Water Desalination technologies

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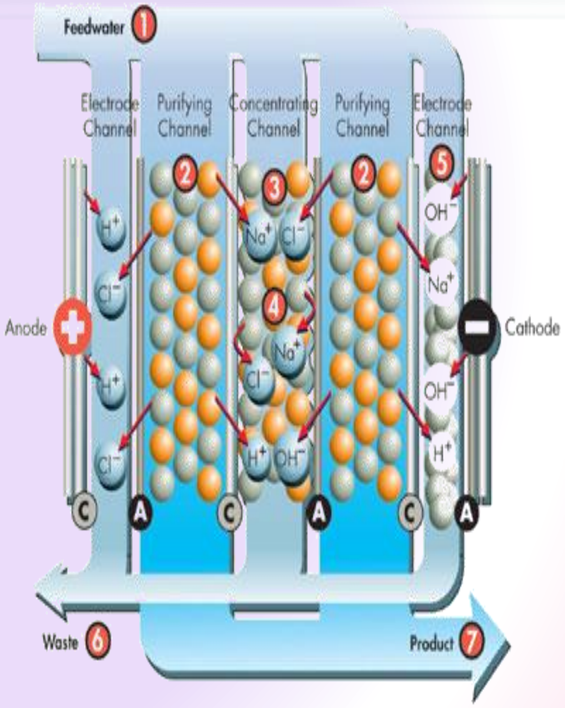

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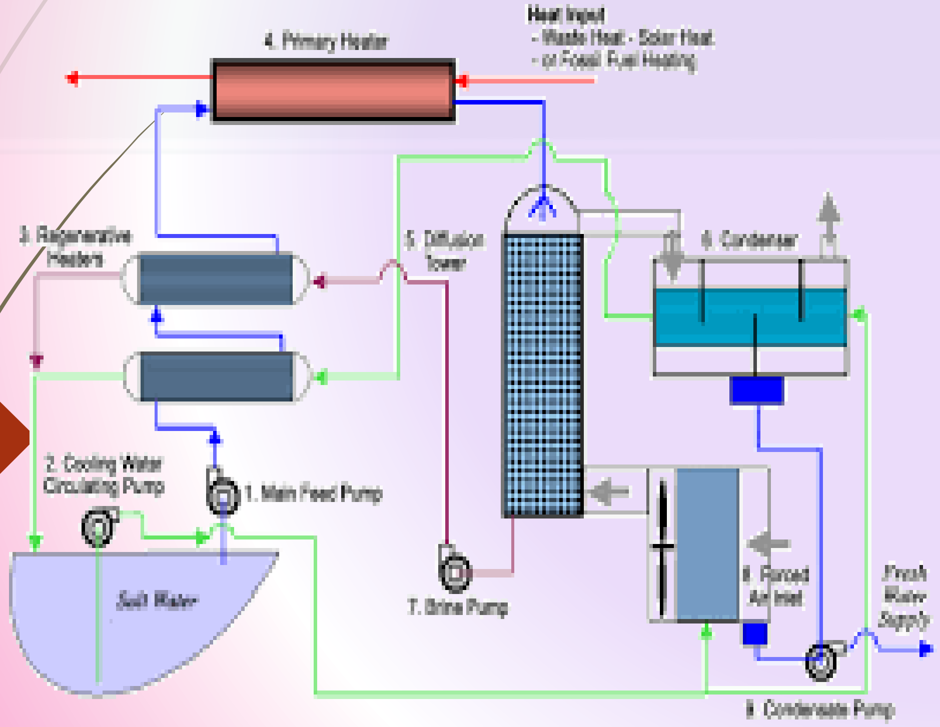

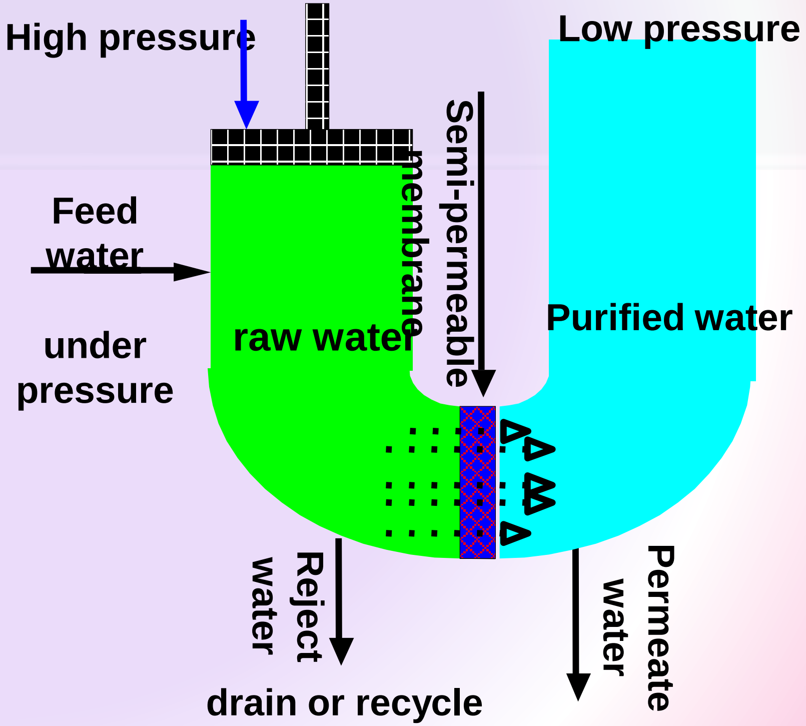

About the presenter

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- Member of the Board scientists Egypt.
- Member of Scientific Professions Syndicate.
- Member of the Arab Society for experts and Safety Professionals.
- Member of the International Association of Engineers.
- Expert of water and waste water treatment technologies.
- Certified trainer in water treatment field .
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Terminology

- ***Total dissolved solids:*** *the concentration of which is expressed in milligrams per liter (mg/L)/ parts per million (ppm) or parts per thousand (ppt).*
- ***thermal distillation****: freshwater is separated from the saline source by evaporation.*
- ***Reverse osmosis desalination****: freshwater is produced from saline source water by pressure-driven* transport through semipermeable membranes.

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- ***Electrodialysis (ED) :*** *is electrically driven desalination in which salt ions are* removed out of the source water through exposure to direct electric current.
- ***Ion Exchange (IX) :*** is the selective removal of salt ions from water by adsorption onto ion-selective resin media.

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- ***Potable water standard:***

(US EPA) *have established a maximum TDS concentration of 500 mg/L as a potable water standard.*

- ***Water classification according TDS :***

Type	TDS in mg/l	Example
Fresh	less than **500** mg/l	Rivers
brackish	500-15000 mg/l	Ground water wells
Sea water	Higher than **15000** mg/l	sea, bay, and ocean waters

Desalination Process Applicability

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Separation Process	Range of Source Water TDS Conc. for Cost-Effective Application, mg/L
Distillation	20,000–100,000
Reverse osmosis	50–46,000
Electrodialysis	200–3000
Ion exchange	1–800

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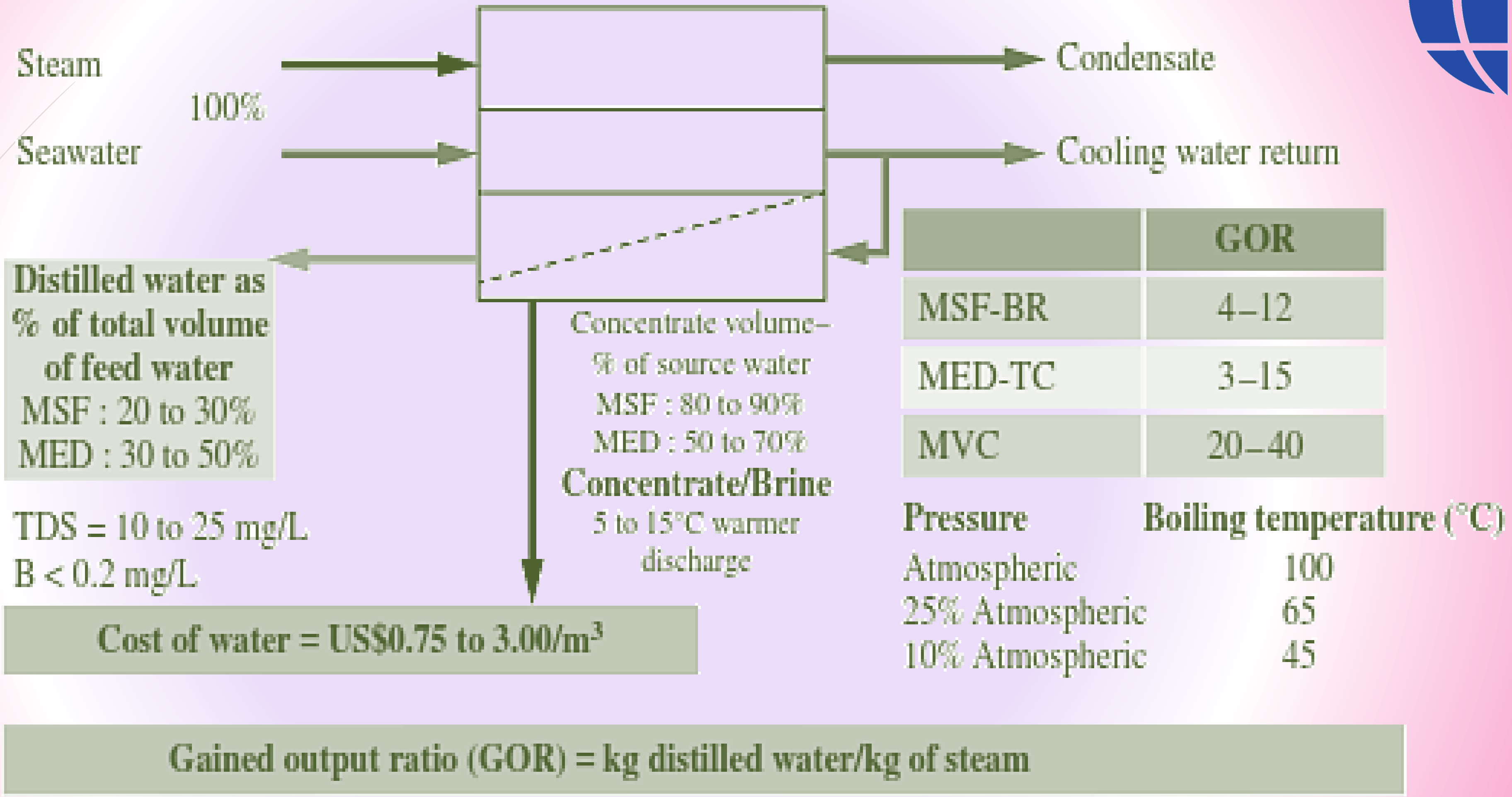

Figure 1.1 General schematic of thermal evaporation technologies.

Thermal desalination technologies

- Thermal desalination technologies
  - Vapor compression (VC)
  - Multieffect distillation (MED)
  - Multistage flash distillation (MSF)

Multistage Flash Distillation

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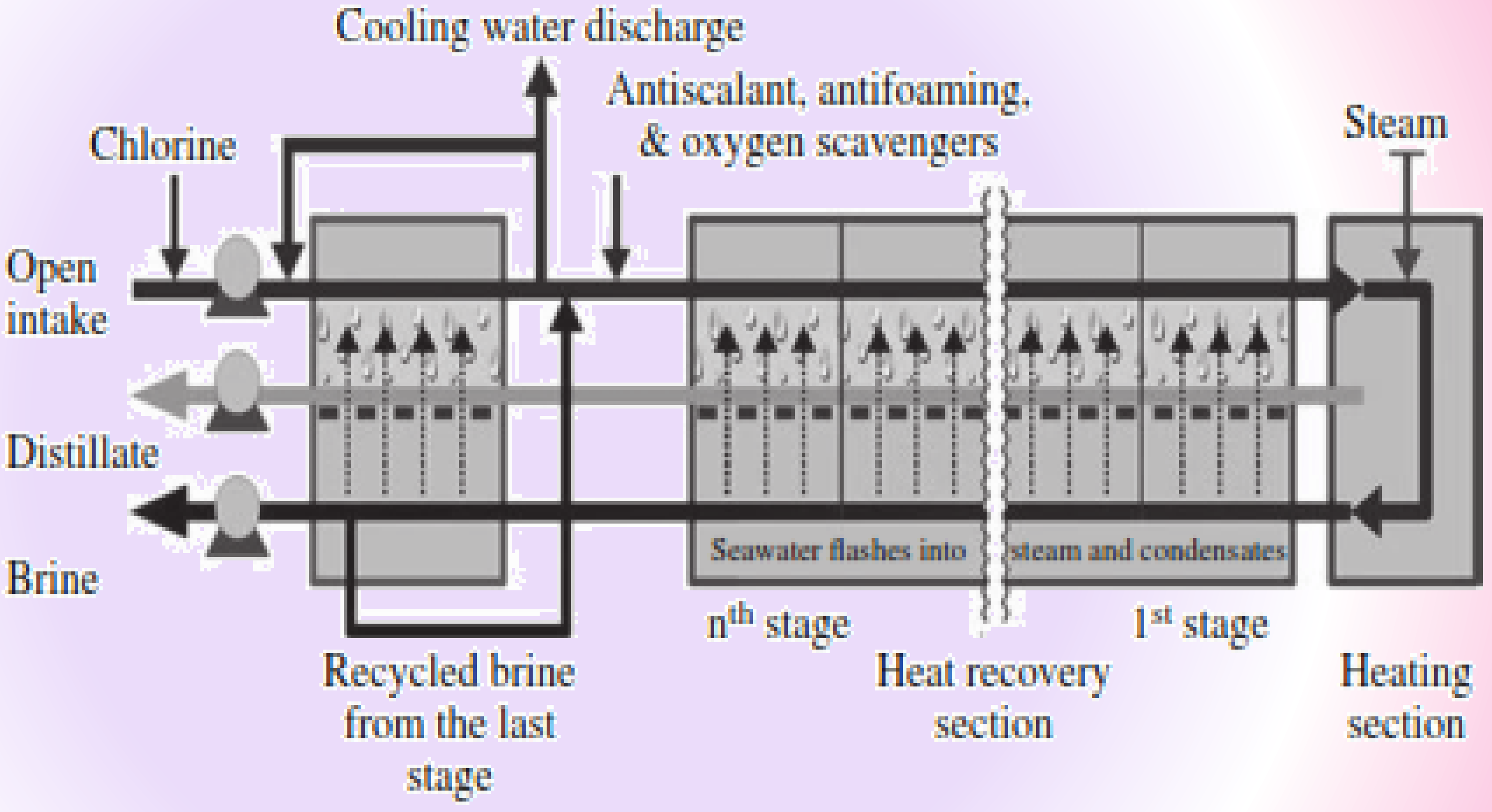

Figure 1.2 Schematic of an MSF distillation system.

Recovery of MSF plant

- *The total MSF plant recovery (i.e., the volume of distillate expressed as a percentage of the total volume of processed source water) is typically 19 to 28 percent.*
- *For comparison, RO seawater desalination plants have a recovery of 40 to 45 percent.*

Multiple-Effect Distillation

- In multiple-effect distillation (MED) systems, saline source water is typically not heated; cold source water is sprayed via nozzles or perforated plates over bundles of heat exchanger tubes.
- This feed water sprayed on the tube bundles boils, and the generated vapor passes through mist eliminators, which collect brine droplets from the vapor.

Multiple-Effect Distillation

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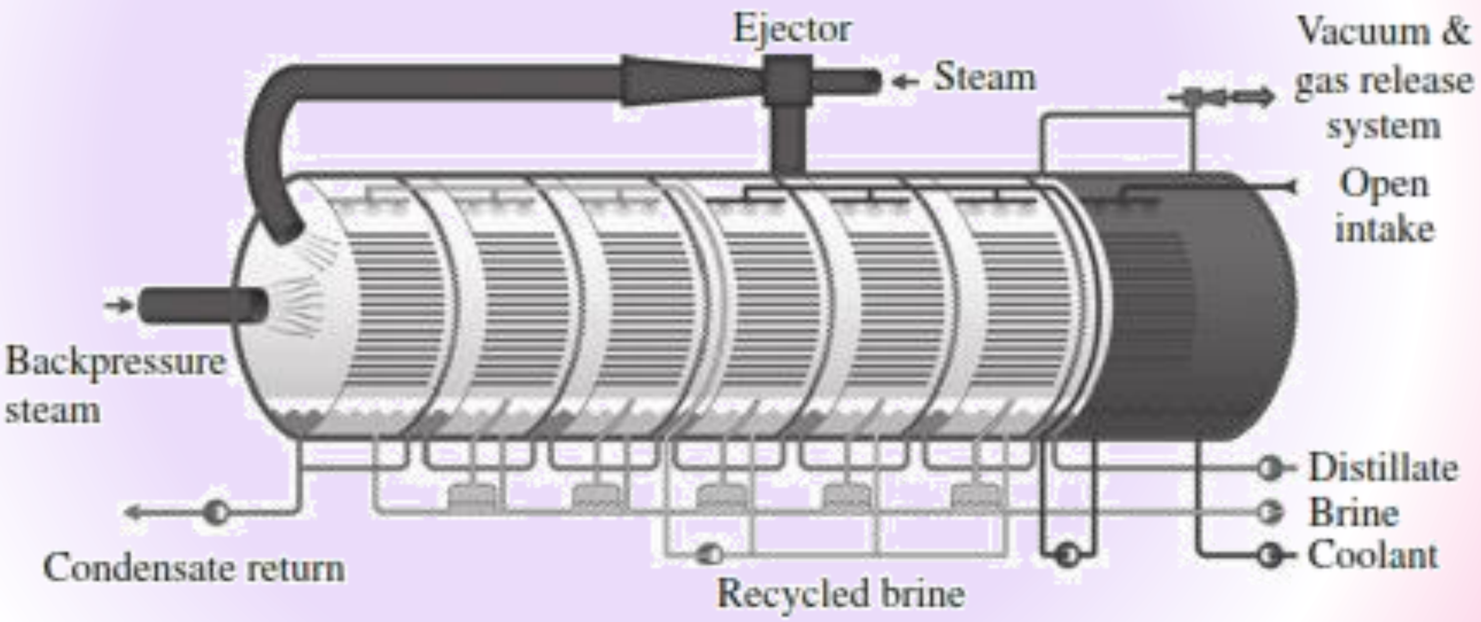

Figure 1.3 Schematic of an MED system.

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- MED desalination systems typically operate at lower temperatures than MSF plants
- The newest MED technologies, which include vertically positioned effects may yield a GOR of up to 24 kg of potable water per kilogram of steam.

Vapor Compression

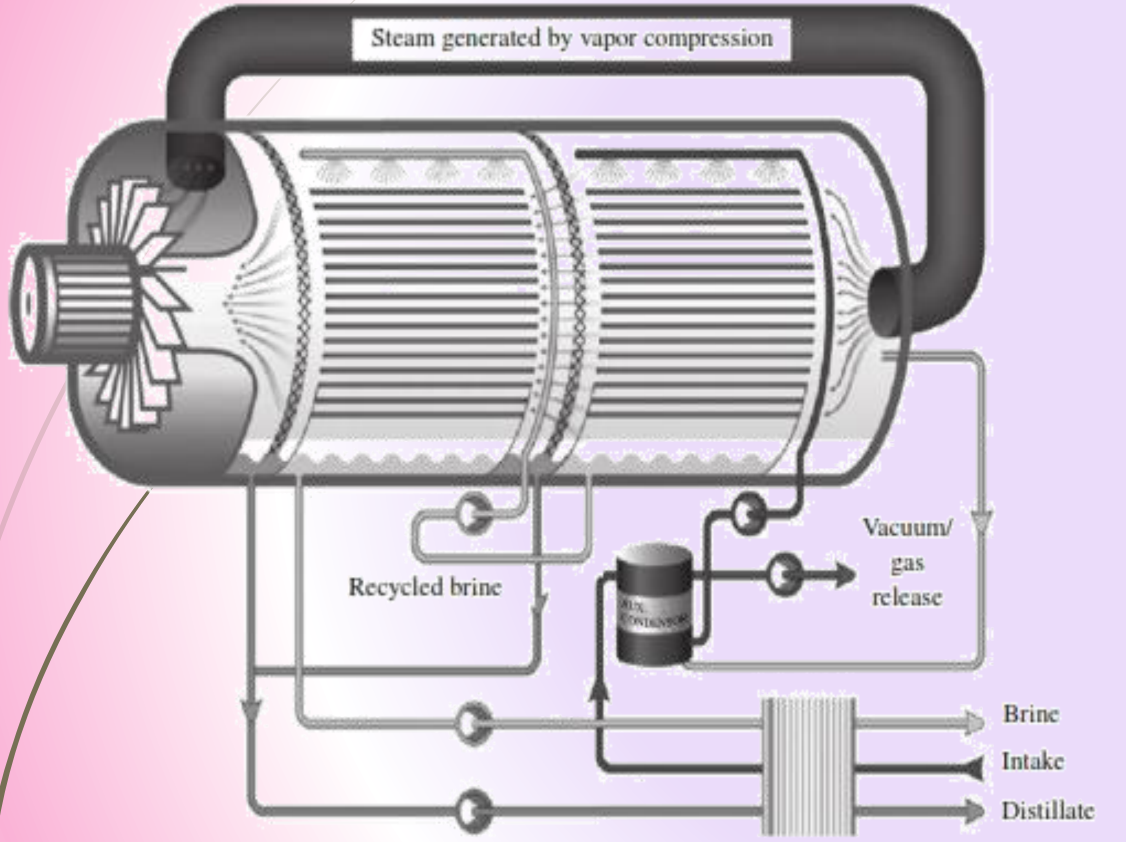
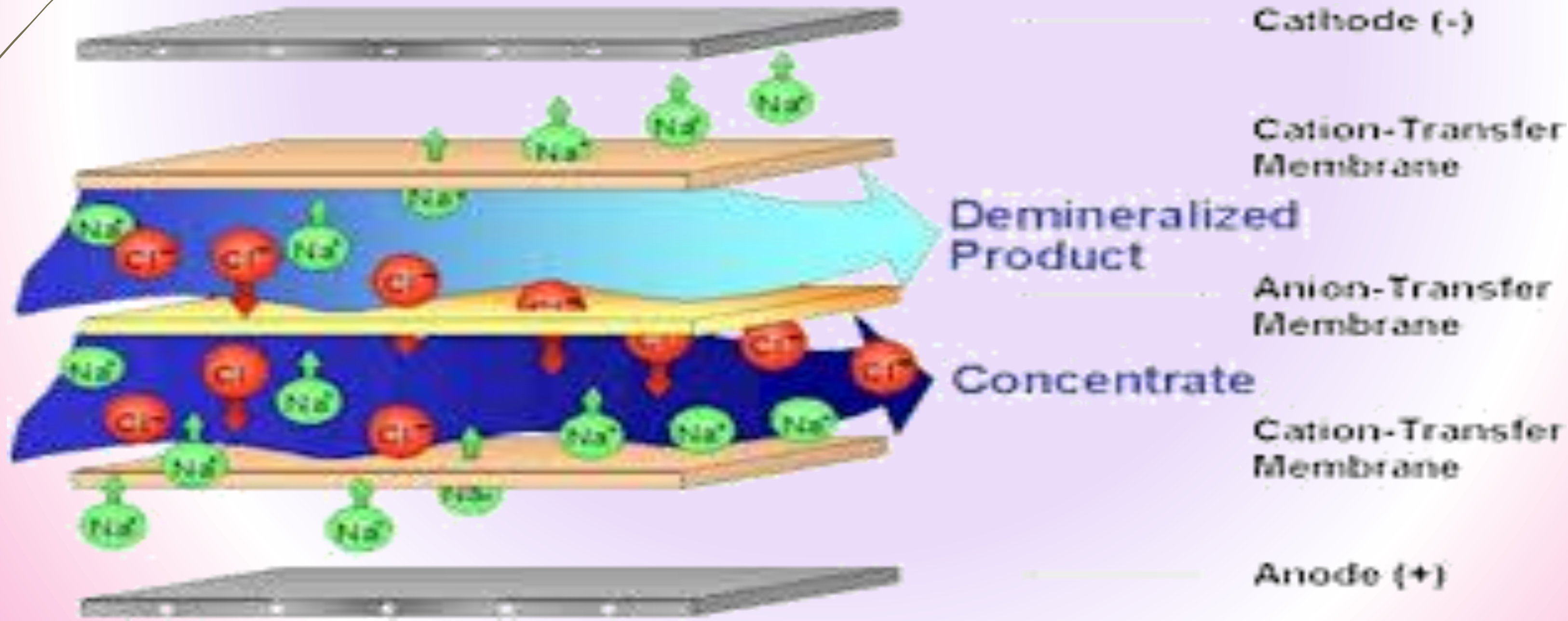


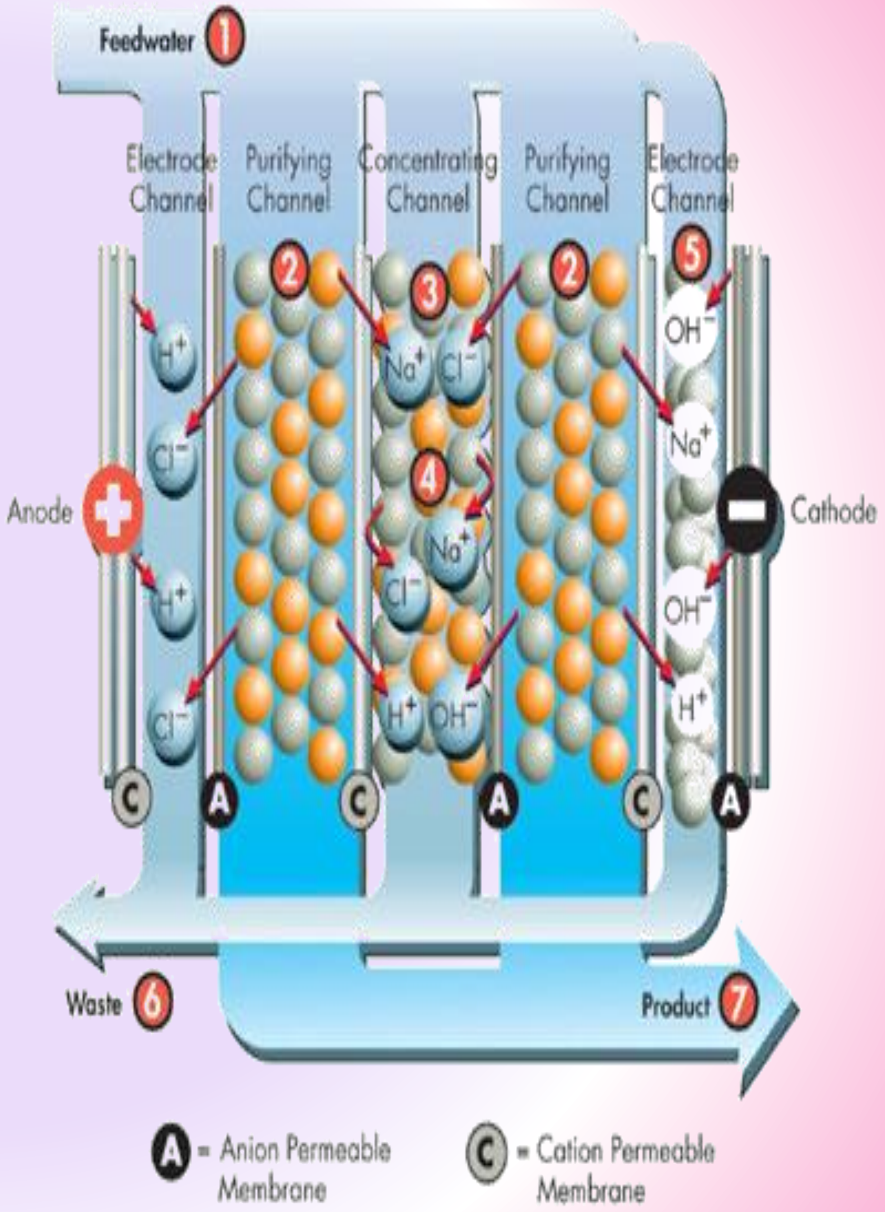
FIGURE 1.4 Schematic of a VC system.

- The heat source for vapor compression (VC) systems is compressed vapor produced by a mechanical compressor or a steam jet ejector rather than a direct exchange of heat from steam.

Electrodialysis

- In Electrodialysis (ED)–based desalination systems, the separation of minerals and product water is achieved through the application of direct electric current to the source water.





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Contaminant removal efficiency

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Contaminant	Distillation (%)	ED/EDR (%)	RO (%)
TDS	>99.9	50–90	90–99.5
Pesticides, Organics/VOCs	50–90	<5	5–50
Pathogens	>99	<5	>99.99
TOC	>95	<20	95–98
Radiological	>99	50–90	90–99
Nitrate	>99	60–69	90–94
Calcium	>99	45–50	95–97
Magnesium	>99	55–62	95–97
Bicarbonate	>99	45–47	95–97
Potassium	>99	55–58	90–92

Table 1.2 Contaminant Removal by Alternative Desalination Technologies

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Source Water Quality Parameter	Pretreatment Issues and Considerations
Turbidity, NTU	Levels above 0.1 mg/L are indicative of a high potential for fouling. Spikes above 50 NTU for more than 1 h would require sedimentation or dissolved air flotation treatment prior to filtration.
Silt density index (SDI_{15})	Source seawater levels consistently below 2 all year round indicate that no pretreatment is needed. An SDI greater than 4 indicates that pretreatment is necessary.
Total suspended solids, mg/L	Needed to assess the amount of residuals generated during pretreatment. It does not correlate well with turbidity beyond 5 NTU.
Chlorophyll a	Indicative of algal bloom occurrence. If water contains more 0.5 μg/L, the source water may be in an algal bloom condition.
Algal count, cells per milliliter	Indicative of algal bloom occurrence. If water contains more than 2000 cells per milliliter, the source water is in an algal bloom condition.

Table 2.4 Water Quality Parameters for Characterization of Particulate Foulants

Reverse Osmosis

- **Reverse osmosis (RO)** is a process where *source water contaminants* is forced under pressure through a semipermeable membrane.
- **semipermeable membrane** : selectively allows water to pass through it at much higher rate than the transfer rate of any *contaminants* in the water.

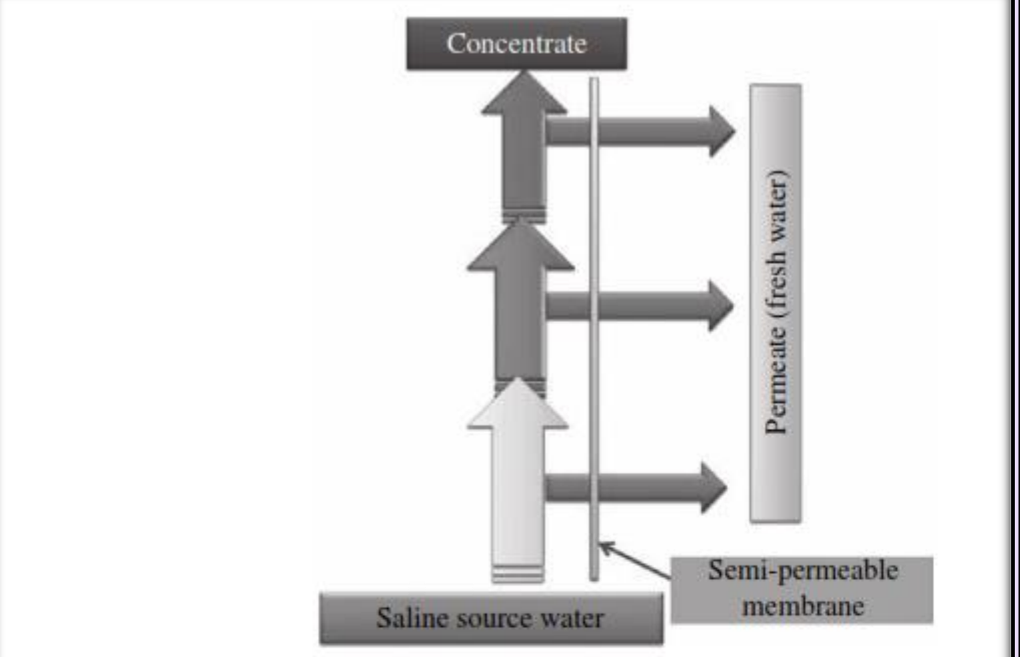

FIGURE 3.2 Reverse osmosis process.

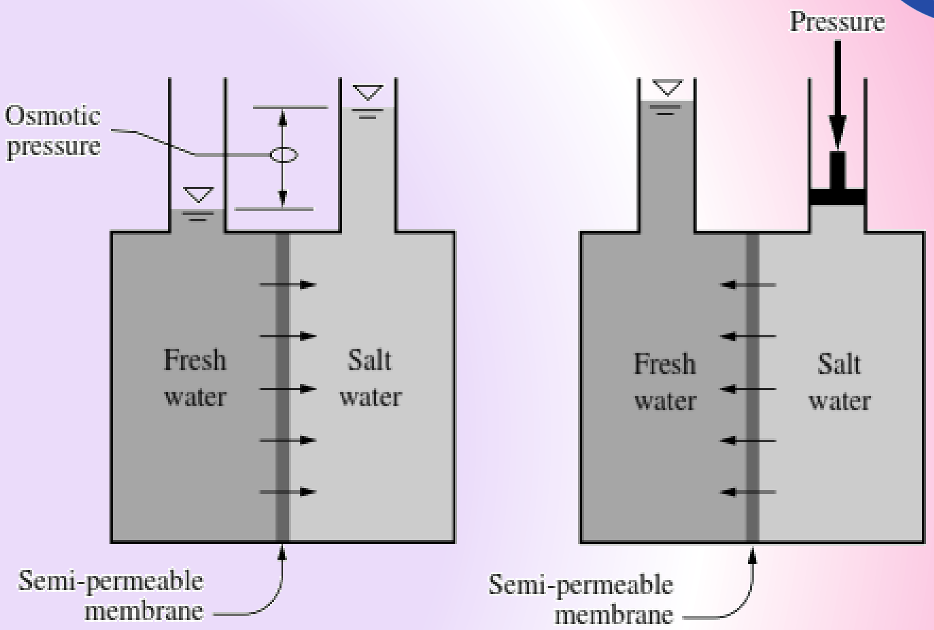

FIGURE 3.1 Osmosis and reverse osmosis.

Membrane problems

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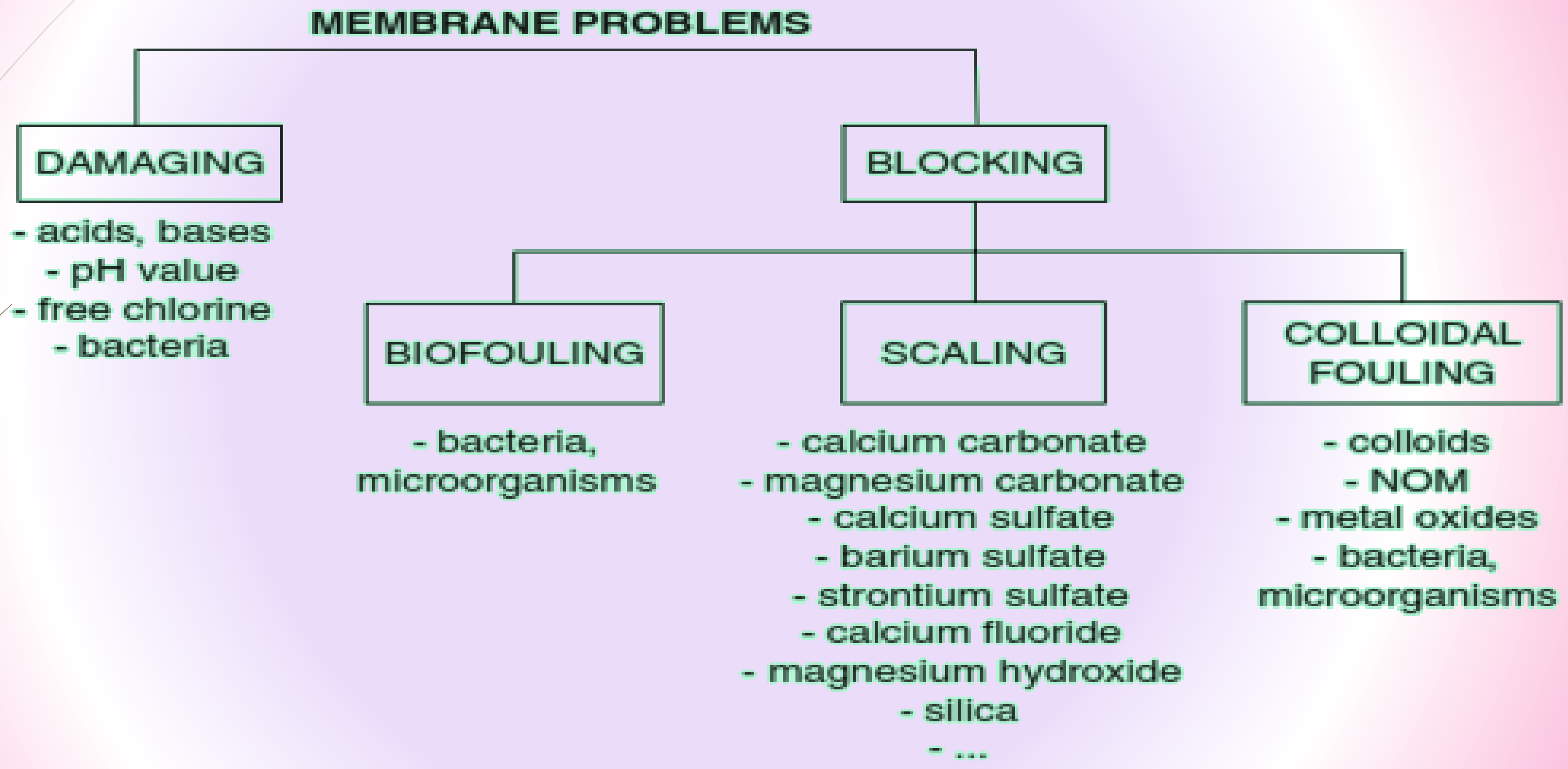

Fig. 3.11 List of common agents which create problems in membrane processes

Source Water Quality Characterization

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- A desalination plant's source water quality has an impact on the treatment needed and ultimately on the quality of the produced drinking water.

Cations	Anions
Sodium	Chloride
Magnesium	Carbonate
Calcium	Bicarbonate
Potassium	Sulfate
Barium	Nitrate
Strontium	Fluoride
Boron	Phosphate
Bromide	Sulfur

Parameter	Orange County, California	Rio Grande, Texas	Tularosa, New Mexico	Cape Hatteras, North Carolina
Cations, mg/L				
Calcium	140.0	163.0	420.0	545.0
Magnesium	10.0	51.0	163.0	1398.0
Sodium	300.0	292.0	114.0	4961.0
Potassium	35.0	0.0	2.30	99.0
Boron	0.8	0.0	0.14	1.2
Bromide	7.4	4.5	0.70	12.5
Total Cations	**493.2**	**510.5**	**700.14**	**7016.7**
Anions, mg/L				
Bicarbonate	275.0	275.0	270.0	223.0
Sulfate	350.0	336.0	1370.0	173.0
Chloride	350.0	492.0	170.0	6523.0
Fluoride	0.8	0.08	0.0	1.3
Silica	10.0	35.0	22.0	22.0
Nitrate	1.0	1.5	10.0	1.0
Total Anions	**986.8**	**1139.58**	**1842.0**	**6943.3**
TDS mg/L	**1480.0**	**1650.0**	**2542**	**13,960.0**

Table 2.3 Brackish Water Quality of Several Sources

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Iron in reduced form (Fe^{2+}), mg/L	Foulant if > 0.05 mg/L
Iron in oxidized form, mg/L	Foulant if > 2.0 mg/L Membrane damage by chlorine if > 0.5 mg/L
Manganese, mg/L	Foulant if > 0.02 mg/L
Aluminum, mg/L	Foulant if > 0.1 mg/L
Copper, µg/L	Potential membrane damage if > 50 µg/L
Arsenic	Potential toxicant if > 10 µm/L in permeate
Turbidity	Accelerated fouling if > 0.1 NTU
Total suspended solids (TSS), mg/L	Accelerated fouling if > 1 mg/L
Silt density index (SDI)	Accelerated fouling if > 5
Total hydrocarbons, mg/L	Foulant if > 0.02 mg/L
Silica (colloidal), mg/L	Foulant if > 100 mg/L in concentrate
Total organic carbon (TOC), mg/L	Potential for accelerated fouling if > 2 mg/L
UV_{254}, cm^{-1}	Potential for accelerated fouling if > 0.5 cm^{-1}
Total algal count, algal cells per milliliter	Algal bloom if > 2000 algal cells per milliliter
Hydrogen sulfide	Odor and membrane fouling if > 0.1 mg/L.
Ammonia, mg/L	Membrane damage if bromide > 0.4 mg/L
Free chlorine, mg/L	Membrane damage if > 0.01 mg/L
Oxidation reduction potential, mV	Membrane damage if > 250 mV
Total coliform count, Most Probable Number (MPN) per 100 mL	Potential pathogen contamination if > 10^4

Table 2.9 Source Water Quality Analysis for Reverse Osmosis Desalination

Total Dissolved Solids TDS

- The TDS of the source water is the most important water quality parameter in RO desalination for two main reasons:

   1. **TDS is a main factor in determining the feed pressure.**
   2. **and therefore, the energy needed to produce freshwater from a given saline water source.**

- The ratio between TDS and EC in source water is site specific and usually varies in a range between 0.67 and 0.70.
- Every 100 mg/L of TDS in the source water creates approximately 0.07 bar of osmotic pressure

- For example, seawater that contains 35,000 mg/L of TDS will create approximately 24.5 bar of osmotic pressure.
- In addition, TDS concentration of the source water is a key factor in determining the expected product water quality

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- Besides sodium and chloride, which need to be removed in order to produce freshwater, other key inorganic constituents of TDS are various minerals (mainly salts of calcium and magnesium).
- These bivalent salts can precipitate on the surface of the membrane and form a thin layer of crystalline scale

Dissolved Gases

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- Both seawater and brackish water often contain various dissolved gases. The most common gases are oxygen, carbon dioxide, hydrogen sulfide, and ammonia.
- All of these gases pass through RO membranes, and thus desalination is typically not a suitable technology for degasification.
- The dissolved oxygen concentration of these waters typically varies between 5 and 8 mg/L.
- Groundwater aquifers have a very low oxygen content (0.5 mg/L or less)

Particulate Membrane Foulants

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- Particulate foulants are organic and inorganic particles contained in the source water, such as fine debris, plankton, detritus, and silt. These solids cannot pass through RO membranes.
- **Turbidity:**

The turbidity level in the source water is indicative of the content of clay, silt, suspended organic matter, and microscopic aquatic life, such as phyto and zooplankton. It is expressed in *nephelometric turbidity units (NTU)*.

Silt Density Index (SDI)

- ***Silt density index (SDI)*** *is a parameter that provides an indication of the particulate fouling* potential of source water.
- ***Particulate membrane fouling*** will result in a decline of system productivity (membrane flux) over time.
- and is based on the measurement of the time in seconds it takes to collect a 500-mL sample through a paper filter of size 0.45 μm and diameter 45 mm
- the source water has flowed through the filter under a driving filtration pressure of 2.1 bar.

$$SDI_{15} = \frac{1-(t_0/t_n)}{n}100$$

Total Suspended Solids

- ***Total suspended solids (TSS)*** is measured by filtering a known volume of water (typically 1 L) through a pre weighed glass-fiber filter, drying the filter with the solids retained on it at 103 to 105°C, and then weighing the filter again after drying.

Chlorophyll a

- The chlorophyll *a concentration of a source water is an indicator of the content of algae* with green pigmentation in the water.
- This parameter is measured using a fluorometer or spectrophotometer.
- It should be pointed out that content of algae and chlorophyll *a naturally varies* diurnally and seasonally, and also changes with depth.
- In general, algal content is proportional to the intensity of solar irradiation and typically increases significantly in the summer, as compared to the average annual algal content.

Colloidal foulants

- Colloidal foulants are inorganic and organic compounds that naturally exist in suspension and may be concentrated by the RO separation process and precipitate on the membrane surface, thereby causing membrane flux to decline over time.

Iron and Manganese

- If iron and manganese are in reduced form and they are below 1.0 and 0.1 mg/L, respectively, they can be removed by RO membranes without causing accelerated fouling.

- However, if iron and manganese are in oxidized form, their levels should be reduced below 0.05 and 0.02 mg/L, respectively, to prevent mineral fouling of the membranes.

Silica

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- Total silica (silicon dioxide) in the source water consists of reactive silica, which is in soluble form, and unreactive silica, which is in colloidal form.
- While reactive silica is not a challenge for RO membranes, colloidal silica in the saline source water can cause significant membrane fouling.

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Source Water Quality Parameter	Pretreatment Issues and Considerations
Iron, mg/L	If iron is in reduced form, RO membranes can tolerate up to 2 mg/L. If iron is in oxidized form, a concentration of more than 0.05 mg/L will cause accelerated fouling.
Manganese, mg/L	If manganese is in reduced form, RO membranes can tolerate up to 0.1 mg/L. If manganese is in oxidized form, a concentration of more than 0.02 mg/L will cause accelerated fouling.
Silica, mg/L	Concentrations higher than 100 mg/L in concentrate may cause accelerated fouling.
Total hydrocarbons, mg/L	Concentrations higher than 0.02 mg/L will cause accelerated fouling.

Table 2.5 Water Quality Parameters for Characterization of Colloidal Foulants

Natural Organic Foulants

- **Natural organic foulants :**

  This NOM is easily biodegradable and provides a food source for biogrowth of bacteria on the RO membrane.

- **Microbiological foulants (biofoulants):**

  The phenomenon of accumulation of aquatic organisms and their metabolic products on the membrane surface is known as *biological fouling or biofouling*.

Total Organic Carbon

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- ***Total organic carbon (TOC)*** *is one of the most widely used measures for the organic* content of saline source water.
- **TOC** concentration measures the content of both NOM and easily biodegradable organics, such as polysaccharides, released during algal blooms.

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UV_{254} Absorbance

- **UV_{254}** The *ultraviolet (UV) absorbance of a seawater sample at 254 nm is an indirect measure* of NOM.
- The UV absorbance of a saline water sample is determined by filtering the sample through a 0.45-μm filter and measuring the filtrate's absorbance of UV with a spectrophotometer.
- ***Specific UV absorbance*** *(SUVA) is defined as the UV absorbance divided by the concentration* of dissolved organic carbon in the source water.

Source Water Quality Parameter	Pretreatment Issues and Considerations
Total organic carbon, mg/L	If this parameter is below 0.5 mg/L, biofouling is unlikely. Above 2 mg/L, biofouling is very likely.
UV_{254}, cm^{-1}	If this value is below 0.5 cm^{-1}, the saline source water has low potential for organic fouling and biofouling.
Specific UV absorbance	If this is greater than 4, the source water is dominated by aquatic humic matter and biofouling is unlikely. If it is less than 2, the source water is experiencing algal bloom and biofouling is likely.

Table 2.8 Water Quality Parameters for Characterization of Organic Foulants

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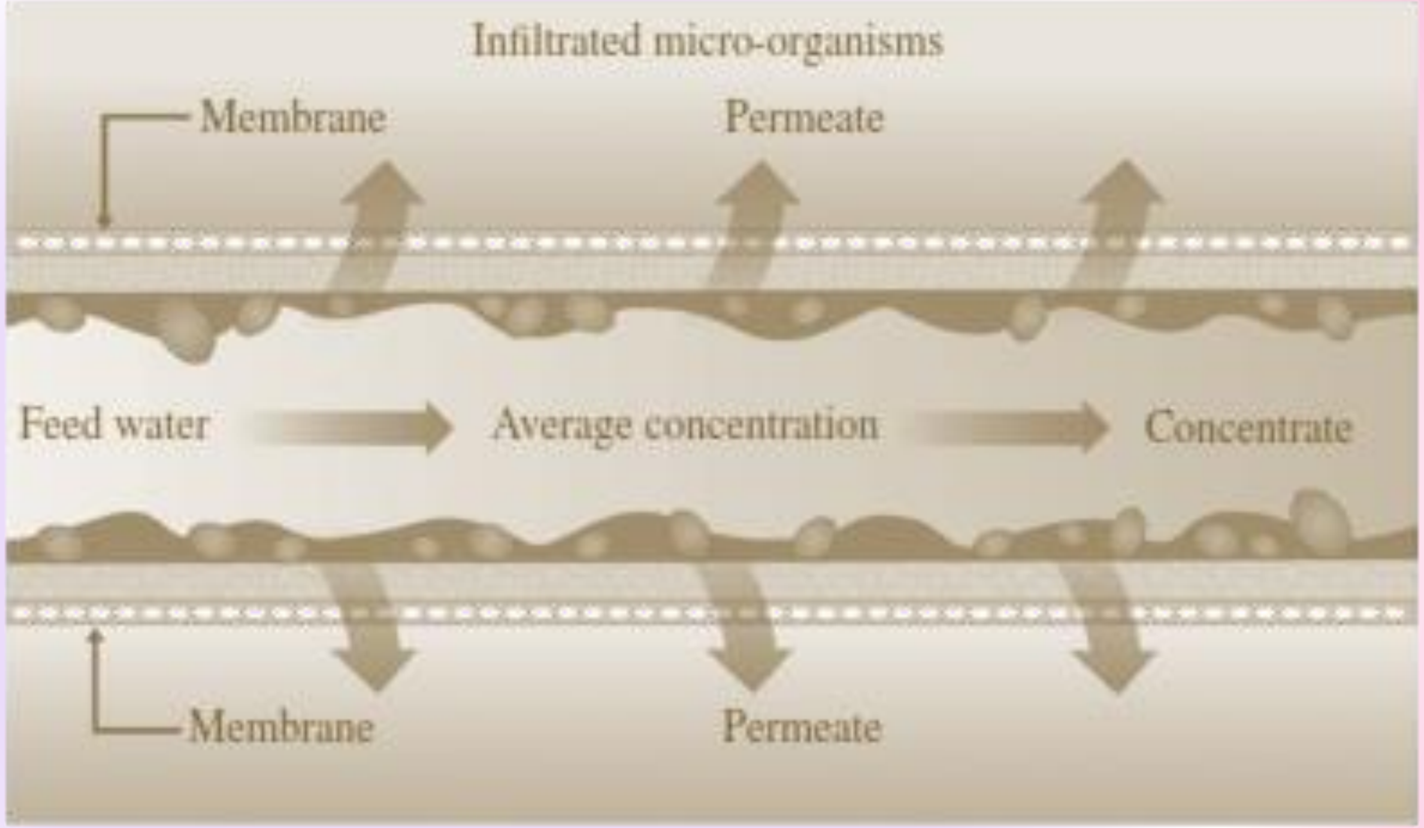

Figure 2.5 Biofilm accumulation in the spacer of an RO membrane.

Reverse Osmosis Membrane Structures, and Materials

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Parameter	Polyamide Membranes	Cellulose Acetate Membranes
Salt rejection	High (> 99.5%)	Lower (up to 95%)
Feed pressure	Lower (by 30 to 50%)	High
Surface charge	Negative (limits use of cationic pretreatment coagulants)	Neutral (no limitations on pretreatment coagulants)
Chlorine tolerance	Poor (up to 1000 mg/L-hours); feed dechlorination needed	Good; continuous feed of 1 to 2 mg/L of chlorine is acceptable
Maximum temperature of source water	High (40 to 45°C; 104 to 113°F)	Relatively low (30 to 35°C; 86 to 95°F)
Cleaning frequency	High (weeks to months)	Lower (months to years)
Pretreatment requirements	High (SDI < 4)	Lower (SDI < 5)
Salt, silica, and organics removal	High	Relatively low
Biogrowth on membrane surface	May cause performance problems	Limited; not a cause of performance problems
pH tolerance	High (2 to 12)	Limited (4 to 6)

TABLE 3.1 Comparison of Polyamide and Cellulose Acetate Membranes

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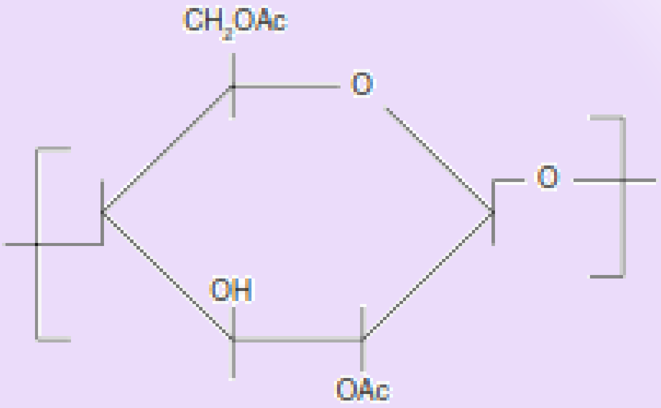
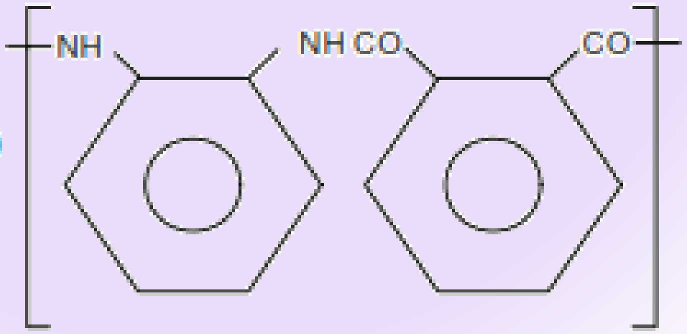
Table 3.3 Common polymeric materials used in the preparation of NF and RO membran

Polymer	Structure	Properties
Cellulose acetate (CA)		Very hydrophilic; sensitive to thermal and chemical degradation; low tensile strength
(Aromatic) Polyamide (PA)		Hydrophilic; good solvent resistance

Separation spectrum of pressure-driven membrane processes

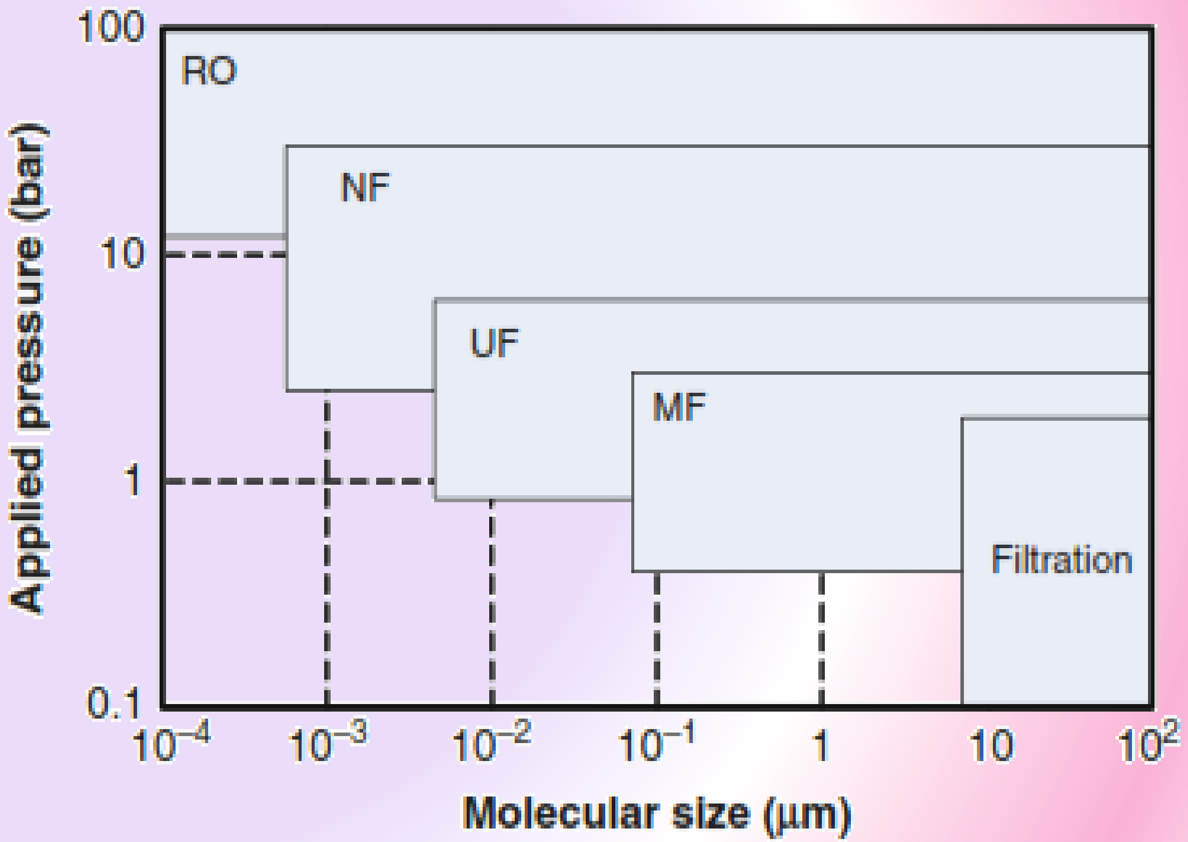


Fig. 3.6 Separation spectrum of pressure-driven membrane processes

RO membrane element

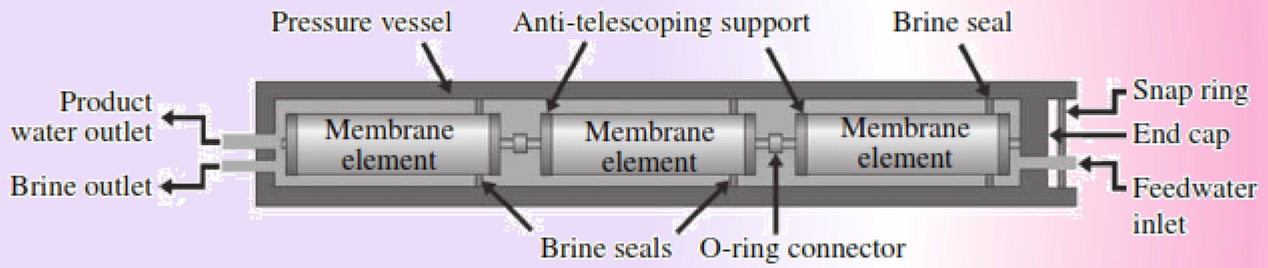


FIGURE 3.9 Membrane elements installed in a pressure vessel.

RO membrane element

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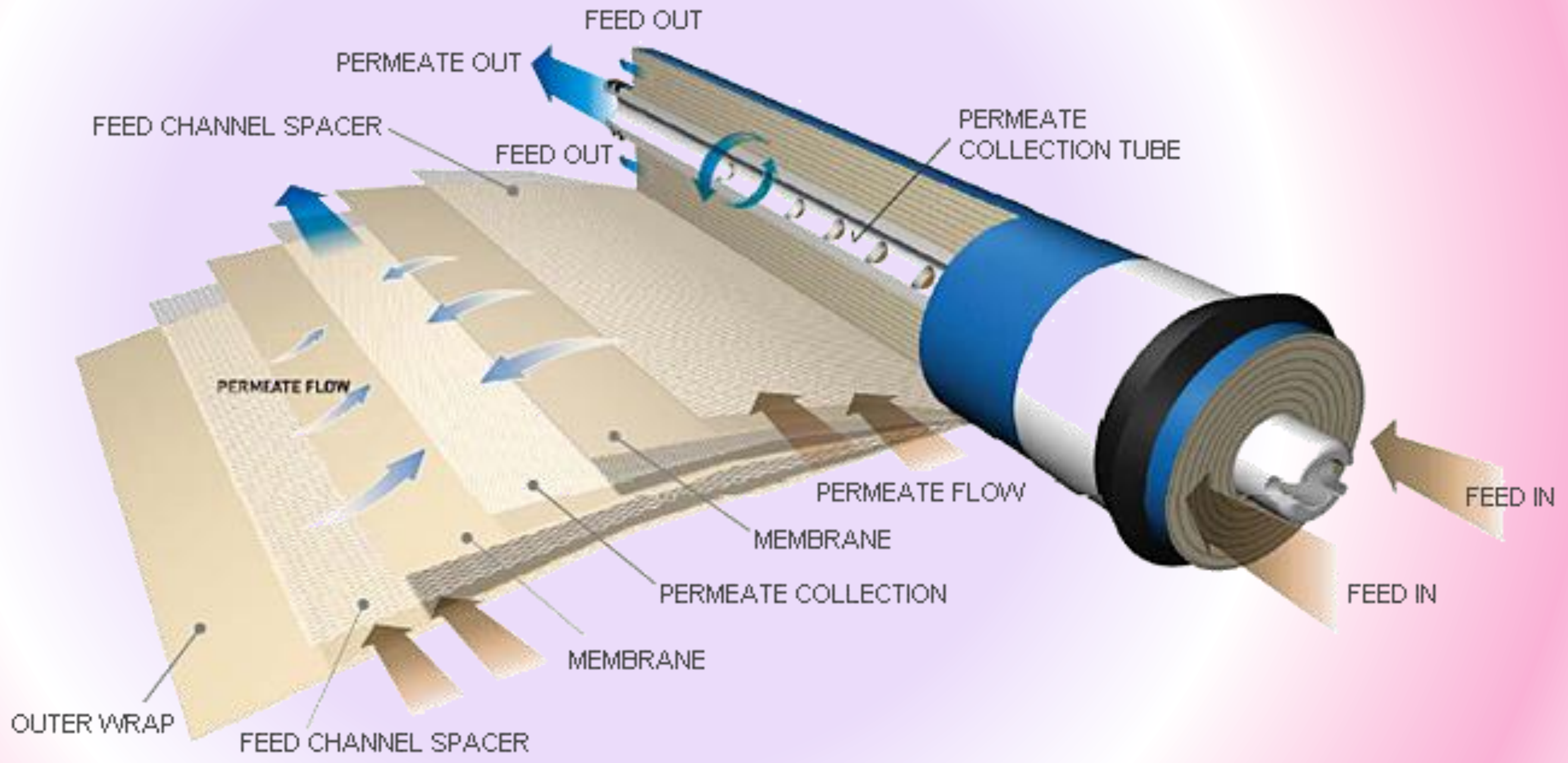
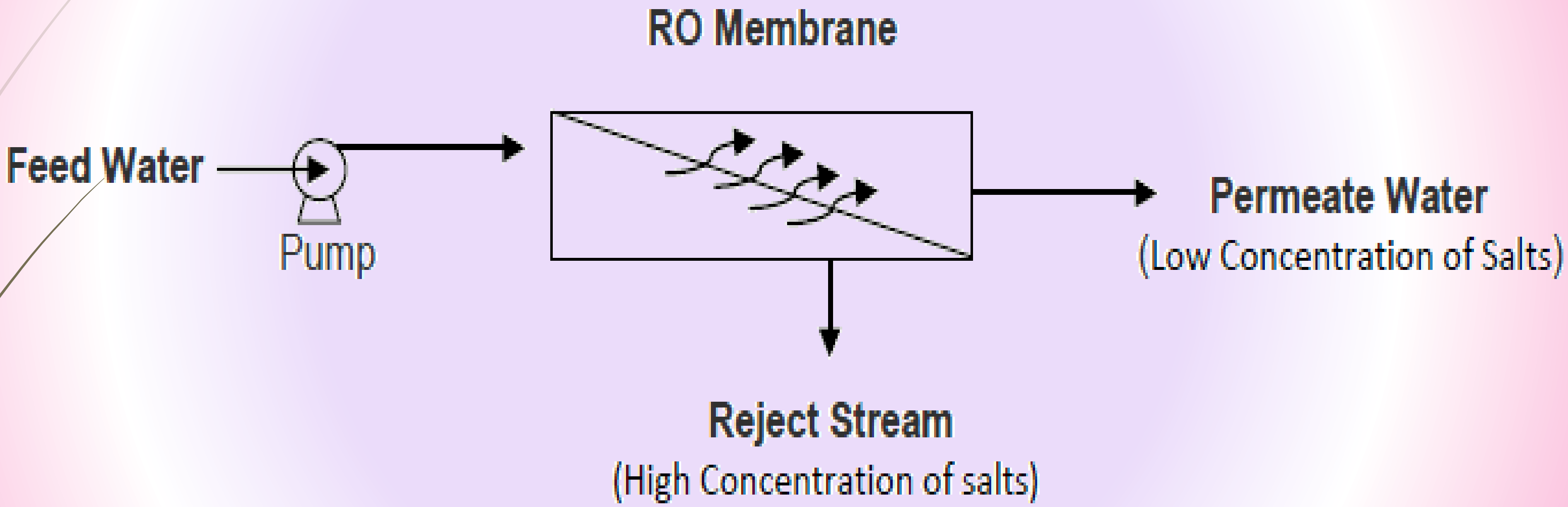


How does Reverse Osmosis work?



Permeate water :

The good produced water that comes out of an RO system has the majority of contaminants removed

Concentrate , Reject , Brine :

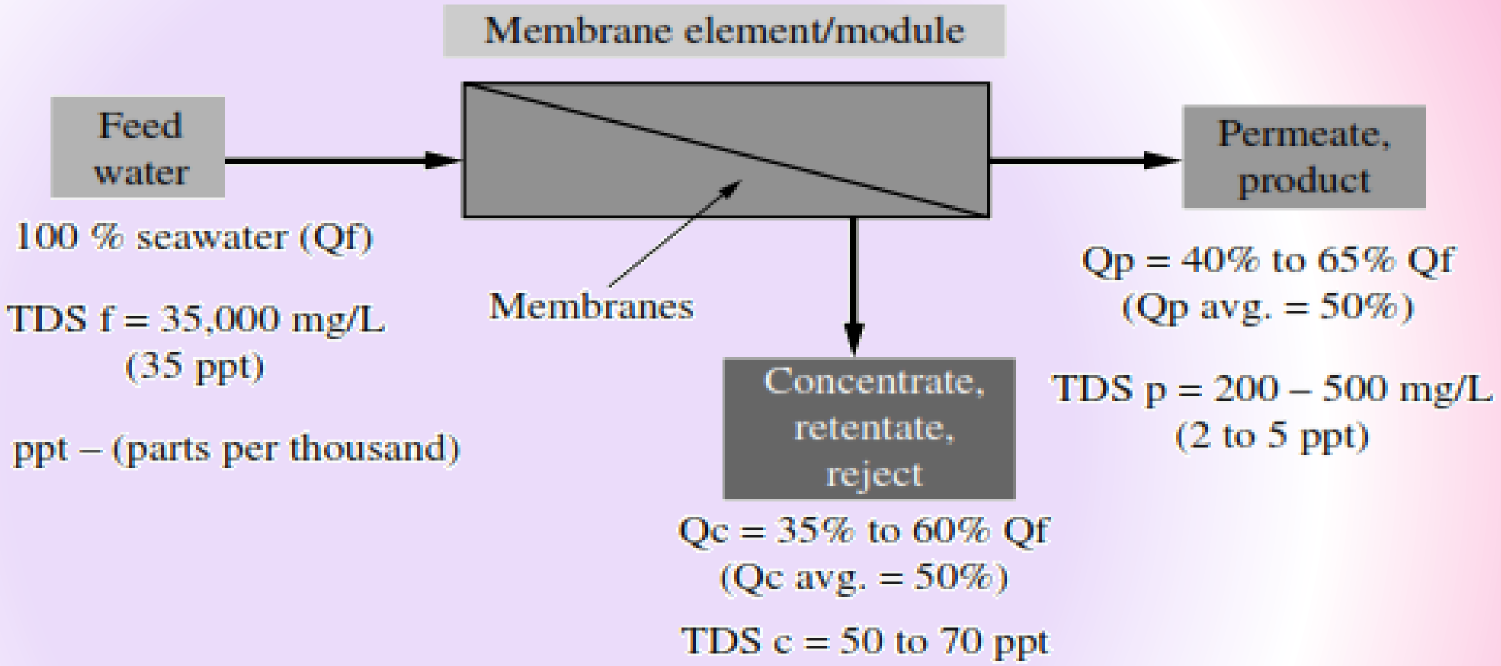
Is the water that contains all of the contaminants that were unable to pass through the RO membrane.

Recovery % :

Percent Recovery is the amount of water that is being 'recovered' as good permeate water.

$$\% \text{ Recovery} = \frac{\text{Permeate Flow Rate (gpm)} \times 100}{\text{Feed Flow Rate (gpm)}}$$

Recovery



$$\% \text{ Recovery} = \frac{\text{Permeate Flow (Qp)}}{\text{Feed Flow (Qf)}} \times 100 = \frac{50\% \text{ Qf}}{\text{Qf}} = 50\%$$

Figure 3.17 Recovery of a typical SWRO system.

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Salt Rejection % :

This equation tells you how effective the RO membranes are removing contaminants. A well designed RO system with properly functioning RO membranes will reject 95% to 99% of most feed water contaminants.

$$\text{Salt Rejection \%} = \frac{\text{Conductivity of Feed Water} - \text{Conductivity of Permeate Water} \times 100}{\text{Conductivity of Feed}}$$

Salt Passage % :

This is the amount of salts expressed as a percentage that are passing through the RO system. The lower the salt passage, the better the system is performing

$$\text{Salt Passage \%} = (1 - \text{Salt Rejection\%})$$

Concentration Factor :

- The concentration factor is related to the RO system recovery and is an important equation for RO system design.

- The more water you recover as permeate (the higher the % recovery), the more concentrated salts and contaminants you collect in the concentrate stream.

- This can lead to higher potential for scaling on the surface of the RO membrane when the concentration factor is too high for the system design and feed water composition.

Concentration Factor = (1 / (1-Recovery %)

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Flux :

It's the rate of permeate transferred per unit membranes area (gfd) or (L/m2.h)

$$\text{Flux (Gfd)} = \frac{\text{permeate flow (gpd)}}{\text{total no of membranes} \times \text{membrane surface area}}$$

Flux value is Known depending on the source of feed water and type of used membranes for example for DOW filmtec mem. LE---440i

Feed Water Source	Gfd
Sewage Effluent	5---10
Sea Water	8---12
Brackish Surface Water	10---14
Brackish Well Water	14---18
RO Permeate Water	20---30

Source Water Temperature

Minimum Monthly Average Temperature, °C	Flux Correction, %
5	55
10	30
15	15
20	0
25	−10

TABLE 12.3 Temperature Correction Factor

- Saline water viscosity increases with a decrease in temperature. Viscosity affects a membrane's ability to produce filtered water, as more pressure is required to overcome the resistance associated with flow across the membrane surface area when operating at a constant flux .
- Typically, average design membrane flux is established for the average annual temperature, flow, and turbidity and adjusted down for the minimum monthly average temperature using the correction factor.

Pretreatment

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- The purpose of the first step **source water pretreatment** is to remove the suspended solids and prevent some of the naturally occurring soluble solids from turning into solid form and precipitating on the RO membranes during the salt separation process.

RO system

- The second step the RO system **separates the dissolved solids from the pretreated source water**, thereby producing fresh low-salinity water suitable for human consumption, agricultural uses, and for industrial and other applications.
- The key components of the RO separation system include filter effluent transfer pumps , high-pressure pumps, reverse osmosis trains, energy recovery equipment, and the membrane cleaning system.

post-treatment

- The third step of the desalination plant treatment process is referred to as post-treatment once the desalination process is complete, the freshwater produced by the RO system is further **treated for corrosion and health protection and disinfected prior to distribution for final use.**

Diagram of a conventional pretreatment process

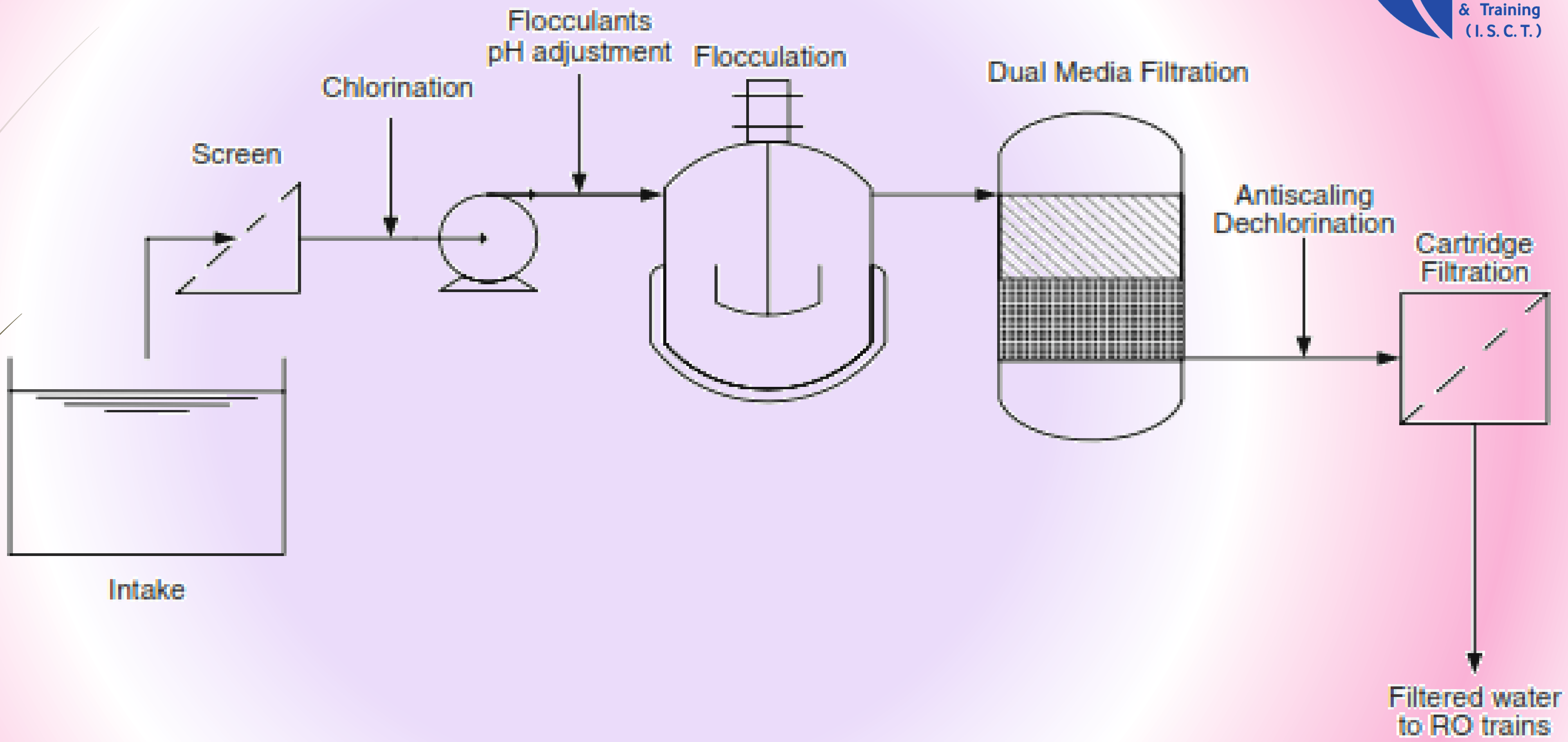

Fig. 3.13 Typical process diagram of a conventional pretreatment process

Disadvantages of conventional pretreatment

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- fluctuations of feed water quality
- difficulties in supplying a constant SDI < 3.0
- difficulties in removing particles smaller than 10–15 μm
- large space occupation due to slow filtration velocities

Screens

- Screens are used to protect water pumps from clogging and to remove coarse floating solids from feed water.

- The screens can be located onshore, or at the end of a channel that extends out beyond the surf zone, or at the end of a pipe that extends out into the sea, terminating in a vertical "velocity cap"

Chlorination

- **Chlorination is a basic disinfection method aimed at destroying or inactivating pathogenic microorganisms including bacteria, amoebic cysts, algae, spores and viruses.**

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

- Or

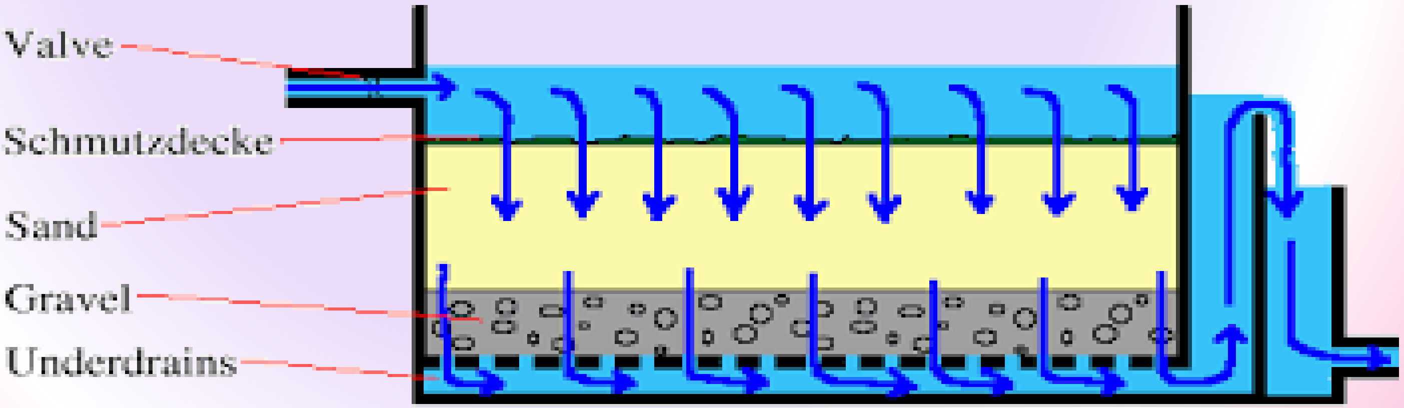
$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Coagulation and Flocculation

- Coagulation is applied to remove the fine suspended solids that fail to settle during the sedimentation process, as well as soluble organic and toxic substances, and trace metals (size range of 1 nm to 1.0 μm)

Slow Sand Filtration

- Slow sand filtration includes biological activity in addition to physical and chemical mechanisms to remove impurities from water.
- It can be successfully applied if the water turbidity is less than 50 NTU.
- Basic operation involves passing water through a bed of fine sand at a low velocity, which causes the retention of suspended matter in the upper 0.5–2 cm of the filter bed.



Dual Media Filtration

- Dual Media Filters (DMFs) remove remaining suspended solids and lower the turbidity of the RO feed water to about 0.4 NTU with an SDI of 2.5 or less.

- The DMF consists of coarse anthracite coal over a bed of fine sand .

- A process called backwashing is used to break up surface scum and dirt in the filter medium. Gravity flow is more economical than pressure flow as a means of cleaning filters for large storage tanks.

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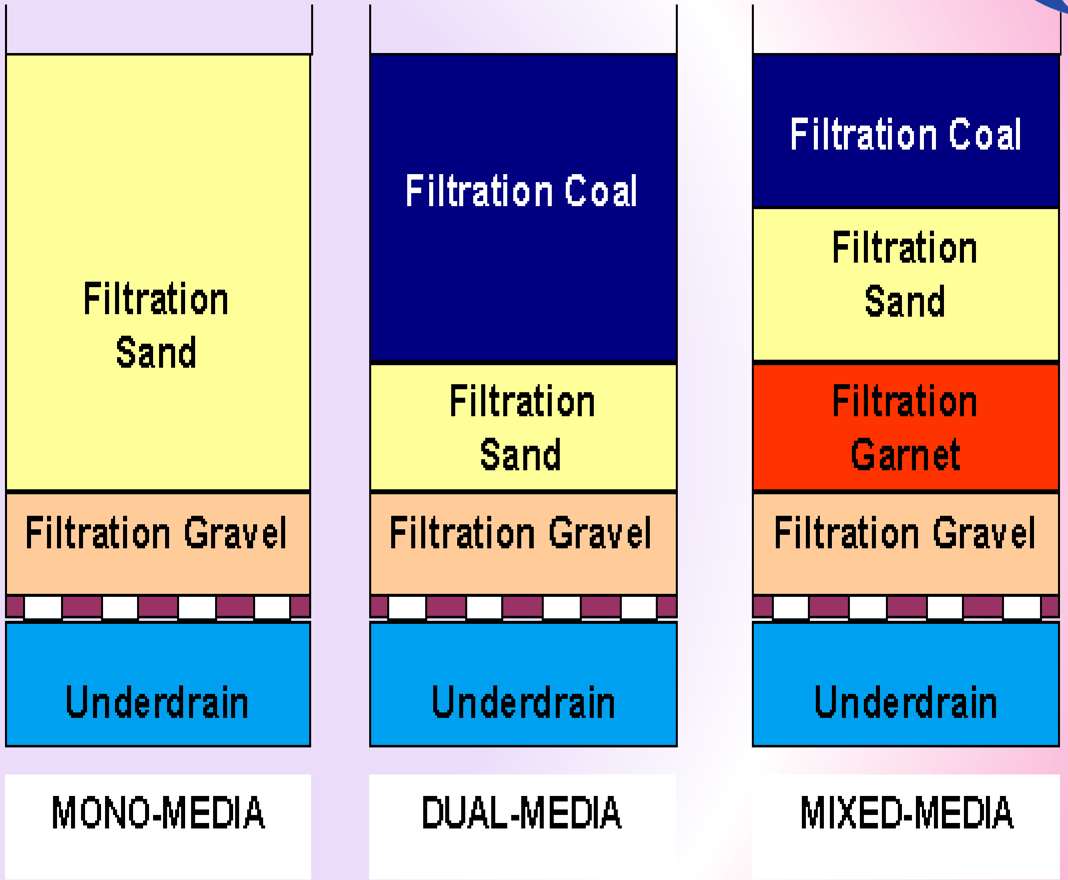

pH Adjustment

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- Before entering the cartridge filters and the subsequent RO stages, the pH value has to be adjusted to around 7.5 thus preventing calcium carbonate caking of the filters.

Anti-scaling Agents

- The addition of anti-scaling agents is advisable for seawater RO systems that work with recoveries greater than 35% .
- anti-scalant such as polyphosphates and polyacrylates widely used.

Dechlorination

- Dechlorination has to be performed prior to the RO stage in order to avoid oxidation damage by residual chlorine in the feed water.
- Commonly, **sodium metabisulphite** is used for dechlorination due its high cost effectiveness.

$$Na_2S_2O_5 + H_2O \rightarrow 2NaHSO_3$$

The sodium bisulphite then reduces the hypochlorous acid:

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

In practice, 3.0 mg of sodium metabisulphite is typically used to remove 1.0 mg of free chlorine.

Cartridge Filters

- Cartridge filters are preferred systems for low water contamination.
- Usual pore size ranges from 5 to 10 µm.

MF/UF Pretreatment

- Microfiltration is a low energy-consuming technique extensively used to remove suspended solids and to lower COD/BOD and SDI to values below 5.

- the UF membrane separation method remains economically competitive compared to conventional pretreatments.

- Turbidity is also greatly decreased, and SDI is always below 2 .

Intake

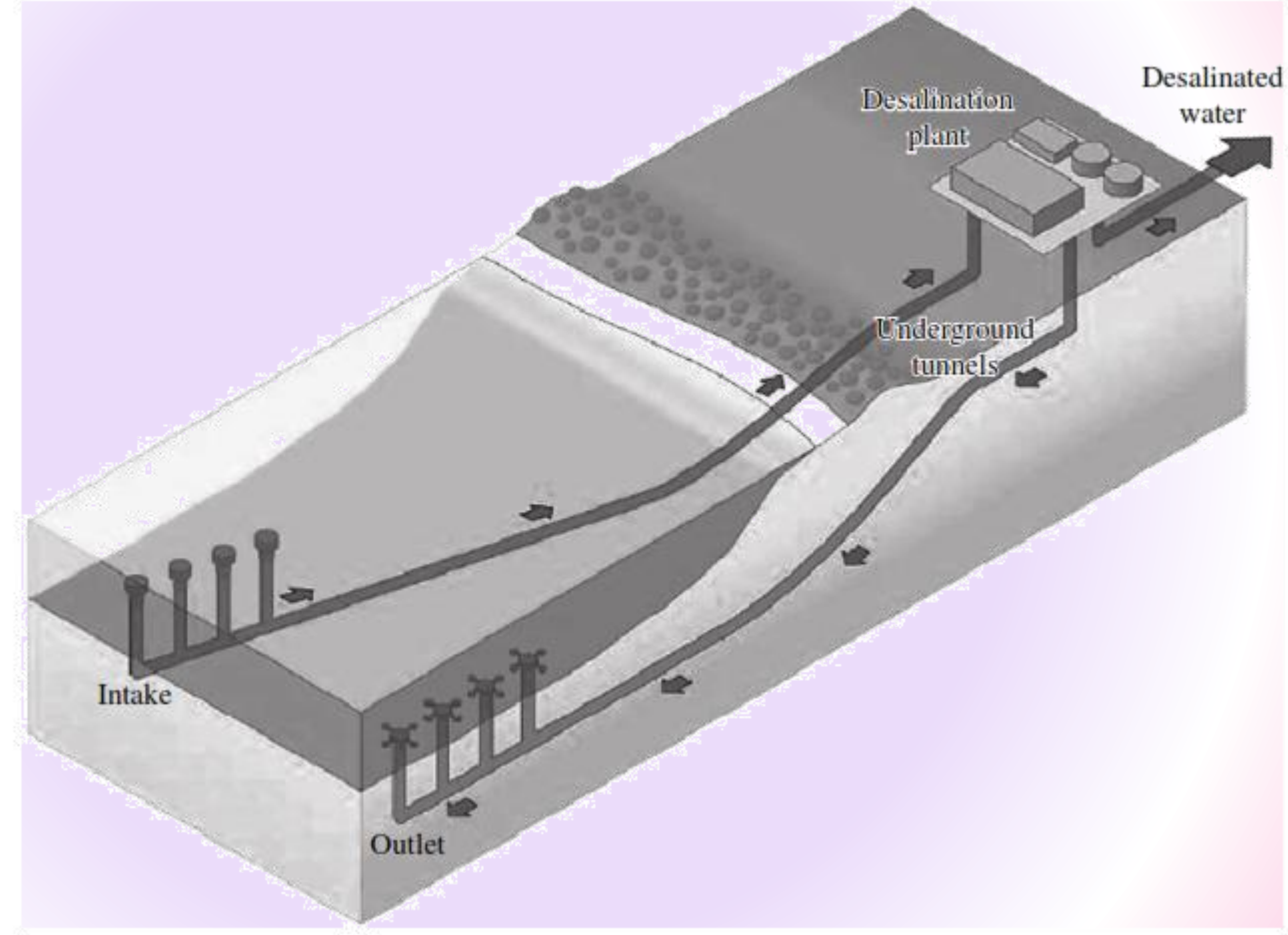

FIGURE 4.3 Desalination plant with offshore intake. (*Source: Sydney Water.*)

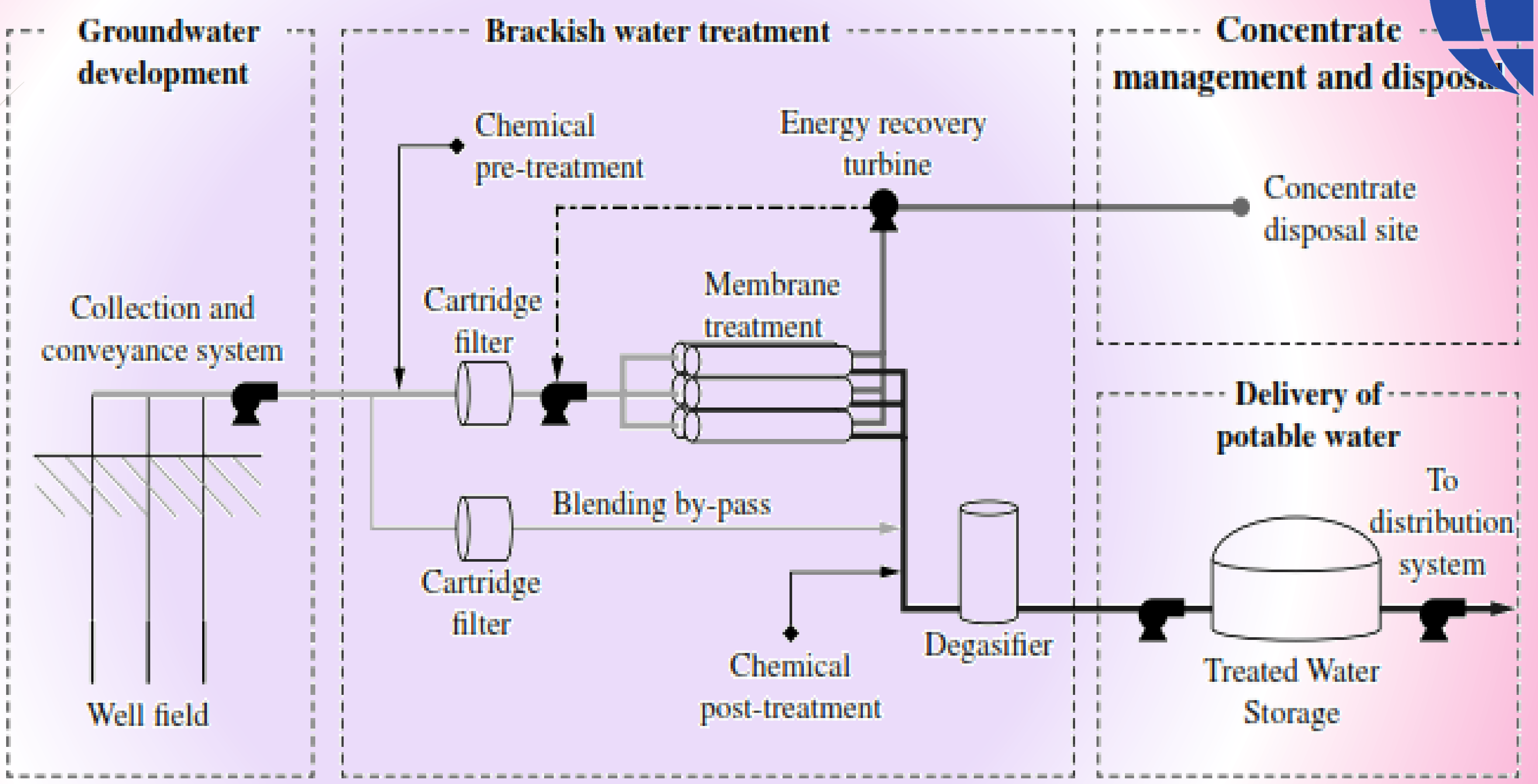

FIGURE 4.8 BWRO plant schematic. (*Source: NRS Consulting Engineers.*)

Energy use

Water Supply Alternative	Energy Use, kWh/m^3
Conventional treatment of surface water	0.2–0.4
Water reclamation	0.5–1.0
Indirect potable reuse	1.5–2.0
Brackish water desalination	0.3–2.6
Seawater Desalination	2.5–4.0

*$1\ kWh/m^3 = 3.785\ kWh$ per 1000 gal

Table 4.3 Energy Use of Various Water Supply Alternatives*

Chemicals Commonly Used in Desalination Plants

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Chemical	Dosage, mg/L	Point of Application and Purpose
Ferric chloride or ferric sulfate	0.5–30	• Upstream of pretreatment systems for enhanced removal of solids and silt
Sulfuric acid	30–100	• At intake forebay for control of shellfish growth control in open intakes • Upstream of pretreatment systems for enhanced removal of solids and silt • Upstream of RO system for scale inhibition • Into permeate for reduction of pH and enhanced dissolution of calcite in post-treatment contactors • Into permeate for adjustment of the final product water's pH
Polymer (flocculant)	0–2	• Upstream of pretreatment systems for enhanced removal of solids and silt
Sodium hypochlorite	0–15	• At intake forebay (for open intakes) or well heads (for well intakes) and in intake pump station wet well for control of biogrowth • Upstream of secondary pretreatment for control of biofouling
Sodium bisulfite	0–50	• Upstream of RO system for removal of oxidant residual
Antiscalant	0.5–2	• Downstream of the point of addition of sodium bisulfite and upstream of the RO system for inhibition of scaling
Sodium hydroxide	10–40	• Into feed water of first or second RO passes for enhanced removal of boron • Into finished water for adjustment of pH
Lime	50–100	• Into RO permeate for addition of hardness and alkalinity
Carbon dioxide	30–80	• Into RO permeate for addition of alkalinity and enhanced dissolution of lime and calcite

Table 4.5 Chemicals Commonly Used in Desalination Plants

Relationship between plant size and cost of water production

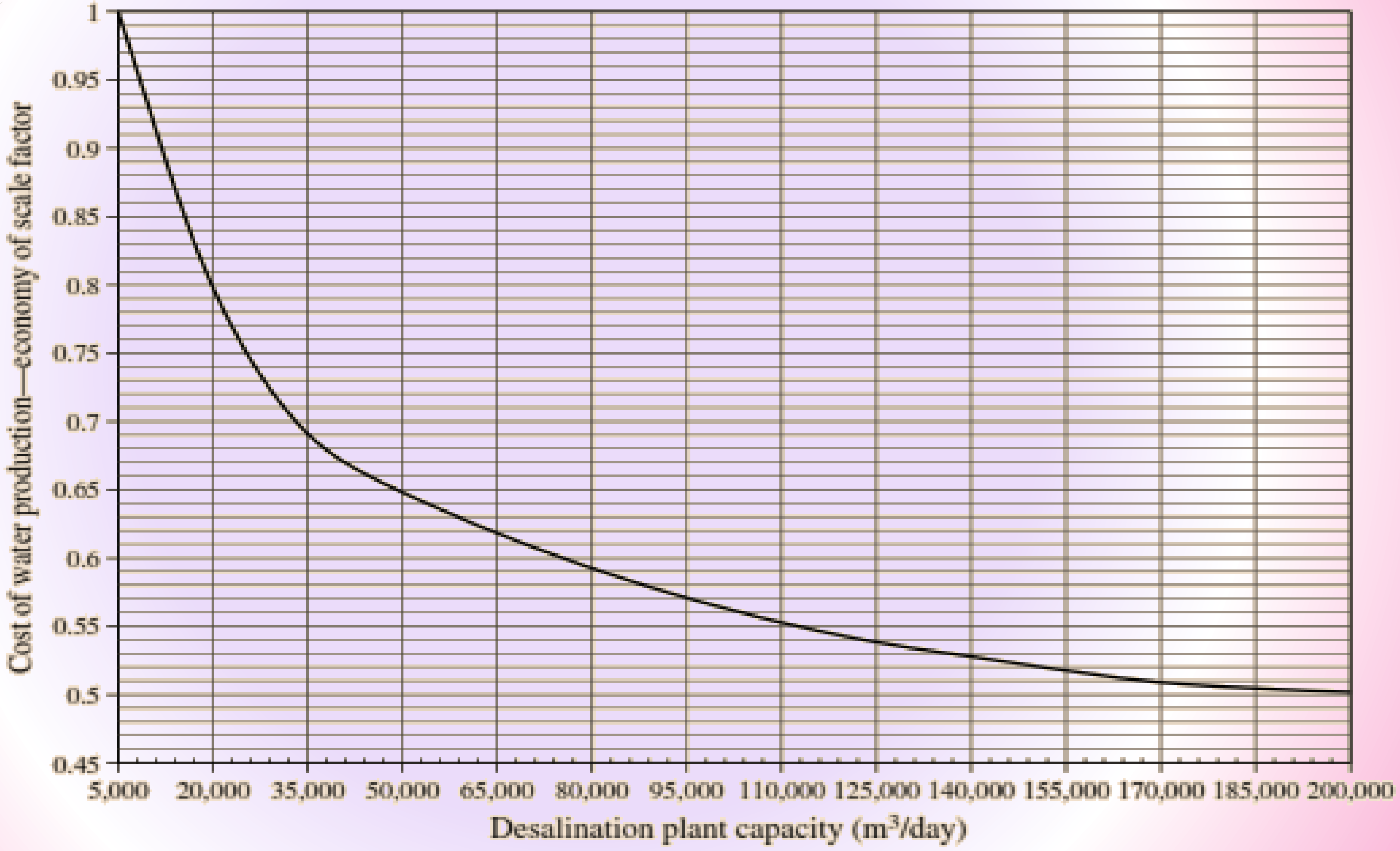

Figure 4.12 Relationship between plant size and cost of water production.

Target Minimum Pretreated Water Qualit

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Parameter	Concentration/Level
Turbidity (daily average/maximum), NTU	< 0.1/0.5
Silt density index	< 3 (at least 95 % of the time) < 5 (at all times)
Total organic carbon, mg/L	< 1
pH (minimum/maximum)	4.0/9.0
Oxidation-reduction potential, mV	< 200
Chlorine residual, mg/L	≤ 0.02
Total hydrocarbons, mg/L	≤ 0.04

TABLE 11.1 Target Minimum Pretreated Water Quality

Filter Media Backwash

- Granular media filters are typically backwashed using filtered source water or concentrate from the RO membrane system.
- The backwash frequency of filter cells is usually once every 24 to 48 h.
- The **uniformity coefficient** is an important parameter because it indicates how similar the media particles are in size. In general, for media of the same size, a higher uniformity coefficient allows for an increased filter cycle length.

uniformity coefficient

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Medium	Typical Effective Grain Size, mm	Specific Density, tons/m^3 (lb/ft^3)	Uniformity Coefficient
Pumice	0.8–2.0	1.2 (75)	1.3–1.8
Anthracite	0.8–2.0	1.4–1.7 (87–104)	1.3–1.8
Silica sand	0.4–0.8	2.60–2.65 (162–165)	1.2–1.6
Garnet	0.2–0.6	3.5–4.3 (218–268)	1.5–1.8

TABLE 11.2 Typical Filter Media Characteristics

Direct flow-through desalination system

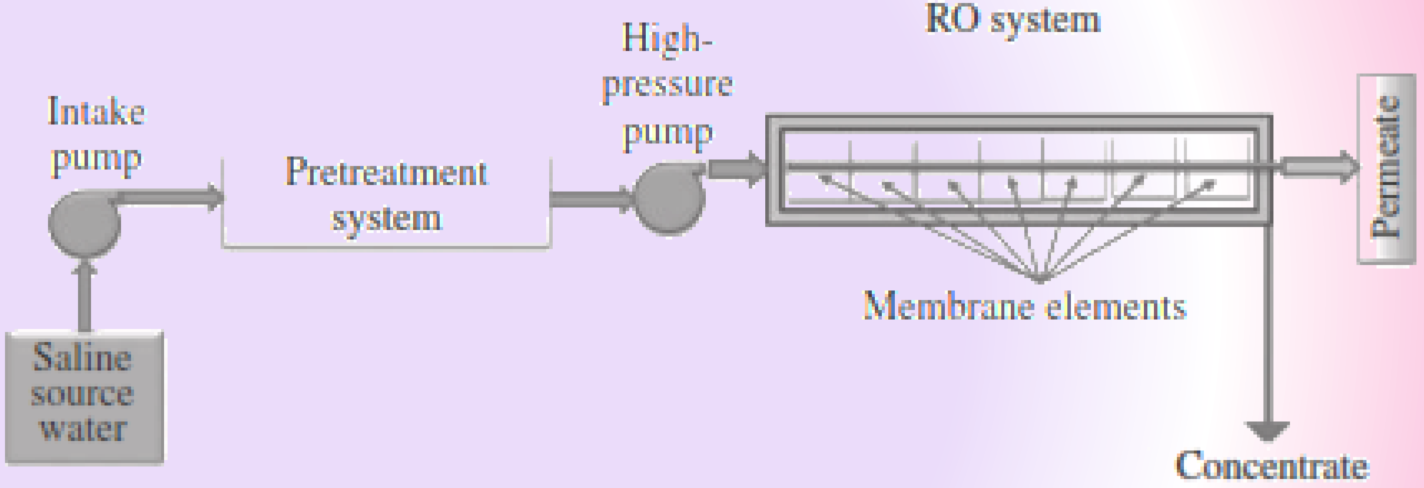

FIGURE 14.2 Direct flow-through desalination system.

passes and stages in a Reverse Osmosis (RO) system

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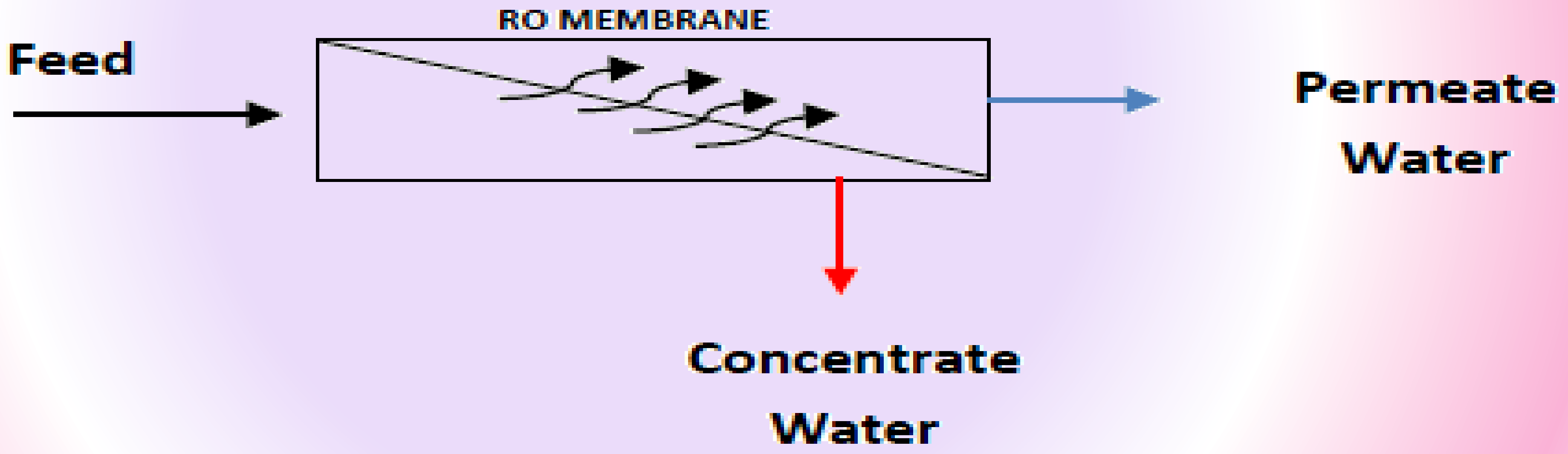
1 stage RO system

→ Feed Water
→ Permeate Water
→ Concentrate Water

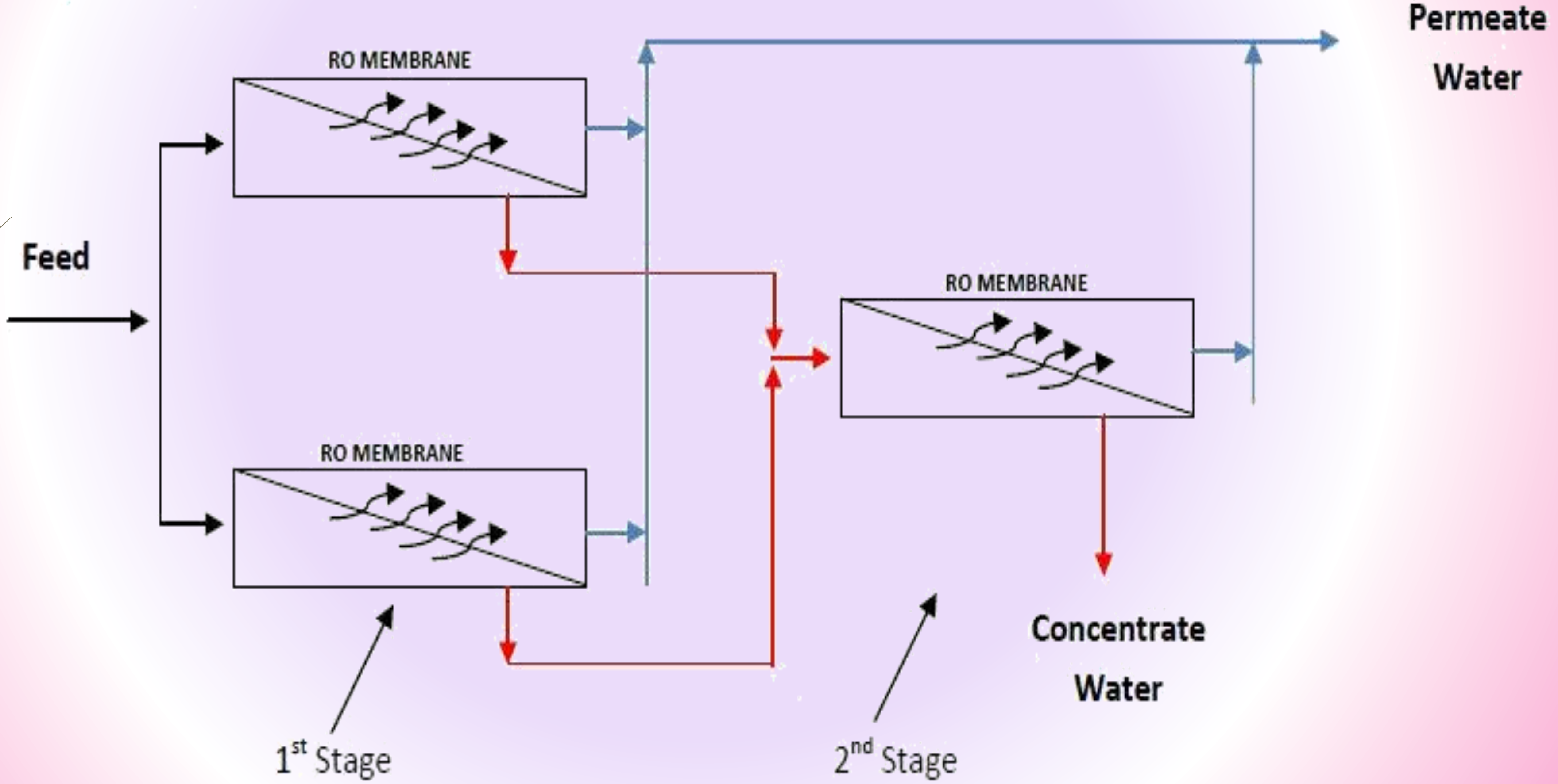


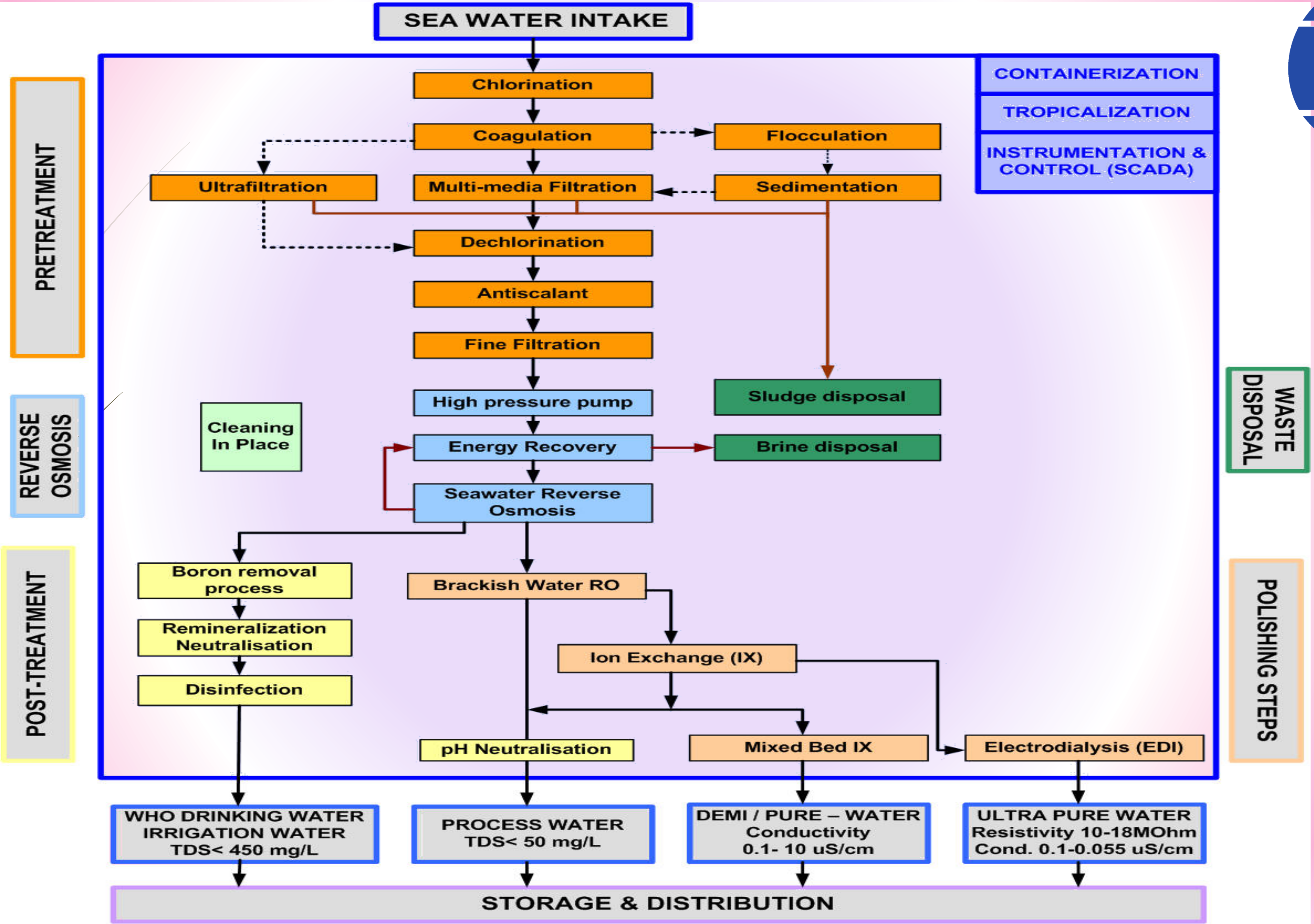
2 stage RO system

→ Feed Water

→ Permeate Water

→ Concentrate Water





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- ***Seawater Desalination , Conventional and Renewable Energy Processes. Andrea Cipollina , et.al.***

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Thank you