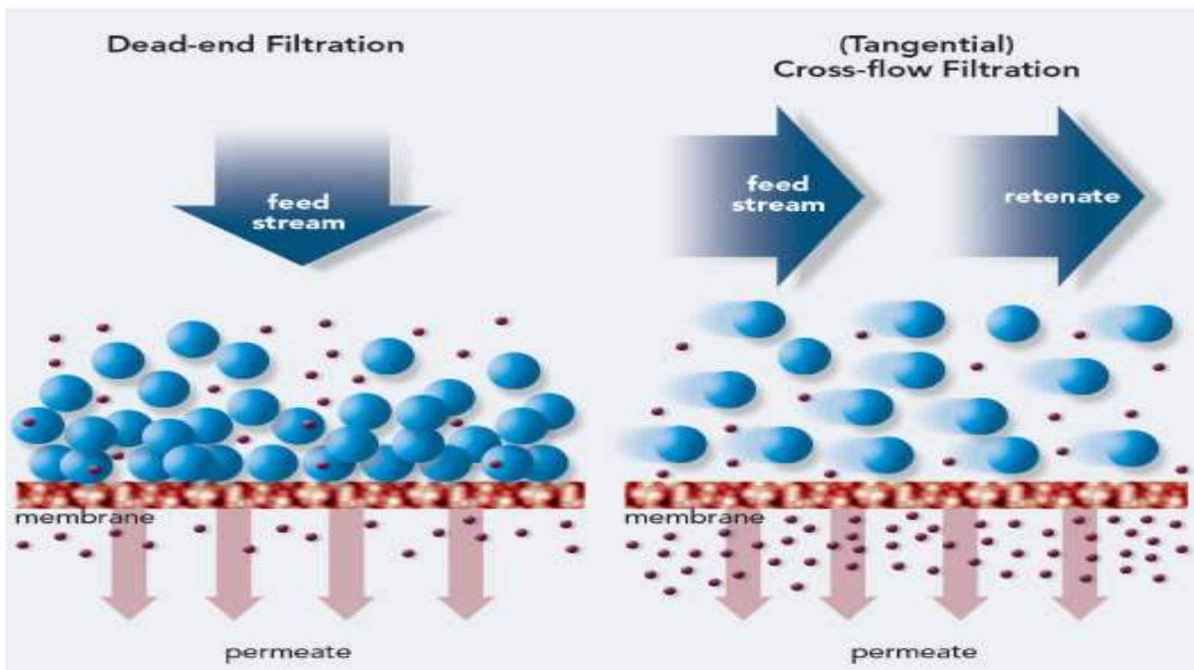
- ✓ Low energy (60 % of thermal Desalination plant)
- ✓ Less Area (50 % of thermal Desalination plant)
- ✓ Low capital cost
- ✓ High development

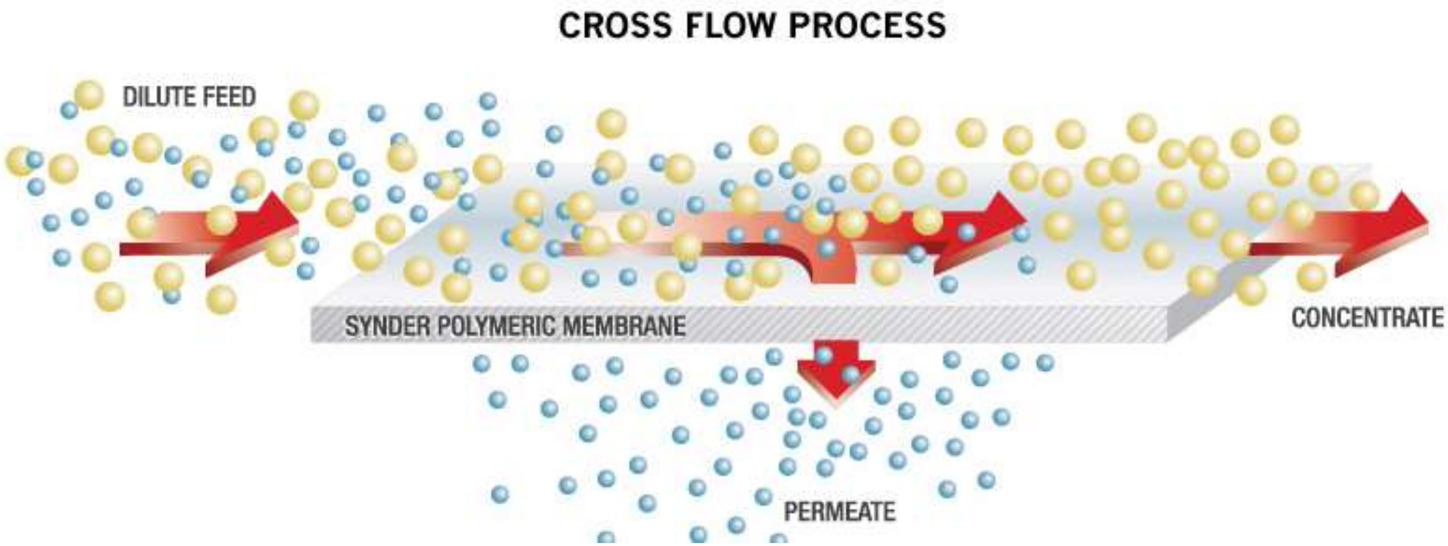
- ✗ The membranes are sensitive to abuse
- ✗ The feedwater usually needs to be pretreated

Flow in R.O membrane

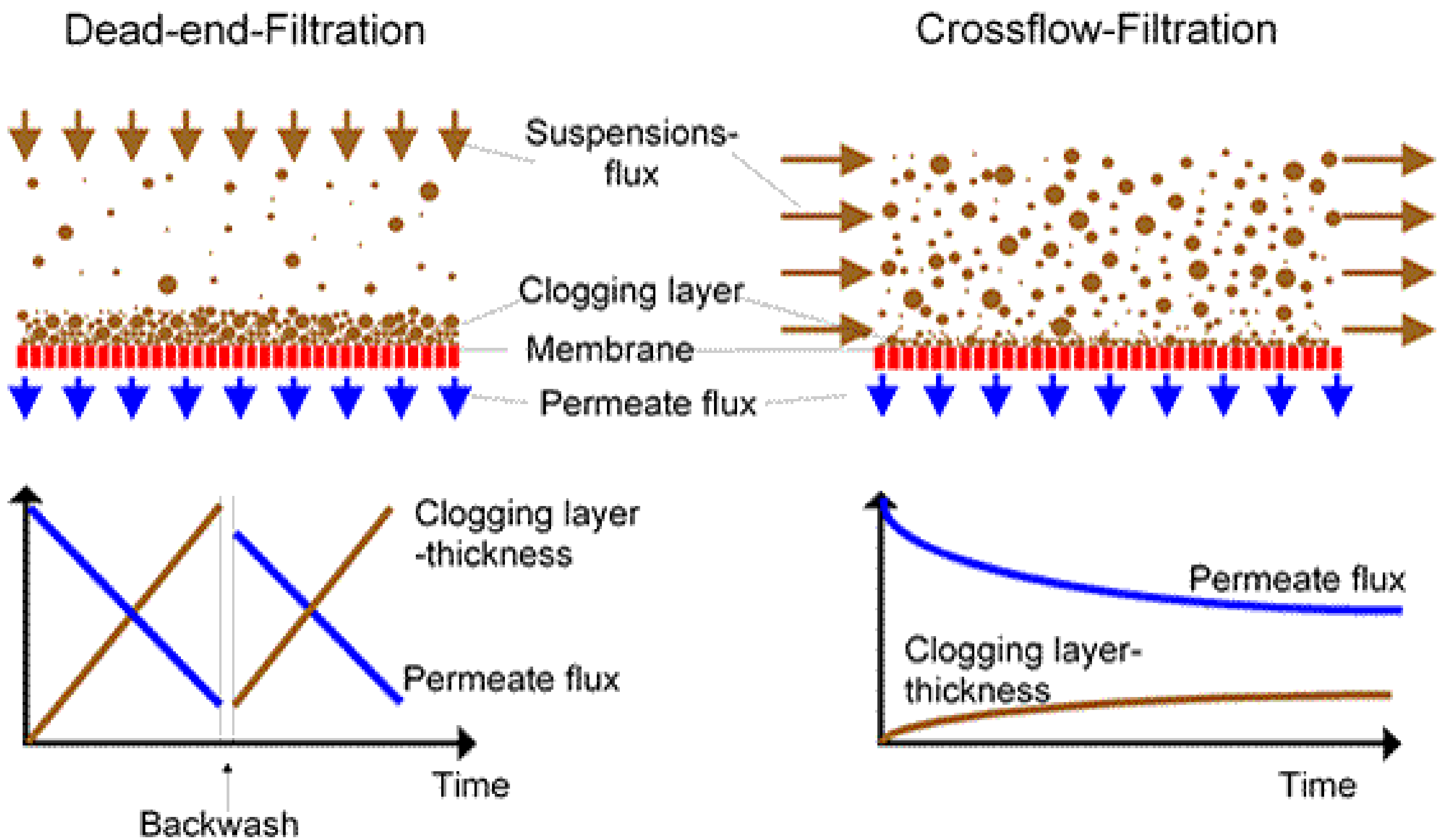
Cross Flow

Filtration flow

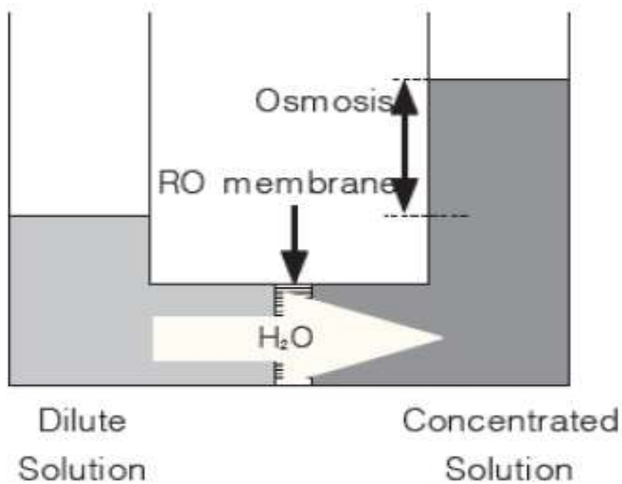




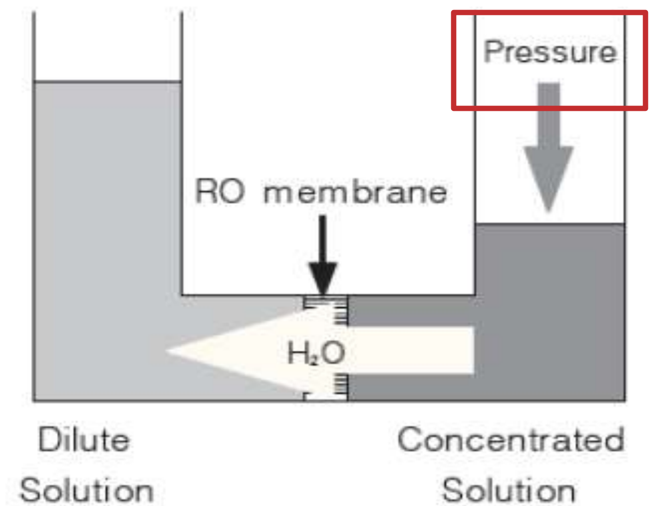
Cross flow	Dead End Filtration Flow
High permeate flow	Low permeate flow
Reject flow	No reject flow
No backwash	Backwash
R.O membrane	Sand filter


Dead-end-Filtration
Crossflow-Filtration
Suspensions-
flux
Clogging layer
Membrane
Permeate flux
Clogging layer
-thickness
Permeate flux
Time
Backwash
Permeate flux
Clogging layer-
thickness
Time

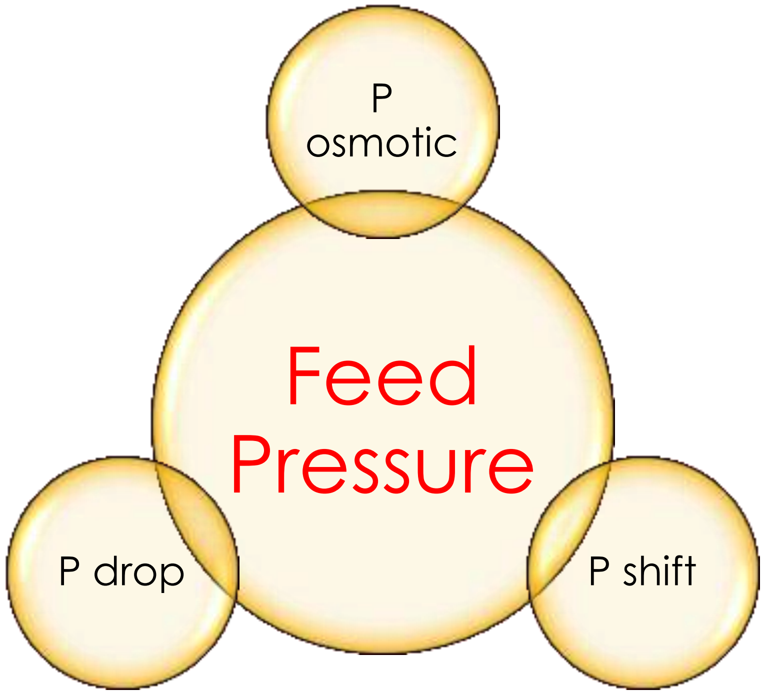
Theory of reverse osmosis



A) Osmatic pressure process



B) Reverse Osmatic pressure process



Feed pressure = P osmotic + P drop + P shift

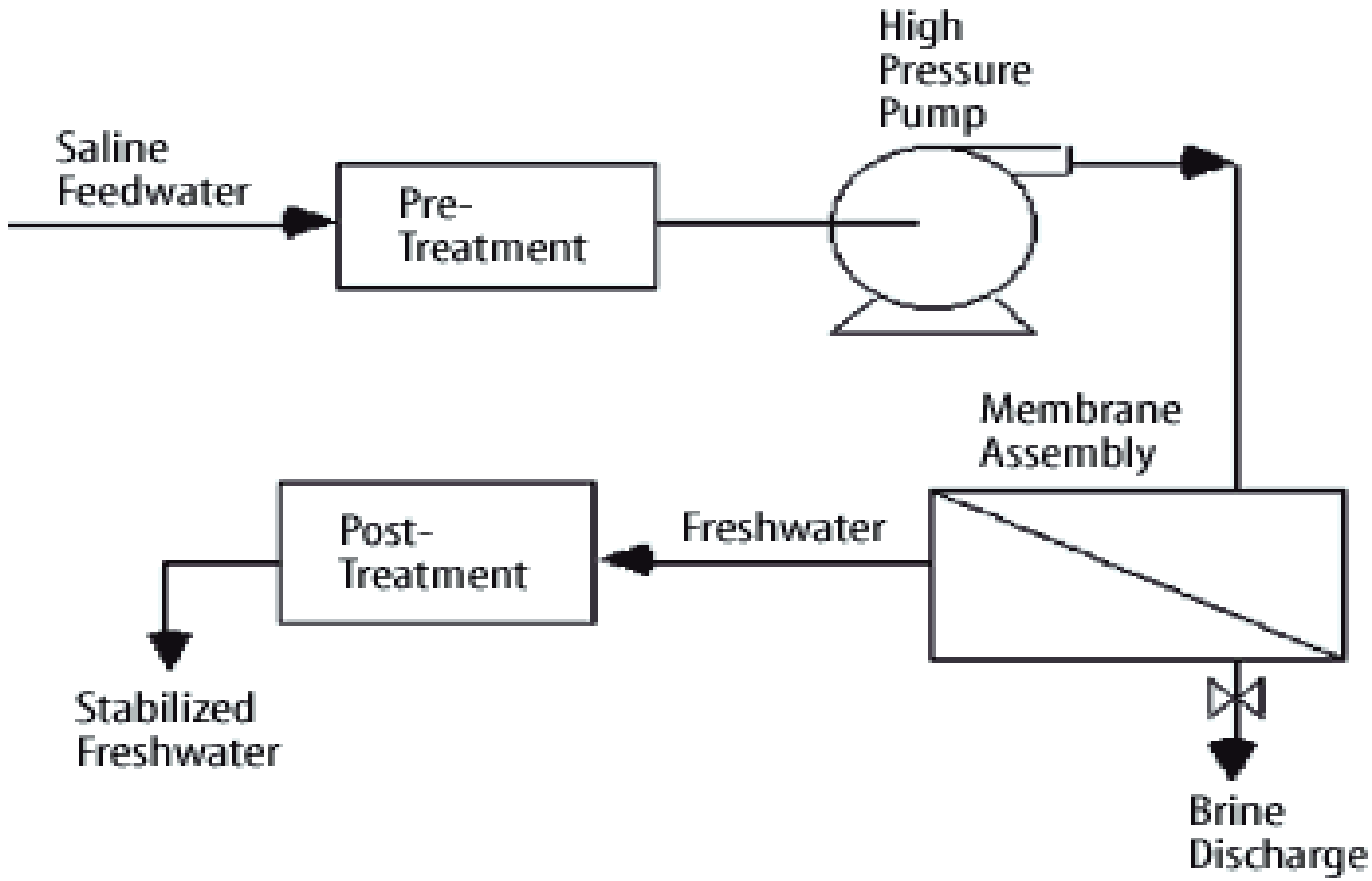
Major components of reverse osmosis unit

Pre treatment

High Pressure pump

Membrane separation

Post treatment


High
Pressure
Pump
Saline
Feedwater
Pre-
Treatment
Membrane
Assembly
Post-
Treatment
Freshwater
Stabilized
Freshwater
Brine
Discharge

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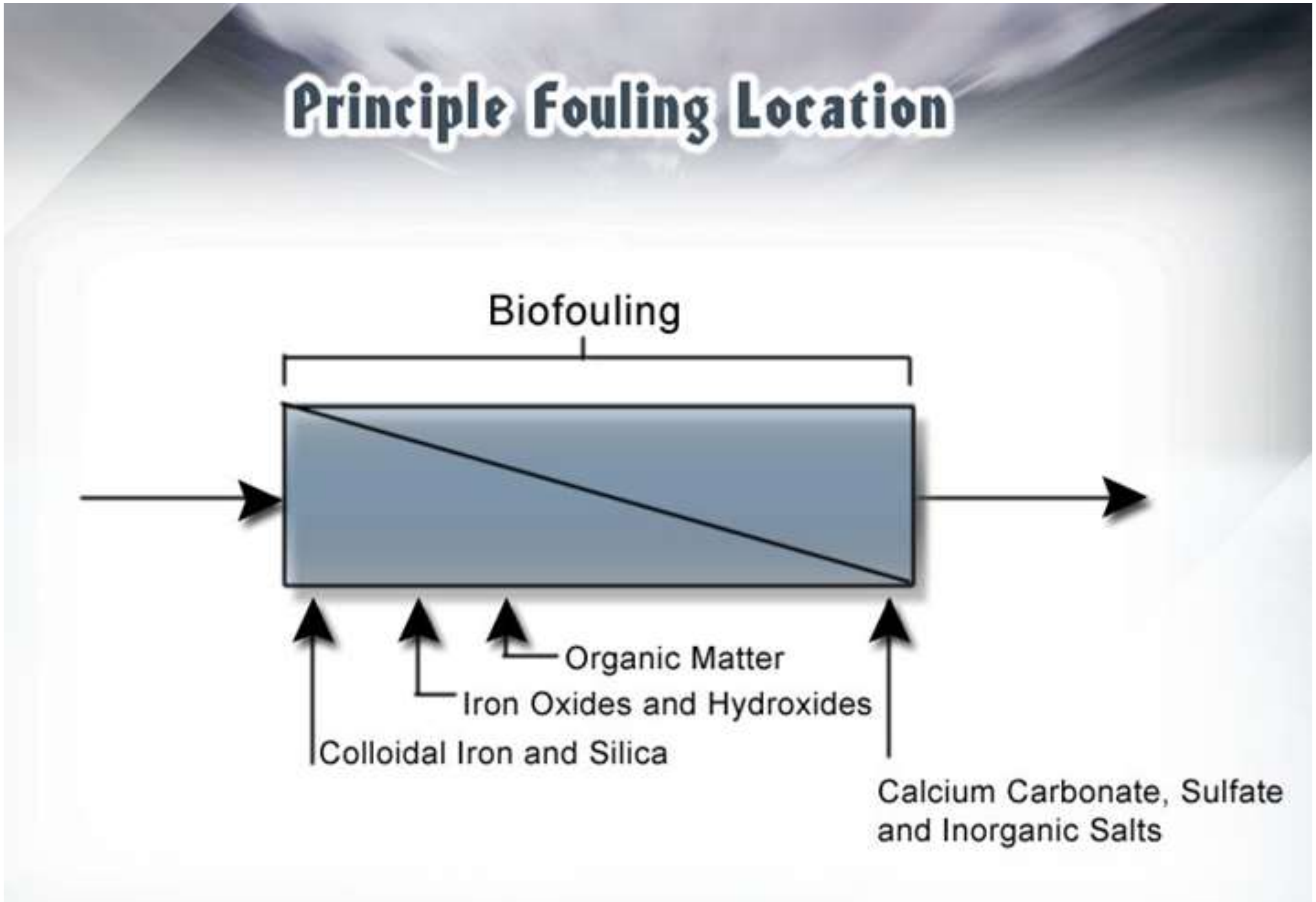
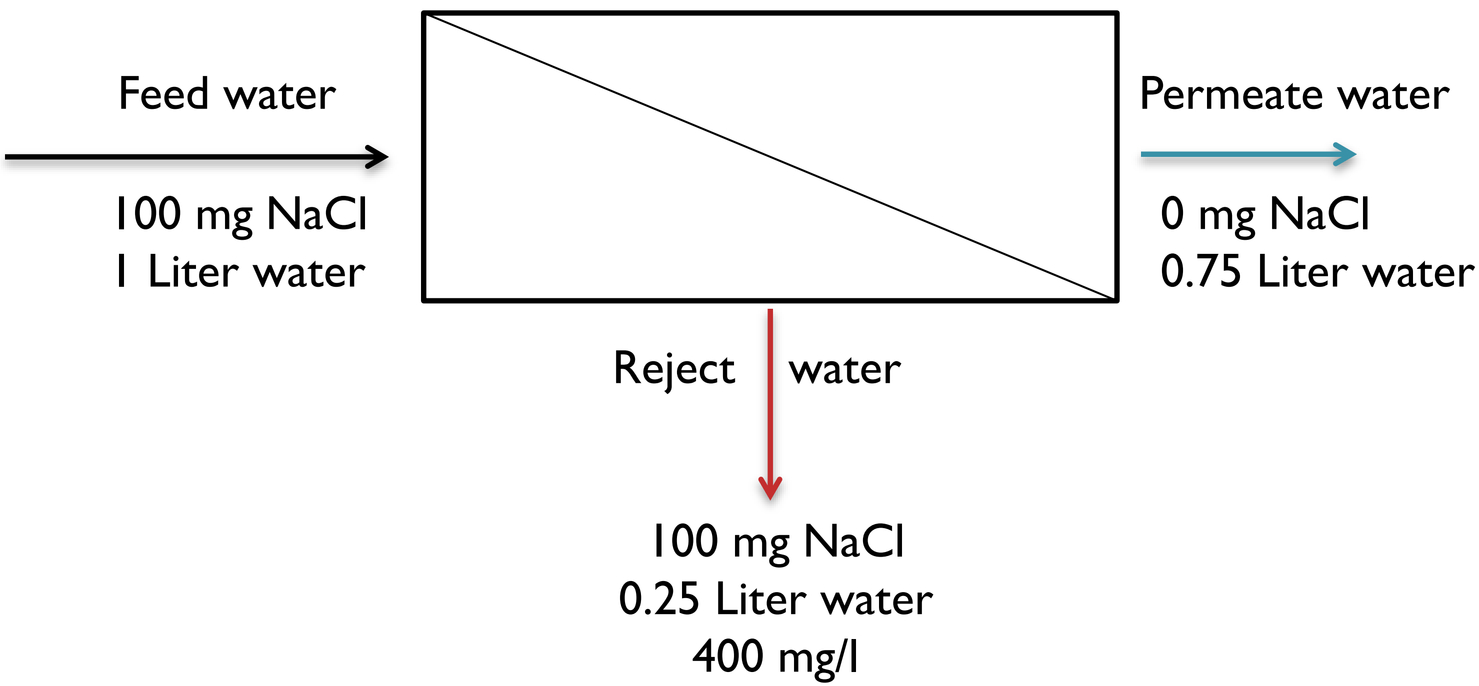
Major pollutants affects on R.O membrane

- suspended solid
- Scaling (Hardness)
- Colloid
- Organic compound
- Anoxic ions
- Oxidation agent
- Microorganisms


Principle Fouling Location
Biofouling
Organic Matter
Iron Oxides and Hydroxides
Colloidal Iron and Silica
Calcium Carbonate, Sulfate
and Inorganic Salts


Serial No. 22106518
DESAL MEMBRANE PRODUCTS
Phone (952) 933 - 2277
OSMONICS
CSM
CSM

100 mg NaCl in 1 liter water >> Conc = 100 mg/l
100 mg NaCl in 0.25 liter water >> Conc = 400 mg/l



Membrane Data sheet

	Membrane Element	ESPA1
Performance:	Permeate Flow:	12,000 gpd (45.4 m^3/d)
	Salt Rejection:	99.3 % (99.0 % minimum)
Type	Configuration:	Spiral Wound
	Membrane Polymer:	Composite Polyamide
	Membrane Active Area:	400 ft^2 (37.1m^2)
Application Data*	Maximum Applied Pressure:	600 psig (4.16 MPa)
	Maximum Chlorine Concentration:	< 0.1 PPM
	Maximum Operating Temperature:	113 °F (45 °C)
	pH Range, Continuous (Cleaning):	2-10 (1-12)*
	Maximum Feedwater Turbidity:	1.0 NTU
	Maximum Feedwater SDI (15 mins):	5.0
	Maximum Feed Flow:	75 GPM (17.0 m^3/h)
	Minimum Ratio of Concentrate to Permeate Flow for any Element:	5:1
	Maximum Pressure Drop for Each Element:	10 psi

Tests

The test considered to be one of the most important factors for the success of any desalination plant, there are so many benefits of the testing, because designing and building of a treatment plant is depending on it. as its reduce the problems that may affect the plant later, and give officials on the station a future predictions for plant efficiency and quality of work and expected problems in the future.

1- Initial tests

2- Periodic tests

3- Special tests

Initial and periodic test

- Total dissolved solid (TDS)
- Turbidity (suspended and colloidal particulate)
- SDI , Silica
- Hardness , Cl2 , Alkalinity
- PH ,Temperature
- Al , Fe , Mn
- Others

Biological test

1- Culture Techniques

The number of colony forming units (CFU) is a quantitative expression of the number of culturable microorganisms in a water sample. The main advantage of this method is that it can be performed easily without expensive equipment. The test results, however, are only available after up to seven days, and the counted colonies may represent as little as 1-10 % or less of the total bacteria count (TBC).

2- Total Bacteria Count (TBC)

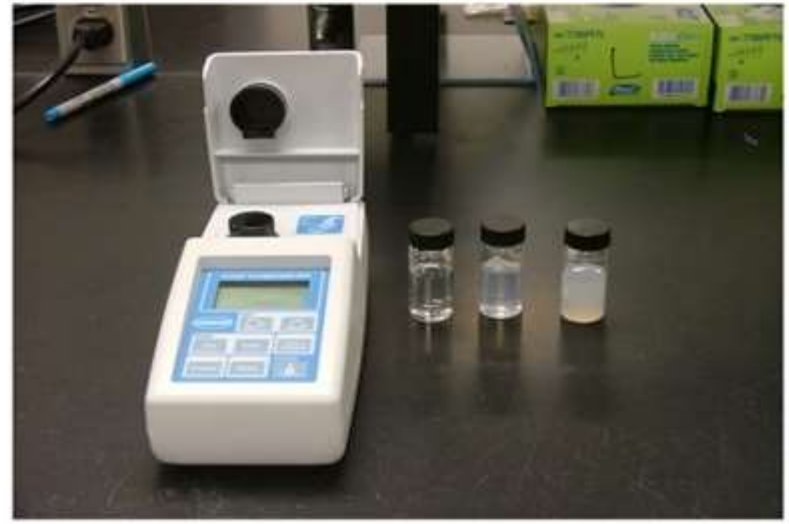
The total bacteria count (TBC) is determined with direct count techniques. These employ filtration of the water sample and counting the retained microorganisms on the filter plate directly under a microscope.

3- Assimilable Organic Carbon (AOC)

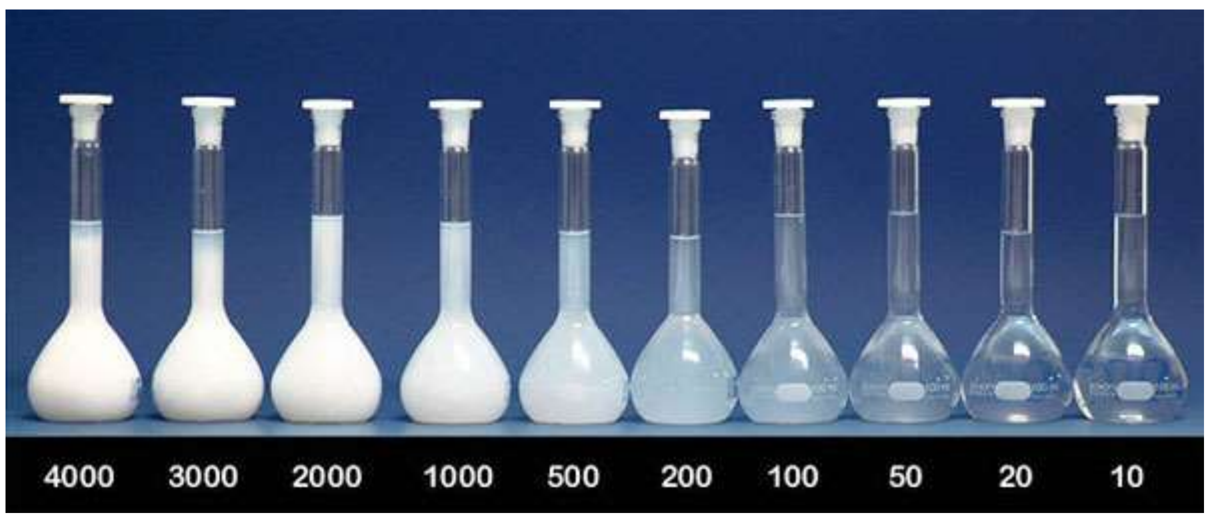
The AOC test addresses the growth potential of microorganisms in a given water sample with given nutrients. proposed a standard of 10 μg/L to prevent biological fouling

4- Biofilm Formation Rate (BFR)

The BFR value is determined with an online operated biofilm monitor at a continuous flow rate of 0.2 m/s. BFR values exceeding 100 pg/cm2 ATP were observed with severe biofouling, and BFR values of less than 1 pg/cm2 ATP were measured in cases of stable operation without any cleaning needs . The BFR value is most closely correlated with the degree of biofouling in a membrane plant .



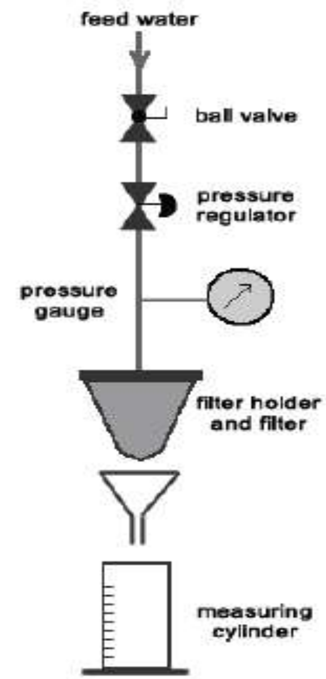
Turbidimeter. Three standards are shown- 5, 50, and 500 NTRU.



SDI (Silt density index)

SDI stands for silt density index and is a test that attempts to quantify the amount of particulate contamination in a water source. The results are used to estimate how quickly feed water will foul a membrane .It is one of the most important parameter for the design and operation of RO membrane process.

Pressure 2 bar



$$SDI_T = \frac{\% P_{30}}{T} = \frac{\left[1 - \frac{t_i}{t_f}\right] X\,100}{T} \qquad (1)$$

SDI T = Silt Density Index value.

%P30 = plugging filter at 30 psi.

ti = initial filtration time (in seconds),

tf = filtration time (in seconds) after Time,

T = interval between the two readings in most cases 15 minutes

SDI < 1	**Several years without colloidal fouling**
SDI < 3	**Several months between cleaning**
SDI 3 – 5	**Particular fouling likely a problem, frequent cleaning**
SDI > 5	**Unacceptable, additional pre-treatment is needed**

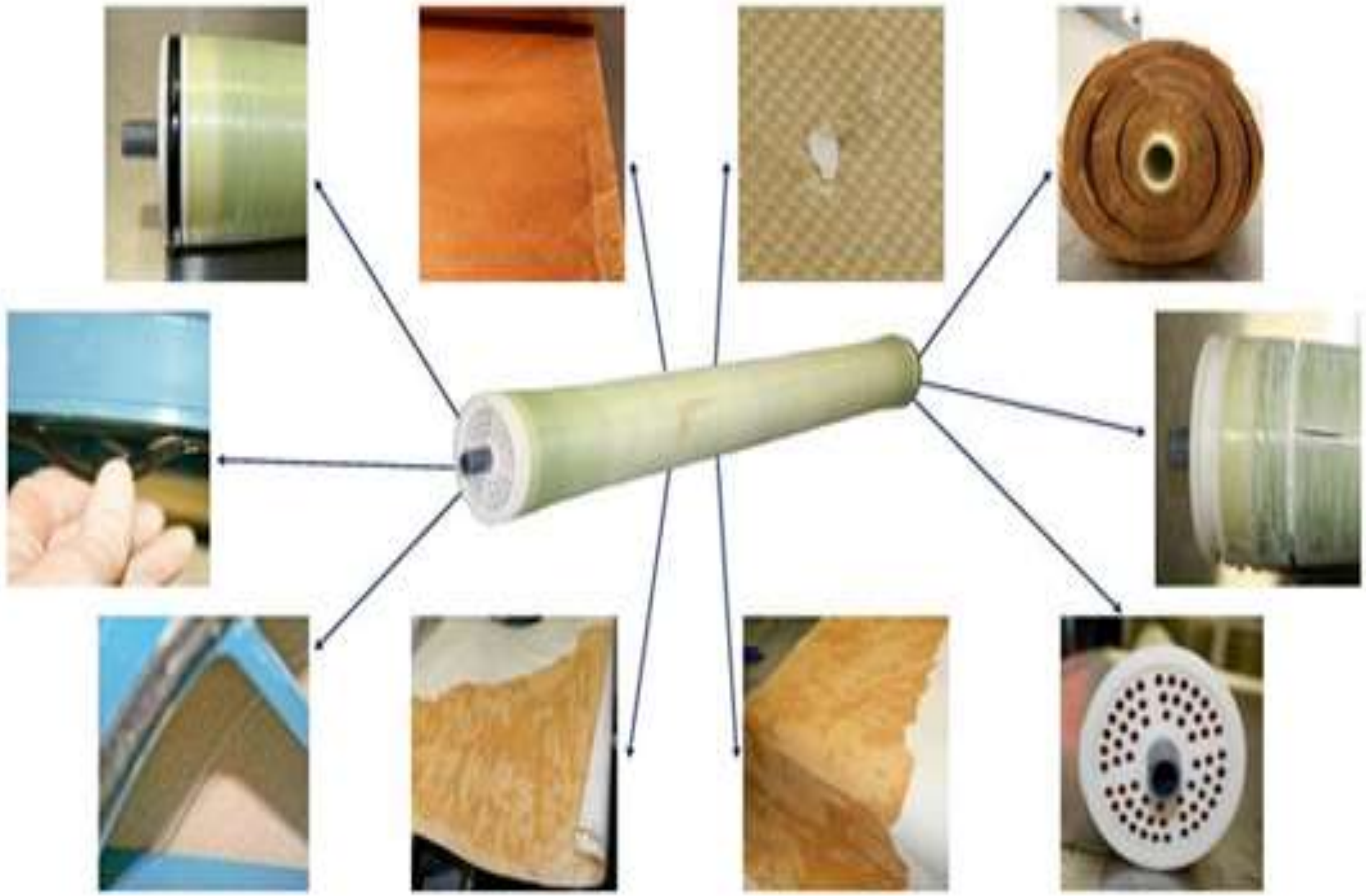
LSI & SDSI Test

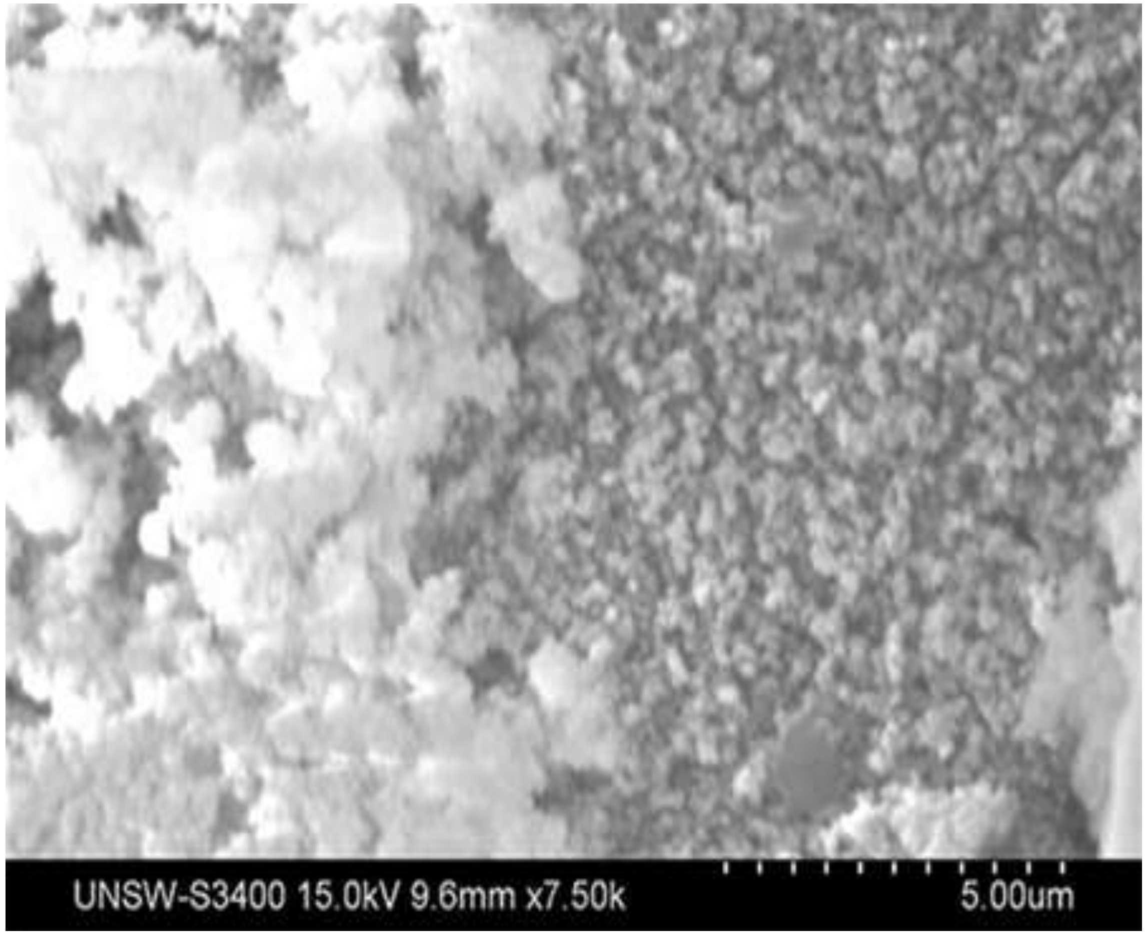
The most common method for determining the solubility of calcium carbonate ($CaCO_3$) in water.

LSI (Carrier)	Indication
-2,0<-0,5	Serious corrosion
-0,5<0	Slightly corrosion but non-scale forming
LSI = 0,0	Balanced but pitting corrosion possible
0,0<0,5	Sligthly scale forming and corrosive
0,5<2	Scale forming but non corrosive

Membrane Autopsy

- Internal and external visual examination
- The Fujiwara test
- Biological Activity Reaction Test(BART)
- Fourier transform infrared spectrometry (FTIR)
- Scanning electron microscopy (SEM)/Energy dispersive x-ray spectroscopy (EDS)
Wet testing/Dye integrity testing
- Inductively coupled plasma (ICP)/Optical emission spectroscopy (OES/AES)
- X-Ray Diffraction (XRD)




UNSW-S3400 15.0kV 9.6mm x7.50k
5.00um

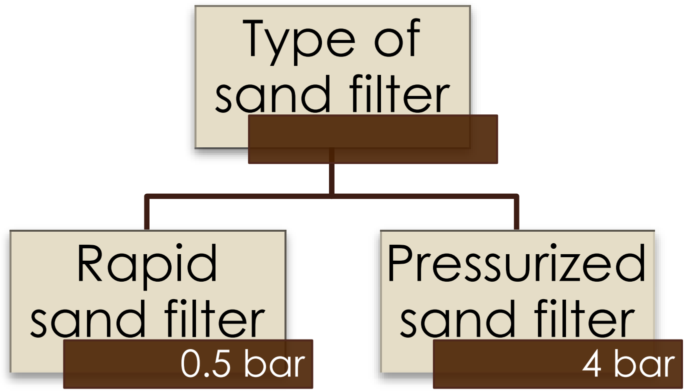
Questions number 1 ?!

Coagulation & Flocculation

- Type of coagulants
  - Aluminum salts (alum)
  - Ferric and ferrous salts
  - Lime
  - Polymers

For raw waters containing high concentrations of suspended matter resulting in a high SDI, the classic coagulation-flocculation process is preferred. The hydroxide flocs are allowed to grow and settle in specifically designed reaction chambers. The hydroxide sludge is removed, and the supernatant water is further treated by media filtration.

Sand Filter

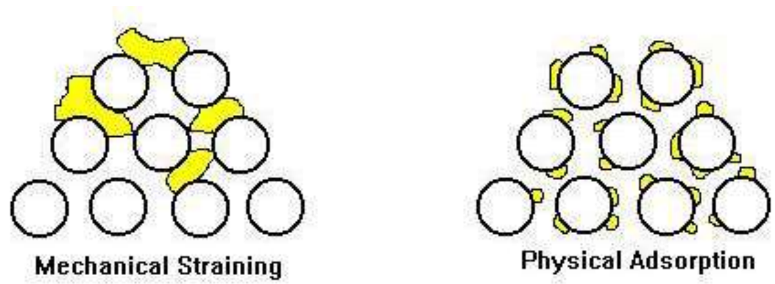


Dual filter media with anthracite over sand permit more penetration of the suspended matter into the filter bed, thus resulting in more efficient filtration and longer runs between cleaning. The design depth of the filter media is a minimum of 31 inches (0.8 m). In the dual filter media, the filters are usually filled with 20 inches (0.5 m) of sand covered with 12 inches (0.3 m) of anthracite.

More details about sand filter

- Media : Silica Sand + gravel
- Filtration Process , Mechanical + Adsorption
- Removal , 75 % of TSS + 60 % of Turbidity

Filtration process



when the differential pressure increase between the inlet and outlet of the pressure filter is (0.3–0.6 bar), and about (0.14 bar) for the gravity filter, the filter is backwashed and rinsed

In-Line filtration(in-line coagulation)

The efficiency of media filtration can be markedly improved if the colloids in the raw water are coagulated and/or flocculated prior to filtration. In-line filtration can be applied to raw waters with a SDI only slightly above 5.

Ferric sulfate and ferric chloride are used to destabilize the negative surface charge of the colloids and to entrap them into the freshly formed ferric hydroxide microflocs. Aluminum coagulants are also effective, but not recommended because of possible fouling problems with residual aluminum. Rapid dispersion and mixing of the coagulant is extremely important. An in-line static mixer or injection on the suction side of a feed pump is recommended. The optimum dosage is usually in the range of 10–30 mg/L, but should be determined case by case.

Cartridge filters

A cartridge filter with an absolute pore size of less than 10 µm is the suggested minimum pretreatment required for every RO system. It is a safety device to protect the membranes and the high pressure pump from suspended particles. Usually it is the last step of a pretreatment sequence. A pore size of 5 µm absolute is recommended

Melt Blown

- For SS Removal

Activated Carbon

- For Cl_2 removal

Biological Fouling Introduction

All raw waters contain microorganisms such as bacteria, algae, fungi, viruses, and higher organisms. The typical size of bacteria is about 1 µm. The difference between microorganisms and non-living particles, however, is the ability of microorganisms to reproduce and form a biofilm under favorable conditions.

Microorganisms entering a RO/NF system find a large membrane surface where dissolved nutrients from the water are enriched due to concentration polarization, thus creating an ideal environment for the formation of a biofilm. Biological fouling of the membranes may seriously affect the performance of the RO system.

A biofilm is difficult to remove because it protects its microorganisms against the action of shear forces and chemicals. In addition, if not completely removed, remaining parts of a biofilm lead to a rapid regrowth.

Chlorination

Chlorine (Cl_2) has been used for many years to treat municipal and industrial water and waste waters to control microorganisms because of its capacity to inactivate most pathogenic microorganisms quickly. The effectiveness of chlorine is dependent on the chlorine concentration, time of exposure, and the pH of the water. A free residual chlorine concentration of 0.5–1.0 mg/L or higher needed.

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. Dechlorination upstream of the membranes is required, however, to protect the membranes from oxidation.

Chlorine is most commonly available as chlorine gas and the hypochlorites of sodium and calcium. In water, they hydrolyze instantaneously to hypochlorous acid:

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$
$$NaOCl + H_2O \rightarrow HOCl + NaOH$$
$$Ca(OCl)_2 + 2\,H_2O \rightarrow 2\,HOCl + Ca(OH)_2$$

$$HOCl \leftrightarrow H^+ + OCl^-$$

Dechlorination

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

Sodium metabisulfite (SMBS) is commonly used for removal of free chlorine. Other chemical reducing agents exist (e.g., sulfur dioxide), but they are not as cost-effective as SMBS.

When dissolved in water, sodium bisulfite (SBS) is formed from SMBS:

$Na_2S_2O_5 + H_2O \rightarrow 2\ NaHSO_3$

SBS then reduces hypochlorous acid according to:

$2NaHSO_3 + 2HOCl \rightarrow H_2SO_4 + 2HCl + Na_2SO_4$

Shock treatment

Sodium bisulfite can be added into the feed stream (for a limited time period) during normal plant operation. This intermittent application is often referred to as shock treatment. In a typical application, 500–1,000 mg/L $NaHSO_3$ is dosed for 30 minutes.

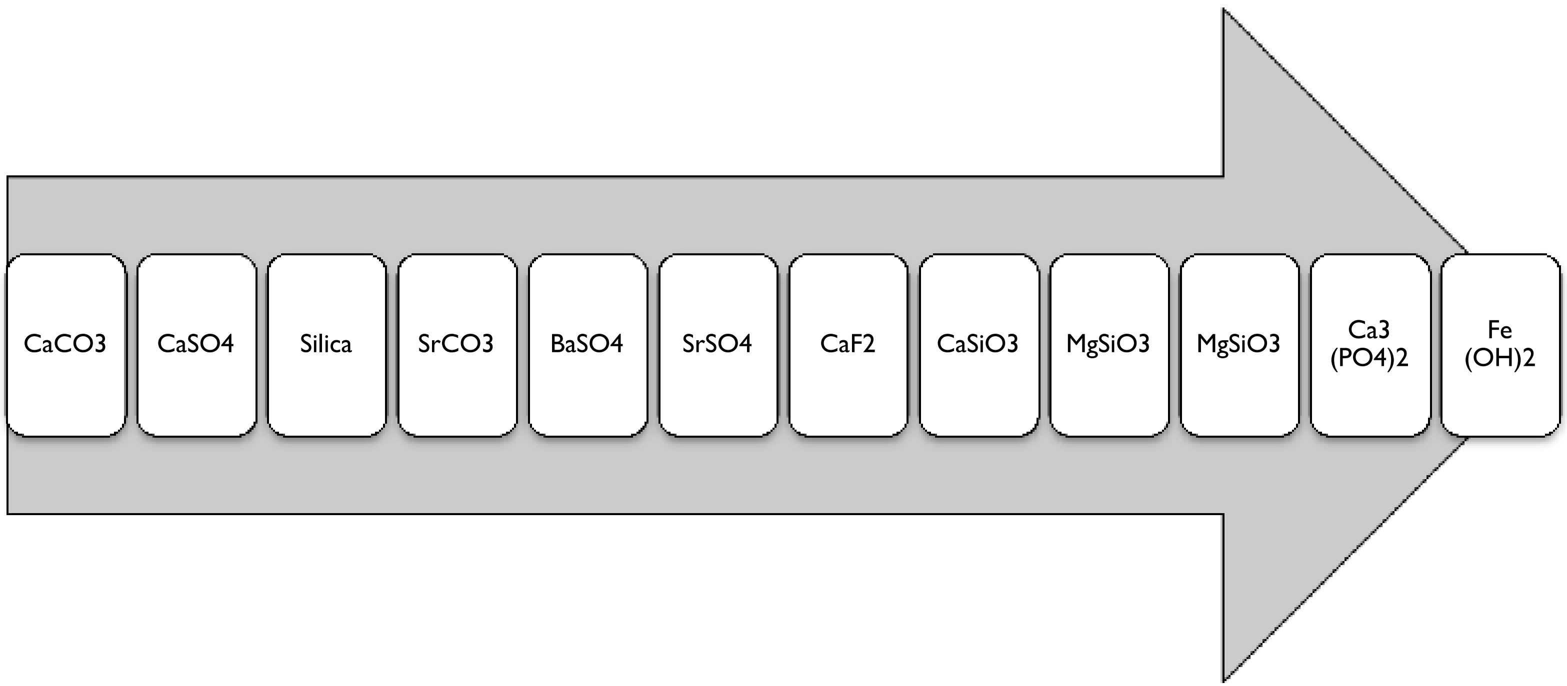
The treatment can be carried out on every 24 hours or only when biogrowth is suspected.

Copper sulfate can be used to control the growth of algae. Typically, copper sulfate is fed continuously at concentrations of 0.1 to 0.5 ppm. pH of the water must be low (to prevent the precipitation of copper hydroxide).

Ozone is an even stronger oxidizing agent than chlorine. However, it decomposes readily. A certain ozone level must be maintained to kill all microorganisms. The resistance of the materials of construction against ozone has to be considered. Usually, stainless steel is employed. Removal of ozone must be performed carefully to protect the membranes

Scaling problem

Scaling of an RO membrane may occur when sparingly soluble salts are concentrated in the RO element beyond their solubility limit.



Acid addition

To control calcium carbonate scaling by acid addition alone, the LSI or S&DSI in the concentrate stream must be negative. Acid addition is useful to control carbonate scale only.

For seawater systems, a dosage of typically 10 mg/L sulfuric acid is required to achieve a pH of about 7 and a negative S&DSI in the concentrate.

$$Ca^{2+} + HCO_3^- \leftrightarrow H^+ + CaCO_3$$

Anti Scalants

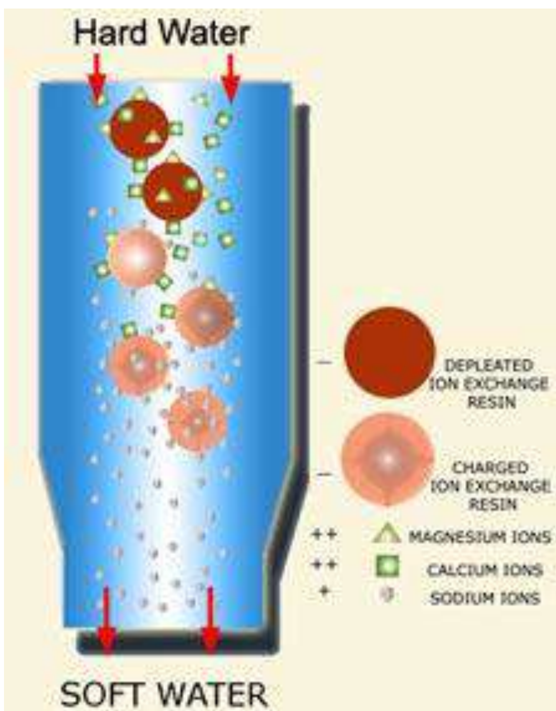
Scale inhibitors (anti-scalants) slow the precipitation process of sparingly soluble salts by being absorbed on the forming salt crystals to prevent the attraction of the supersaturated salt to the crystal surfaces.

- Type of Anti Scalants
- SHMP
- Organophosphonates
- Polyacrylic acids
- Anti Scalants + Acid addition

scale inhibitor is recommended when operating above a recovery of 35%.

Water Softener with a Strong Acid Cation Exchange Resin

In the ion exchange softening process, the scale-forming cations, such as Ca^{2+}, Ba^{2+} and Sr^{2+}, are removed and replaced by sodium cations . The resin is regenerated with NaCl at hardness breakthrough . ion exchange resins, the removal efficiency for Ca^{2+}, Ba^{2+}, and Sr^{2+} is greater than 97%, which usually eliminates any risk of carbonate or sulfate scaling.



Dealkalization with a Weak Acid Cation Exchange Resin

Dealkalization with a weak acid cation exchange resin is used mainly in large brackish water plants for partial softening to minimize the consumption of regeneration chemicals.

In this process, only Ca2+, Ba2+, and Sr2+ associated with bicarbonate alkalinity (temporary hardness) are removed and replaced by H+

The advantages

- For regeneration, acid of not more than 105% of the stoichiometric value is needed .
- High Capacity (2 time of strong acid resin).

The disadvantages are:

- Residual hardness.
- Variable pH of the treated water.

Lime Softening

Lime softening can be used to remove carbonate hardness by adding hydrated lime:

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2\ CaCO_3 + 2\ H_2O$
$Mg(HCO_3)_2 + 2\ Ca(OH)_2 \rightarrow Mg(OH)_2 + 2\ CaCO_3 + 2H_2O$

The noncarbonate calcium hardness can be further reduced by adding sodium carbonate (soda ash):

$CaCl_2 + Na_2CO_3 \rightarrow 2\ NaCl + CaCO_3$
$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

The lime-soda ash process can also be used to reduce the silica concentration (20 mg/l Max in R.O feedwater) with or without magnesium oxide or sodium aluminate.

silica adsorption onto $Mg(OH)_2$.

Increasing Efficiency

-Hot water 60–70°C
-pH 10-11

With lime softening, barium, strontium, and organic substances are also reduced

Greensand filter

Water with divalent iron and manganese, sometimes hydrogen sulfide and ammonium, but no oxygen; therefore, they are also called anoxic water .

Anoxic water can treated by oxidation and filtration.
Oxidation and filtration can be accomplished in one step by using a filter media with the ability to oxidize divalent iron and manganese by electron transfer. Greensand is such a granular medium, which is a green (when dry) mineral glauconite. It can be regenerated with KMnO4 when its oxidizing capability is exhausted.

Birm filtration has also been used effectively for Fe^{2+} removal from RO feed water

Carbon Filter

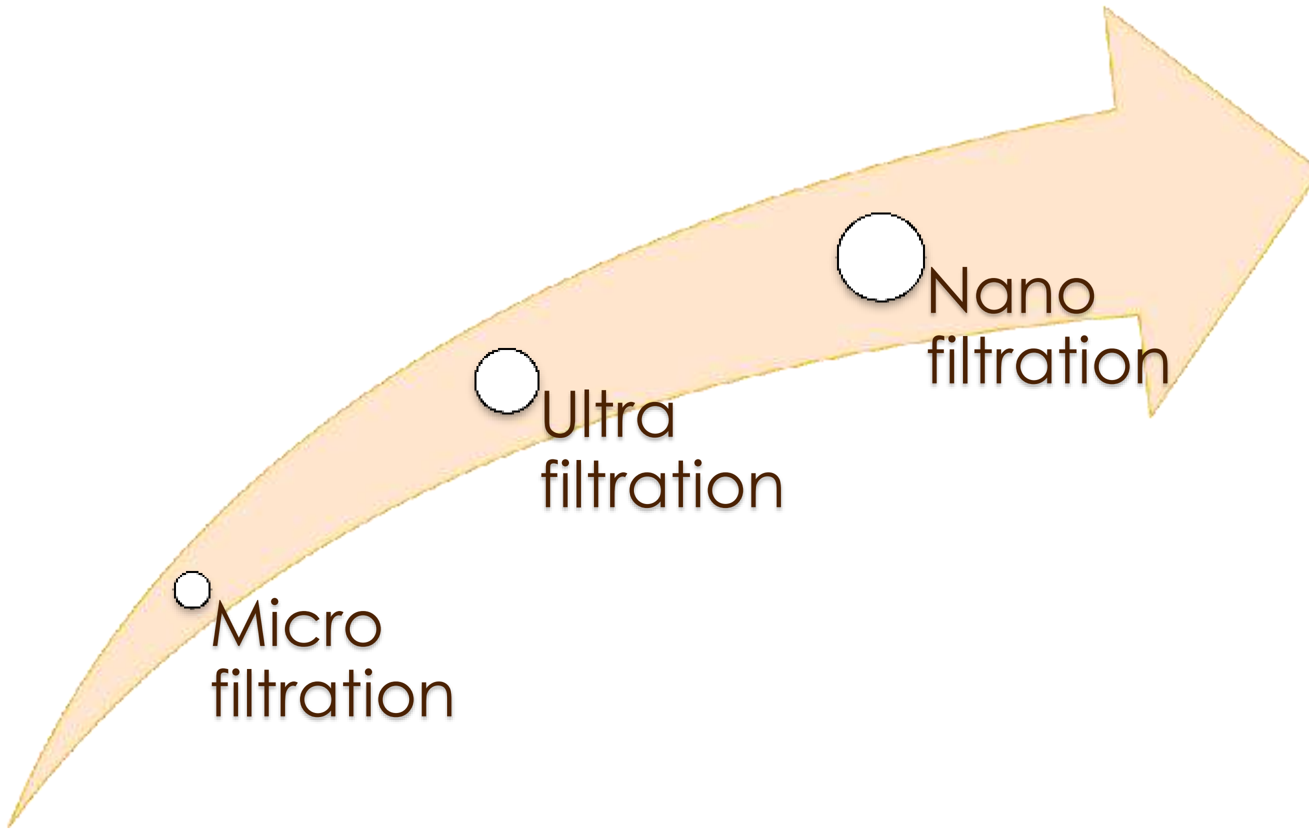
Carbon filtering is a method of filtering that uses a piece of activated carbon to remove contaminants and impurities, utilizing chemical adsorption. Each piece of carbon is designed to provide a large section of surface area, in order to allow contaminants the most possible exposure to the filter media.

An activated carbon bed is very effective in the dechlorination of RO feed water according to following reaction:

$C + 2Cl_2 + 2H_2O \rightarrow 4HCl + CO_2$

Carbon filter and media filter example

Membrane as pretreatment

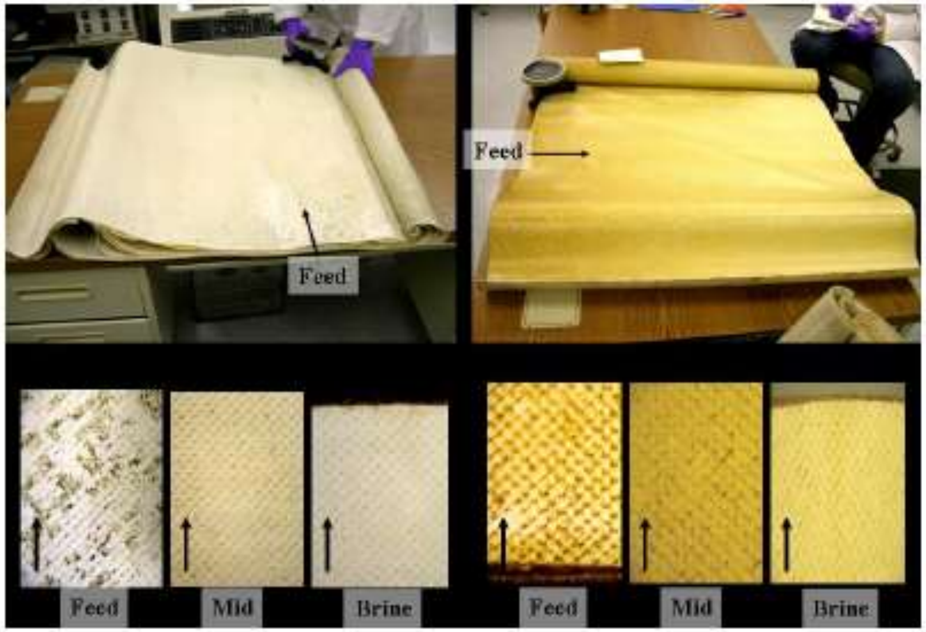


Micro filtration

- Remove particles in range 0.1 to 1 micron
- Remove SS , large colloid , Bacteria
- Low exit turbidity
- 0.7 bar (Applied pressure)

Ultra Filtration

- Remove particles in range 2 Nano to 0.1 Micron
- colloid , Bacteria , Proteins , microbiological contaminants
- Remove biological fouling
- 1-7 bar (Applied pressure)



MF/UF Pretreatment

Conventional Pretreatment

Nano Filtration

- Remove particles in range 1 Nano
- Calcium , Sodium , magnesium , color , TOC
- Softening , surface water , waste water
- 3.5-16 bar (Applied pressure)

Pre treatment

Table 1

Pretreatment	$CaCO_3$	$CaSO_4$	$BaSO_4$	$SrSO_4$	CaF_2	SiO_2	SDI	Fe	Al	Bacte-ria	Oxid. Agents	Org. Matter
Acid Addition	●							○				
Scale Inhibitor	○	●	●	●	●	○						
Softening with IX	●	●	●	●	●							
Dealkalization with IX	○	○	○	○	○							
Lime Softening	○	○	○	○	○	○	○	○				○
Preventive Cleaning	○					○	○	○	○	○		○
Adjustment of Operation Parameter		○	○	○	○	●						
Media Filtration						○	○	○	○			
Oxidation-Filtration							○	●				
In-Line-Coagulation							○	○	○			○
Coagulation-Flocculation						○	●	○	○			●
Micro-/ Ultrafiltration						●	●	○	○	○		●
Cartridge Filter						○	○	○	○	○		
Chlorination										●		
Dechlorination											●	
Shock Treatment										○		
Preventive Disinfection										○		
GAC Filtration										○	●	●

○ Possible ● Very effective

Feed Water Characteristics	Treatment
Turbidity (SS)	Coagulation, filtration
Particulate	Cartridge filter
Colloids	Coagulation , UF
Color	Coagulation, filtration
Odor (see dissolved gases)	Chlorination, Absorption
Taste	Chlorination, Absorption
Chemical Characteristics	**Treatment**
Hardness (Ca and Mg salts)	pH, softening, conversion control
Minerals (Na, K, Cl, SO_4, HCO_3)	RO
Mn++	Oxidation
Fe++	Filtration
Silica	Lime softening process
Gases (O_2 , H_2 S, CO_2 , NH_3)	Aeration Degasification
Calcium Carbonate	pH adjustment
Calcium Sulfate	Scale inhibitors
Biological Characteristics	**Treatment**
Bacteria	Chlorination
Algae	UV Irradiation

Component	Unit	Max. level
SDI	1	5
$MFI_{0.45}$	1	4
Oil and grease	mg/L	0.1
TOC	mg/L	3
COD	mg/L	10
AOC	µg/l Ac-C	10
BFR	pg/cm² ATP	5
Free chlorine	mg/L	0.1
Ferrous iron	mg/L	4
Ferric iron	mg/L	0.05
Manganese	mg/L	0.05
Aluminum	mg/L	0.05

Training Course on Planning of Desalination plant using R.O system

- Introduction to Desalination
- Introduction to Reverse osmosis
- Pretreatment
- R.O
- Post treatment
- Others

Basic Terms and Definitions

Reverse osmosis system flow rating

- 10 cubic meter / day R.O = 10 cubic meter permeate flow

Recovery rate

- Q permeate / Q feed

Rejection

- % Rejection = [(Cf- Cp)/ Cf]* 100

Flux

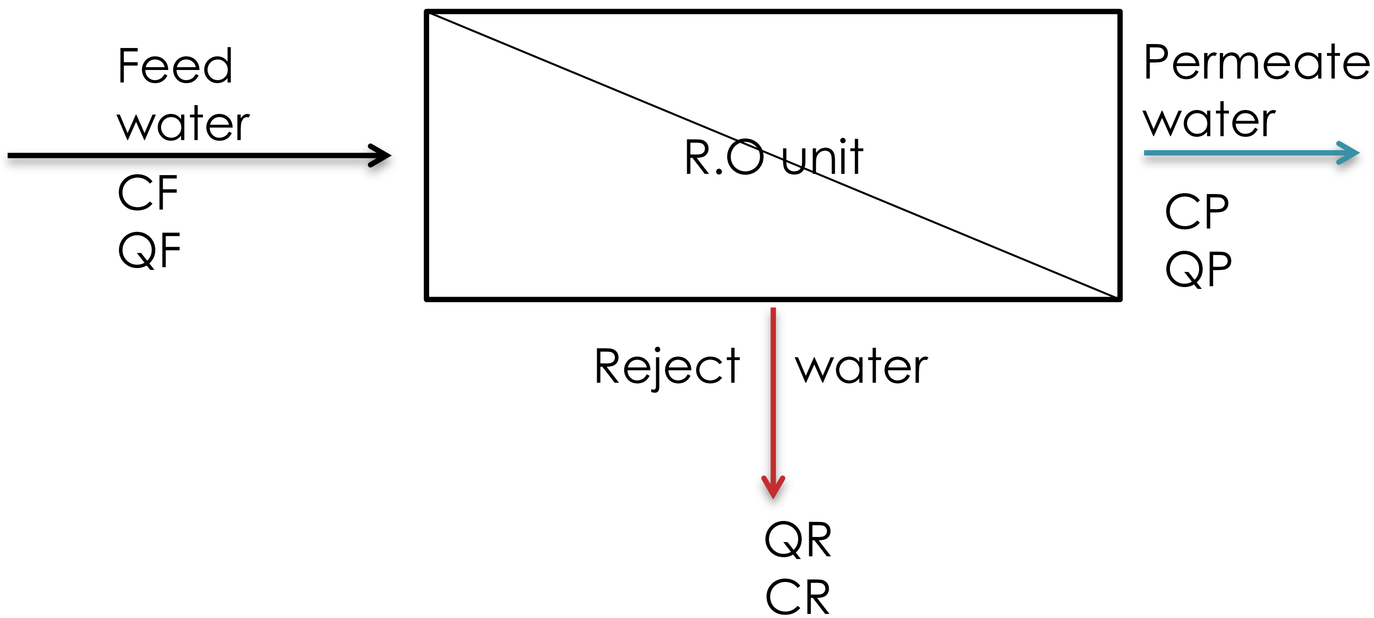
- the volumetric flow rate of a fluid through a given area (Qp / (N *Area of membrane))

Fouling

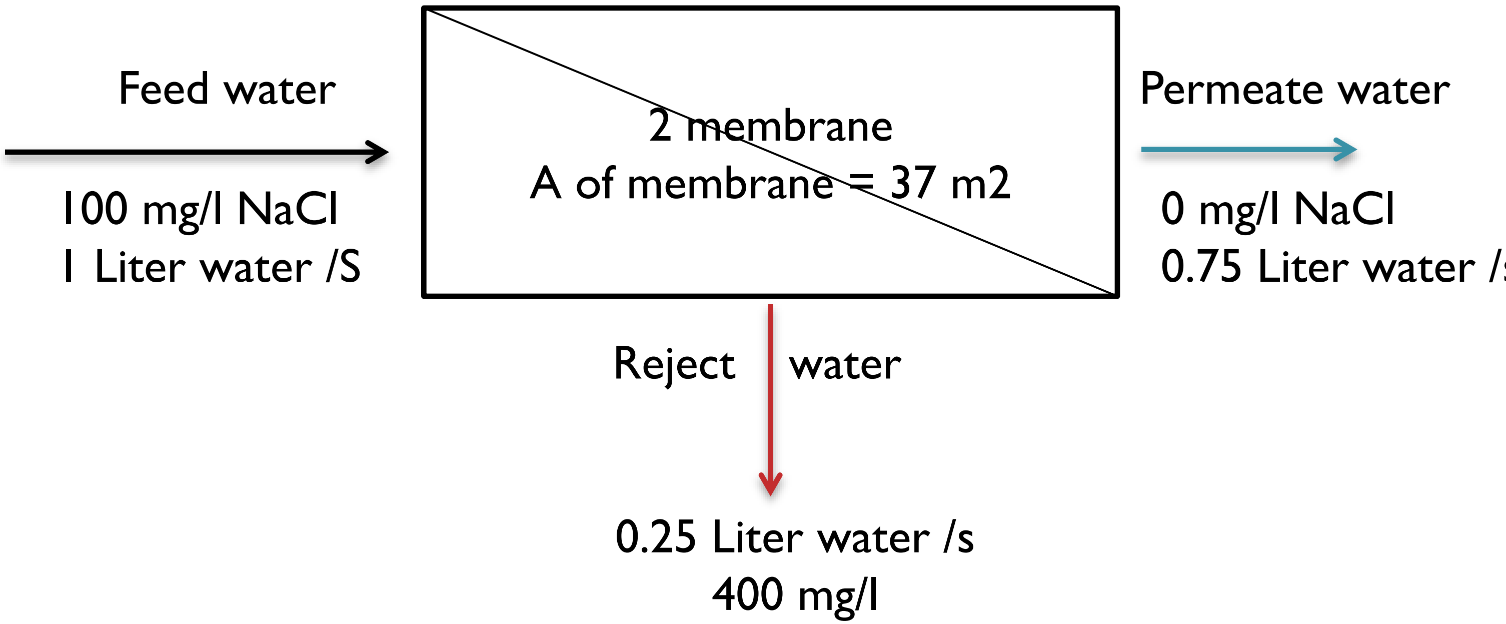
- suspended solids, organics, or microbes on the surface of the membrane

Scaling

- result of precipitation of saturated salts

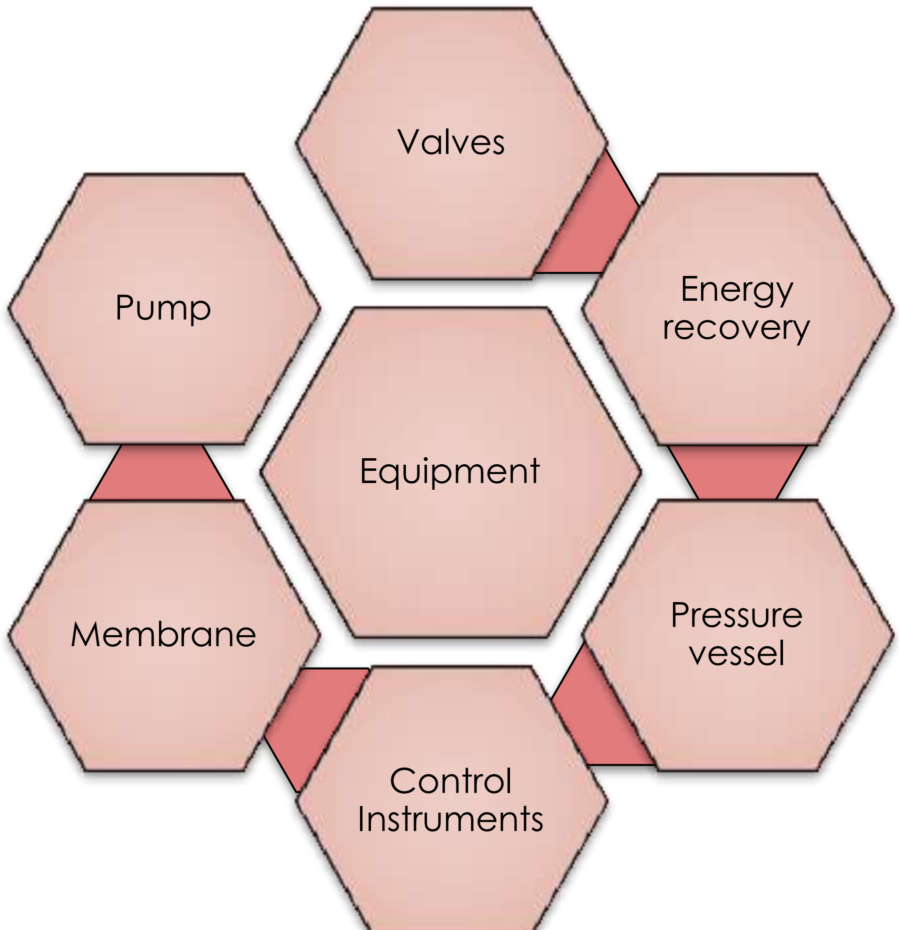


CF : Concentration of feed water
QF : Flow rate of feed water
CP : Concentration of permeate water
QP : Flow rate of permeate water
QR : Flow rate of reject water
CR : Concentration of reject water



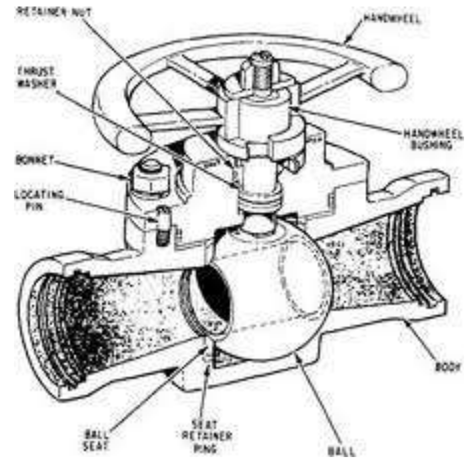
Recovery rate = 0.75 /1=0.75 =75 %
Rejection % = (100-0) / 100 = 1 = 100%
Flux = 0.75 *3600 / (2*37) = 36.5 L/m2/hr

Reverse osmosis unit equipment



Valves

- Plug Valve
- Butterfly and ball Valve
- Automated Valve
- Needle Valve
- Check Valve


RETAINER NUT
HANDWHEEL
THRUST WASHER
HANDWHEEL BUSHING
BONNET
LOCATING PIN
BODY
BALL SEAT
SEAT RETAINER RING
BALL

Pumps

- Source intake pump
- Feed pump
- High pressure pump
- Booster pump
- Dosing pump





Control instrument

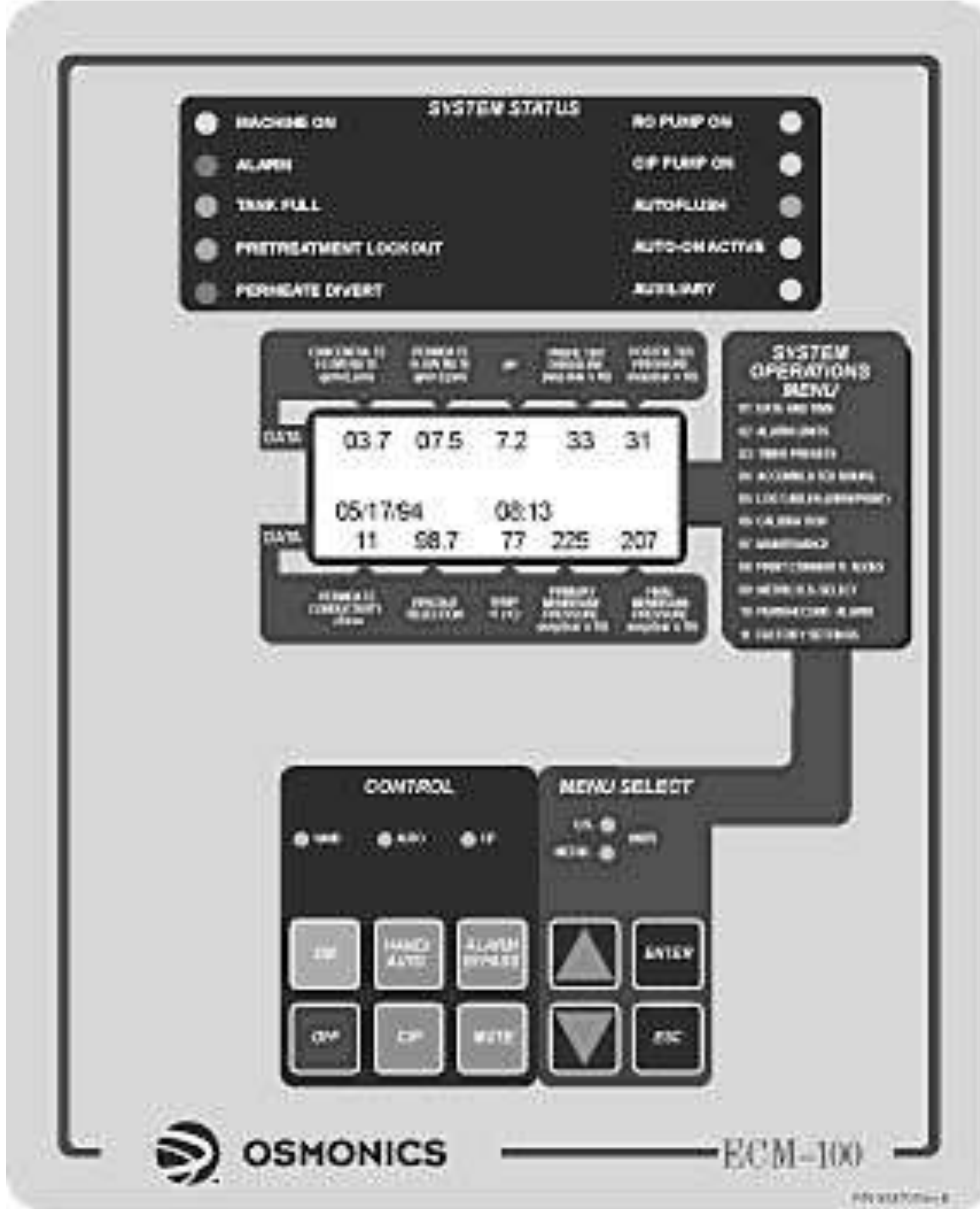
Pressure gage

Flow meter

PH meter

TDS meter

Others


SYSTEM STATUS
MACHINE ON
ALARM
TANK FULL
PRETREATMENT LOCKOUT
PERMEATE DIVERT
RO PUMP ON
CIP PUMP ON
AUTOFLUSH
AUTO-ON ACTIVE
AUXILIARY
SYSTEM OPERATIONS MENU
03.7 07.5 7.2 33 31
05/17/94 08:13
11 98.7 77 225 207
CONTROL
MENU SELECT
ENTER
OFF
CIP
ESC
OSMONICS
ECM-100

Shutdown switches

Undue operating condition	Provision
Too high feed pressure	High pressure shutdown switch in the feed line
Insufficient feed pressure	Low pressure shutdown switch in the pump suction line
Too high feed temperature	High temperature switch in the feed line
Permeate pressure exceeding feed by more than 0.3 bar (5 psi) pressure	Pressure relief mechanism in the permeate line
Too high concentration of colloidal matter in the feed	Turbidity control in the feed line
Too high concentration of sparingly soluble salts in the feed	Dosing pumps for acid and antiscalant should be electrically interlocked with the feed pump drive High pH shutdown switch
Oxidizing agents in the feed	ORP (Oxidation Reduction Potential) control in feed line or chlorine detection monitor with automatic shutdown
Oil in the feed	Oil detector in feed line

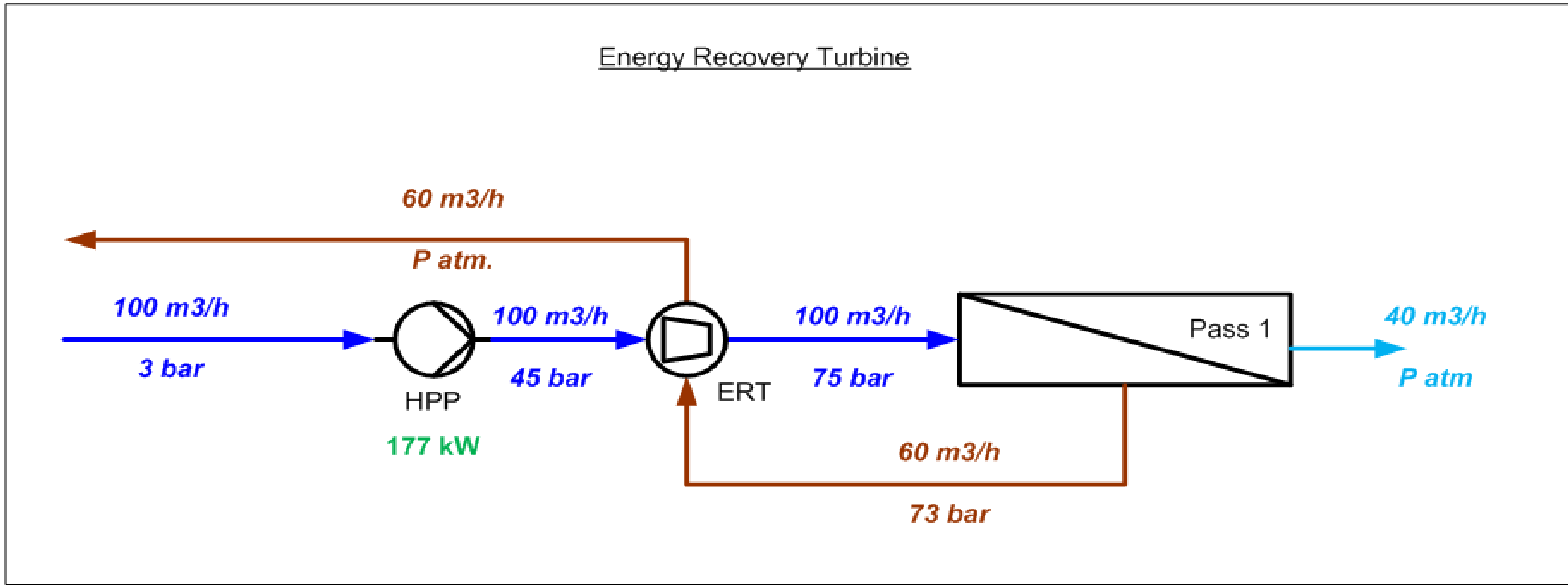

Danfoss

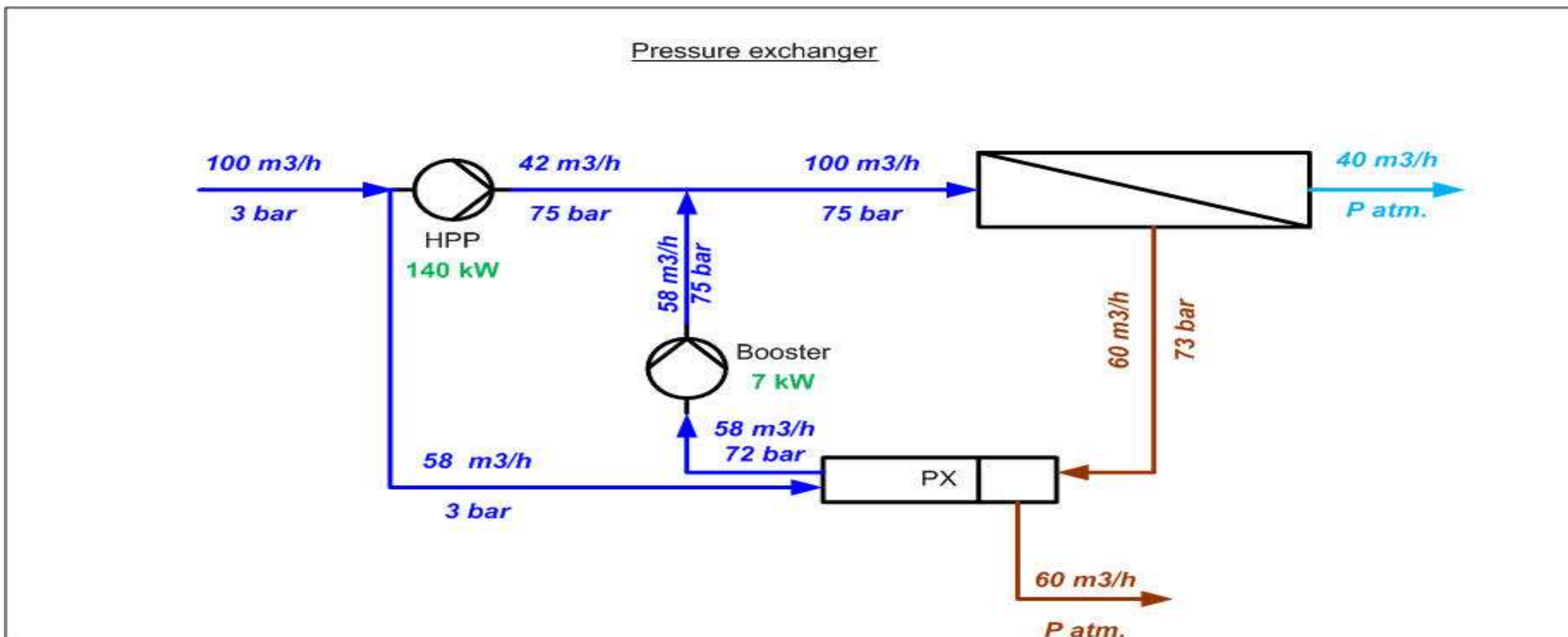
Others
Pic

Energy recovery device

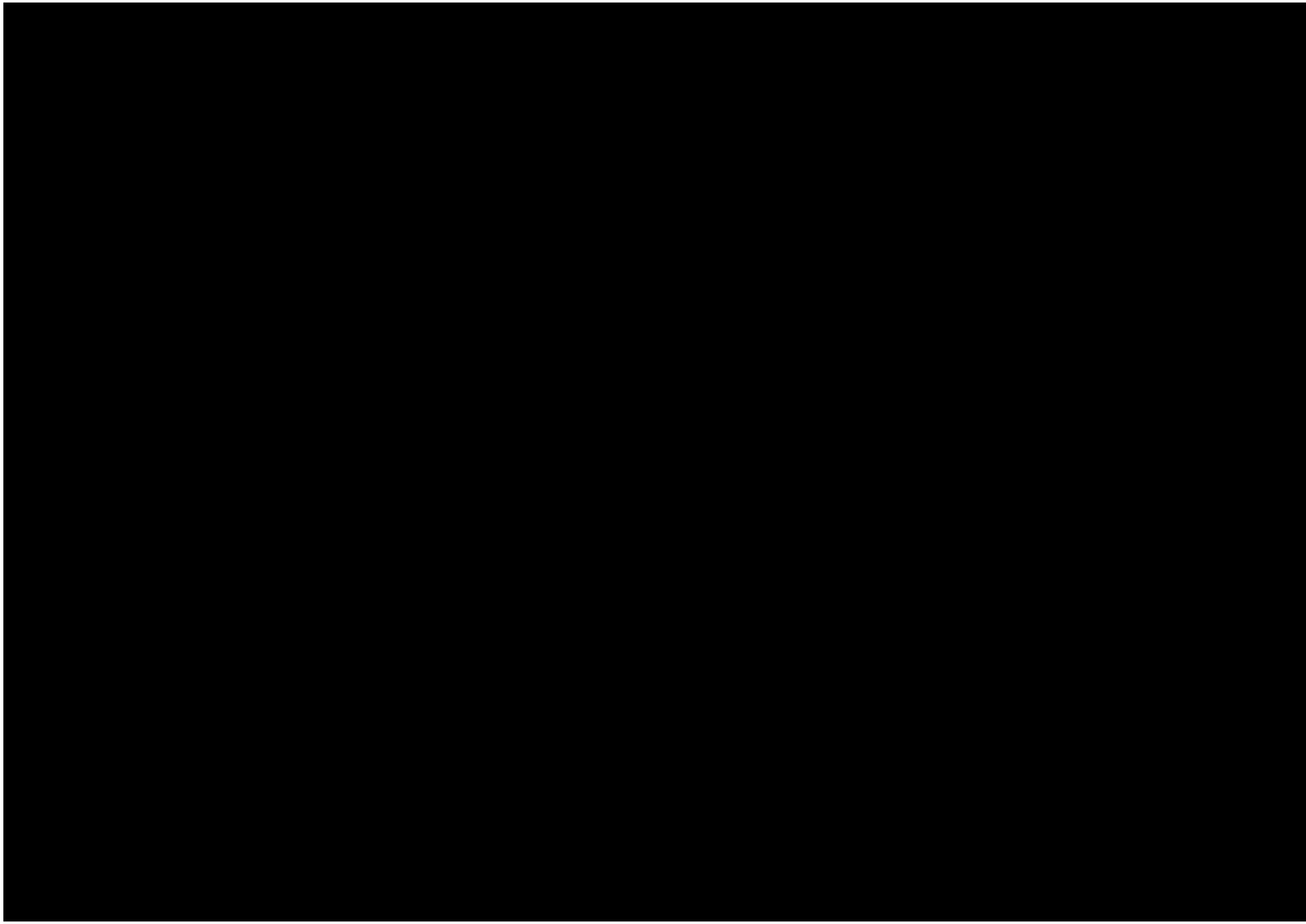
Usually pressure drop in Reject flow (1-3 bar)

- Turbine (30-40 %)
- Pressure exchanger (50-60%)


Energy Recovery Turbine
60 m3/h
P atm.
100 m3/h
3 bar
HPP
177 kW
100 m3/h
45 bar
ERT
100 m3/h
75 bar
Pass 1
40 m3/h
P atm
60 m3/h
73 bar


Pressure exchanger
100 m3/h
3 bar
HPP
140 kW
42 m3/h
75 bar
100 m3/h
75 bar
40 m3/h
P atm.
58 m3/h
75 bar
Booster
7 kW
58 m3/h
72 bar
60 m3/h
73 bar
58 m3/h
3 bar
PX
60 m3/h
P atm.

Pressure exchanger device



Membrane:

The desalination performance of a RO membrane depends largely on the membrane material and the membrane structure.

An industrially useful RO membrane must exhibit several characteristics such as high water flux, high salt rejection, mechanical stability, tolerance to temperature variation, resistance to fouling, and low cost.

Classification of membrane material

> Cellulose acetate (CA)

A good chlorine resistance , less probability to fouling , PH (4-6)

> Polyamide acetate (PA)

A high flux and very high salt rejection, PH (2-12) >>> (MOST USE)

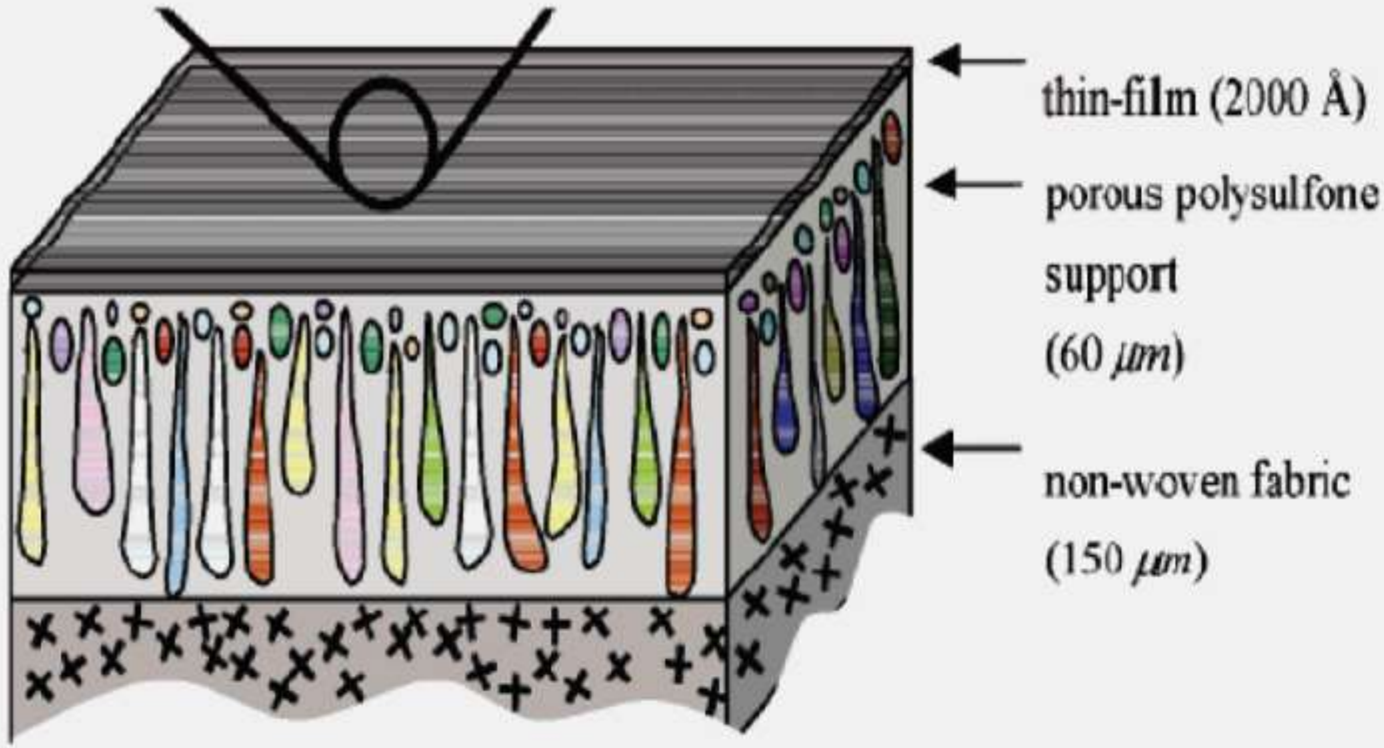
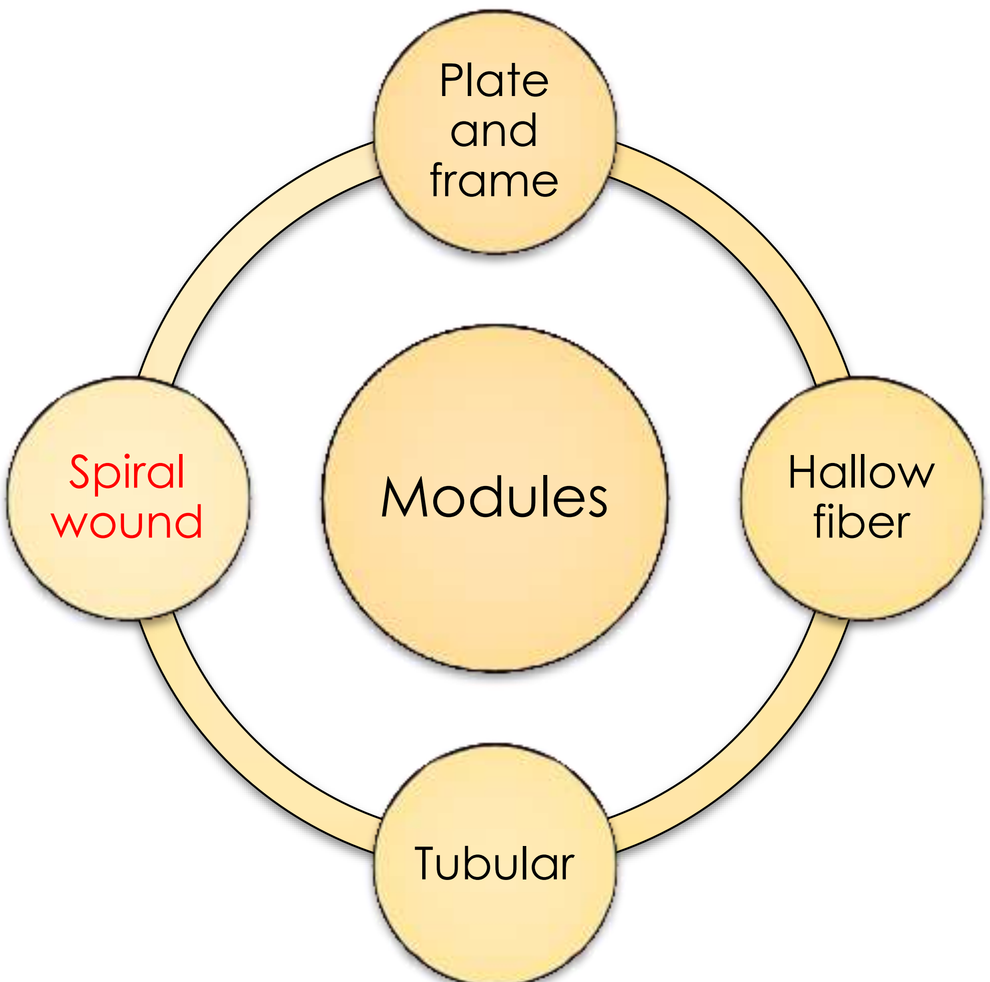


Figure 4.13: Schematic of Thin-Film Composite Membrane

Membrane Modules (structure)



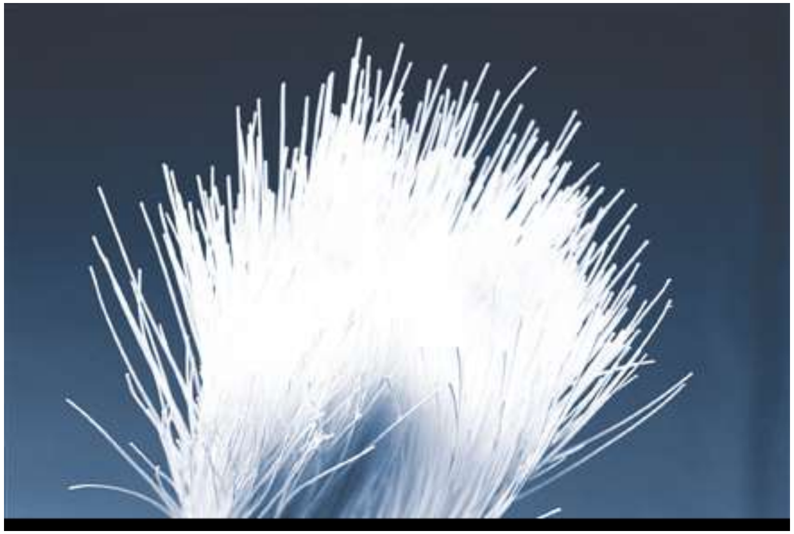
Membrane modules Applications

Plate and frame
For Waste water treatment applications

Hallow fiber
For microfiltration , Ultrafiltration and WWT applications

Tubular
For gas separation

Spiral wound
For desalination



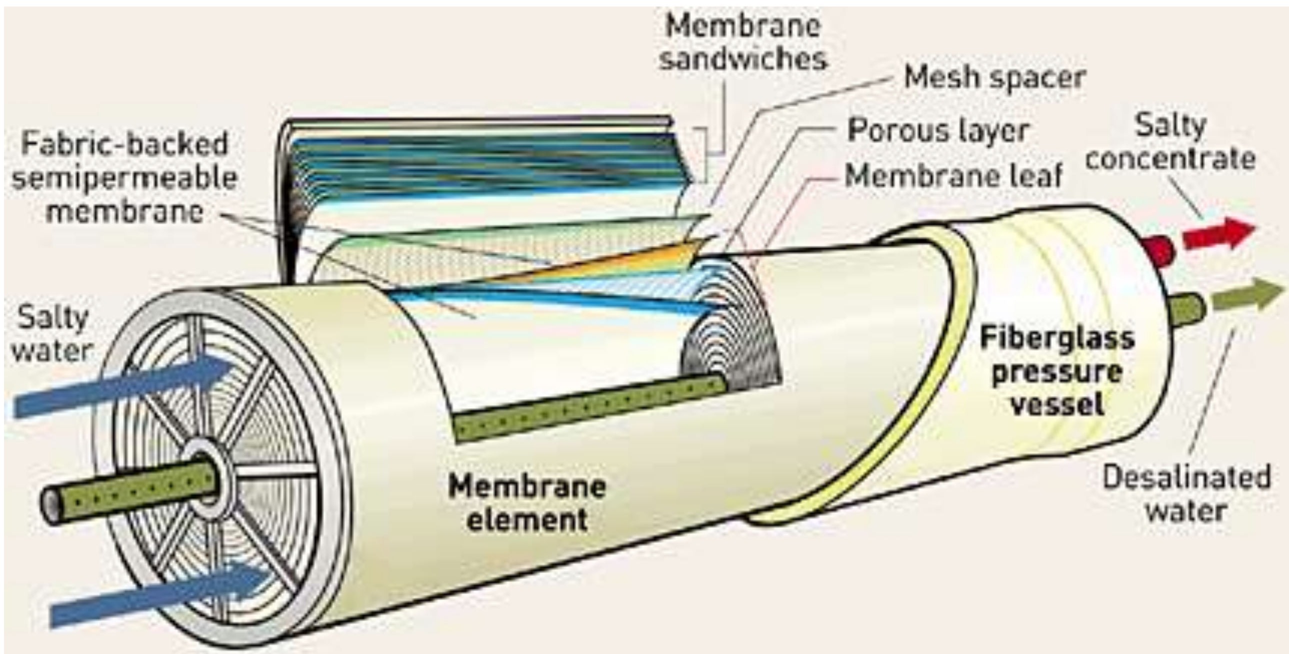

roplant.org

Module	System Cost	Design Flexibility	Required System Space	Energy Use	Susceptibility to Fouling
Plate and Frame	$$$	$$	$$$	$$$	$$
Hollow - Fiber	$	$$$	$	$$	$$$$
Spiral Wound	$	$$$$	$$	$	$$$
Tubular	$$$	$	$$$$	$$$$	$

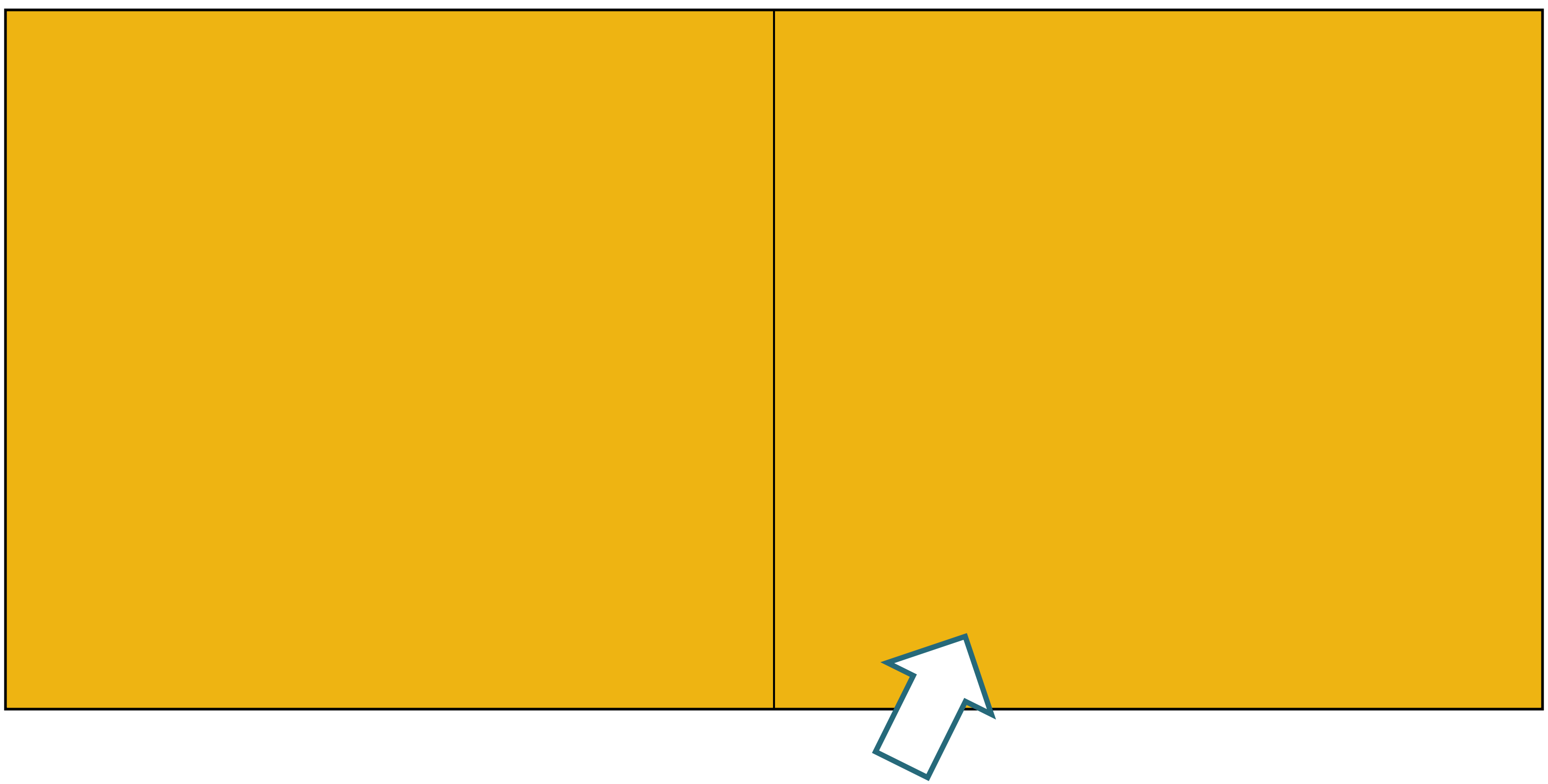
Questions number 2 ?!

Spiral Wound

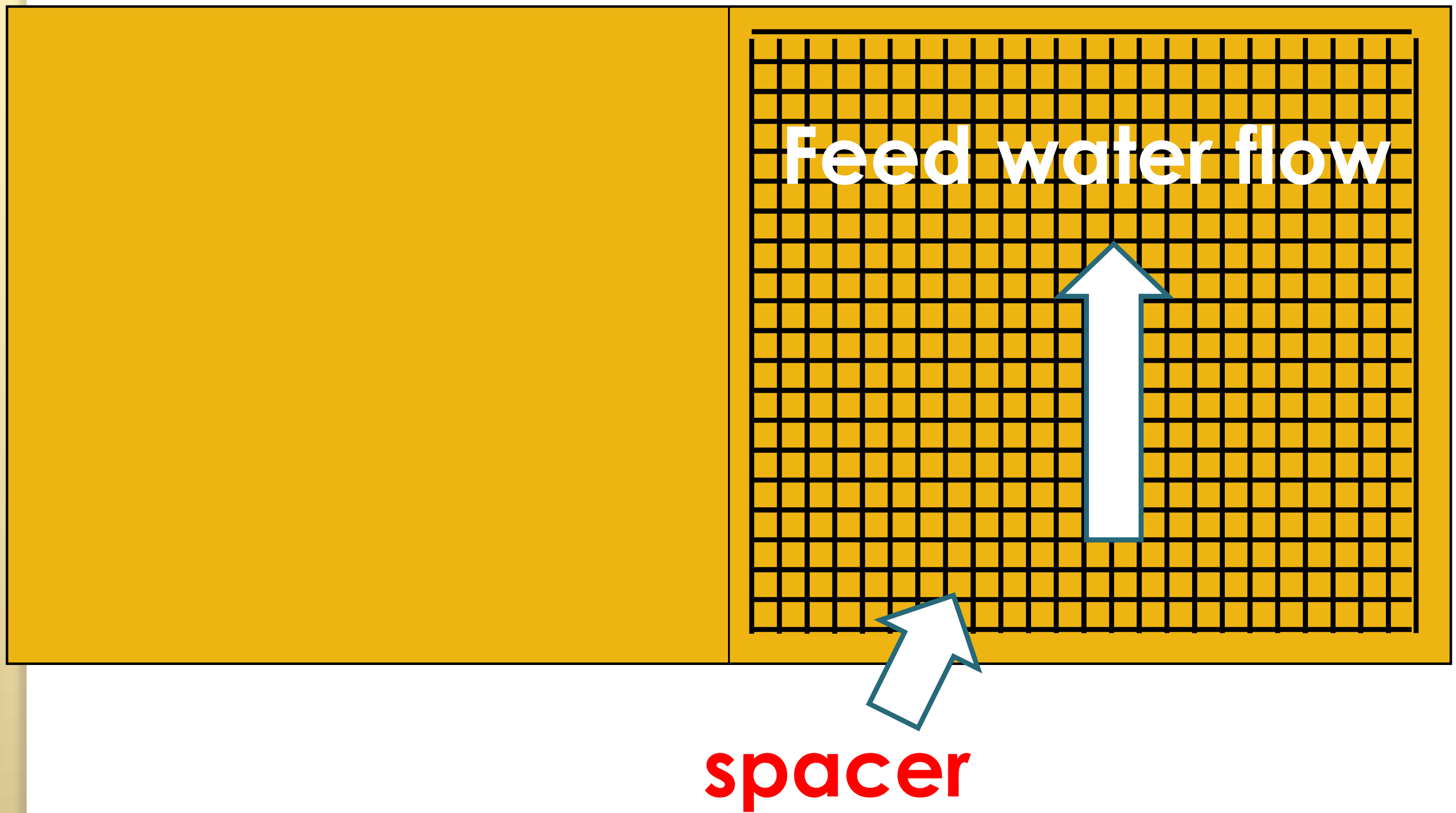
- Spiral wound membrane modules are the most common type of module used for RO today The major advantage of a spiral wound module is that the packing density is fairly high, about 150 - 380 ft2/ft3, higher then for plate and frame or tubular modules.

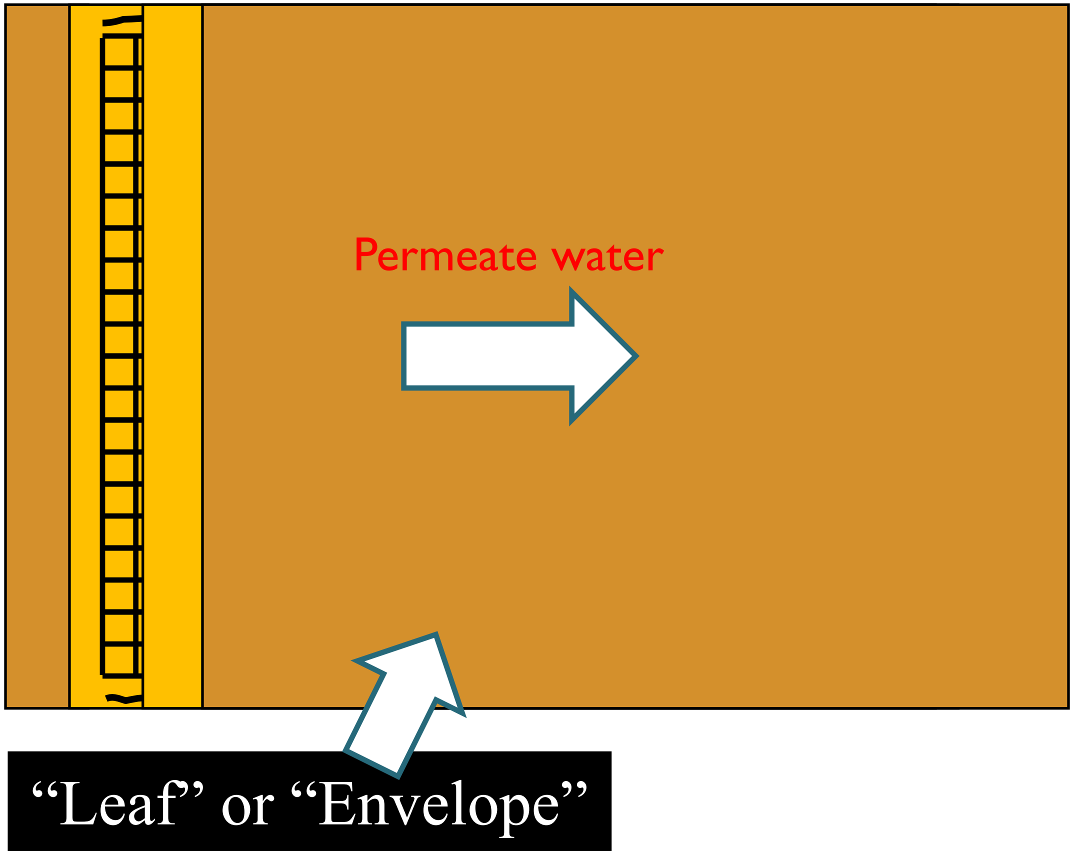


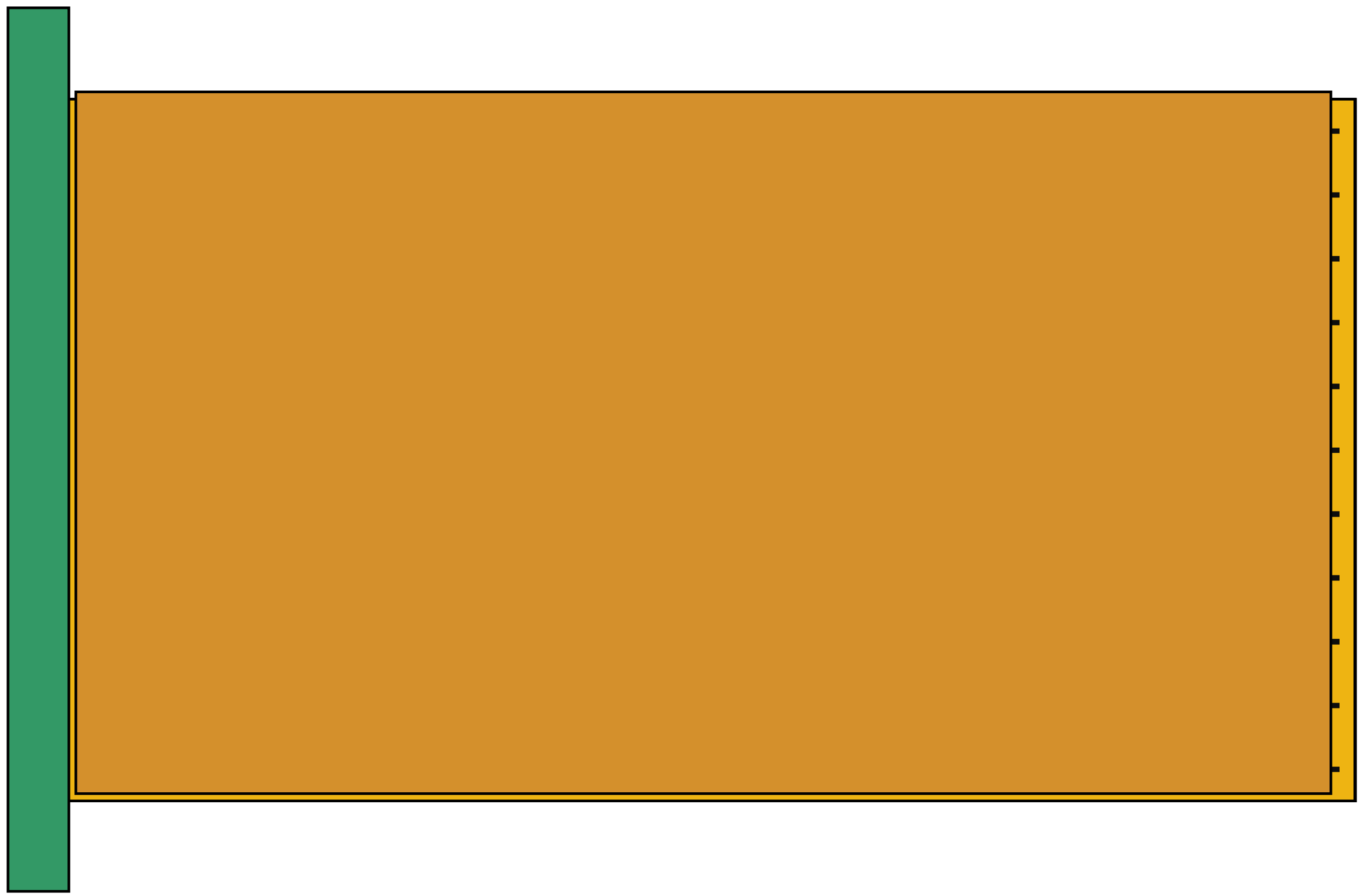
Spiral Wound Modules

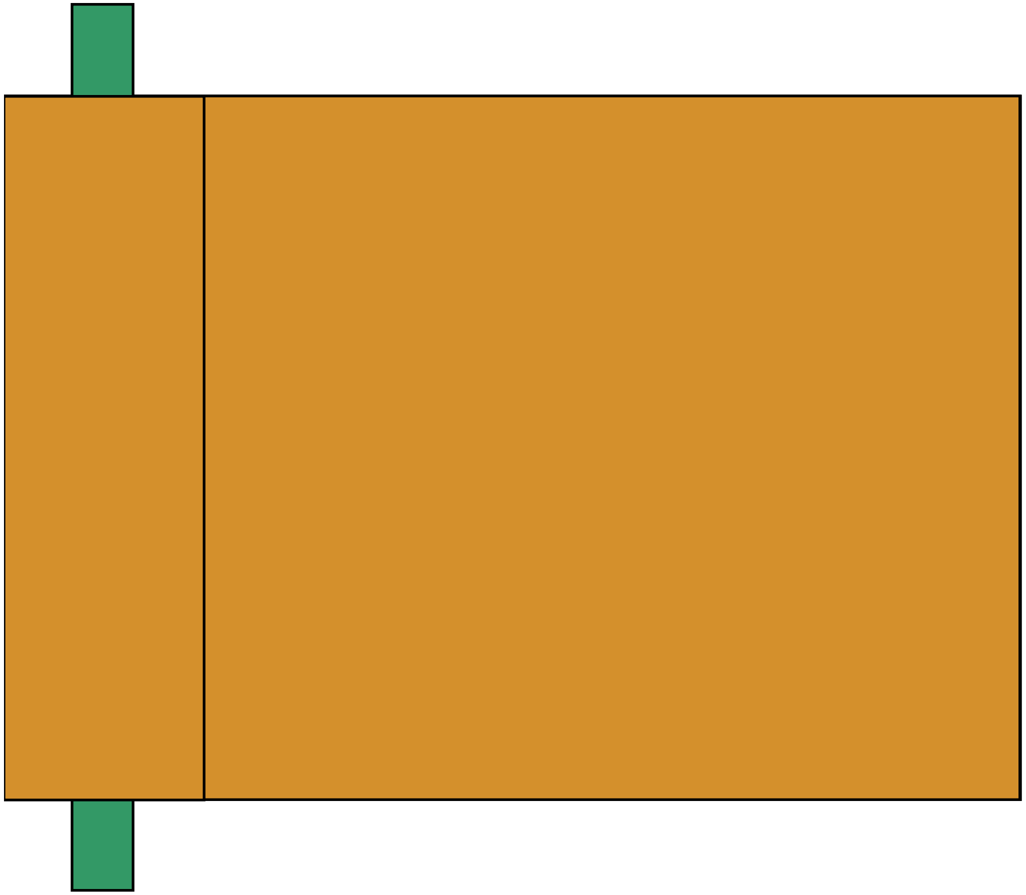


Membrane sheet


Feed water flow
spacer


Permeate water
“Leaf” or “Envelope”

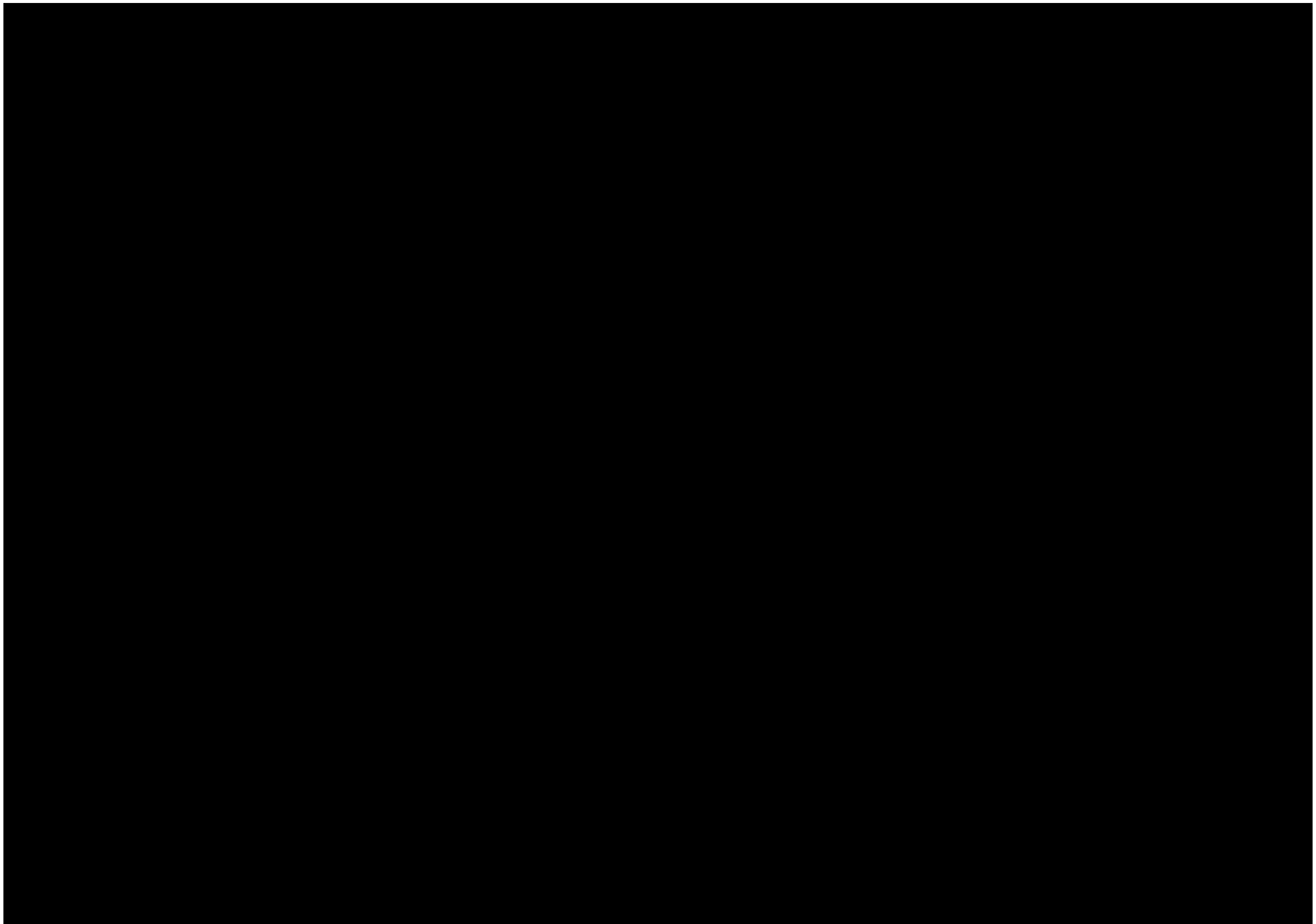




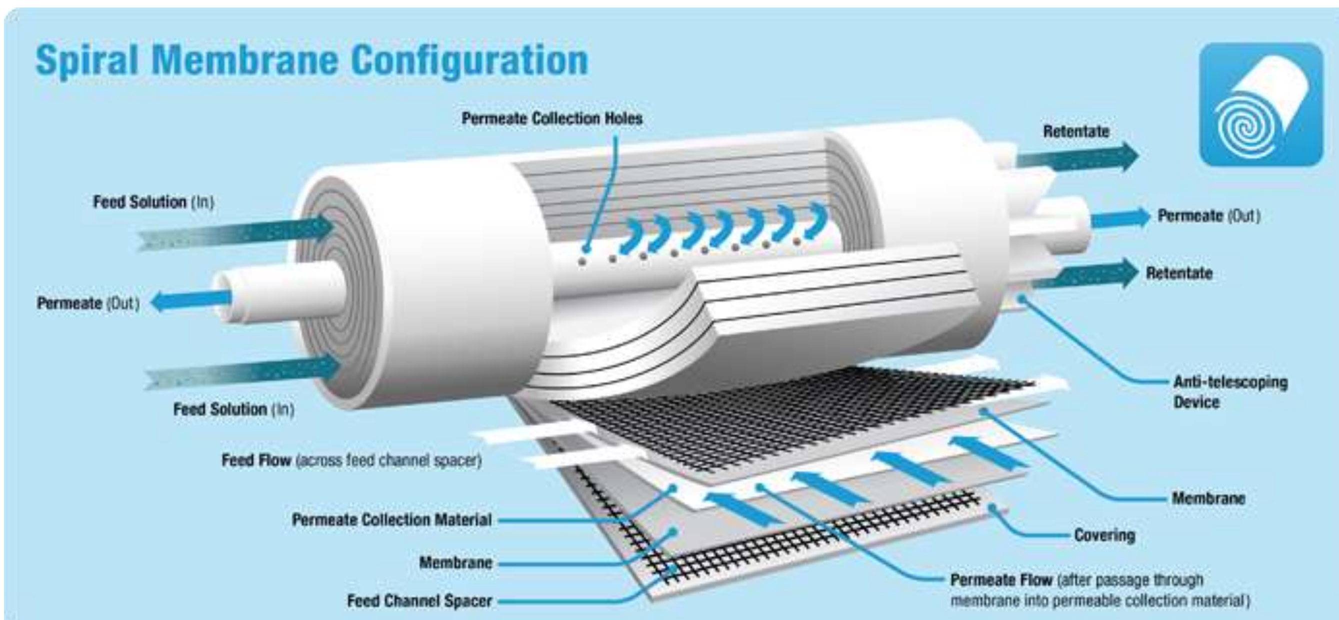
Commercially-Available Membranes

- > Seawater membranes
- > Brackish water membranes
- > Brackish, low-energy membranes
- > Brackish, low-differential pressure membranes
- > Brackish, low-fouling membranes.
- > Other Membrane/Module Types , like Boron rejection membranes.

Spiral wound membrane video




LP21-8040
LP11-4040
SW11-4040
ULP11-4021


Spiral Membrane Configuration
Permeate Collection Holes
Retentate
Feed Solution (In)
Permeate (Out)
Permeate (Out)
Retentate
Feed Solution (In)
Anti-telescoping Device
Feed Flow (across feed channel spacer)
Membrane
Permeate Collection Material
Covering
Membrane
Feed Channel Spacer
Permeate Flow (after passage through membrane into permeable collection material)

8” element
Membrane area 40m2 (430 ft2)
Nominal flow 45 m3/day
Avg. field flow 19 m3/day

16” element
Membrane area 140 m2 (1,500 ft2)
Nominal flow 155 m3/day
Avg. field flow 68 m3/day

Membrane vessel(pressure vessel)

- Pressure vessel (membrane element housing) is designed for specific pressure applications.

- fiber glass reinforced plastic
- Stainless steel

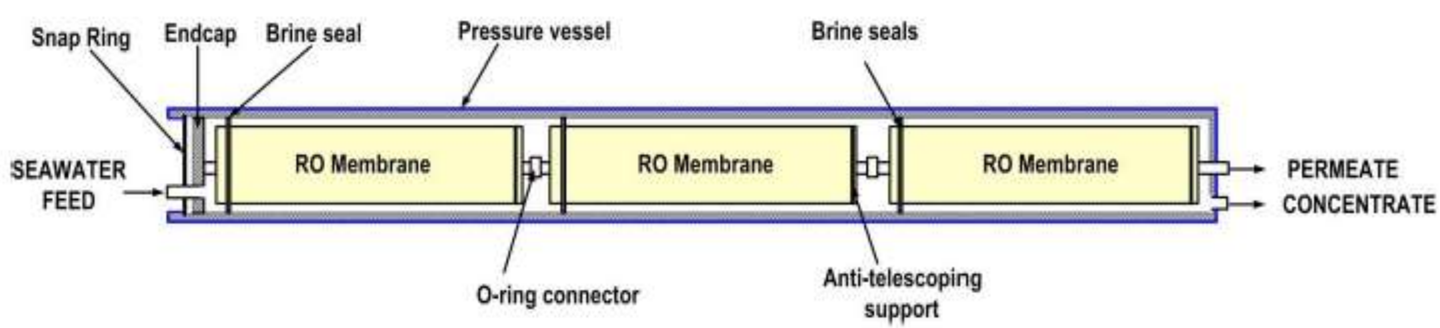
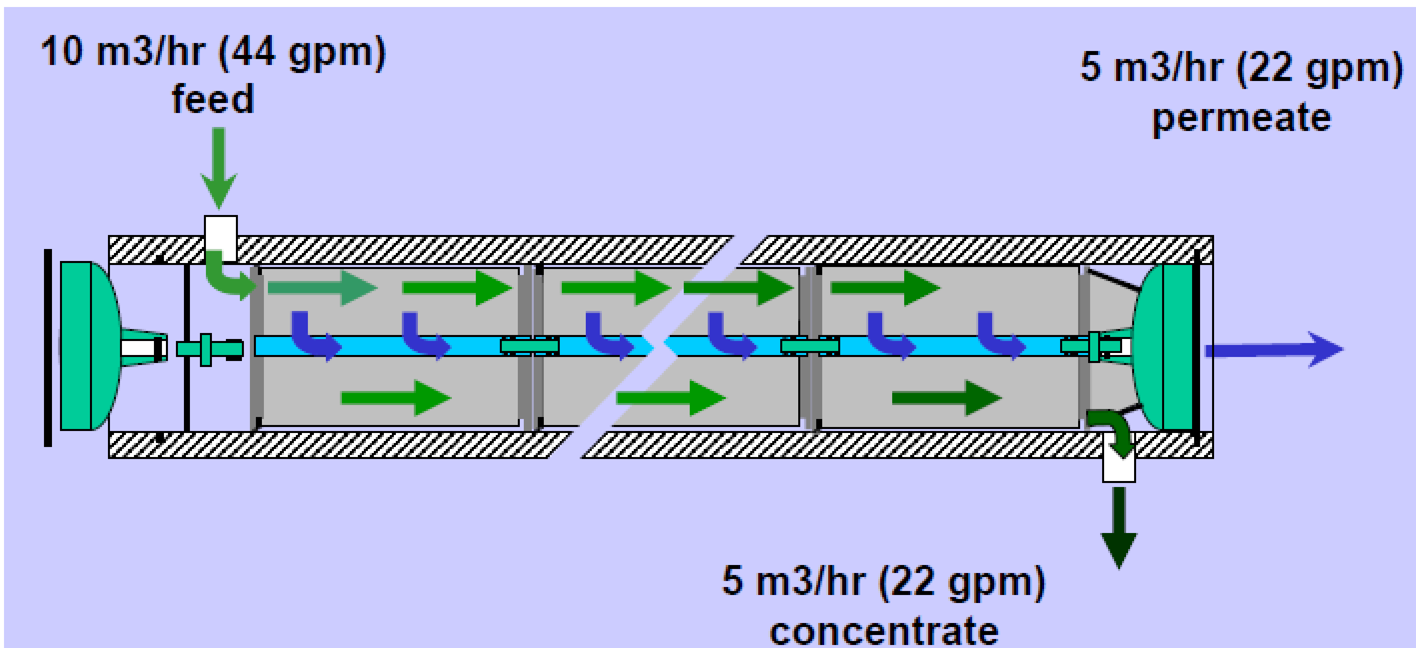


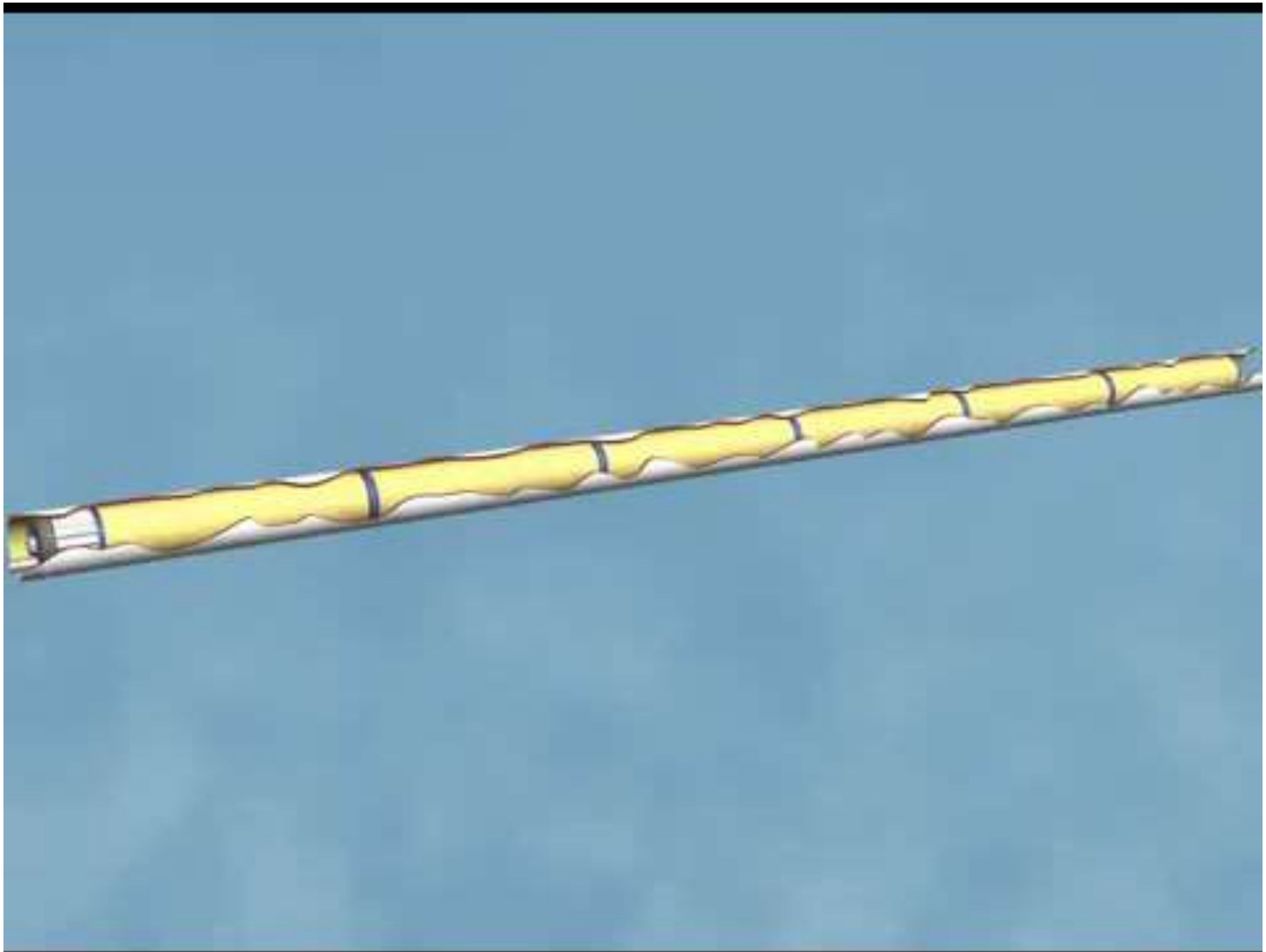
Figure 4.22: cross section Inside the pressure vessel


Hydranautics


Image courtesy of CDM Constructors


10 m3/hr (44 gpm)
feed
5 m3/hr (22 gpm)
permeate
5 m3/hr (22 gpm)
concentrate

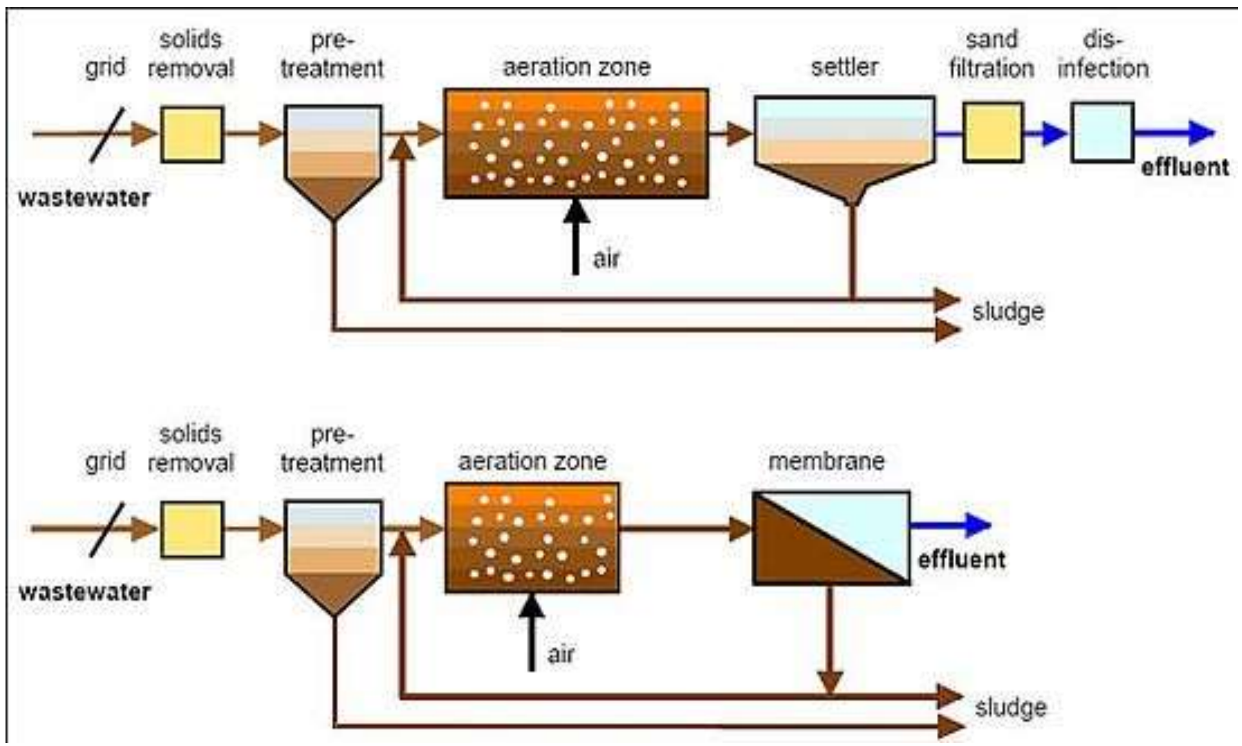
Membrane Pressure vessel video

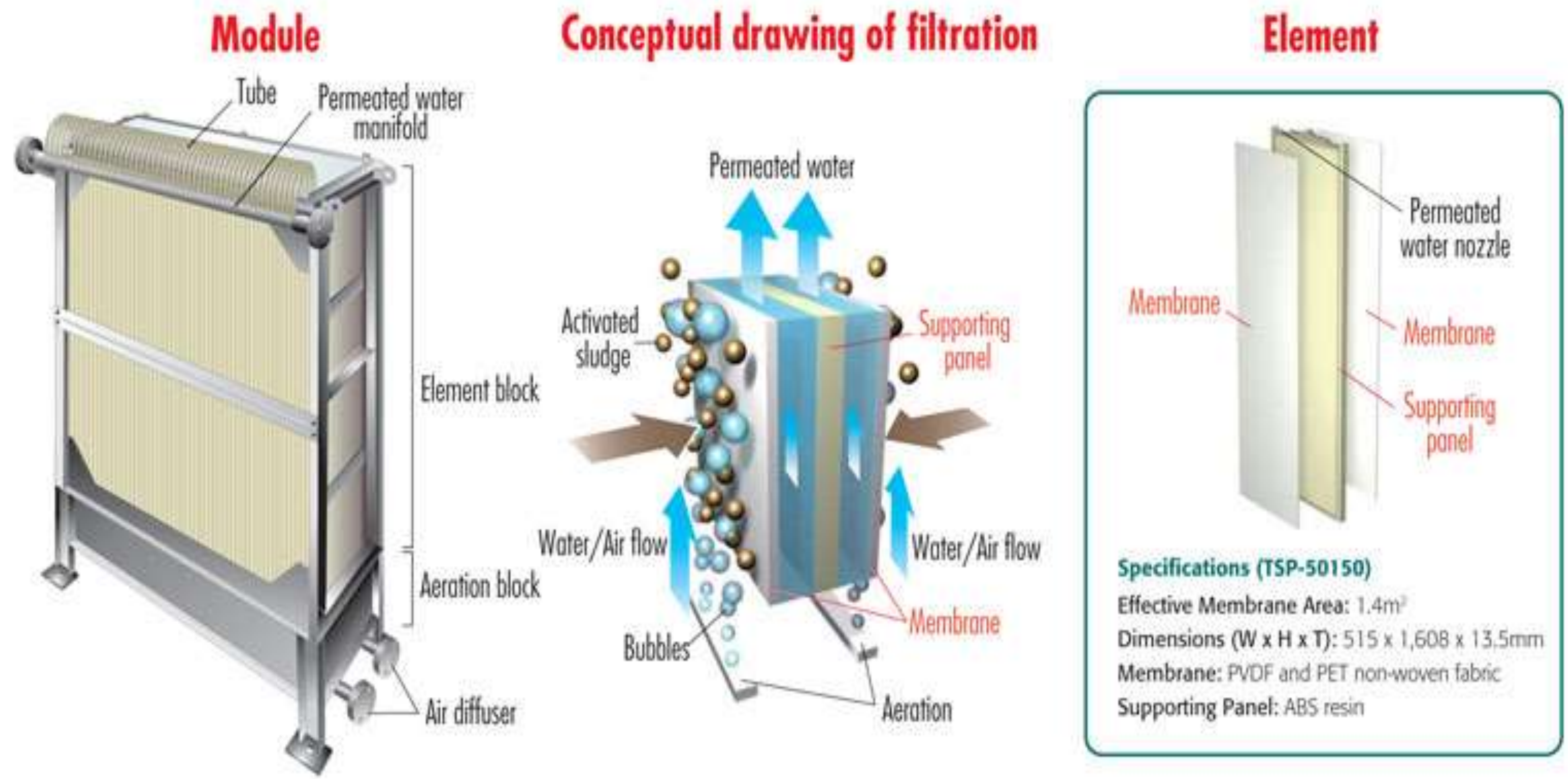


Membrane new technology

- Membrane Bioreactor (MBR)
- Forward osmosis desalination

Membrane bioreactor



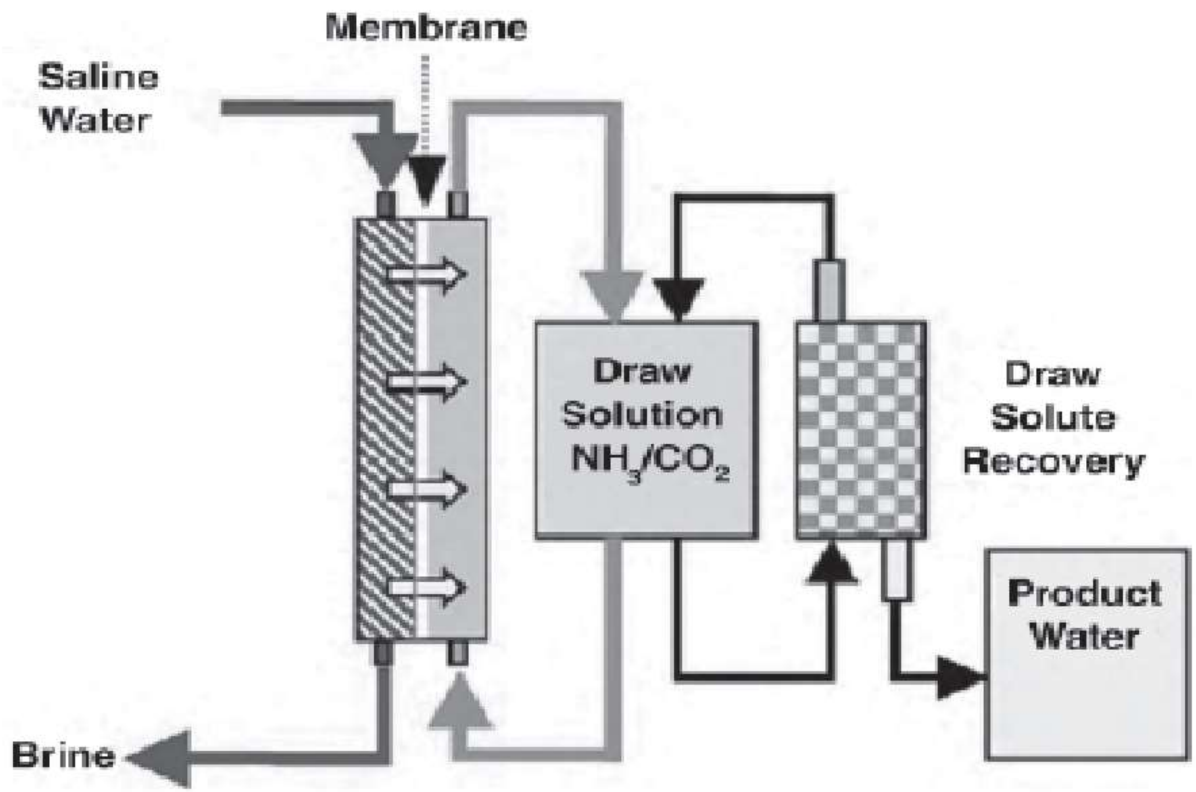

Module
Tube
Permeated water manifold
Element block
Aeration block
Air diffuser
Conceptual drawing of filtration
Permeated water
Activated sludge
Supporting panel
Water/Air flow
Water/Air flow
Bubbles
Membrane
Aeration
Element
Permeated water nozzle
Membrane
Membrane
Supporting panel
Specifications (TSP-50150)
Effective Membrane Area: 1.4m²
Dimensions (W x H x T): 515 x 1,608 x 13.5mm
Membrane: PVDF and PET non-woven fabric
Supporting Panel: ABS resin

- BOD < 2 mg/L
- TSS < 0.5 mg/L
- NH3-N < 0.5 mg/L
- TN < 3 mg/L
- TP < 0.05 mg/L
- Turbidity < 0.2 NTU
- Fecal Coli < 10 CFU/100 mL

Using R.O without pretreatment


Source
UF/MBR System
RO System
UV Disinfection
Product

Forward osmosis desalination



Introduction to design

Factors Affecting Reverse Osmosis Performance (Flux & Salt rejection)

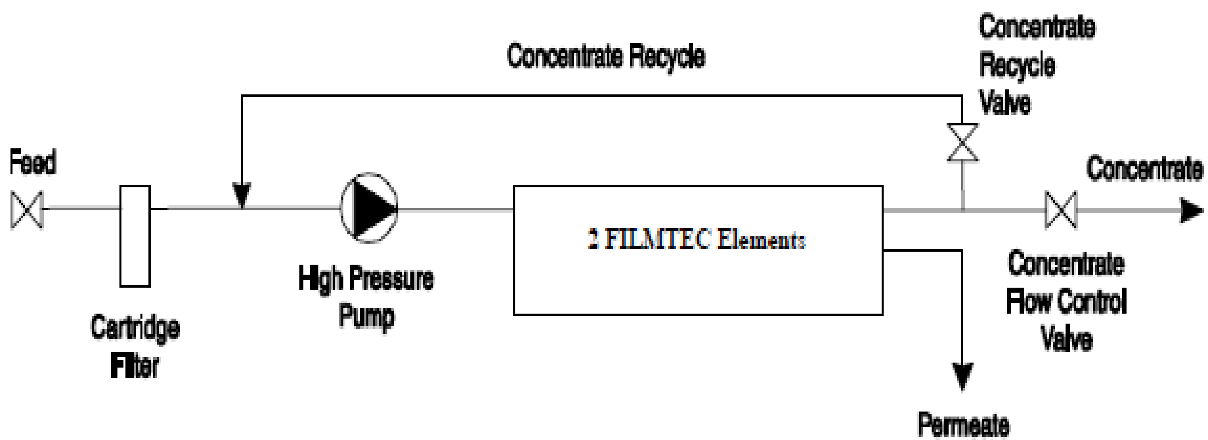
1-Pressure
2-Temperature
3-Recovery
4-Feed water salt concentration

1- Pre treatment
2- Operation
3- Maintenance

Increasing	Permeate Flow	Salt Passage
Effective pressure	↑	↓
Temperature	↑	↑
Recovery	↓	↑
Feed salt correction	↓	↑

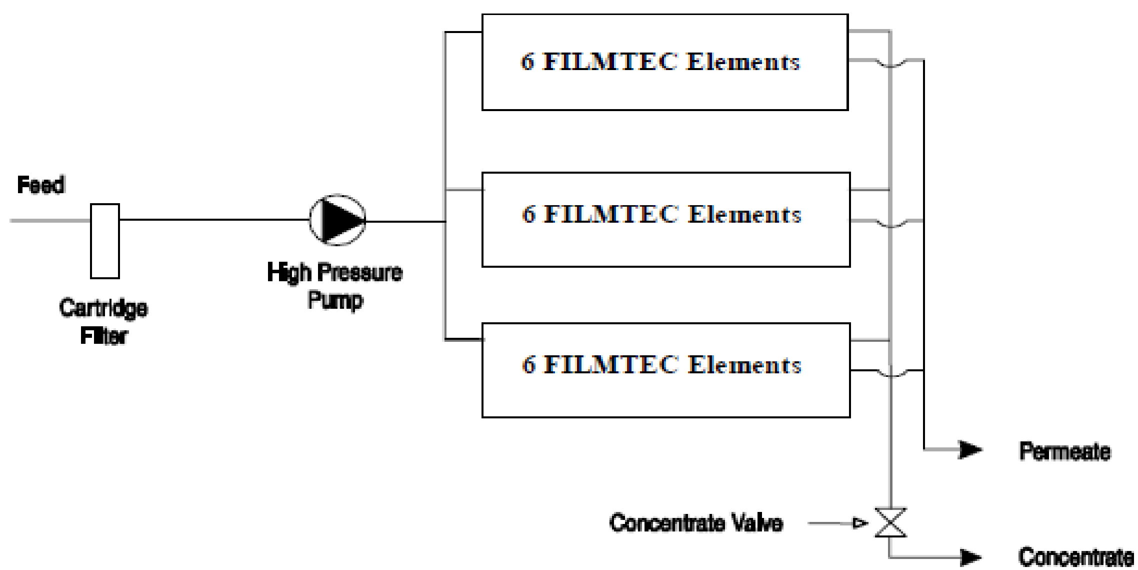
Single-Module System

A module consists of a pressure vessel with up to eight membrane elements, which are connected in series. The concentrate of the first element becomes the feed to the second, and so on. The product tubes of all elements are coupled and connected to the module permeate port. The permeate port may be located on the feed end or on the concentrate end of the module.



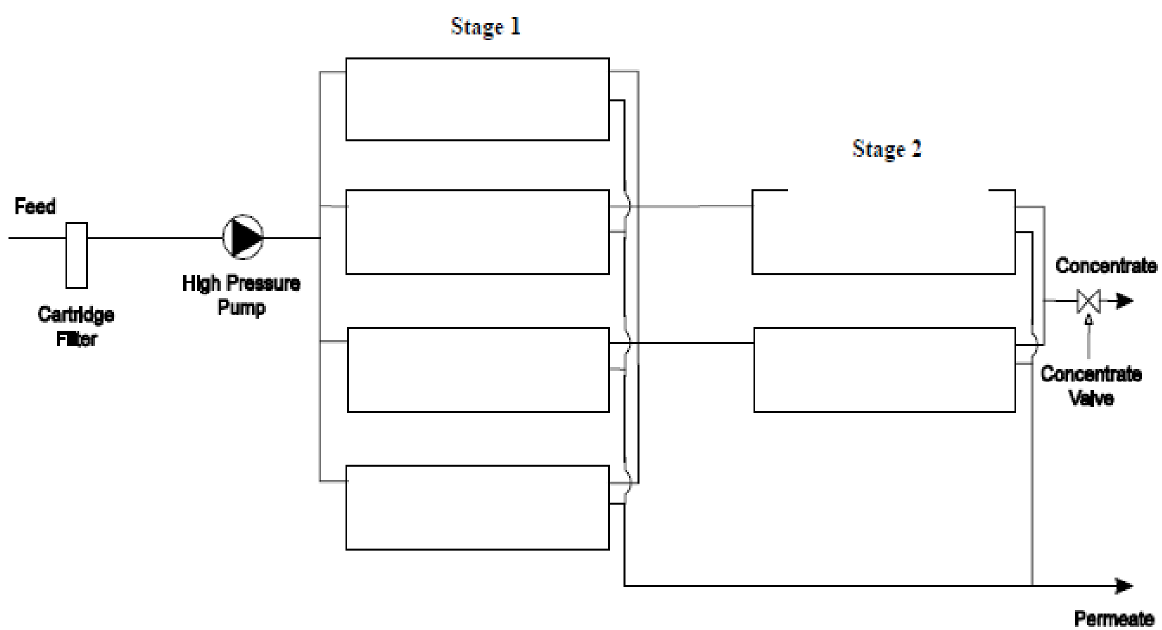
Single-Stage System

In a single-stage system, two or more modules are arranged in parallel. Feed, product and concentrate lines are connected to manifolds. Other aspects of the system are the same as in a single-module system. Single-stage systems are typically used where the system recovery is less than 50%, e.g., in seawater desalination.



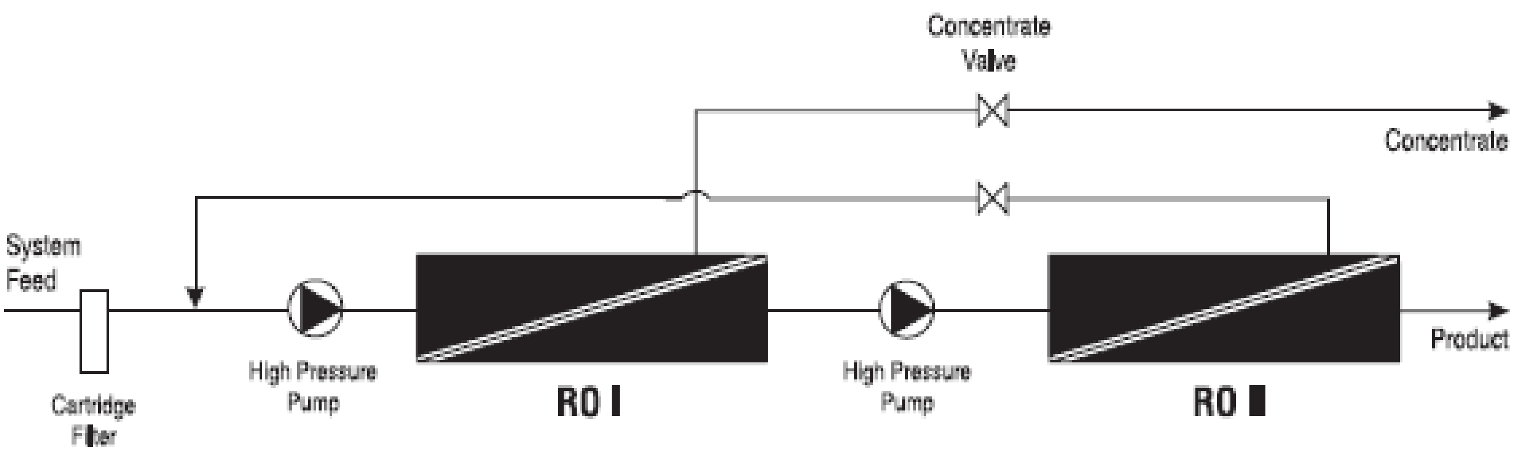
Multi-Stage System

Systems with more than one stage are used for higher system recoveries without exceeding the single element recovery limits. Usually two stages will suffice for recovery up to 75%, and three must be used for higher recovery. These numbers are based on the assumption that standard pressure vessels with six elements are used

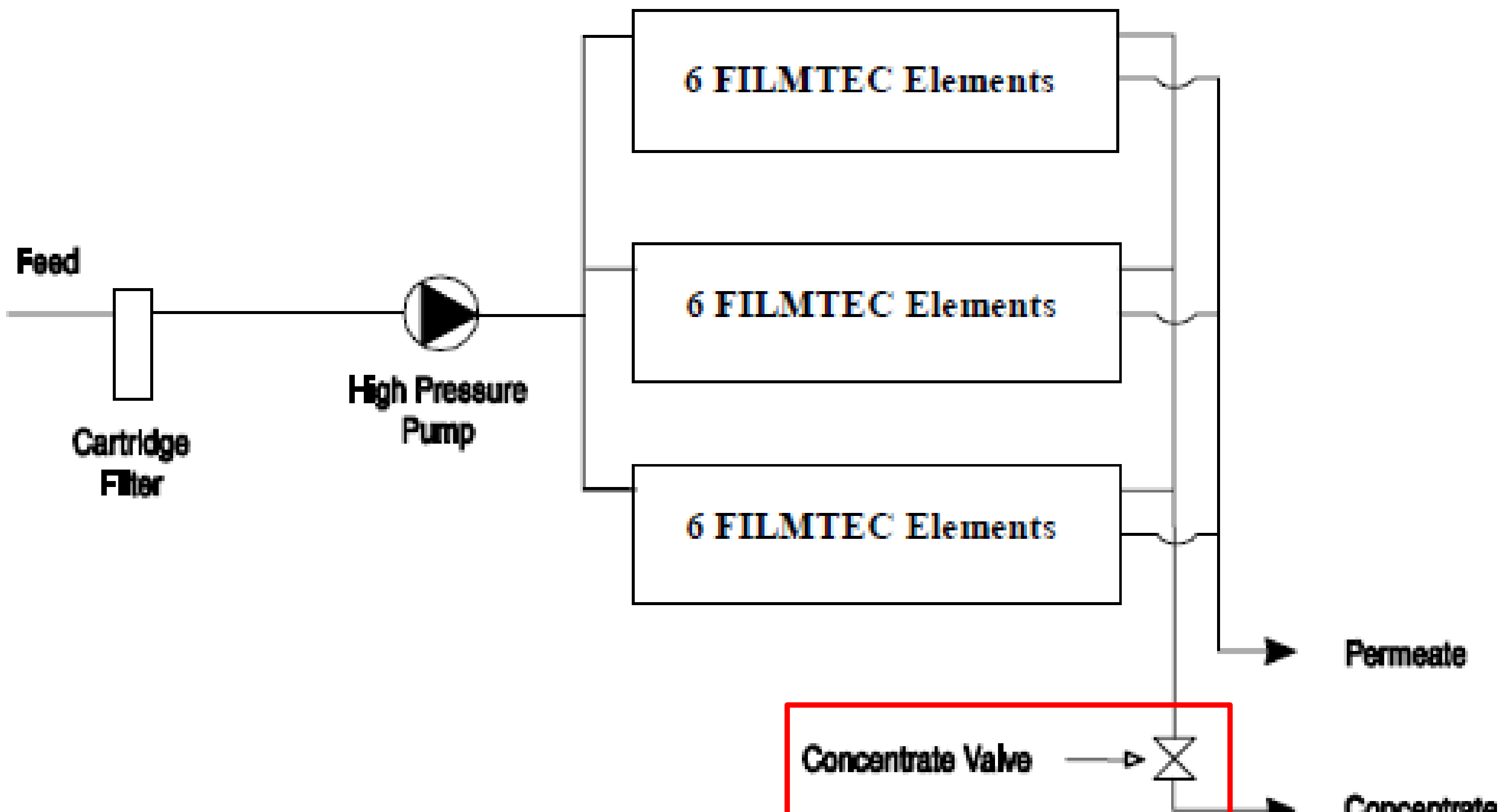


Permeate-Stage System

The production of water for pharmaceutical and medical use is a typical application of permeate staged systems. A permeate staged system is the combination of two conventional RO/NF systems where the permeate of the first system (first pass) becomes the feed for the second system (second pass)



Concentrate flow control & Auto flush valve




GELTRON

Stage of R.O plant (Video)

Zara Ma'in reverse osmosis desalination plant

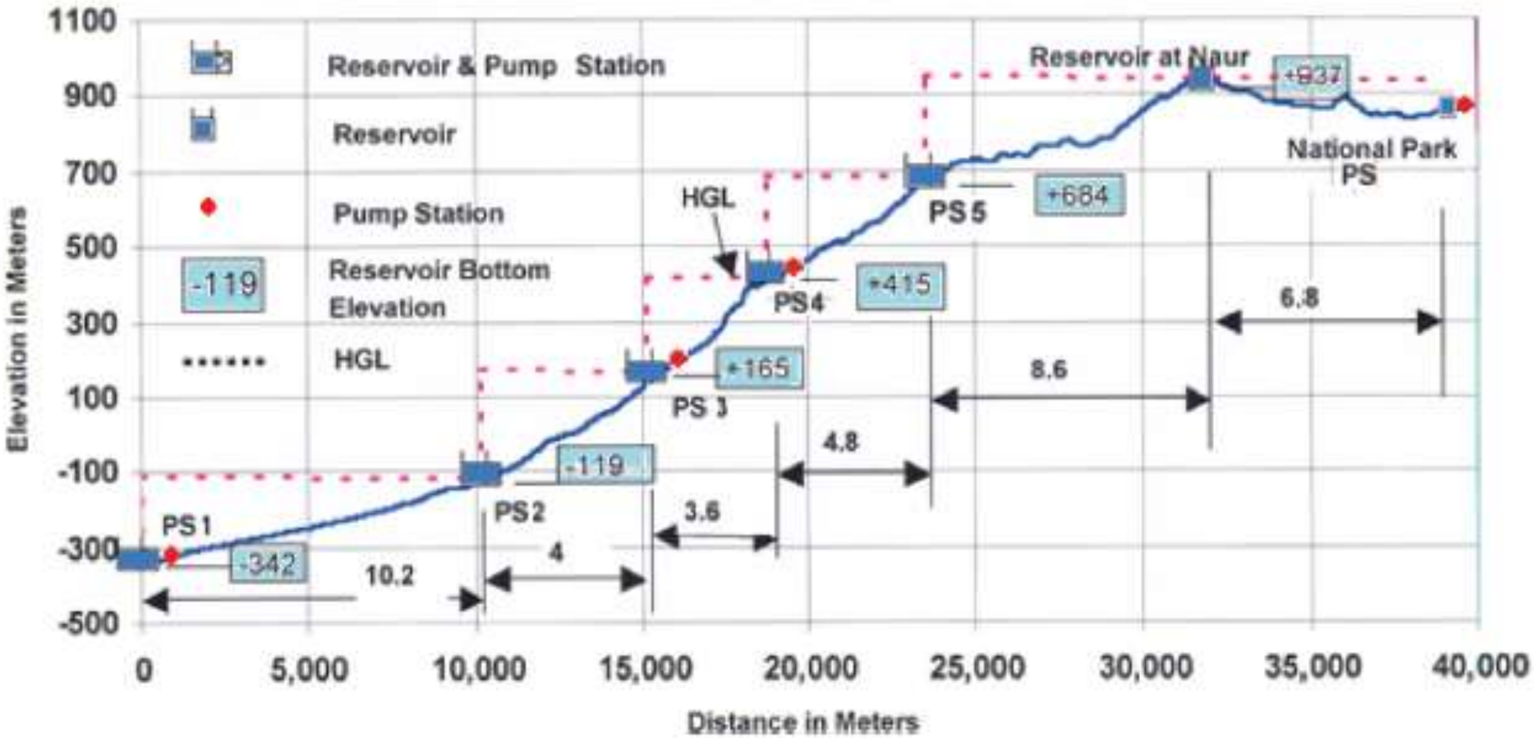
One of the 100 largest desalination plant in the world (2005)
Total Cost = 125 million $

Total feed water = 55MCM/Y

Zara Springs	6.4 MCM/Y	11.7%
Wadi Mujib	27.5 MCM/Y	50.0%
Wadi Ma'In	21.1 MCM/Y	38.3%

Recovery rate = 87.5 %
Number of RO trains = 9
Max number of trains in service = 8
Number of stages = 3
Raw water silt density index (SDI) <3 normally Maximum of 5
Membrane type Spiral wound = 400 ft2
Type 1: BW30-400FR (Dow) , Type 2: LE-400 (Dow)

Feed water TDS = 1460 mg/l
Product water TDS = 185 + blending
RO inlet pressure range =14 bar
Differential pressure across the membrane = 2.31 bar



Reservoir & Pump Station
Reservoir
Pump Station
-119
Reservoir Bottom Elevation
HGL
Reservoir at Naur
+937
National Park PS
HGL
PS 5
+684
PS4
+415
+165
PS 3
-119
PS2
PS1
-342
10.2
4
3.6
4.8
8.6
6.8
Elevation in Meters
Distance in Meters
1100
900
700
500
300
100
-100
-300
-500
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000

Red Dead Sea projects

The largest desalination plant in the world
Total Cost = 13 Billion $

-Total feed water = 2150 MCM/Y
-Total permeate water = 930 MCM/Y (560 MCM/Y in 2035)
-Total rejected water = 1220 MCM/Y (Dead Sea)

Sea water desalination plant # 1

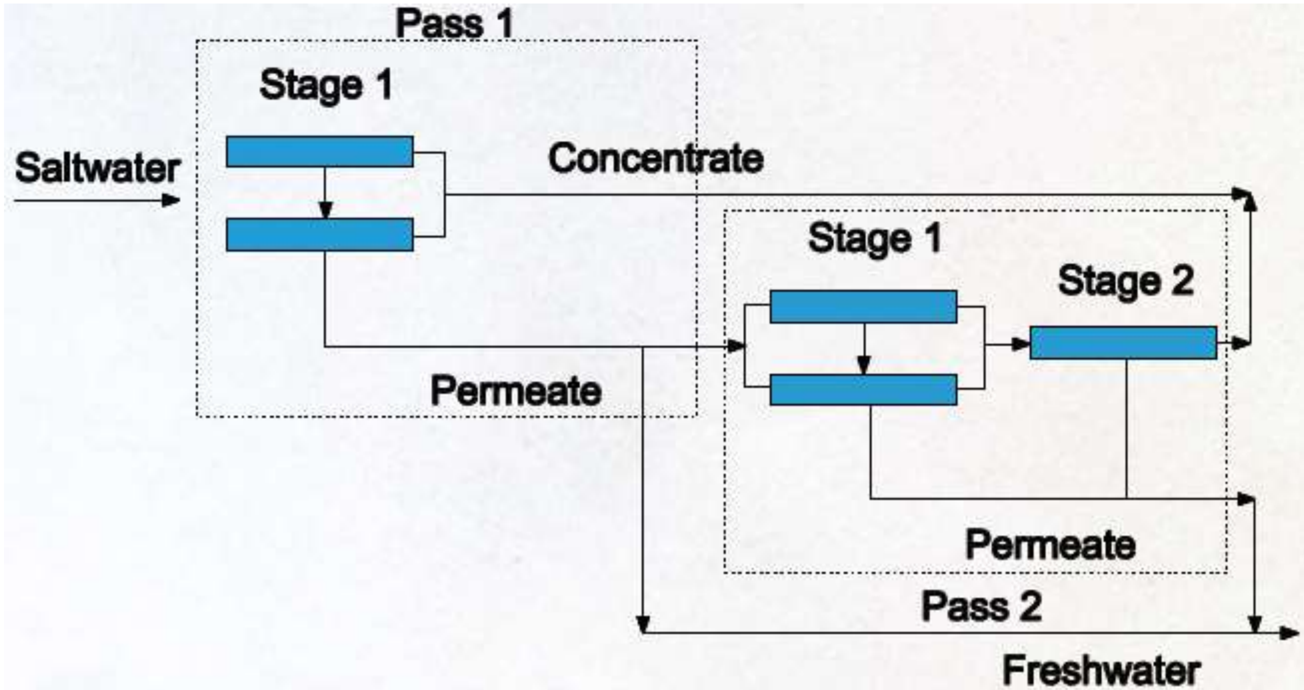
- phase 1= 50 MCM/Y (Aqaba)
- Phase 2 = 80 MCM/Y

Sea water desalination plant # 2

- phase 1= 150 MCM/Y (Amman)
- Phase 2 = 850 MCM/Y

- Hydropower = 180 mega watts


AMMAN
SOUTH AMMAN CITY
1
GATED COMMUNITIES
2
DEAD SEA
MADABA
WADI MUJIB
SOUTH DEAD SEA BAY
3
KARAK
SOUTH DEAD SEA CITY
4
PETRA
NORTH AQABA CITY
5
WADI RUM
RED SEA
AQABA
RESORT
GATED COMMUNITY
NEW CITY
FRESH WATER PUMPS
PRE-TREATMENT PLANT
DESALINATION PLANT
HYDROPOWER STATION
SEA WATER PUMPS
SEA WATER CONVEYANCE
FRESH WATER CONVEYANCE
BRINE & SEA WATER CONVEYANCE



- 930 MCM/Y total freshwater capacity
- 297 pumps require 194,176 kwh of electrical power
- Plant design recovers 50% of energy used
- Worlds largest desalination facilities

Training Course on Planning of Desalination plant using R.O system

- Introduction to Desalination
- Introduction to Reverse osmosis
- Pretreatment
- R.O
- **Post treatment**
- Others

Post treatment

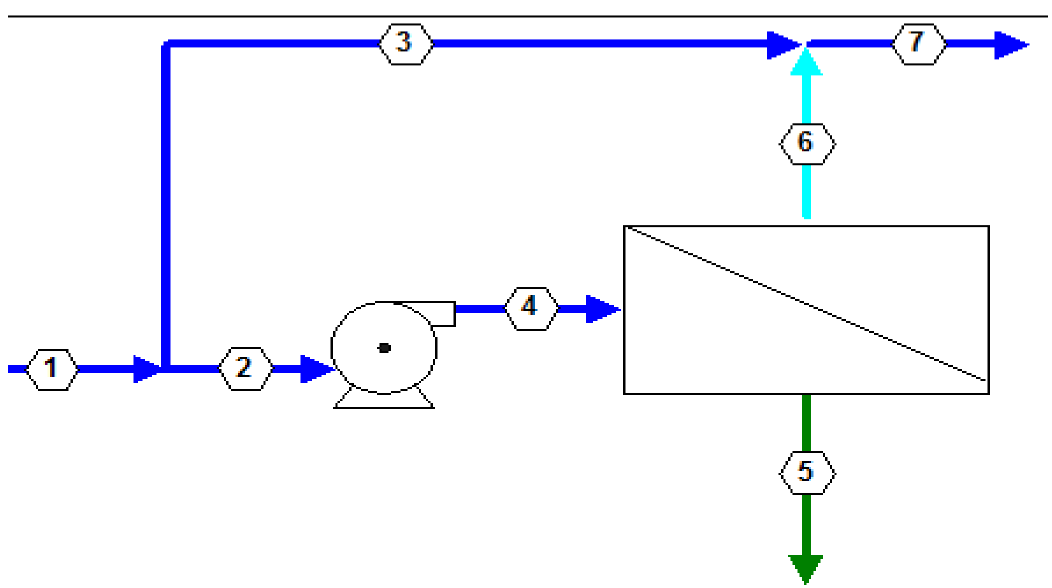
Water from a desalination process is typically void of dissolved solids resulting in finish water with low hardness , low alkalinity and high amount of dissolved gases. As a result, desalinated water without post-treatment is corrosive toward the metal and concrete surfaces of pipelines and other wetted surfaces

The aims of the post treatment:

1-Remove corrosion effect of water
2-Make sure that the water permeate matching the specifications and standards required, such as pH and demineralization

Blending:

Desalinated waters are commonly blended with small volumes of more mineral-rich waters to improve their acceptability and particularly to reduce their aggressive attack on materials, the major ions added are sodium and chloride.



Neutralization and PH adjustment

Reverse Osmosis (RO) Systems can lower the pH of Process Water by (1 - 2)points, creating slightly acidic water so that can pose a risk to piping and equipment of (RO) unit .

The Adjustment of pH as Pre/post treatment and that depend on the applicable conditions.

Degasification or Decarbonation

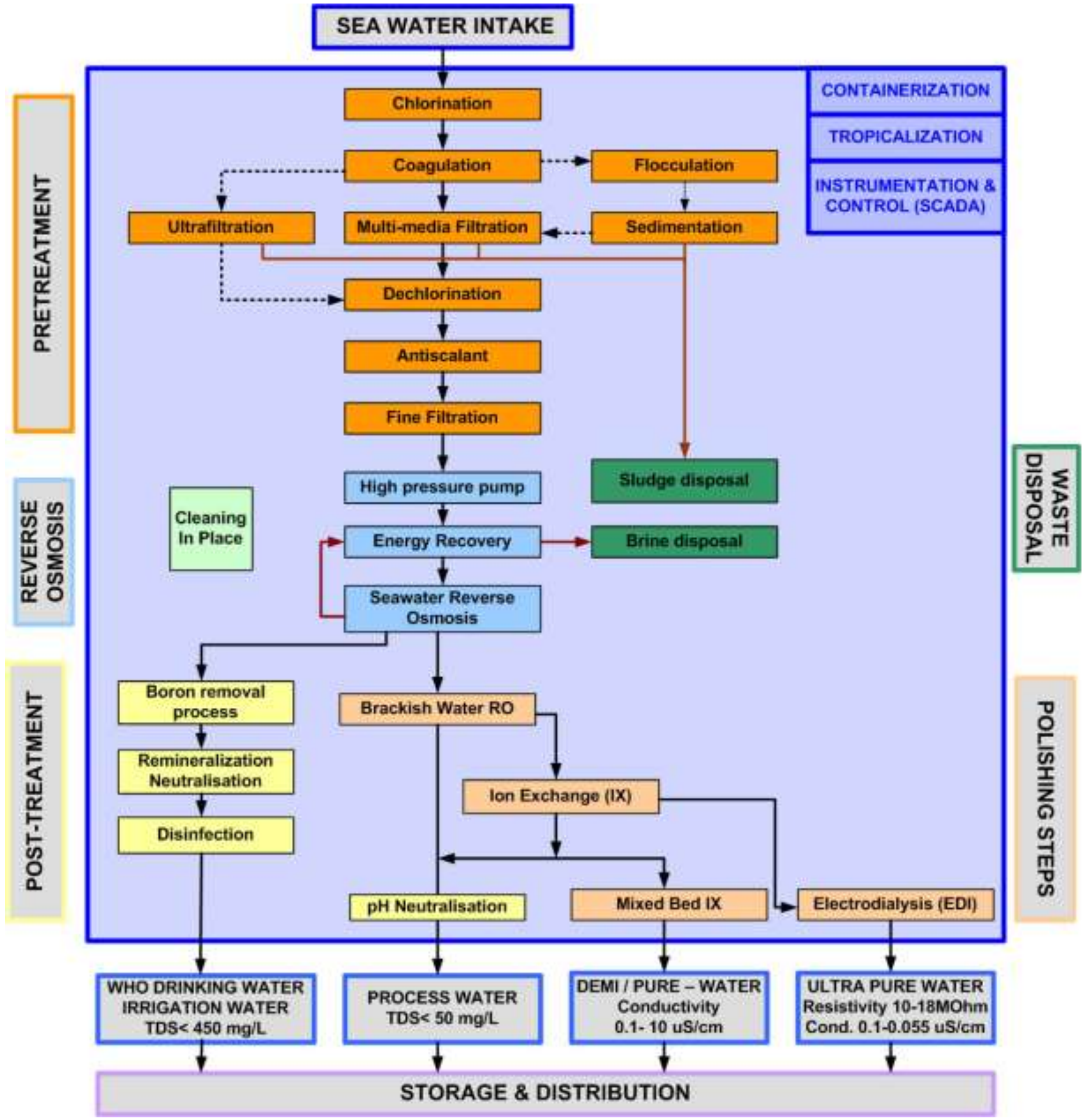
Degasification or Decarbonation is the removal of dissolved gases from liquids, The purpose of the post treatment decarbonation is to remove dissolved carbon dioxide in the reverse osmosis (RO) permeate water in order to increase the pH value.

Corrosion and Corrosion inhibitor

Corrosion is destruction or loss of metal through chemical or electrochemical reaction with its surrounding environment, The solution of Corrosion problem the metal with thin films to prevent free oxygen and water and corrosion inhibitor (Chromate , Zinc and Ortho-phosphate).

Ultra violet (UV)

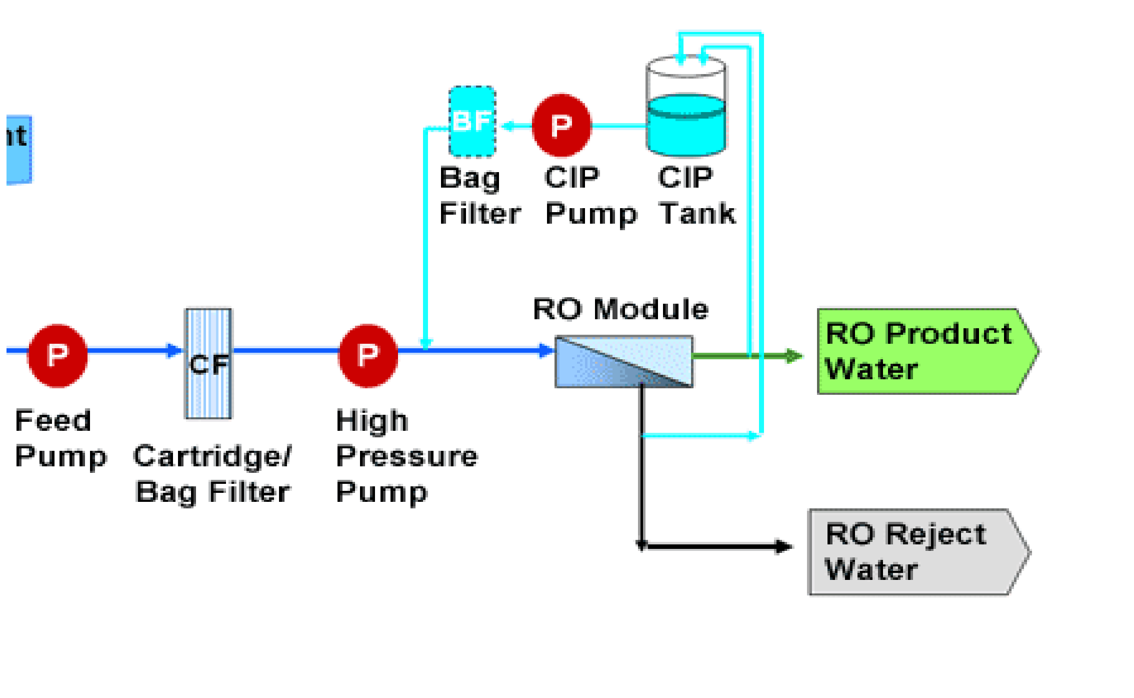
Ultraviolet radiation (254 nm) Uses in pre/post treatment to disinfect water from (M.O) ,that occur when UV rays penetrate the cells of harmful bacteria and viruses in our drinking water, destroying their ability to reproduce, and same any system UV has Advantages and Disadvantages of using .


SEA WATER INTAKE
PRETREATMENT
Chlorination
Coagulation
Flocculation
Ultrafiltration
Multi-media Filtration
Sedimentation
Dechlorination
Antiscalant
Fine Filtration
CONTAINERIZATION
TROPICALIZATION
INSTRUMENTATION & CONTROL (SCADA)
REVERSE OSMOSIS
High pressure pump
Cleaning In Place
Energy Recovery
Seawater Reverse Osmosis
WASTE DISPOSAL
Sludge disposal
Brine disposal
POST-TREATMENT
Boron removal process
Remineralization Neutralisation
Disinfection
POLISHING STEPS
Brackish Water RO
Ion Exchange (IX)
pH Neutralisation
Mixed Bed IX
Electrodialysis (EDI)
WHO DRINKING WATER IRRIGATION WATER TDS< 450 mg/L
PROCESS WATER TDS< 50 mg/L
DEMI / PURE – WATER Conductivity 0.1- 10 uS/cm
ULTRA PURE WATER Resistivity 10-18MOhm Cond. 0.1-0.055 uS/cm
STORAGE & DISTRIBUTION

Membrane cleaning (CIP)

When:

- permeate flow decrease 10%
- salt passage increases 5 - 10%
- pressure drop increases 10 - 15%


nt
BF
P
Bag
Filter
CIP
Pump
CIP
Tank
RO Module
P
CF
P
RO Product
Water
Feed
Pump
Cartridge/
Bag Filter
High
Pressure
Pump
RO Reject
Water

Cleaning Procedure

1. Make up cleaning solution.

2. Low-flow pumping . Use only enough pressure to compensate for the pressure drop from feed to concentrate. The pressure should be low enough that essentially no or little permeate is produced.

3. Recycle ,for 15 min

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.

5. High-flow pumping. for 30-60 minutes.

6. Flush out. RO permeate or deionized water is recommended for flushing out the cleaning solution.

Each fouling type need special cleaning solution

Cost determination

1. The capital cost include:

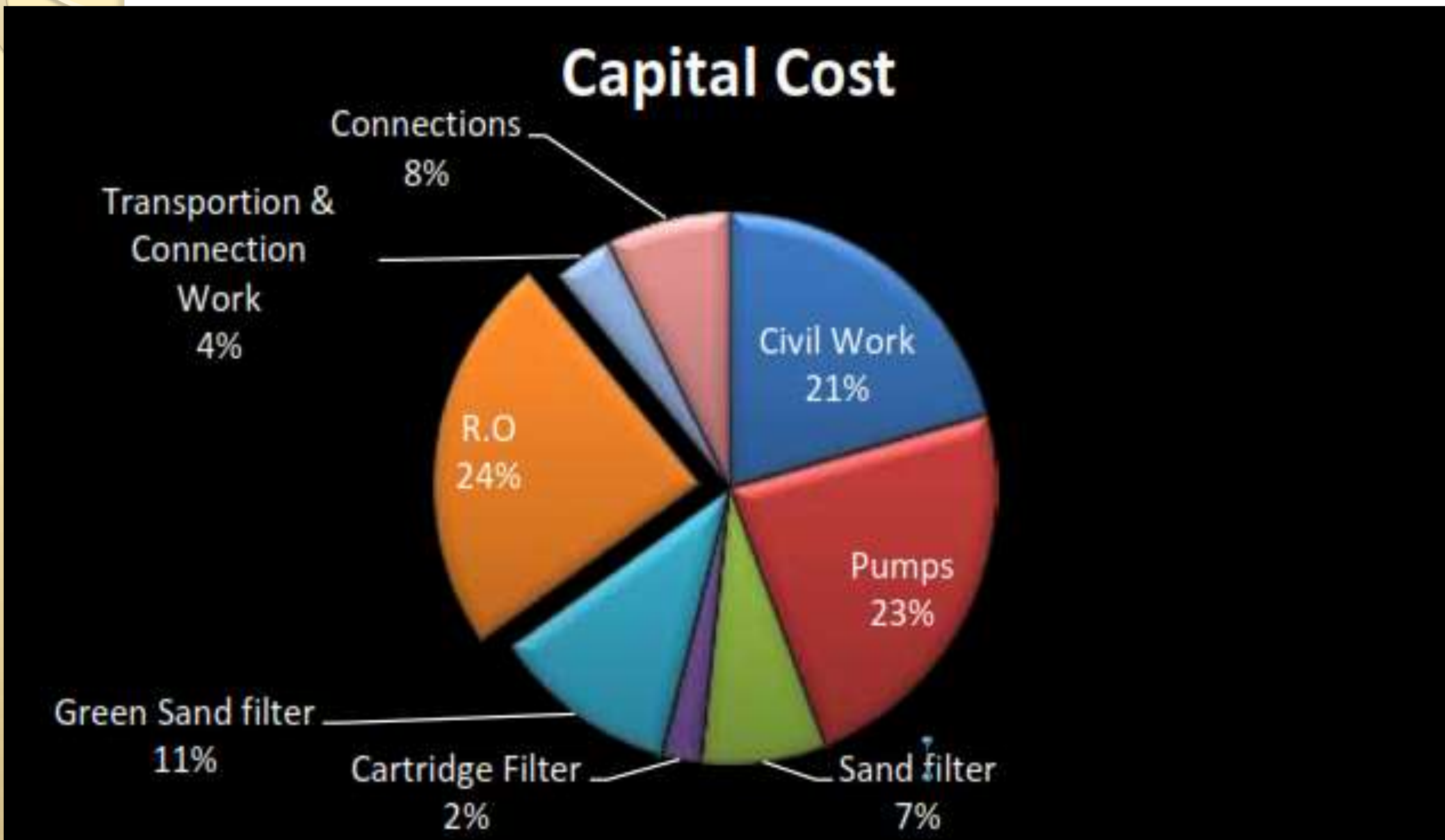
- Civil work cost (water tank , plant cover ,concrete ground…..)
- Pumps (feed , dosing ,source ……)
- Pretreatment (sand , carbon , green sand ,cartridge ……)
- R.O (pressure vessel , membrane , skid , control……)
- Transportation , Connections work
- Others (pipe , fitting , control instrument …..)

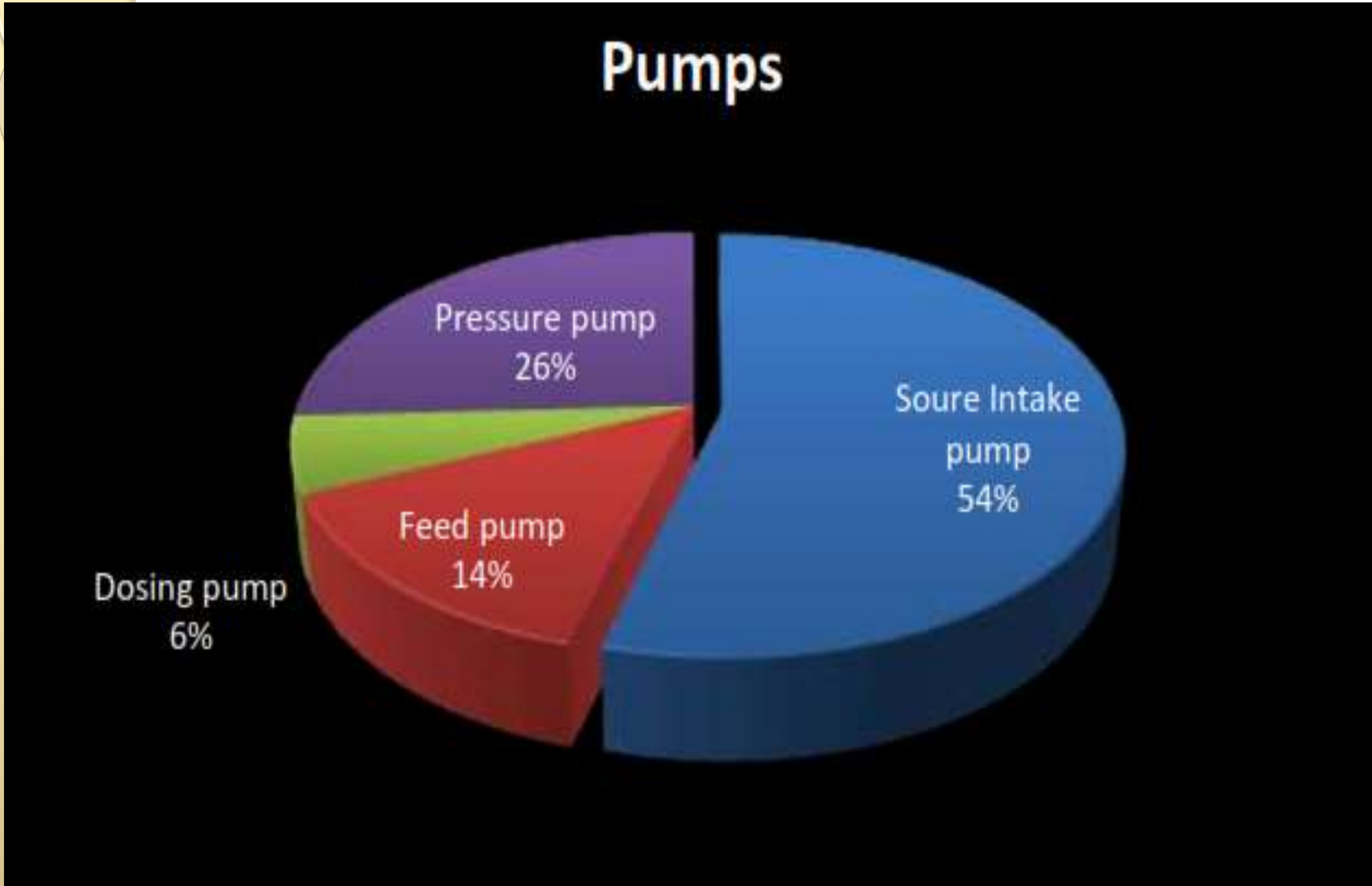
2. The running cost includes :

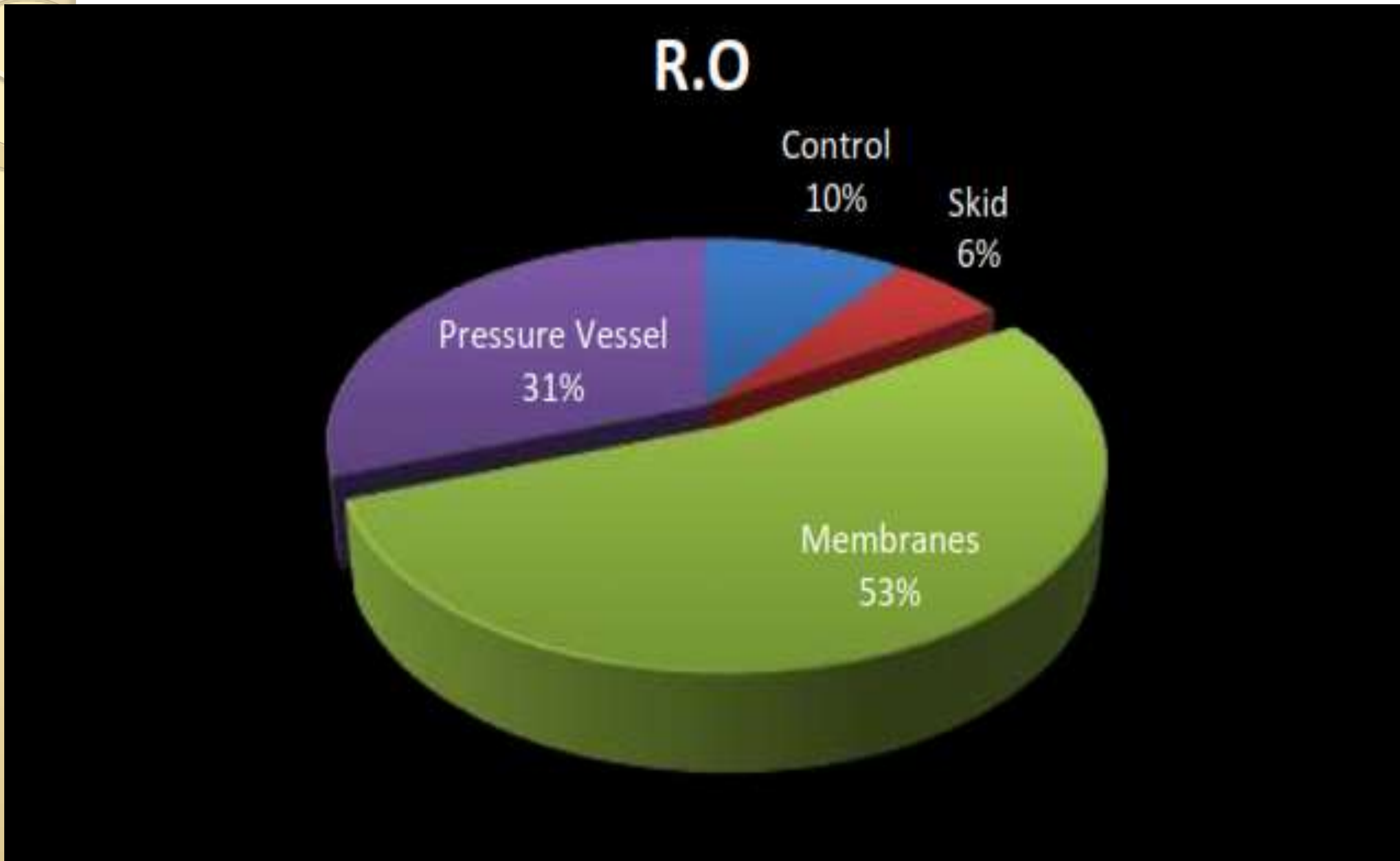
- Chemicals Cost (Anti scalants , chlorine , Acid addition….)
- Staff Cost
- Energy Cost (pump , A/C , lighting …)
- Maintenance Cost (membrane & filter replacement ….)

	Cost ($ / cubic meter)
Sea water reverse osmosis	0.52-1.0
Brackish water reverse osmosis	0.25-0.50
ED	0.25-0.50
Nanofiltration	0.15-0.25
Ultra/Micro Filtration	0.05-0.10

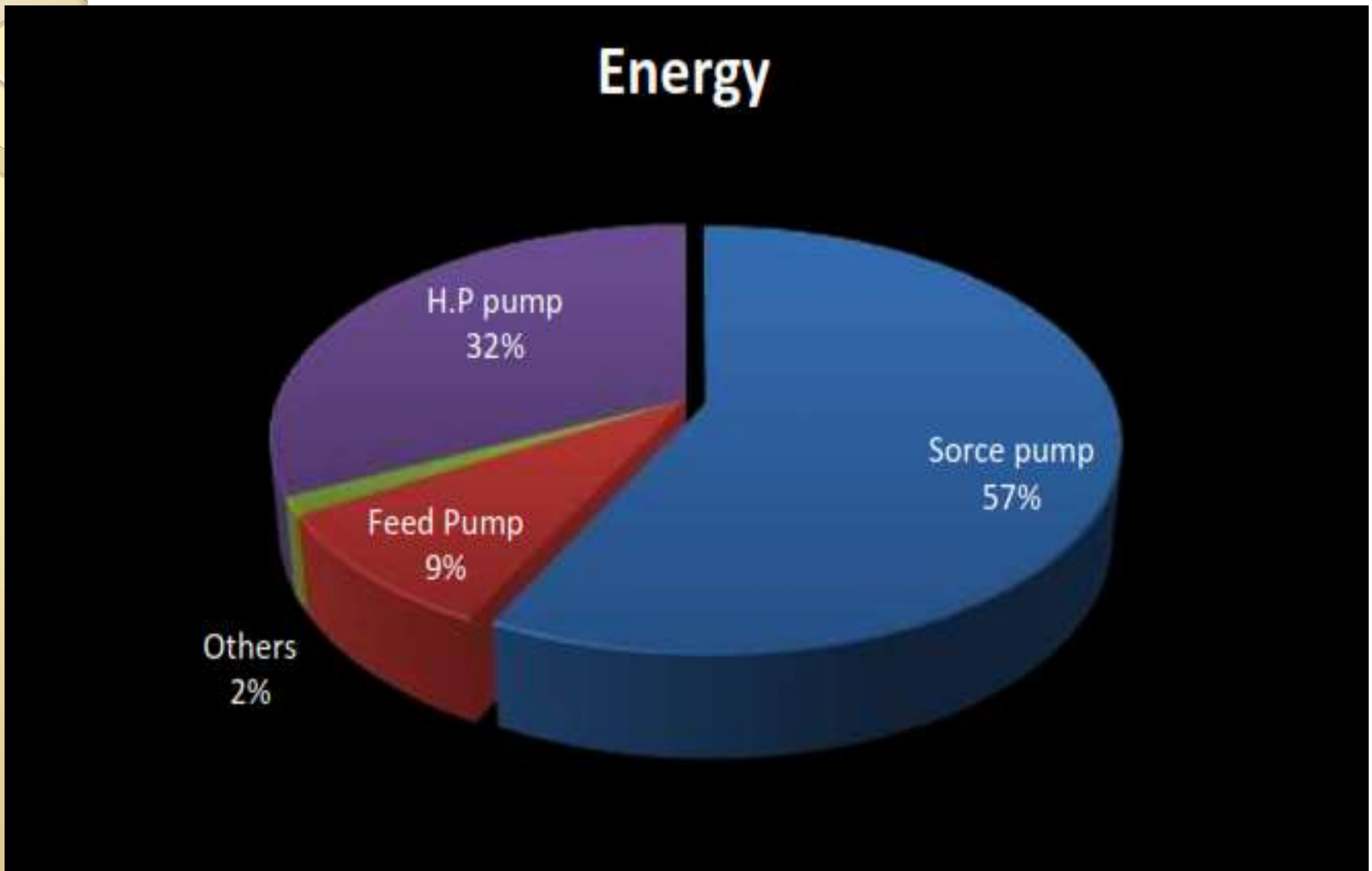
Capital Cost analysis

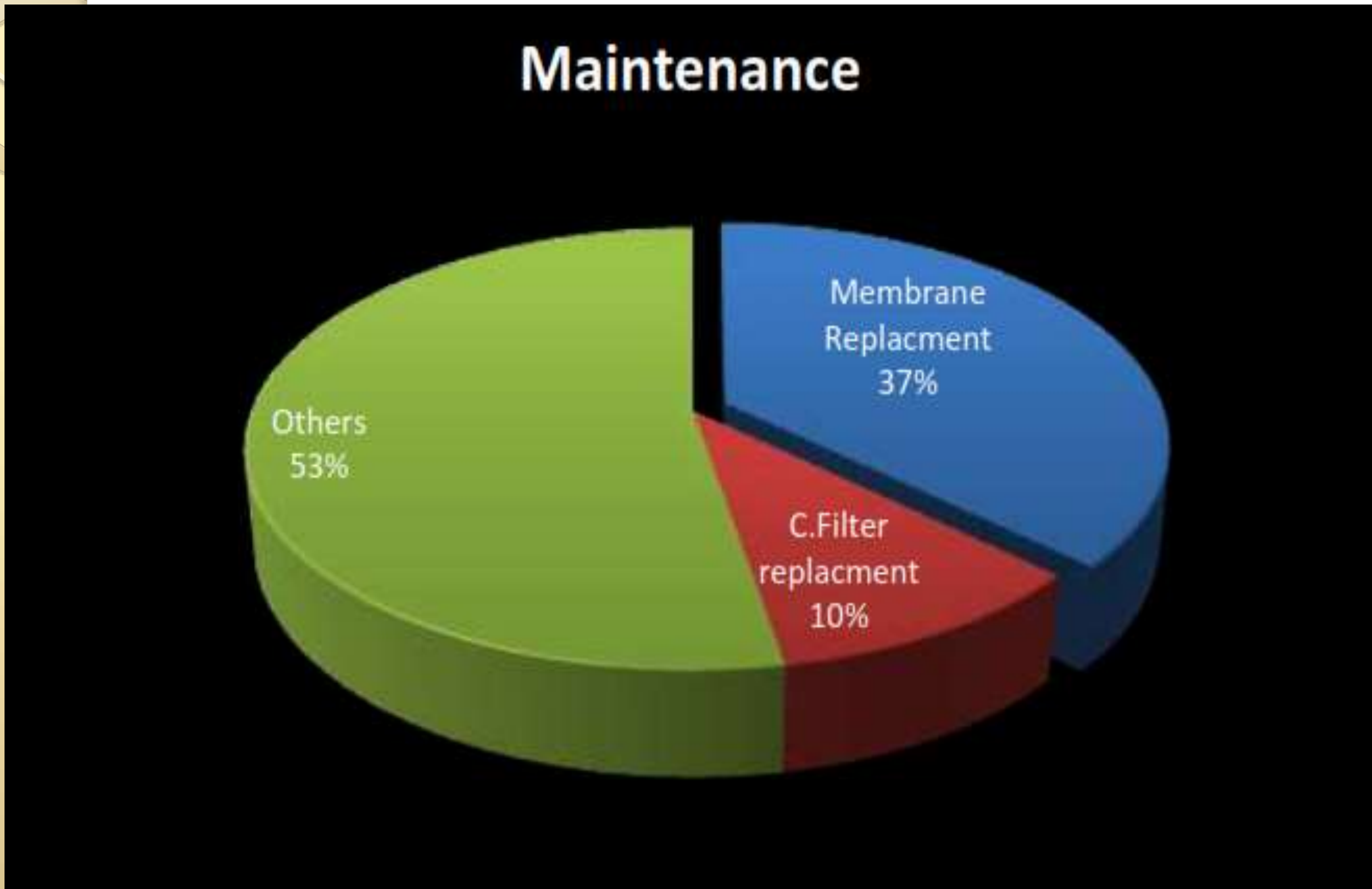



Pumps
Pressure pump
26%
Soure Intake
pump
54%
Feed pump
14%
Dosing pump
6%

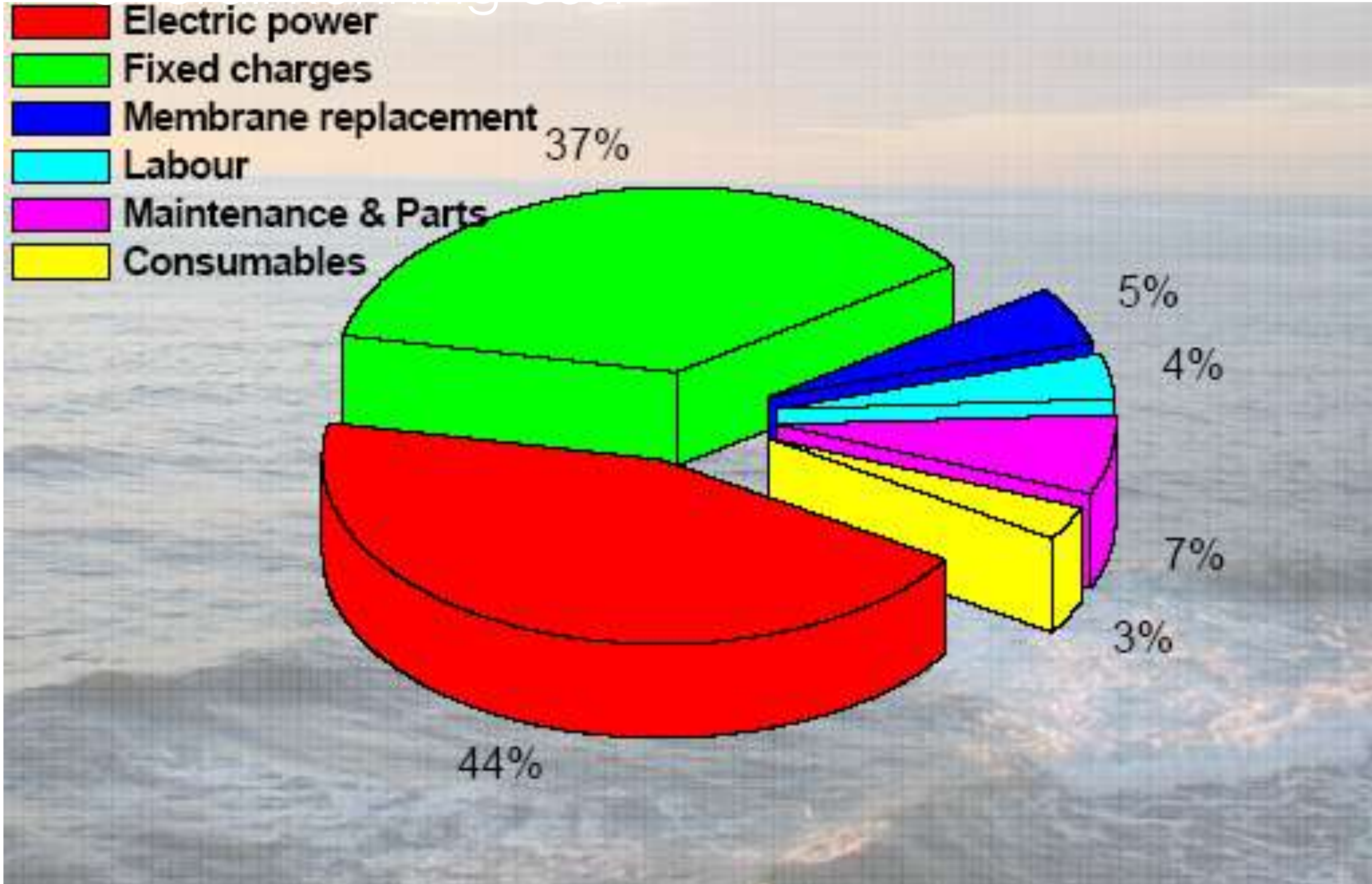

R.O
Control
10%
Skid
6%
Pressure Vessel
31%
Membranes
53%

Running Cost analysis


Energy
H.P pump
32%
Sorce pump
57%
Feed Pump
9%
Others
2%


Maintenance
Membrane
Replacment
37%
Others
53%
C.Filter
replacment
10%

Sea water desalination Cost analysis



Questions
number 3
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+ O&M Paper
+ AL krameh
well