RO Pretreatment & System

Presented by: Engr. Jawad Faris

CSM

RO Plant

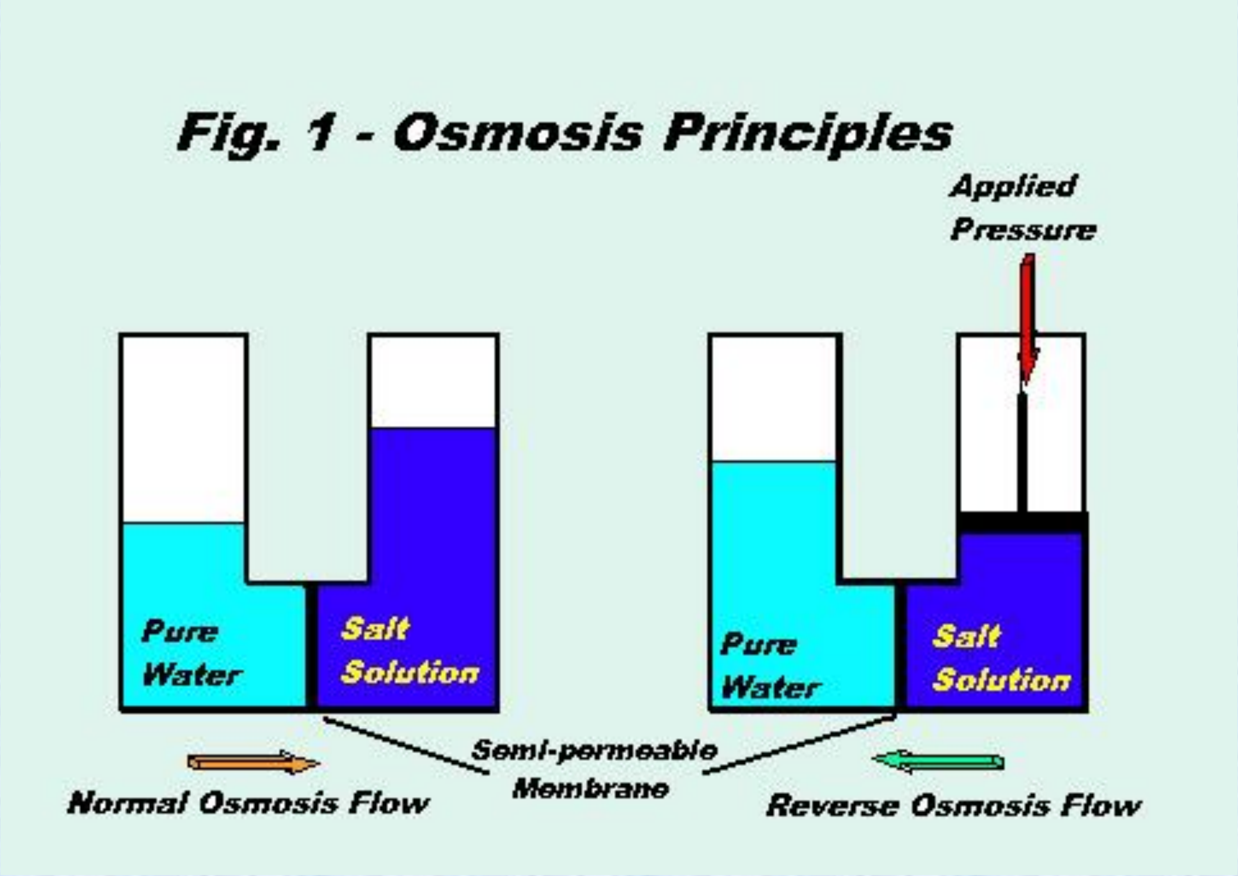
CSM

What is Reverse Osmosis(RO) ?

- To understand **reverse Osmosis** we must first understand **osmosis**. During natural **osmosis**, water flows from a less concentrated solution through semi permeable membrane to a more concentrated saline solution until concentrations on both sides of the membrane are equal. (see figure 1).
- **Reverse Osmosis (RO):**

  Reverse osmosis requires external pressure to reverse natural osmotic flow. As pressure is applied to the saline solution, water flows from a more concentrated saline solution through the semi permeable membrane. (see figure 1).

Osmosis Principles



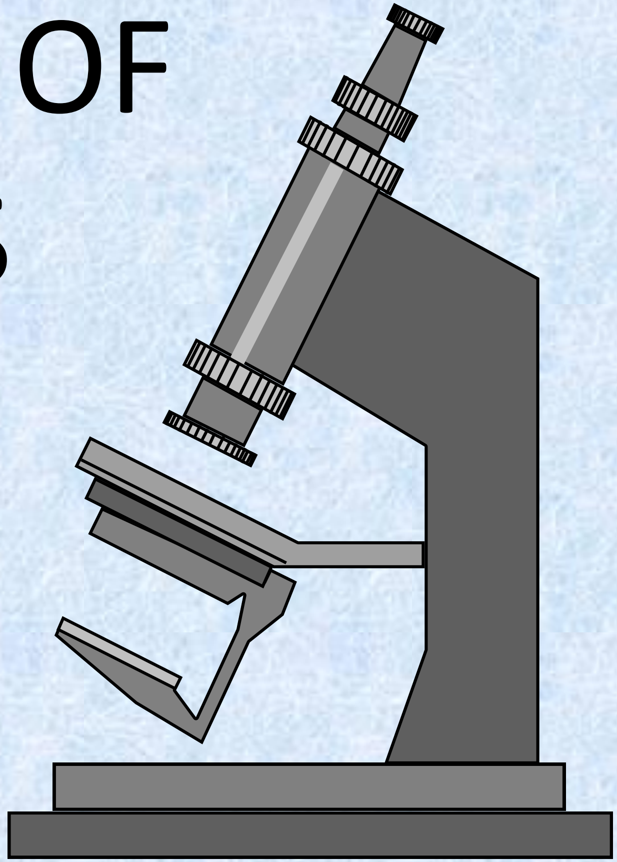
CSM

Reverse Osmosis(RO) Principle

- However, the goal in our water purification system is to separate the dissolved salt from the pure water. So it is necessary to reverse the natural osmotic flow by forcing the water from the salt solution through the membrane in the reverse direction. This can be accomplished by applying sufficient pressure to the salt water as it is fed into the system. This pressure creates the condition known as "reverse osmosis."

CSM®

WATER CHEMISTRY OF THE RO PROCESS

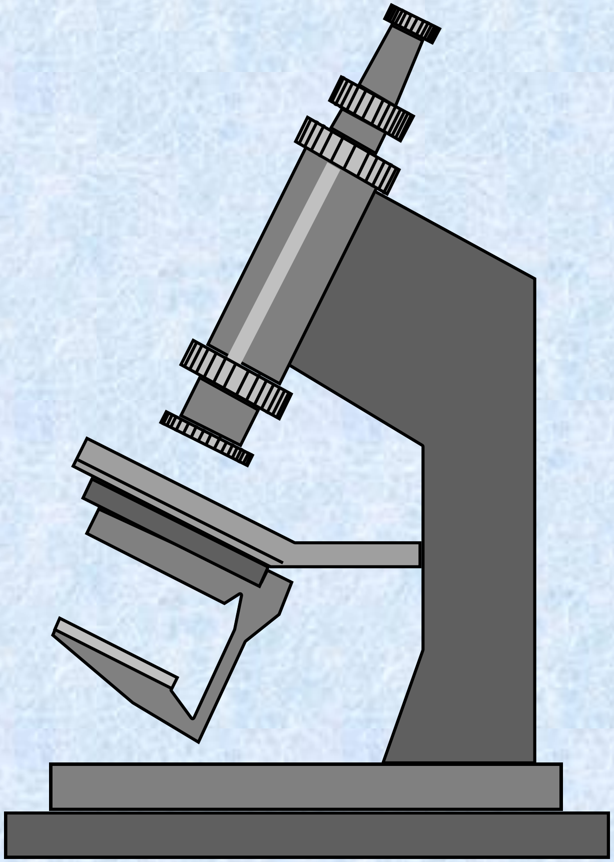


CSM®

Water Chemistry

A basic knowledge of water quality is very important consideration in the design and operation of the system. Therefore, the ability to read and understand a water quality analysis is very useful.

In order to understand how to best serve a customers needs, a system integrator needs to understand water chemistry and how the customers process affects the water molecule.

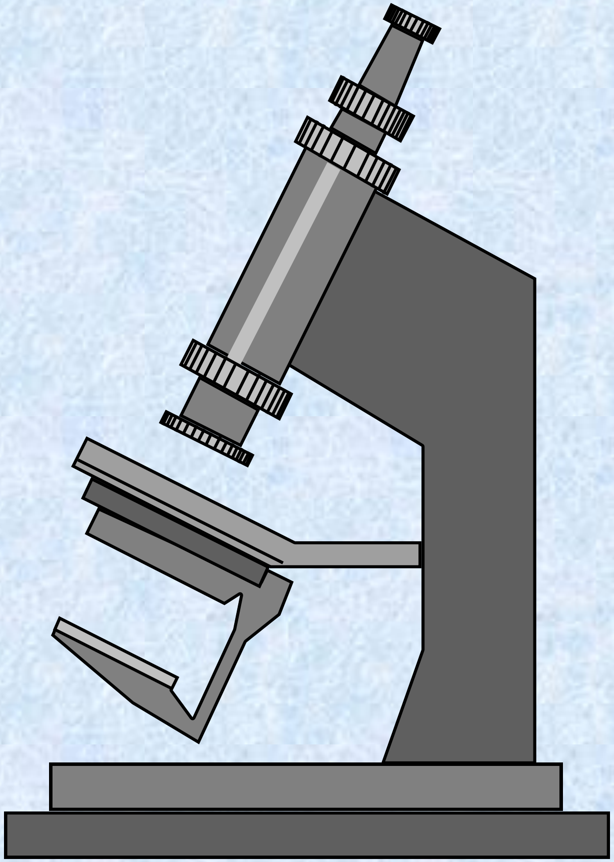


CSM®

Water Chemistry

- Universal Solvent

Everything dissolves in water



CSM®

Feed water Quality & Sources

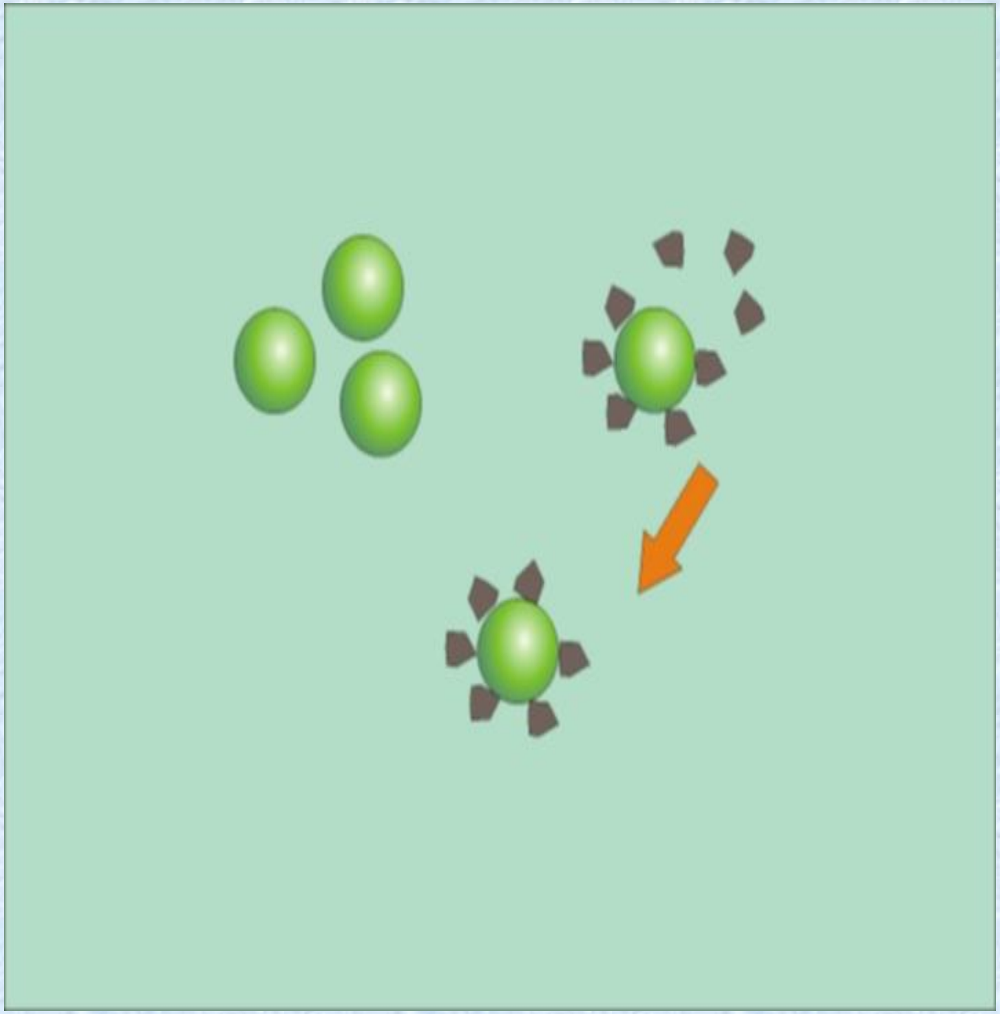
- **Water chemistry & characteristics :**
- **Feed Analysis:**

CATIONS	ANIONS
Ca^{++}	HCO_3^-
Mg^{++}	SO_4^-
Na^+	Cl^-
K^+	Br^-
Sr^{++}	F^-
Ba^{++}	NO_3^-
Fe^{++}	
Fe^{+++}	

Periodic Table

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Hardness



- Magnesium and calcium levels in water create “hard” water. Resin bed systems remove the magnesium and calcium through Ion Exchange. Salt is used to regenerate the resin.

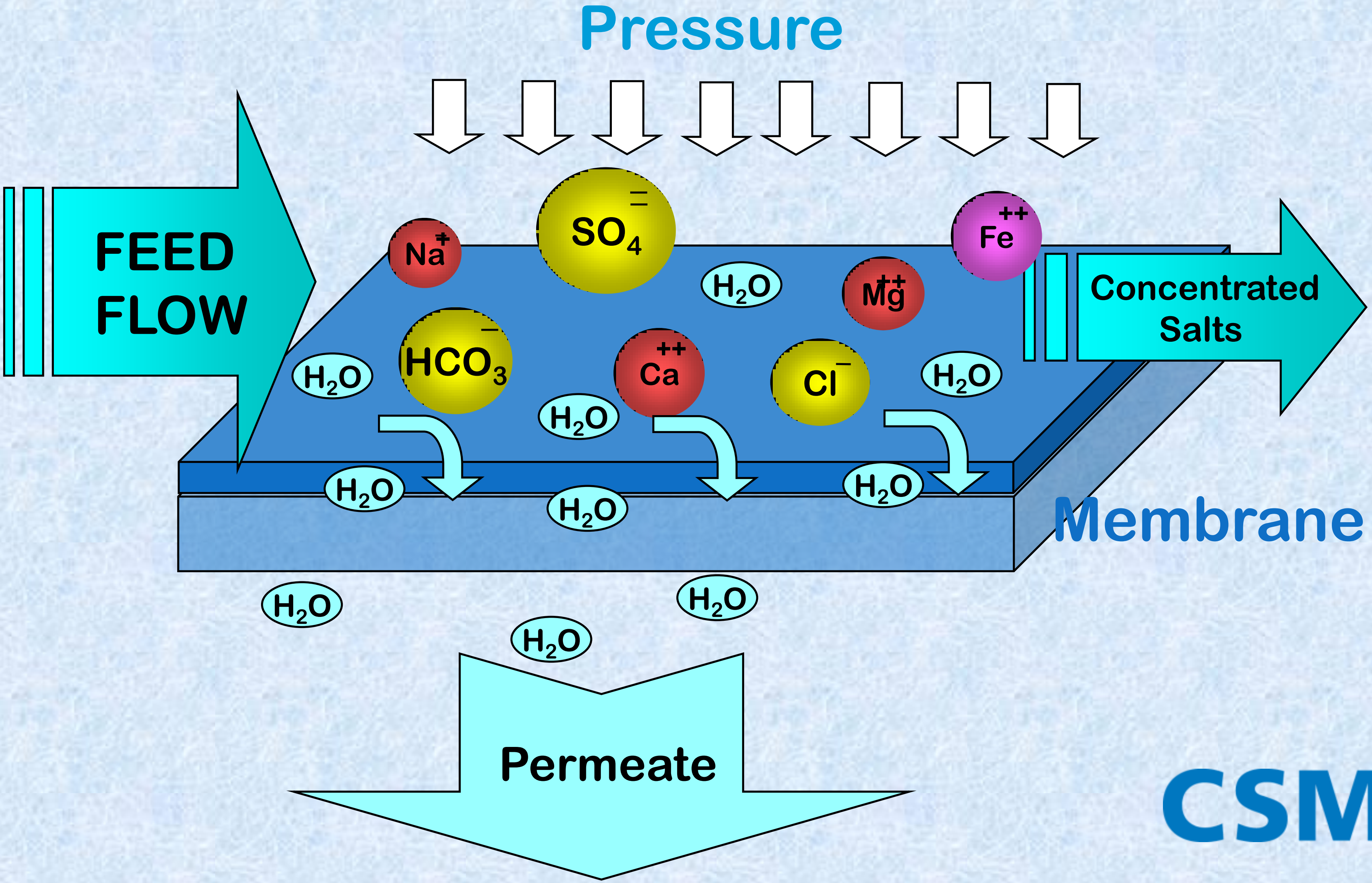
CSM®

Total Dissolved Solids

- TDS — Total dissolved solids : Sum of concentration of dissolved ions in water.

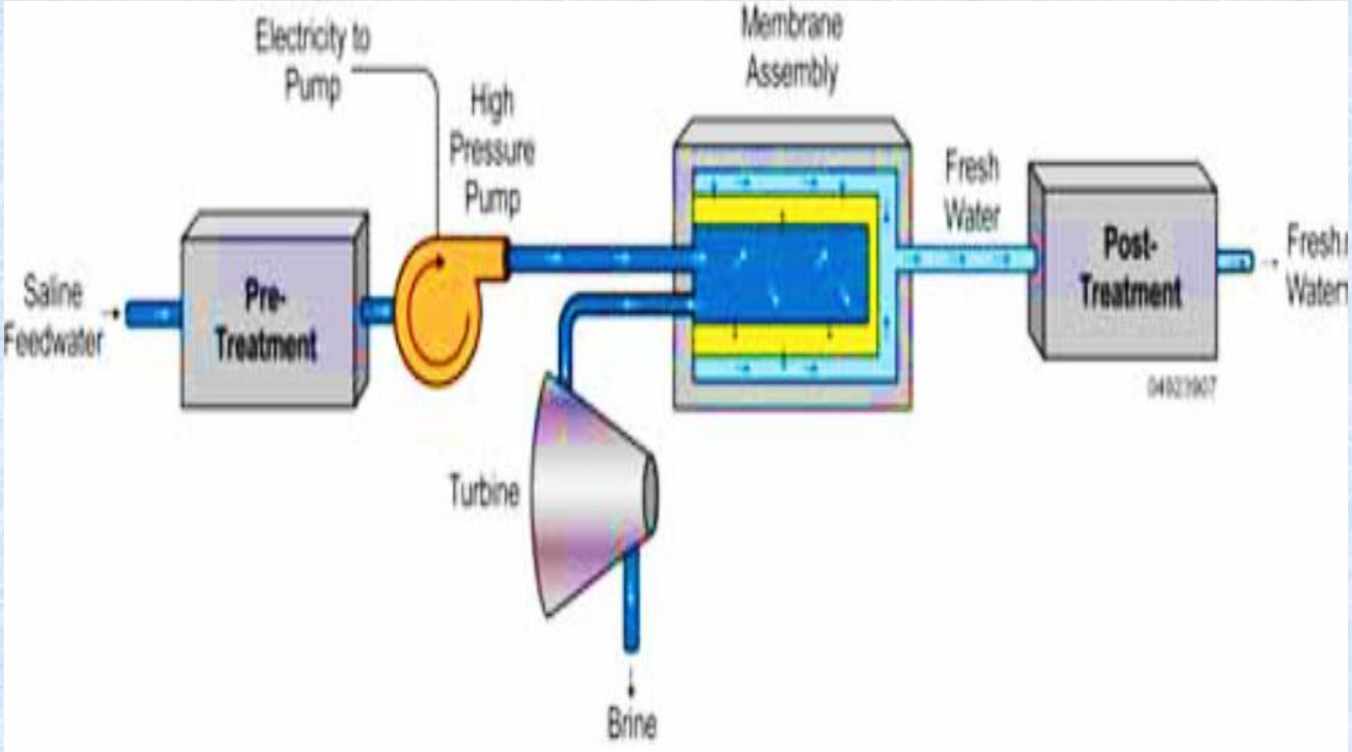
- ppm — parts per million : Units of concentration of dissolved ions in water. Equivalent to the concentration units of mg/l and g/m3.

RO Membrane Separation Mechanism



CSM®

Reverse osmosis process

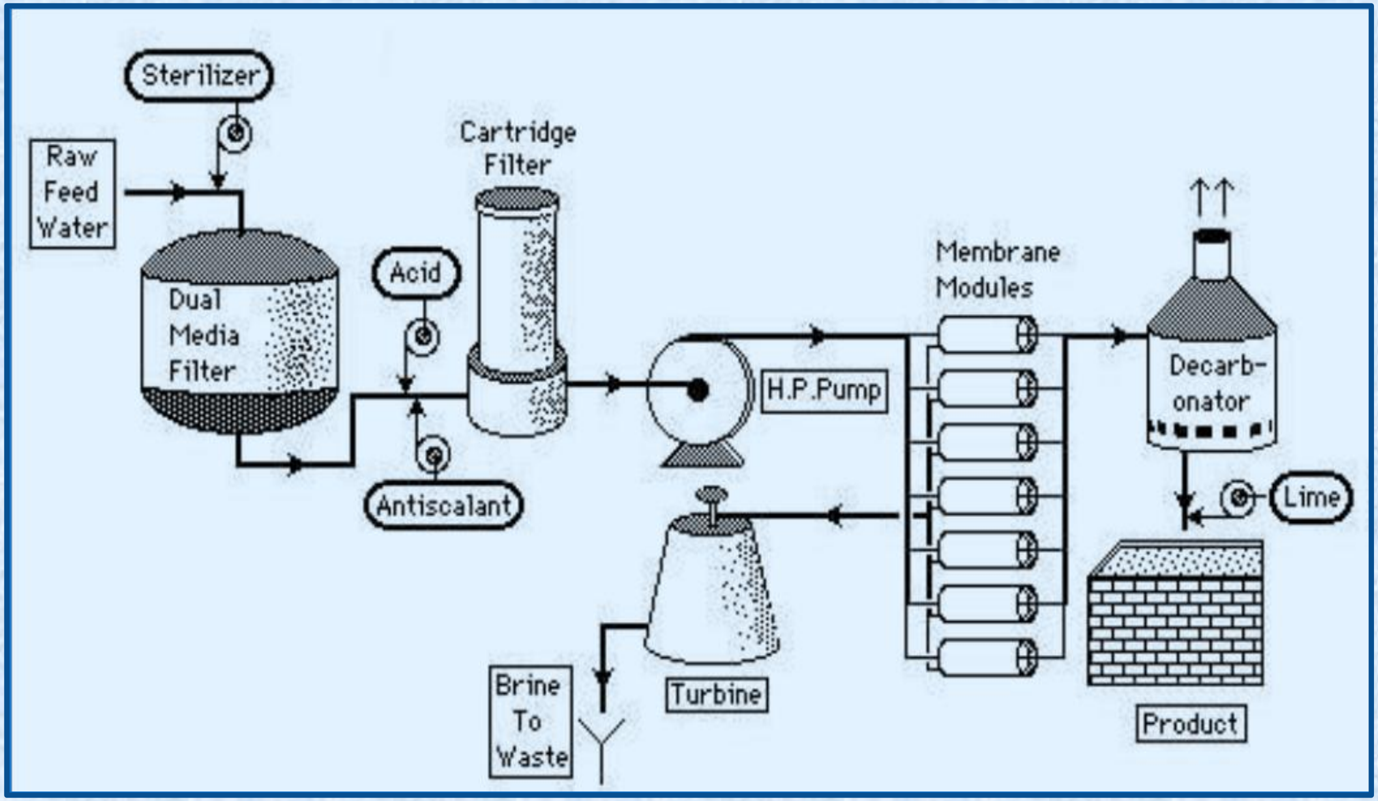


Design Consideration

- What is the water source?
- What is the water Quality?
- What membrane type is suitable?
- What types of pretreatment are required?
- Application of RO water; where you want to use the permeate: (Haemodialysis Plants, Bottling Plants, Industrial uses, ect..)

CSM®

RO SYSTEM CONFIGURATION



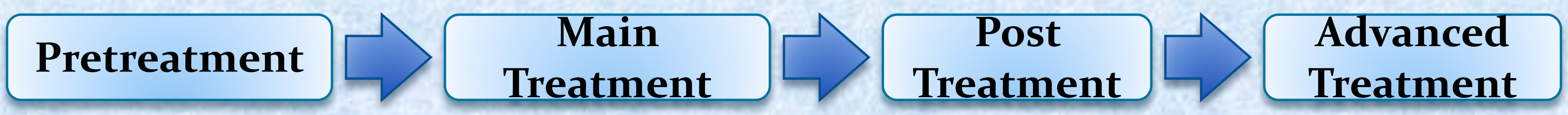
CSM®

RO Process

- **Treatment Processes & Definitions:**

A)Purification & Treatment Steps:

- A typical purification or treatment process includes four steps: Pre treatment, Main Treatment, Post Treatment and Advanced Treatment.



RO Process

1-a)Pretreatment (Physical):

- The efficiency and life of a reverse osmosis system depends on the effective pretreatment of the feed water. The pre-treatment includes any process which can minimize fouling, scaling and membrane degradation in order to optimize product flow, salt rejection, product recovery and operating costs.

- Physical pre treatment of Reverse Osmosis plant starts at the intake system. Raw water will be then pumped to raw water tank. Feed water contains significant amount of dissolve ions which will be removed by using special type of RO membranes.
- From the tanks, feed water will undergo a physical treatment by pumped using low pressure pumps to Multimedia Filters (sand/grave & anthracite) to remove such as suspended solids.

- Before and after these physical units a chemical pre treatment injection will take place so the water will be safe chemically to be introduced to the RO membranes, however, there are still some physical constituents that may not be removed completely.

CSM®

RO Process

- Thus a Five (5) micron cartridge filter will be installed after the media filter prior to the RO membranes modules. The cartridge filters are considered as the final defense criterion for the membranes. This will protect the membranes from any silt and suspended solids above 5 microns that will be released from the media filters. The five microns cartridge filter will reduce the turbidity of the water to minimum levels that will not be considered harmful to the membranes.

RO Process

1-b)Pretreatment (Chemical):

- A chemical injection should be used in the chemical treatment process which will depend on the kind of the physical treatment. Type of dosing chemicals is determined by the requirement of feed water characteristic. Chemical injection points are also dependent on the physical treatment unit use.

CSM®

RO Process

2) **Main Treatment:**

- It includes all equipment required for water purification treatment.

- In water purification's it includes all the equipment required to achieve the purification goal. For example in case of desalination for drinking purposes, Membrane Separation equipment (Reverse Osmosis) are included for dissolved solids reduction to the required level accepted for drinking purposes.

- High pressure pumps will boost the water from the 5 micron filter outlet (even the water from the break tank will be originally from Raw Sea Water at the required pressure to the membranes. The membranes require a certain specific pressure (depend on the feed TDS) in order to attain the separation process of the water ions and produce desalinated water with low TDS content.

- The rejected water will be directed to the drain for disposal and permeate water will be store in the permeate water storage tank.

CSM®

RO Process

3) **Post Treatment:**

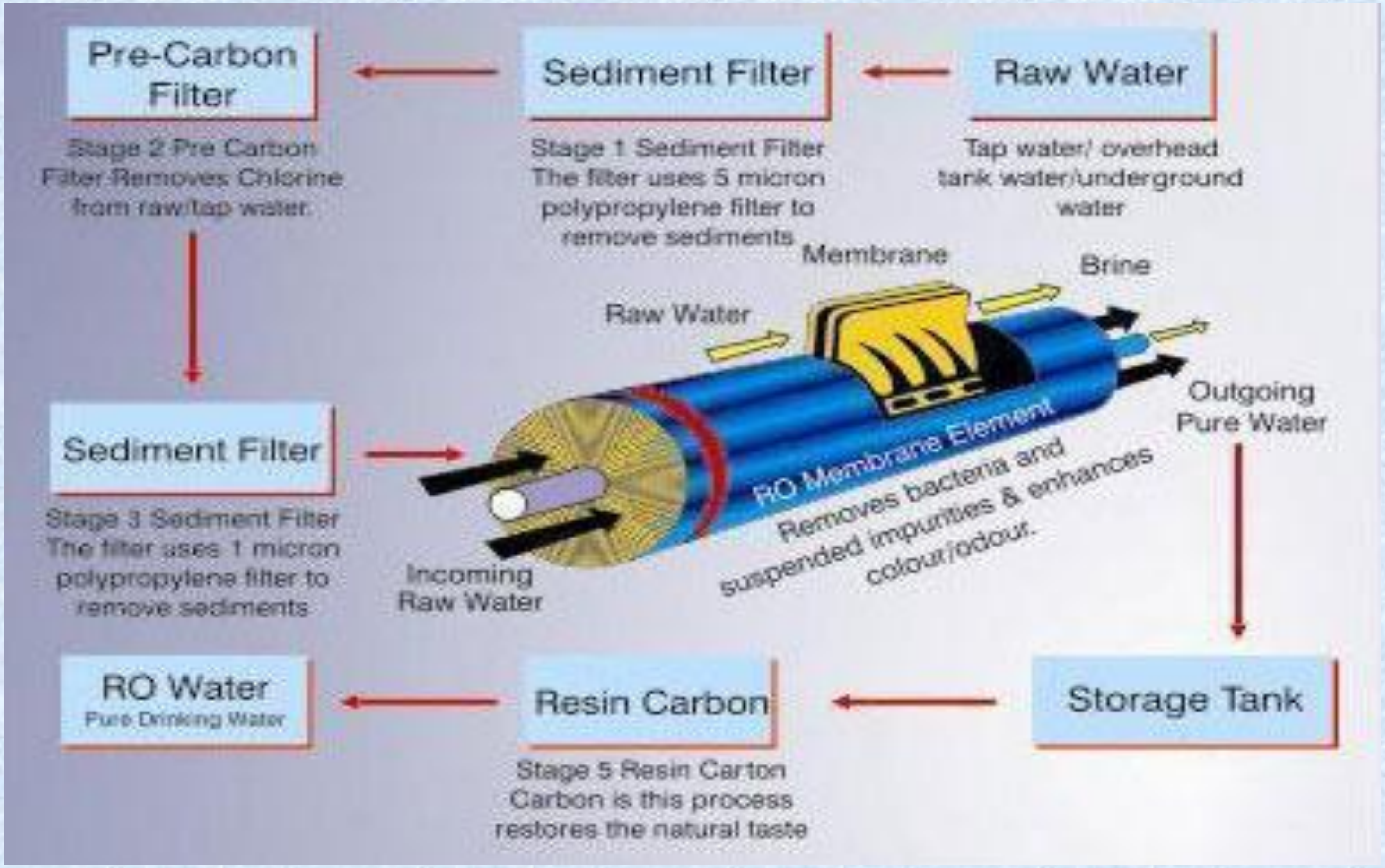
- It includes all process necessary for the conditioning of purified water from the Main Treatment process to the required quality limits.

4) **Advanced Treatment:**

- In some cases additional advanced treatment steps are required to enhance the purified water and obtain Polished High Purity water such as water for injection in pharmaceutical applications or industrial processes. The most common advanced treatment equipment includes Membrane Separation Systems, Deionizers, Ozone and UV Sterilizers.

CSM®

RO Process



Pre-Carbon Filter
Stage 2 Pre Carbon Filter Removes Chlorine from raw/tap water
Sediment Filter
Stage 1 Sediment Filter The filter uses 5 micron polypropylene filter to remove sediments
Raw Water
Tap water/ overhead tank water/underground water
Membrane
Brine
Raw Water
Outgoing Pure Water
Sediment Filter
Stage 3 Sediment Filter The filter uses 1 micron polypropylene filter to remove sediments
Incoming Raw Water
RO Membrane Element
Removes bacteria and suspended impurities & enhances colour/odour.
RO Water
Pure Drinking Water
Resin Carbon
Stage 5 Resin Carton Carbon is this process restores the natural taste
Storage Tank

RO Systems

RO systems consist of the following **basic components:**

- Feed water supply unit
- Pretreatment system
- High pressure pumping unit
- Membrane element assembly unit
- Instrumentation and control system
- Permeate treatment and storage unit
- Cleaning unit (CIP)

CSM®

RO Systems

Feed water supply unit – wells

- Well only or well followed by particle separation device: screen or hydro-cyclone.
- Well should be equipped with foot valve to prevent back flow on shut down.
- Non corroding materials of construction: rubber coated steel and/or plastic piping.
- Raw water storage tanks should be avoided. Sometimes necessary due to multiple wells involved.
- Re-vent of water – air contact, especially for anaerobic sources (H_2S), and avoid exposure to light.

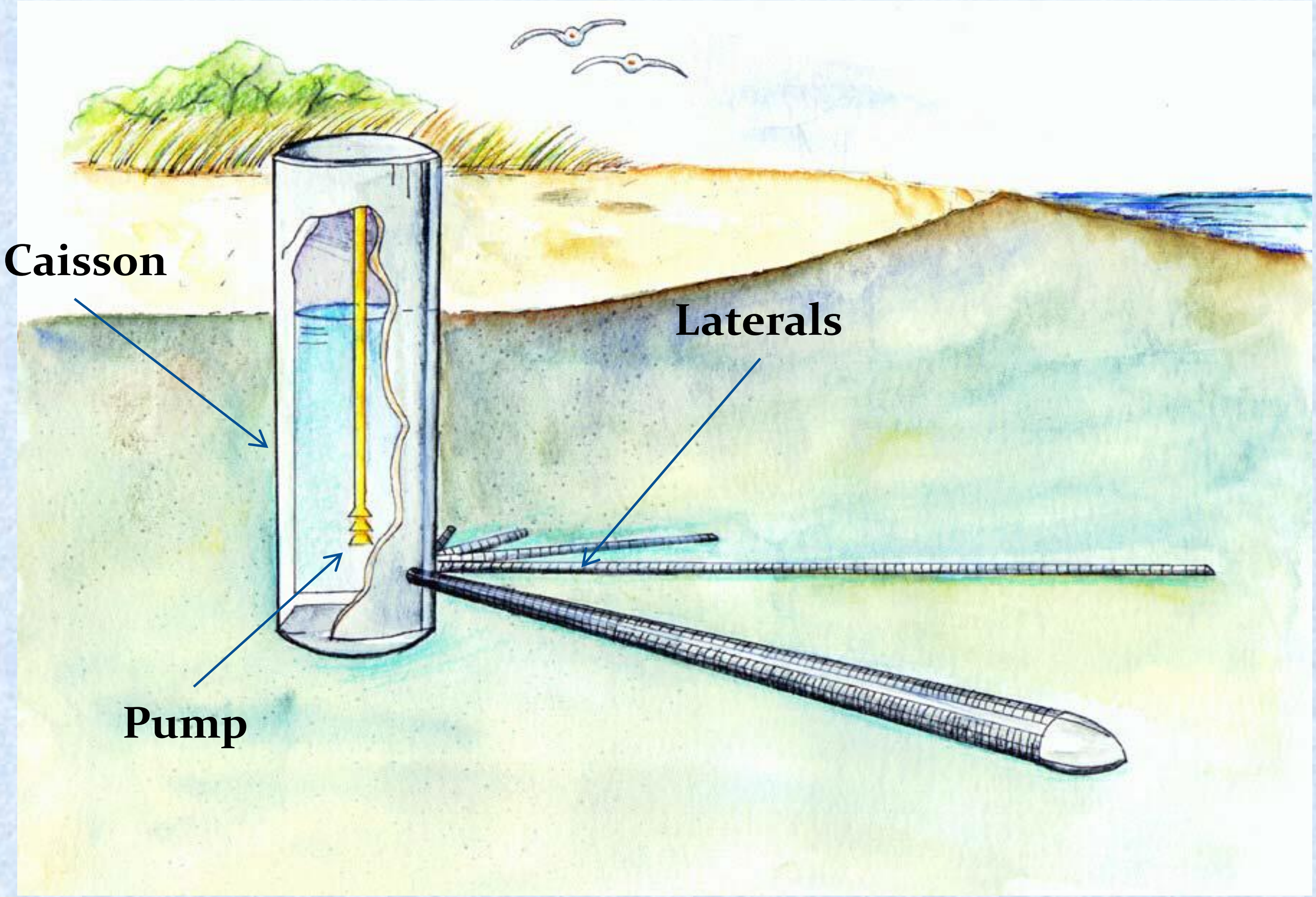
CSM®

Requirements of Designing an RO System

- The Raw water Quality (detailed analysis).
- The Source of raw water.
- The product quality & quantity requirement.
- The Product water required for what purpose.

CSM®

Beach Well Configuration



CSM®

RO Systems

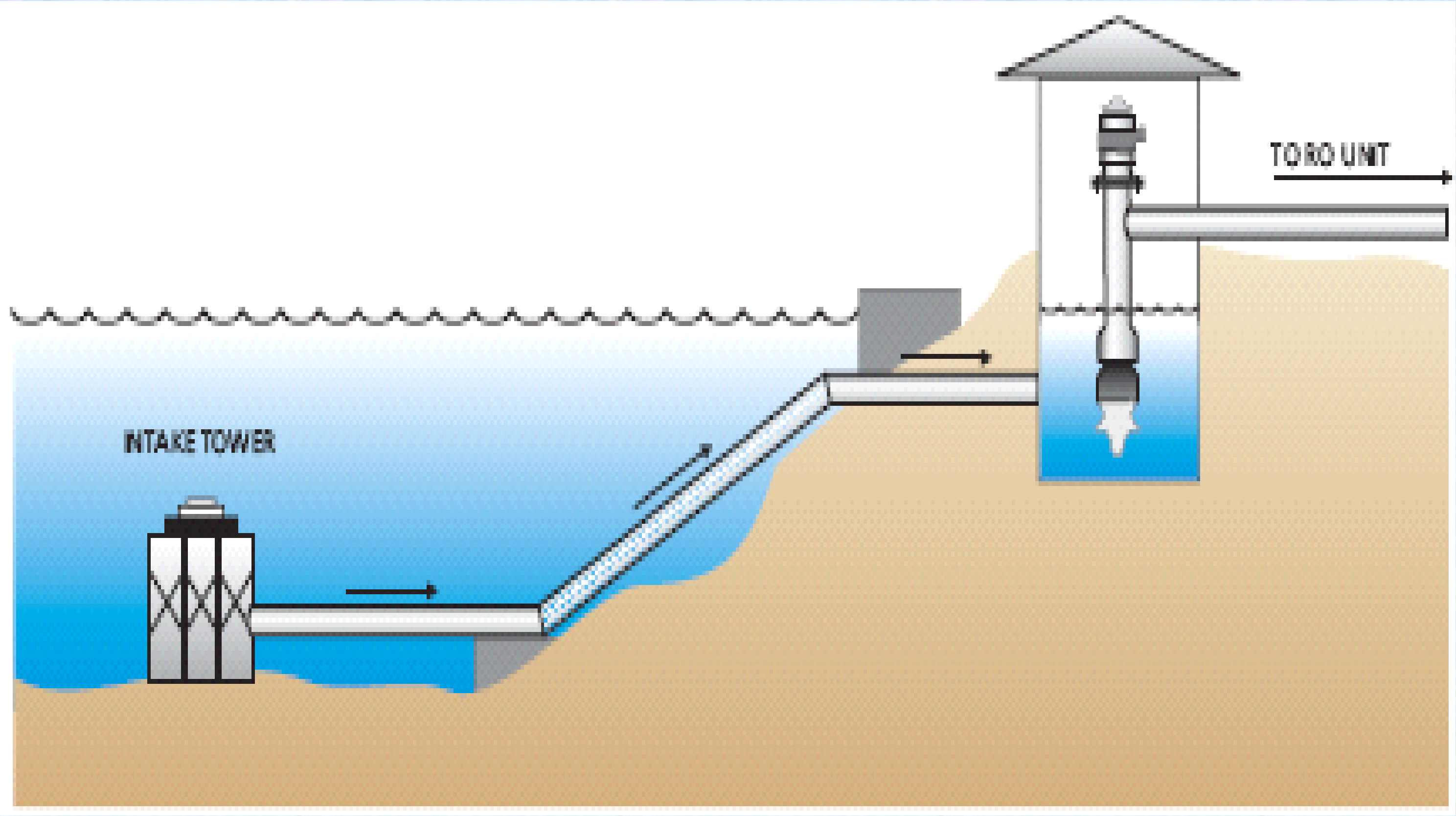
Feed water supply unit – surface **intake**

- Intake structure includes screen (self cleaning) to stop and remove large particles. Intake inlet should be located at water level that assures good and consistent quality.
- Intermittent or continuous chlorination at the intake to prevent

  Bio growth.
- Wet well used as a sedimentation basin.
- Non corroding material of construction, concrete or FRP tanks, rubber coated steel and/or plastic piping.
- Raw water storage tanks should be protected from direct light and not translucent.

CSM®

Feed water supply unit.



CSM®

Intake structure configuration

Delivery of intake piping

CSM®

Delivery of intake piping

CSM

Raw water Quality & Source

The raw water quality & source will decide the following:

1) The type of Pretreatment to be employed for the WTP.

2) The expected recovery of the RO unit, which will decide the capacity of pretreatment.

The raw water source is also important to decide the filtration load criteria.

Raw water Quality & Source

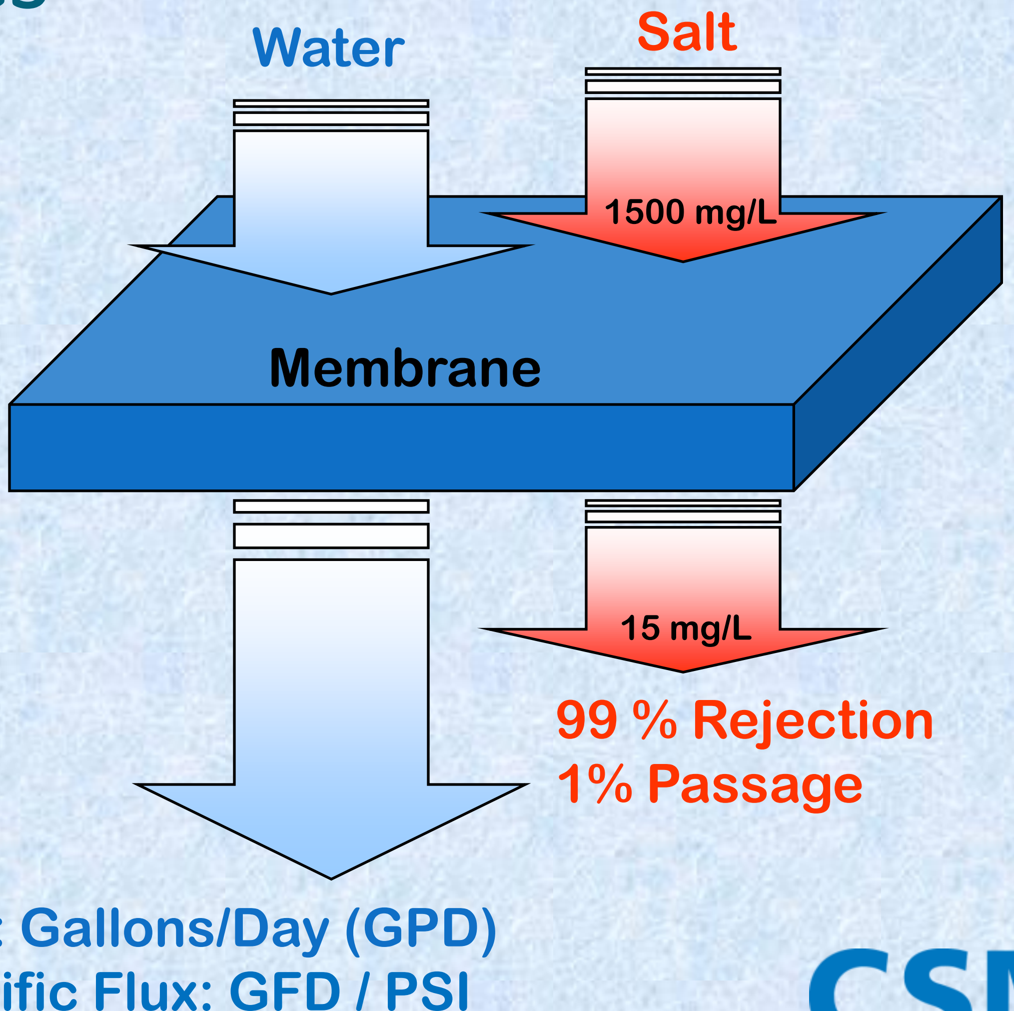
- There are various types/sources of water quality, such as the following(TDS,PPM):

1) Brackish water	: up to 10,000
2) High Brackish water	: 10,000 to 20,000
3) Sea water	: from 25,000-46,000

CSM®

Important Membrane Characteristics

- 1. Salt Rejection
- 2. Salt Passage
- Water Flow
- Specific Flux



CSM®

Plant Recovery

It is the ratio of the permeate produced against the feed water. It is specified in %.

So, 70 % recovery means that if we feed 100 lts of raw water to RO membranes, only 70 lts will be produced & remaining 30% will be drained as reject.

Deciding the plant recovery will define the flow rate of pretreatment (i.e. capacity).

Product Water Quality & Quantity Requirement

The product water quality & use will decide the:

1. RO plant capacity.
2. Blending water capacity
3. Whether post treatment is required or not, & if required, what type.
4. Whether post treatment polishing is required (for bottling, etc).

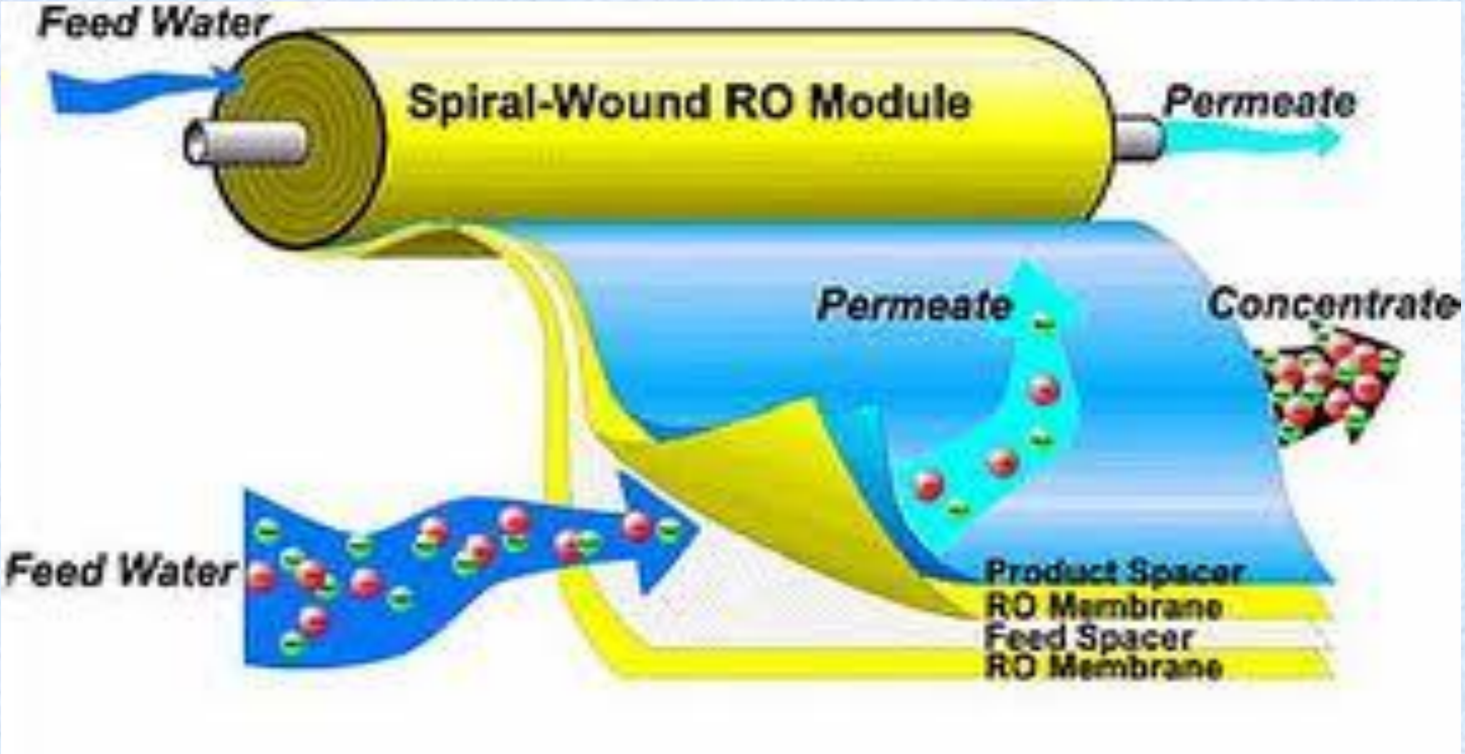
CSM®

Membrane Processes

- As can be noted, there are a wide variety of membrane processes being used to treat water. However the only processes which will remove sodium chloride are Reverse Osmosis and Electrodialysis .
- Advances in RO have been directly linked to advances in membrane technology. A good membrane should be able to pass a high flow of water and limit the amount of salt flow (good rejection).
- Important considerations in RO are salt rejection, flux and membrane life. Usually, high salt rejection is achieved at the expense of low flux and vice versa.

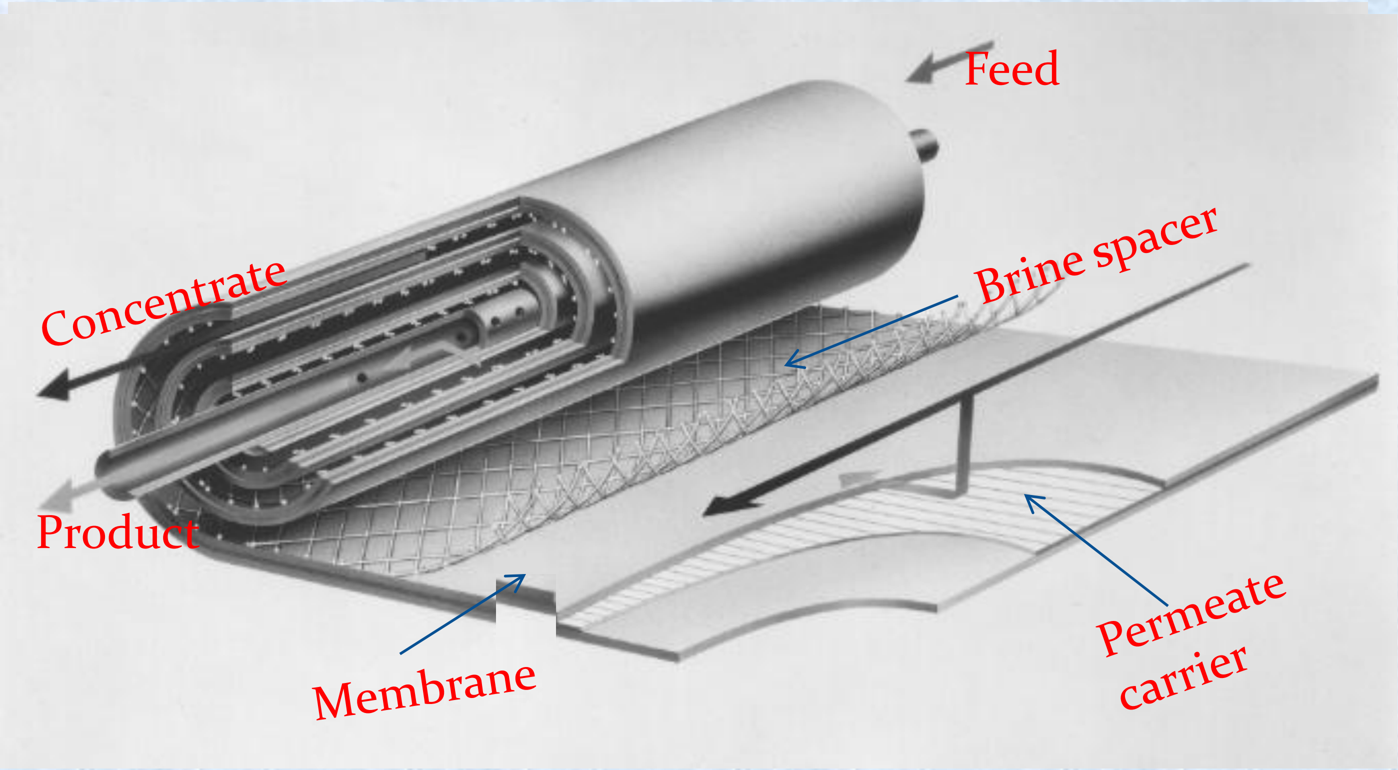
CSM®

Spiral Wound Membrane

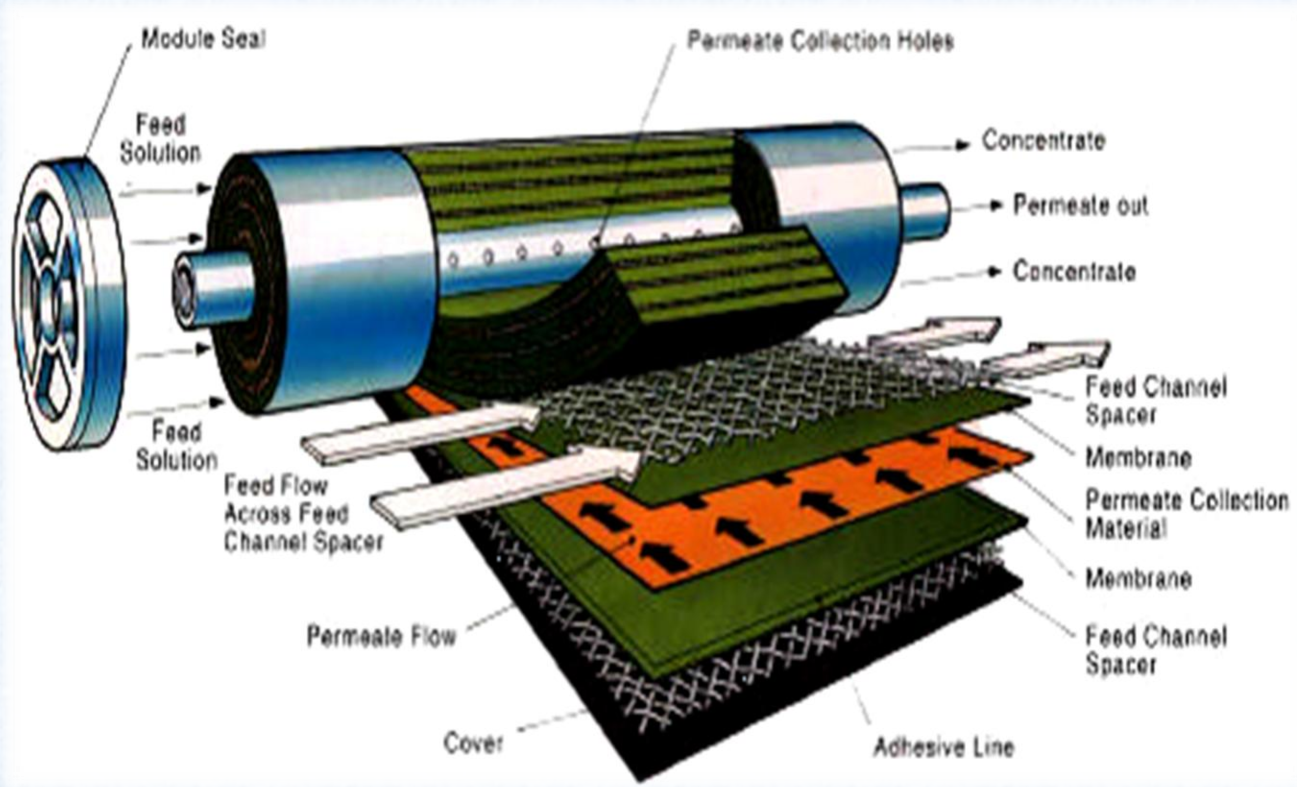


CSM®

RO Spiral Wound Element Schematic



Spiral Wound Membrane



Spiral Wound Membrane

CSM

Membrane Life

- A major problem is linked to the life time of membranes. The supplier's guarantee is usually limited to 3 years.
- Membrane life time varies from plant to plant and may reflect operating conditions. Large plants tend to be well maintained owing to the large capital investment and membrane life may be much longer than 3 years.
- To ensure a long life for membranes, one consequently needs :

1) To foresee all necessary pre-treatment, depending on physical, chemical and biological characteristics of the feed water,
2) To ensure a constant supply of chemicals,
3) To have a very well-trained staff.

Pretreatment Requirements

Value of Pretreatment:

- All feed water contains materials that can foul or harm membranes.
- Well design, operated and maintained pretreatment system is key to optimum performance & prevention of fouling.
- Adequate pretreatment can extend the useful life & efficiency of the membranes.
- With adequate pretreatment and no fouling, periodic cleaning help maintain optimum plant operation, performance & cost-effectiveness.

Pretreatment Requirements

Types of Deposition:

- Biological Growth.
- Deposition of colloids & particulates.
- Soluble & colloidal silica deposition.
- Carbonate & sulfate scaling.
- Metal oxide precipitation.
- Suspended organics fouling.
- Colloidal sulfur deposition (Oxidized H2S).

Pretreatment Requirements

Types of Treatments:

- Disinfection & sterilization.
- Coagulation & flocculation.
- Softening.
- Acid Dosing.
- Anti-scalant dosing .
- Media filtration.

CSM®

Pretreatment

IS ESSENTIAL TO REMOVE:

* Suspended matters as Suspended solids, turbidity, & colour, odor, oil & grease etc.

* Fouling elements as Fe, Manganese, Hardness, Silica, etc.

* Rare components as Bicarbonate, H_2S, NH_3, Al, Nitrate, etc.

CSM®

Pretreatment

Remember that:

*The efficiency and life of a reverse osmosis (RO) system depends on effective pretreatment of the feed water.

** The pretreatment includes any process which can minimize fouling, scaling, and membrane degradation to optimize product flow, salt rejection, product recovery and operating costs.

Therefore; A complete and accurate water analysis must be provide before an RO system design.

CSM®

Pretreatment process

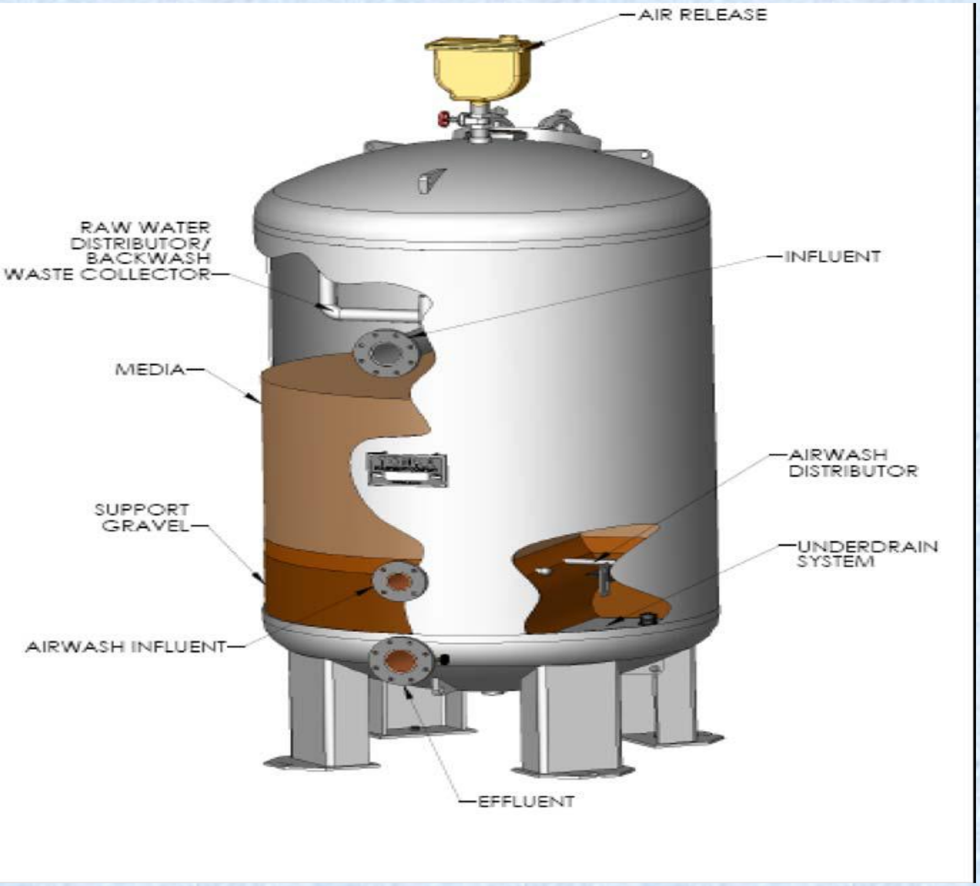
- Removal of large particles using a coarse strainer.
- Water disinfection with chlorine.
- Clarification with or without coagulation and flocculation.
- Clarification and hardness reduction using lime treatment.
- Media filtration.
- Reduction of alkalinity by pH adjustment.
- Addition of scale inhibitor.
- Reduction of free chlorine using sodium bisulfite or activated carbon filter.
- Water sterilization using UV radiation.
- Final removal of suspended particles using cartridge filters.
- Special case: anaerobic water (H2S)

Remember That:

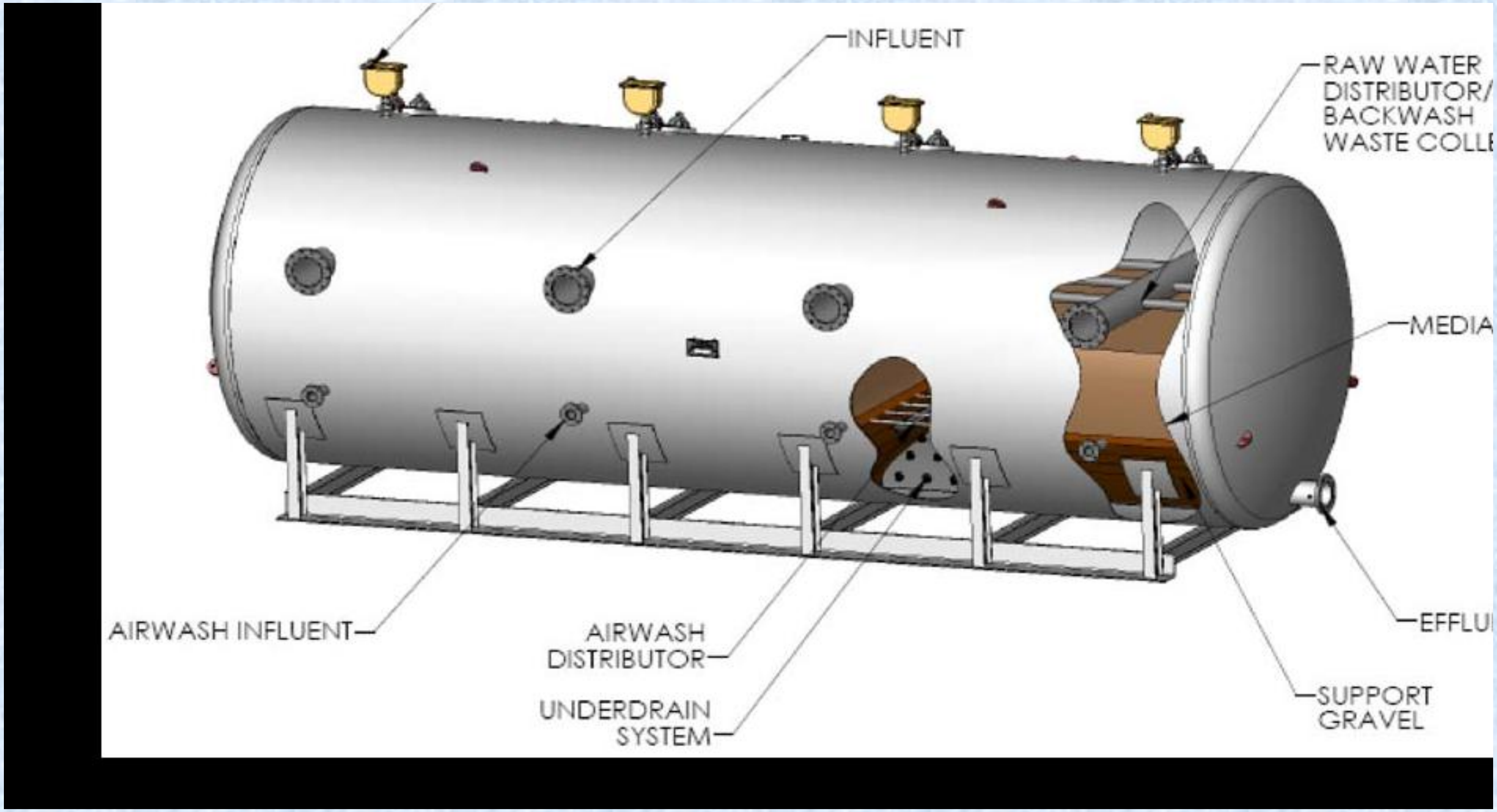
- There are some sub processes that go along with the reverse osmosis system. These processes will be either a pre processes (chemical & physical) to ensure successful & productive RO plant or could be a post process (chemical & physical) to ensure the final quality require permeate water.
- **The right treatment process depends on the following factors:**
- Source of raw water
- Raw water quality
- Required permeate water quality and Intended usage of permeate

CSM®

Dual media, vertical pressure filter configuration



Dual media, horizontal pressure filter configuration



CSM

Filter Calculation

- Area of Filter = Flow rate / Flux
- Area = 3.14 * D^2 / 4
- Where D is the Diameter of the filter.
- Please note that the flux of media can be selected according to the quality of the feed water(untreated water).
- For Example: How to calculate the diameter of Turbidity filter?
- First : the function of turbidity filter is to eliminate the total suspended solids and turbidity from incoming water up to 20 micron.
- According to manufacturer supplier the flux of Gravel and Sand will be 12.2-36.7 m3/hr/m2.

CSM®

Filter Calculation

- Please note that I assume the quality of feed water is not so bad, therefore I select the average flux which recommended by the supplier that is : 25 m3/hr/m2
- Flow Rate(m^3/hr) =3.14 X (D^2 / 4) X 25 (Diameter in meters)
- Flow rate required is 20 m3/hr ; therefore:
- $20 = 3.14 \times (D^2 / 4) \times 25$;
- $D^2 = (20 \times 4)/(3.14 \times 25)$
- D=1.0095 meter (39.7 inch).

CSM®

Filter Calculation

- Please note that for **<u>For High Suspended Solids & Turbidity content, we need to use</u>**
  - Coagulation dosing & Settlement Tank (clarifier).

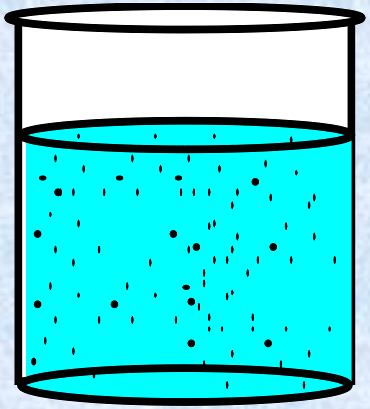
- **Design Basis:**

1. Coagulation Dosing-@ 1 mg/l
2. Settlement tank (clarifier) at a design rate of 0.5-1.0 m/h.
3. Dual media filter with slow filtration rate of 6-8 m/h

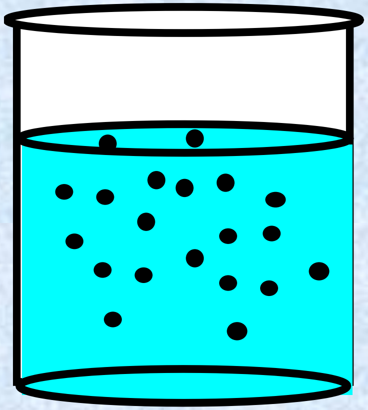
CSM

Coagulation

- “Like” charged particles suspended in solution can neither rise nor fall



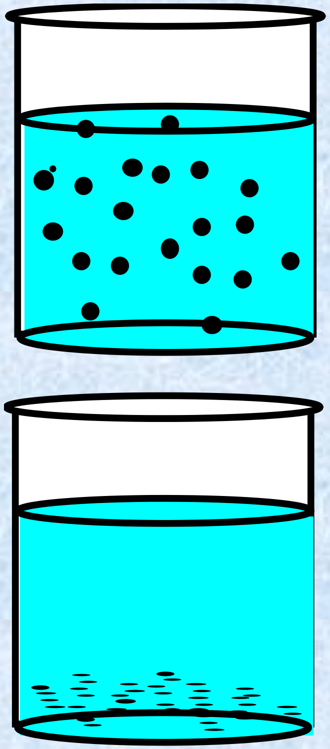
- The coagulant neutralizes the charges allowing the particles to collide



CSM®

Flocculation

- Long chained polymers with molecular weights from a ¼ million to several million
- The polymers attach themselves to the contaminants and fall quickly



CSM®

Removal of fouling elements

1. Iron and Manganese
    1.1 High Ferrous Iron
    1.2 Low Ferrous Iron
2. Hardness
    2.1 By Lime and Soda Softening
    2.2 By Caustic Soda Softening
3. Silicon
    3.1 By Adsorption on Iron Flocs
    3.2 By Magnesium Hydroxide Precipitation

CSM®

Characteristic Property of CSM RO Membranes

Why CSM RO Membrane:

- High permeate flux and high salt rejection
- Chemically stable in a wide range of pH (pH 2 - 12)
- Long membrane life time
- Resistant to a biological attack
- Operable in a wide range of pressure (20 – 1000 psig)
- Operable at a wide range of temperature (4 – 45 ℃)
- Economical
- Warranty
- Commitments (Delivery time, Technical Support, after sales, ect…)

CSM®

Thanks for your Attention!

CSM®