
بسم الله الرحمن الرحيم
وَجَعَلْنَا مِنَ الْمَاءِ
كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ
صدق الله العظيم
زتونة
ZTONA.COM

Discussions about WATER TREATMENT

PREPARED BY :
CHEM. MOHAMED SHAABAN

شكر وتقدير لمجموعة خبراء معالجة المياه

وأخص بالشكر كلاً من م/ محمد خليفة & م/ محمد محمود

م/ محمد خليفة

مؤسس المجموعة

1- What is the water composition ?

2 - What are the different types of water ?

3 - What are we mean by water treatment ?

4 -What are the technologies applied for water treatment?

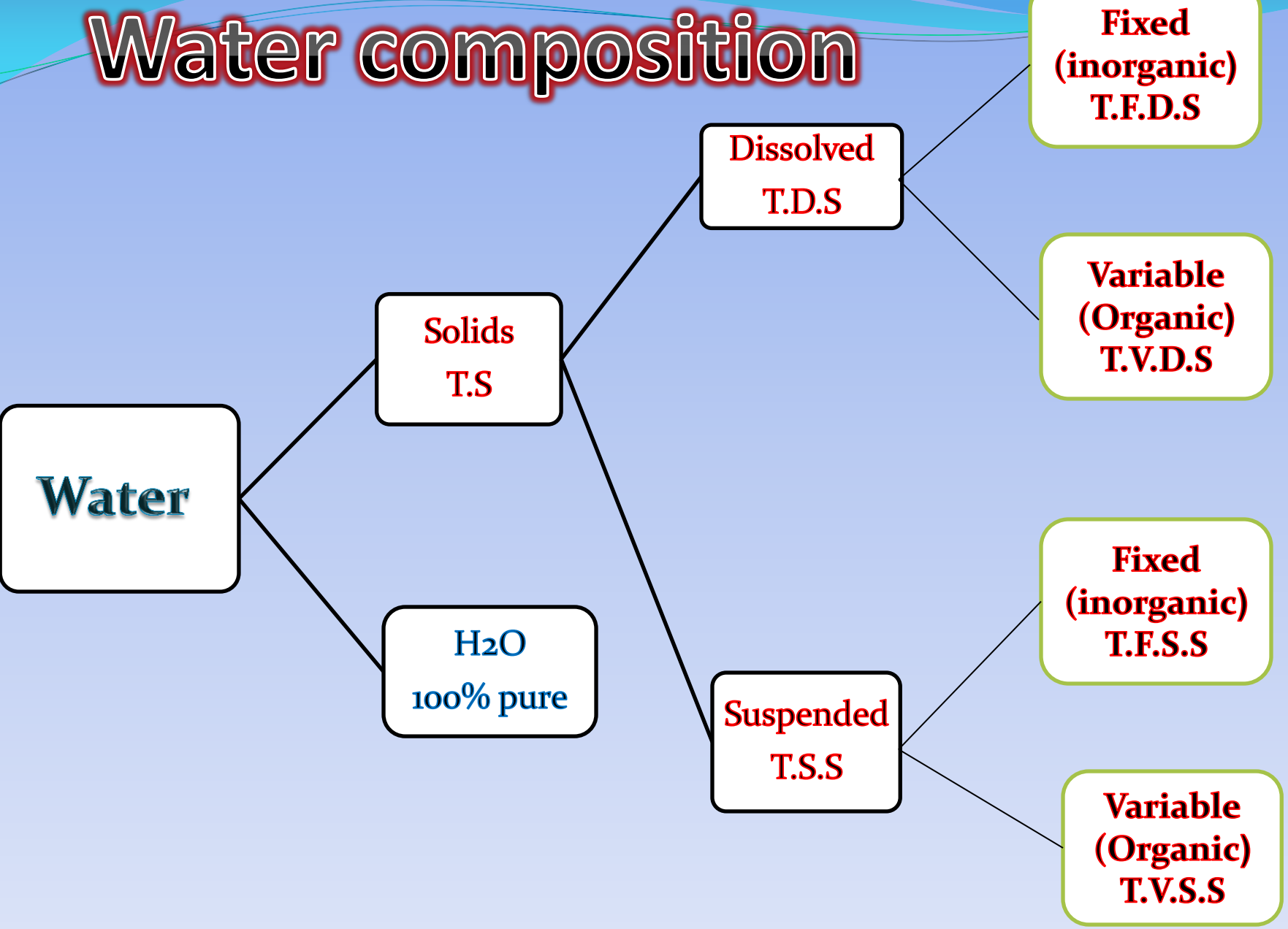
5 - Factors affecting choosing of suitable technique

6 - Desalination flow chart diagram as example

7 – R.O in Detail

8 - Design principles

Water composition



Water can classified According it's source and salinity to :

1- potable water (fresh water) [TDS < 500 ppm]

2- Brackish water (Ground water) [TDS = 500 – 30000 ppm]

3- Sea water (Brine water) [TDS >30000 ppm]

Water salinity based on dissolved salts			
Fresh water	Brackish water	Saline water	Brine
< 0.05%	0.05–3%	3–5%	> 5%

potable water (fresh water)

-Fresh water can be defined as water contain less than 500 ppm of total dissolved salts (TDS).

-Fresh water may come from rains , rivers , lakes and some ground water.

-Fresh water represent Only 2.5–2.75% of world water, including 1.75–2% frozen in glaciers , ice and snow, 0.7–0.8% as fresh groundwater and soil moisture, and less than **0.01% of it as surface water in lakes** , swamps and rivers.

Contaminant	Acceptable limit ranges
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Disinfectants and disinfectant by-products

Group	Substance	Formula	Health based guideline by the WHO
Disinfectants	Chloramines	$NH_nCl^{(3-n)}$, where n = 0, 1 or 2	3 mg/l
	Chlorine	Cl_2	5 mg/l
	Chlorine dioxide	ClO_2	No guideline
	Iodine	I_2	No guideline

Element/ substance	Symbol/ formula	Normally found in fresh water/surface water/ground water	Health based guideline by the WHO
Aluminum	Al		0,2 mg/l
Ammonia	NH_4	< 0,2 mg/l (up to 0,3 mg/l in anaerobic waters)	No guideline
Antimony	Sb	< 4 µg/l	0.005 mg/l
Arsenic	As		0,01 mg/l
Asbestos			No guideline
Barium	Ba		0,3 mg/l
Brillium	Be	< 1 µg/l	No guideline
Boron	B	< 1 mg/l	0,3 mg/l
Cadmium	Cd	< 1 µg/l	0,003 mg/l
Chlorides	Cl		250 mg/l
Chromium	Cr^{+3}, Cr^{+6}	< 2 µg/l	0,05 mg/l
Colour			Not mentioned
Copper	Cu		2 mg/l
Cyanide	CN^-		0,07 mg/l
Dissolved Oxygen	O_2		No guideline

Fluorides	F	< 1,5 mg/l (up to 10)	1,5 mg/l
Hardness	mg/l $CaCO_3$		No guideline
Hydrogen sulfide	H_2S		No guideline
Iron	Fe	0,5 - 50 mg/l	No guideline
Lead	Pb		0,01 mg/l
Manganese	Mn		0,5 mg/l
Mercury	Hg	< 0,5 µg/l	0,001 mg/l
Molybdenum	Mb	< 0,01 mg/l	0,07 mg/l
Nickel	Ni	< 0,02 mg/l	0,02 mg/l
Nitrates & Nitrites	NO_3, NO_2		50 mg/l total nitrogen
Turbidity			Not mentioned
pH			No guideline
Selenium	Se	< < 0,01 mg/l	0,01 mg/l
Silver	Ag	5 – 50 µg/l	No guideline
Sodium	Na	< 20 mg/l	200 mg/l
Sulfate	SO_4		500 mg/l
Inorganic Tin	Sn		No guideline
TDS			No guideline
Uranium	U		1,4 mg/l
Zinc	Zn		3 mg/l

Brackish water (Ground water)

- Brackish water is that has more salinity than fresh water, but not as much as seawater.

-Chemically , brackish water contains between 0.5 and 30 grams of TDS per liter more often expressed as 0.5 to 30 parts per thousand (or %)

- As the total dissolved solids range increase also some quality items affected such total suspended solids which increase the water turbidity and on the other hand due to it is rich by minerals it is good medium of bacterial growth which the total microbial count will increase.

Sea water (Brine water)

Seawater or salt water is water from sea or oceans. On average, seawater in the world's oceans has a salinity of about 3.5% (35 g/L)

Water treatment

treatment of water it means doing some process to make it safe and acceptable for human use.

Other Meaning :

Process for enhancing the quality of water so that it meets the water quality criteria for its fitness for the intended use, and that can be achieved by several technologies.

Technologies applied for water treatment

Treatment can classified to two main classes:

- **Physical treatment.**
  - Sedimentation by HRT (Hydraulic Retention time)
  - Filtration (Sand , GAC , PAC , Membrane filtration)
  - EDI
  - Distillation
- **Chemical treatment.**
  - Flocculation.
  - Sedimentation using chemicals (Coagulation)
  - Oxidation.
  - Disinfection.
  - Ion Exchange.
  - pH adjustment.

- **Factors affecting choosing of suitable technique :**

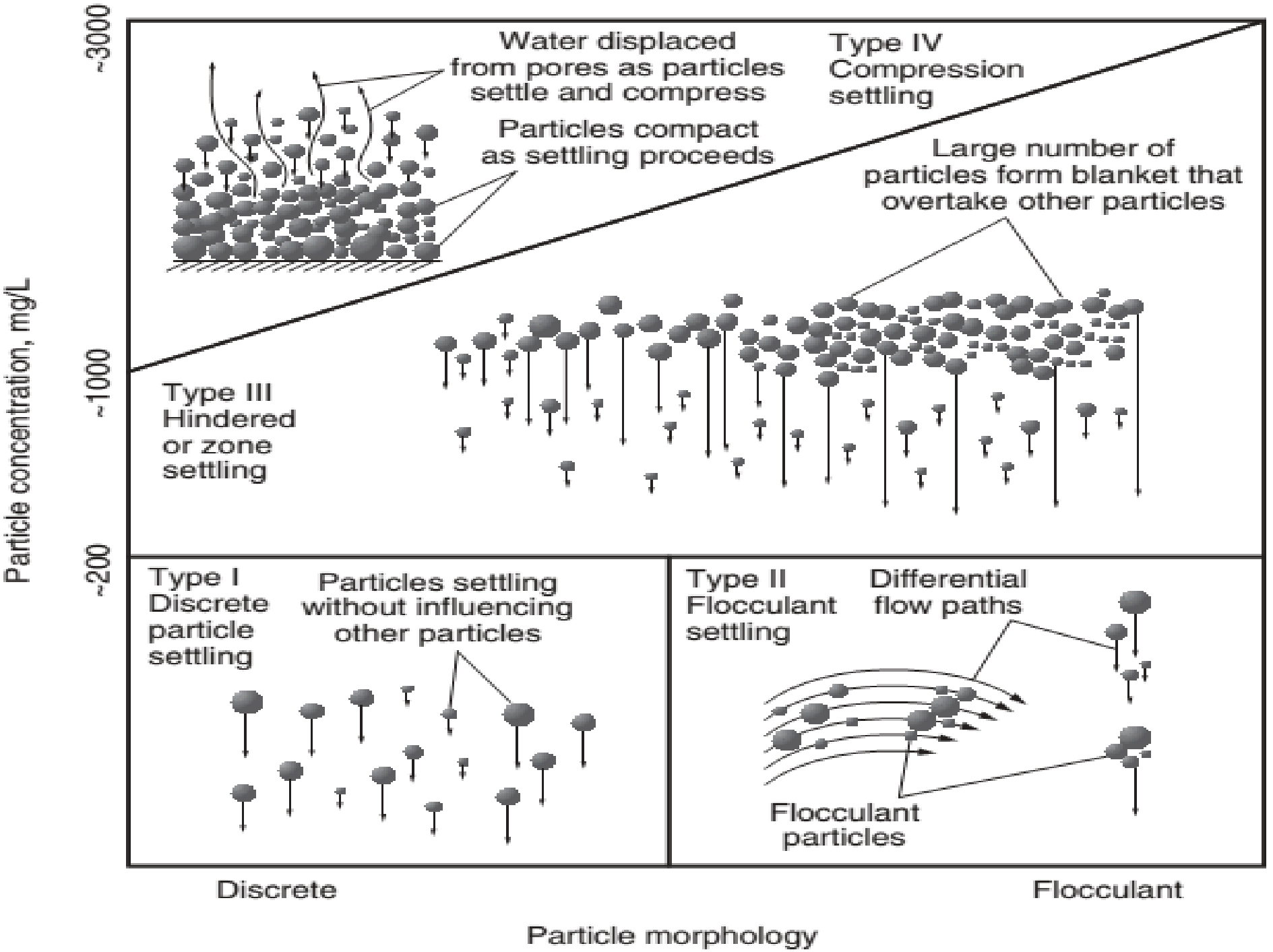
- 1 – Feed water salinity
  2 – Required quality of produced water
- 3 – Required pretreatment
- 4 – Need to specific treatment such removal of specific contaminant or microorganisms
- 5 – Energy and cchemical availability
- 6 – cost

PHYSICAL TREATMENT

Sedimentation by HRT (Gravity Separation)

Gravity separation of suspended material from water is the oldest and most widely used process in water treatment. Gravity separation historically has meant sedimentation, where water is introduced into a large quiescent basin for a long enough period of time so that the majority of the particles in the water settle to the bottom of the basin. Most raw surface waters will contain mineral particles and organic particles. Mineral particles usually have densities ranging from 2000 to 3000 kg/m3 and will settle out readily by gravity, whereas organic particles with densities of 1010 to 1100 kg/m3 may require a long time to settle by gravity

More recently, air bubbles have been used to float particles to the water surface for removal. Adding air bubbles to the water is known as dissolved air flotation (DAF)


~3000
~1000
~200
Particle concentration, mg/L
Water displaced from pores as particles settle and compress
Particles compact as settling proceeds
Type IV Compression settling
Large number of particles form blanket that overtake other particles
Type III Hindered or zone settling
Type I Discrete particle settling
Particles settling without influencing other particles
Type II Flocculant settling
Differential flow paths
Flocculant particles
Discrete
Flocculant
Particle morphology

Filtration

Filtration can be defined as any process for the removal of solids (suspended or dissolved) particles from water.

1- Granular filtration : (Sand filter)

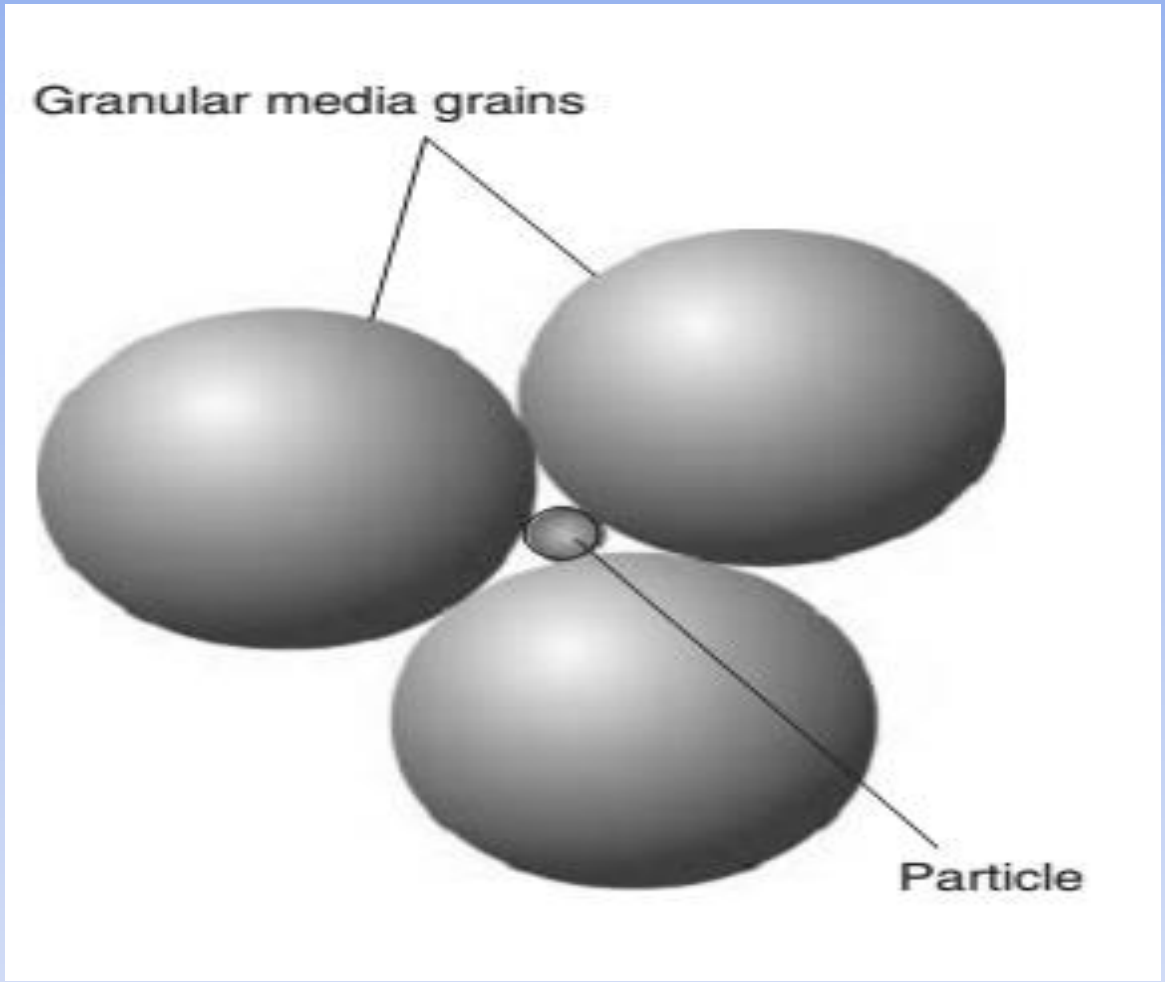
Filtration done by passage of the suspension through a porous medium. In granular filtration, the porous medium is a bed of granular material such as sand , there are two types of sad filtration:

- **Slow filtration :**

process during which water passes slowly down through a bed of sand. Filtration occurs primarily by straining at the surface of the Schmutzdecke located at the top of the bed.

- **rapid filtration (include depth filtration)**

process engineered to achieve filtration rates about 100 times greater than slow sand filtration. Key requirements include coagulation pretreatment, granular media sieved for greater uniformity, and backwashing to remove accumulated particles.


Granular media grains
Particle

Adsorption

GAC & PAC

The primary adsorbent materials used in the adsorption process for drinking water treatment are powdered activated carbon (PAC) and granular activated carbon (GAC).

Adsorption is a mass transfer operation in which substances present in a liquid phase are adsorbed or accumulated on a solid phase and thus removed from the liquid. Adsorption processes are used in drinking water treatment for the removal of taste- and odor-causing compounds, synthetic organic chemicals (SOCs), color-forming organics, and disinfection by-product (DBP) precursors. Inorganic constituents, including some that represent a health hazard, such as perchlorate, arsenic, and some heavy metals, are also removed by adsorption. Reactions with granular activated carbon (GAC), a common adsorbent, can also be used to dechlorinate drinking water

Comparison of adsorption mechanisms between physical adsorption and chemisorption

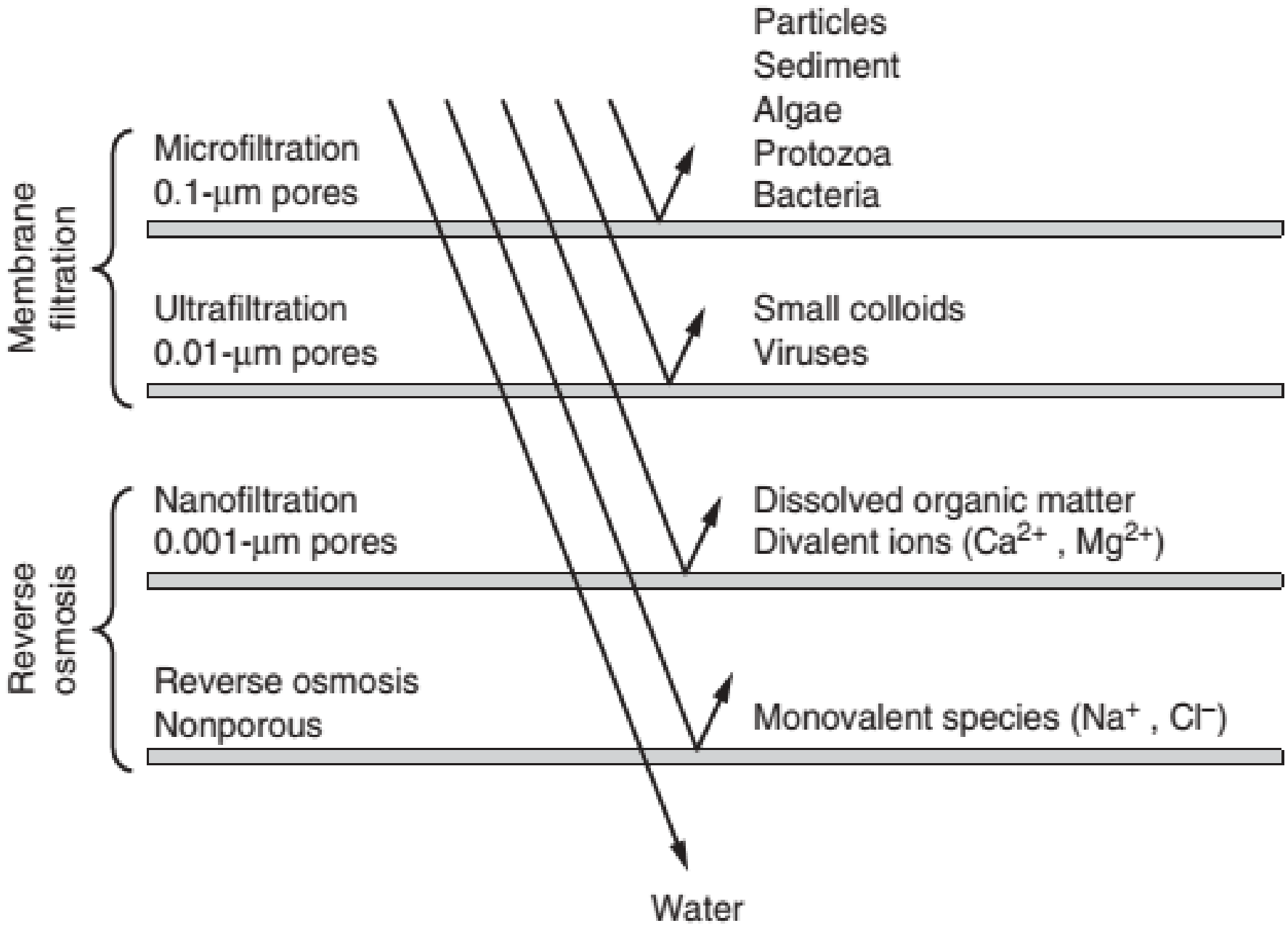
Parameter	Physical Adsorption	Chemisorption
Use for water treatment	Most common type of adsorption mechanism	Rare in water treatment
Process speed	Limited by mass transfer	Variable
Type of bonding	Nonspecific binding mechanisms such as van der Waals forces, vapor condensation	Specific exchange of electrons, chemical bond at surface
Type of reaction	Reversible, exothermic	Typically nonreversible, exothermic
Heat of adsorption	4–40 kJ/mol	>200 kJ/mol

Membrane filtration

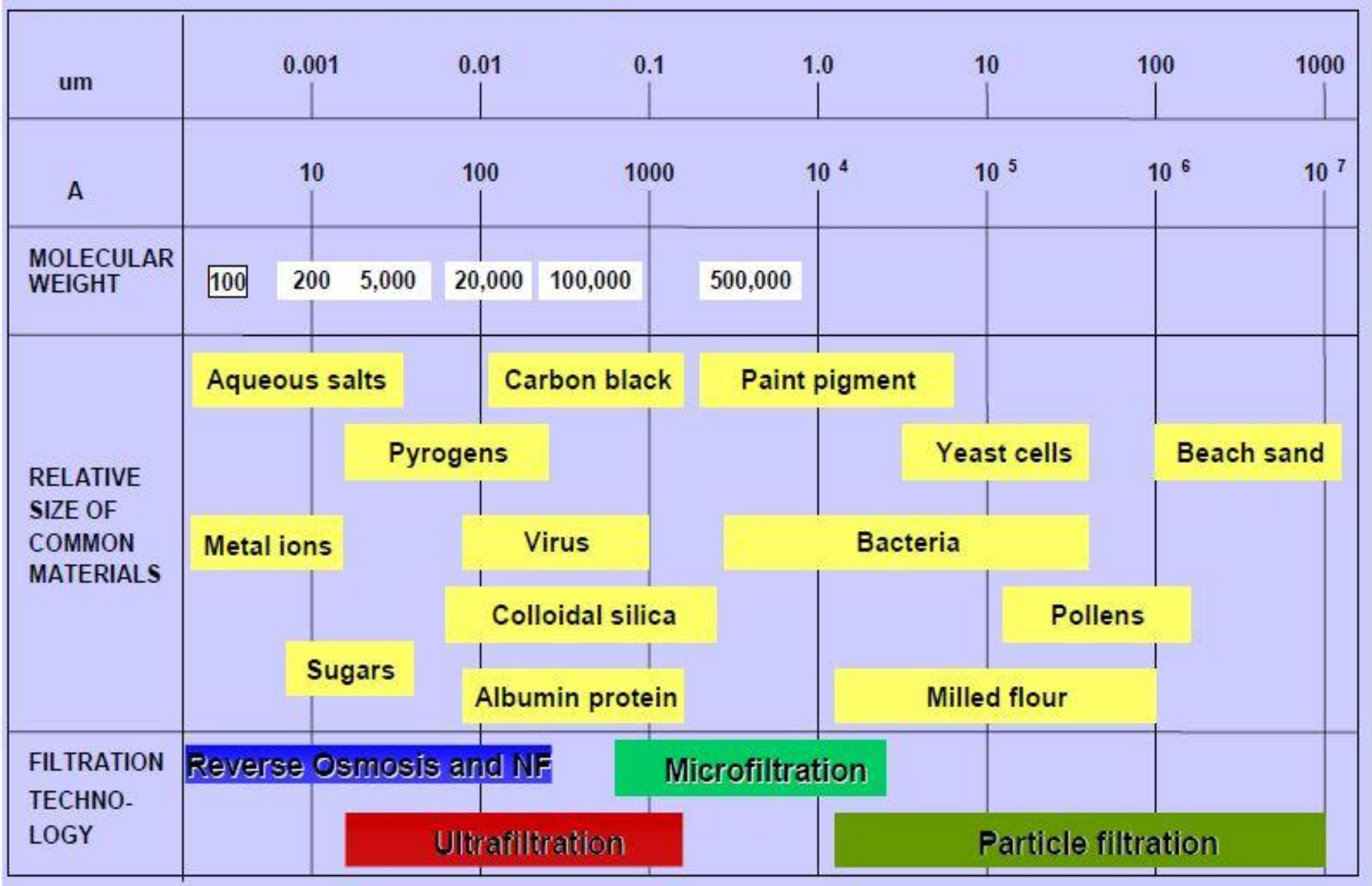
Four types of pressure-driven membranes are currently used in municipal water treatment:

- **microfiltration (MF) membranes,**
- **Ultra filtration (UF) membranes,**
- **Nanofiltration (NF) membranes,**
- **reverse osmosis (RO) membranes.**

the membranes are exactly identified by the types of materials rejected, operating pressures, and nominal pore dimensions


Membrane filtration
Reverse osmosis
Microfiltration
0.1-μm pores
Ultrafiltration
0.01-μm pores
Nanofiltration
0.001-μm pores
Reverse osmosis
Nonporous
Particles
Sediment
Algae
Protozoa
Bacteria
Small colloids
Viruses
Dissolved organic matter
Divalent ions (Ca^{2+} , Mg^{2+})
Monovalent species (Na^{+} , Cl^{-})
Water

THE FILTRATION SPECTRUM



Comparison between membrane filtration and reverse osmosis

Process Characteristic	Membrane Filtration	Reverse Osmosis
Objectives	Particle removal, microorganism removal	Seawater desalination, brackish water desalination, softening, NOM removal for DBP control, specific contaminant removal
Target contaminants	Particles	Dissolved solutes
Membranes types	Microfiltration, ultrafiltration	Nanofiltration, reverse osmosis
Typical source water	Fresh surface water (TDS < 1000 mg/L)	Ocean or seawater, brackish groundwater (TDS = 1000–20,000 mg/L), colored groundwater (TOC > 10 mg/L)
Membrane structure	Homogeneous or asymmetric	Asymmetric or thin-film composite
Most common membrane configuration	Hollow fiber	Spiral wound
Dominant exclusion mechanism	Straining	Differences in solubility or diffusivity
Removal efficiency of targeted impurities	Frequently 99.9999% or greater	Typically 50–99%, depending on objectives
Most common flow pattern	Dead end	Tangential
Operation includes backwash cycle	Yes	No
Influenced by osmotic pressure	No	Yes
Influenced by concentration polarization	No	Yes
Noteworthy regulatory issues	Challenge testing and integrity monitoring	Concentrate disposal
Typical transmembrane pressure	0.2–1 bar (3–15 psi)	5–85 bar (73–1200 psi)
Typical permeate flux	30–170 $L/m^2 \cdot h$ (18–100 $gal/ft^2 \cdot d$)	1–50 $L/m^2 \cdot h$ (0.6–30 $gal/ft^2 \cdot d$)
Typical recovery	>95%	50% (for seawater) to 90% (for colored groundwater)
Competing processes	Granular filtration	Carbon adsorption, ion exchange, precipitative softening, distillation

Electro-Deionization

(EDI – CDI)

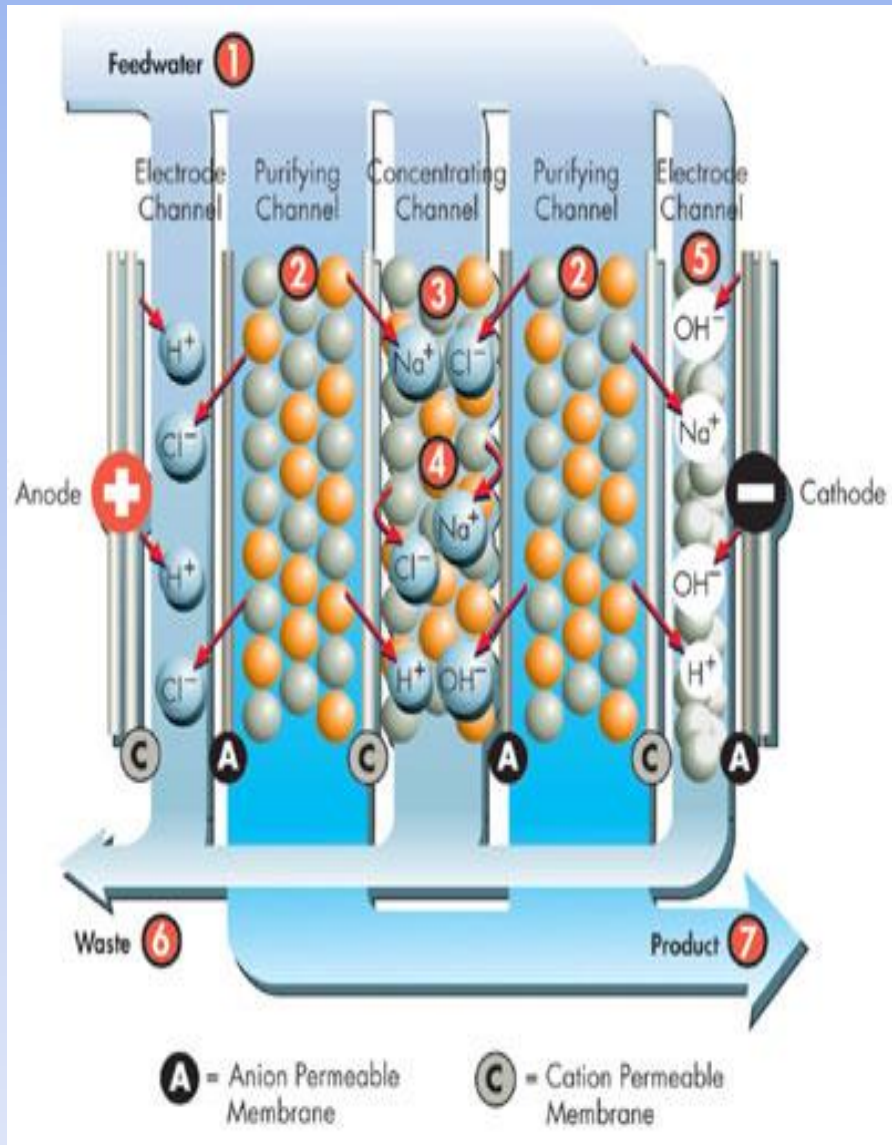
-Mainly it is physicochemical process which combines semi-permeable membrane separation technology and ion exchange media processes to provide high efficiency demineralization process .

- Electro –dialysis employ electrical current and specially prepared membranes which are semi-permeable to ions based on their charge.

- Through electro-dialysis an electrical potential transports and segregates charged aqueous species.

- The electrical current is used to continuously regenerate the resin eliminate the periodical need to regeneration and avoid chemical hazardous.


FEDI


Feedwater 1
Electrode Channel
Purifying Channel
Concentrating Channel
Purifying Channel
Electrode Channel
2
3
2
5
H+
Cl−
Na+
Cl−
OH−
Na+
Anode
4
Cathode
Na+
Cl−
H+
OH−
OH−
H+
Cl−
C
A
C
A
C
A
Waste 6
Product 7
A = Anion Permeable Membrane
C = Cation Permeable Membrane

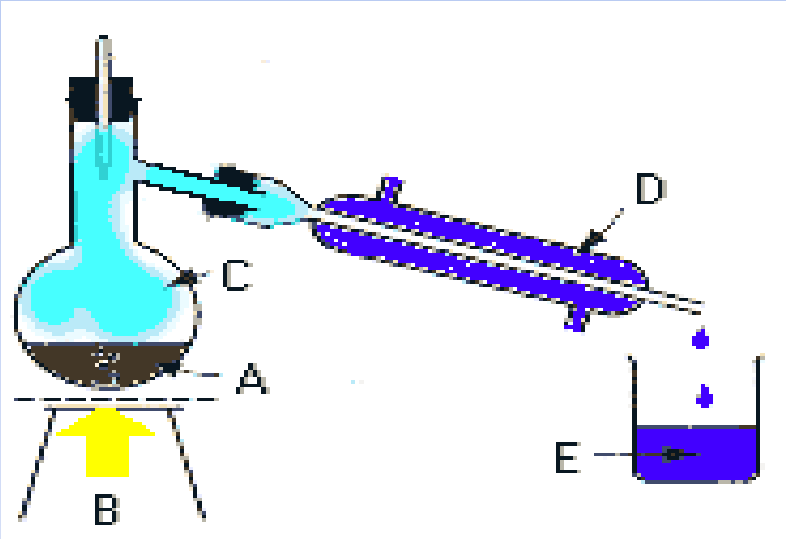
Distillation

Specific for WFI (Water For Injection) production

Different procedures are used for distillation , high quality WFI can be produced using all procedure presented here , the choice of procedure depends on the volume of WFI to be produced and the desired distillate temperature.

Distillation method :

- **simple distillation**
- **heat pump distillation**
- **Multi-stage distillation**



CHEMICAL TREATMENT

Sedimentation using chemicals

in a conventional treatment train, sedimentation follows coagulation and flocculation, which are used to destabilize particles and form large aggregates that will settle out of suspension in a reasonable time period.

Coagulation and Flocculation

Terminology for Coagulation and Flocculation

Term	Definition
Coagulation	Addition of a chemical to water with the objective of destabilizing particles so they aggregate or forming a precipitate that will sweep particles from solution or adsorb dissolved constituents.
Coagulant aid	Chemicals (typically synthentic polymers) added to water to enhance the coagulation process.
Counterions	Ions of opposite charge to the surface charge of particles.
Critical coagulation concentration (CCC)	Concentration of coagulant that reduces the electric double layer to the point where flocculation can occur.
Destabilization	Process of eliminating the surface charge on a particle so that flocculation can occur.
Electric double layer (EDL)	Electrostatic potential surrounding a charged particle in solution, consisting of a layer of counterions adsorbed directly to the surface and a diffuse layer of ions forming a cloud of charge around the particle.

Term	Definition
Enhanced coagulation	Coagulation process with the objective of removing natural organic matter, typically for minimizing the formation of disinfection by-products (see Sec 9-5).
Enmeshment or sweep floc	Entrapment or capture of particles by amorphous precipitates that form when a coagulant is added to water.
Flocculation	Aggregation of destabilized particles into larger masses that are easier to remove from water than the original particles.
Flocculant aid	Organic polymers used to enhance settleability and filterability of floc particles.
Inorganic metal coagulant	Metal salts such as aluminum sulfate and ferric chloride that will hydrolyze, forming mononuclear and polynuclear species of varying charge. When added in excess, metal coagulants form chemical precipitates.
Jar test	Procedure to study effect of coagulant addition to water; used to determine required doses and operating conditions for effective coagulation and flocculation.
Stable particle suspension	Suspension of particles that will stay in solution indefinitely; stable particles have a surface charge that causes them to repel each other and prevent aggregation into larger particles that would settle on their own.
Synthetic organic coagulant	High-molecular-weight (typically 10^4 to 10^7 g/mol) organic molecules that can carry positive (cationic), negative (anionic), or neutral (nonionic) charge.
Zeta potential	Measurement of the charge at the shear plane of particles, used as a relative measure of particle surface charge.

Importance of Coagulation and flocculation process

Due to presence of T.S.S which cause :

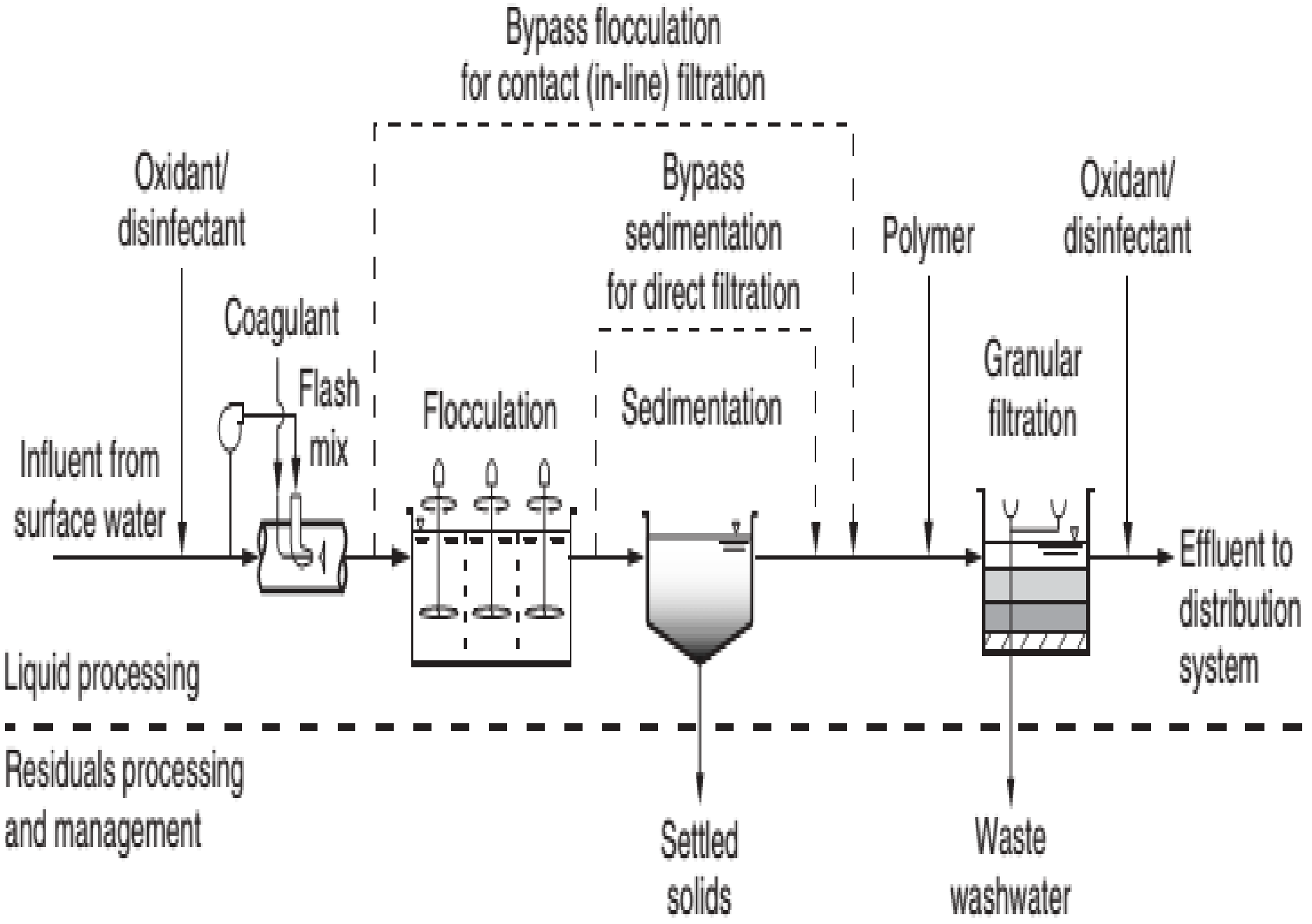
1- Reduce the clarity of water to unacceptable levels (i.e., cause turbidity) as well as impart color to water.

2- Be infectious agents (e.g., viruses, bacteria, and protozoa)

3- Have toxic compounds adsorbed to their external surfaces

4- many of the constituents that comprise dissolved NOM are precursors to the formation of disinfection by-products when chlorine is used for disinfection

So Coagulation & flocculation must applied to water have high suspended matter


Bypass flocculation
for contact (in-line) filtration
Oxidant/
disinfectant
Bypass
sedimentation
for direct filtration
Polymer
Oxidant/
disinfectant
Coagulant
Flash
mix
Flocculation
Sedimentation
Granular
filtration
Influent from
surface water
Effluent to
distribution
system
Liquid processing
Residuals processing
and management
Settled
solids
Waste
washwater

ELECTRICAL DOUBLE LAYER

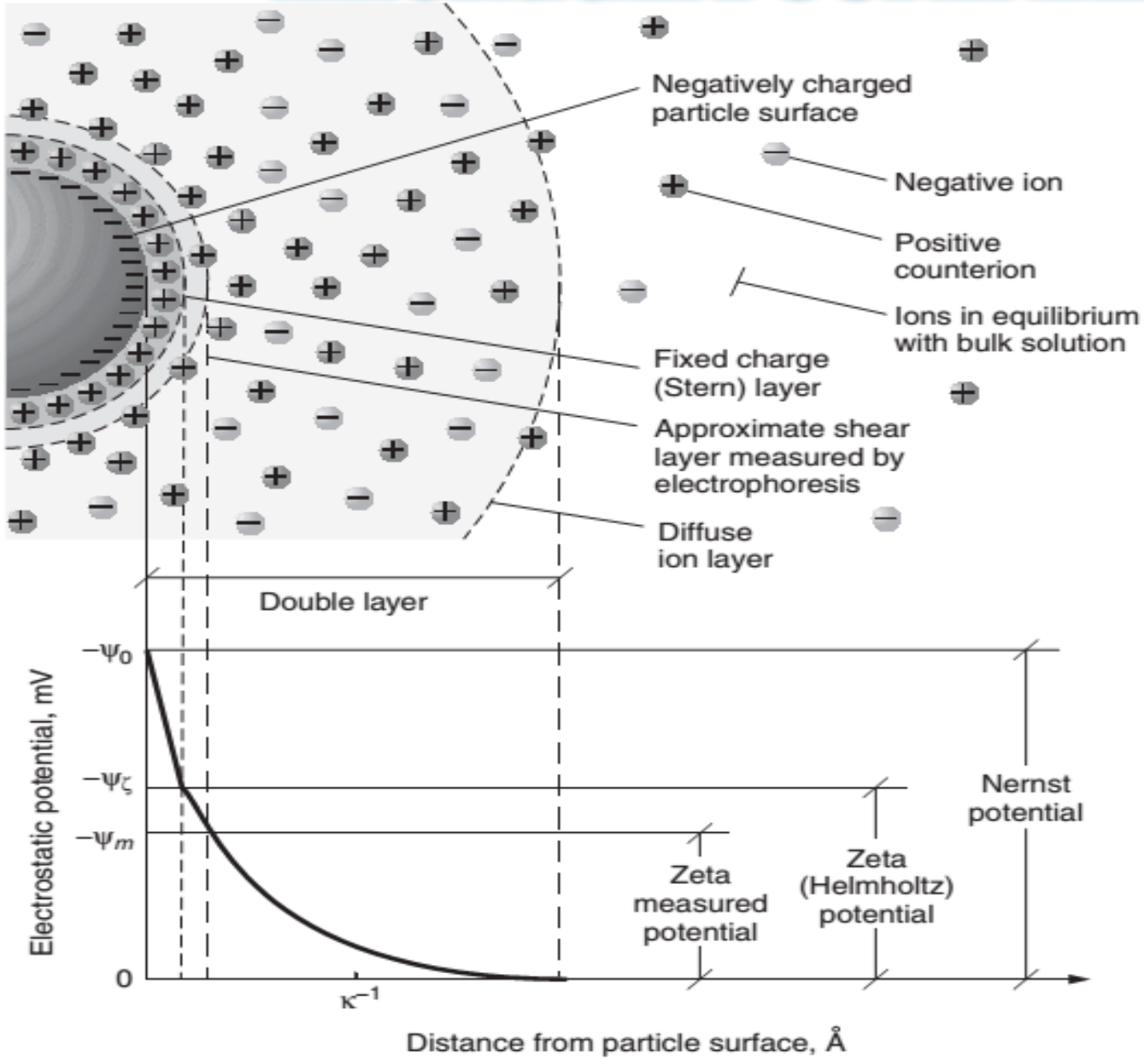
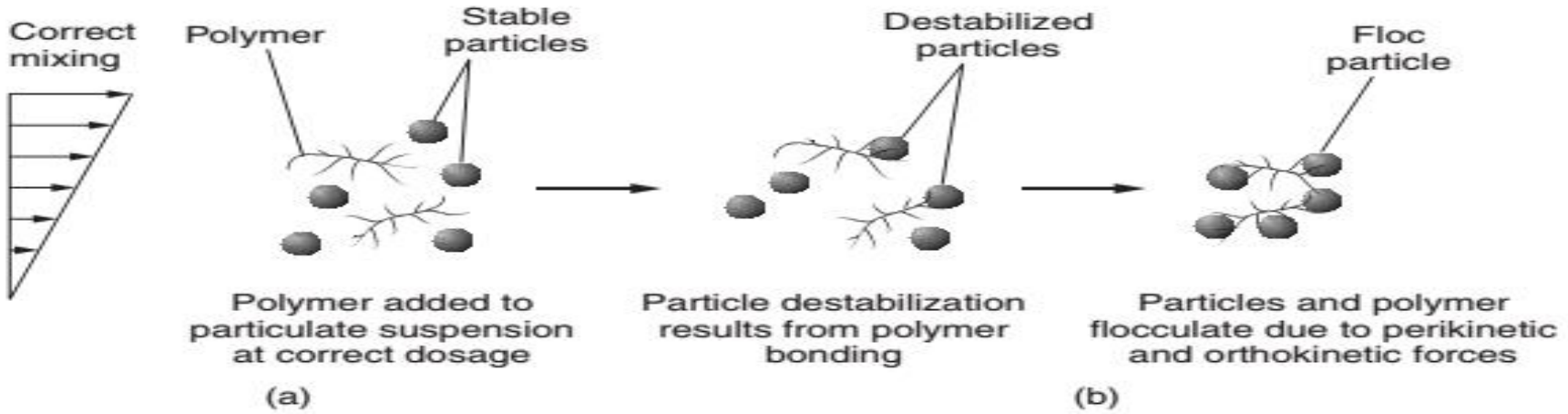
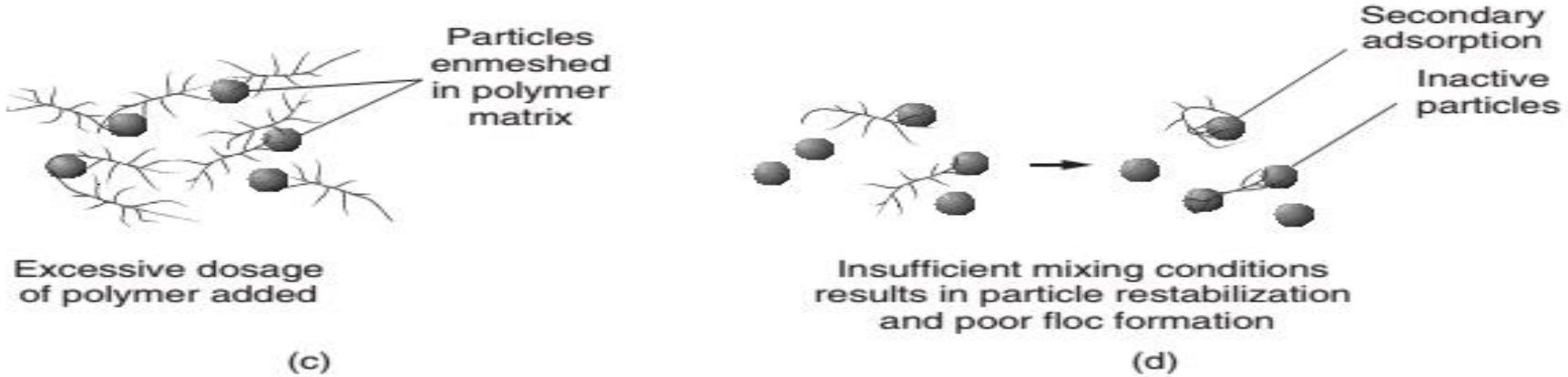
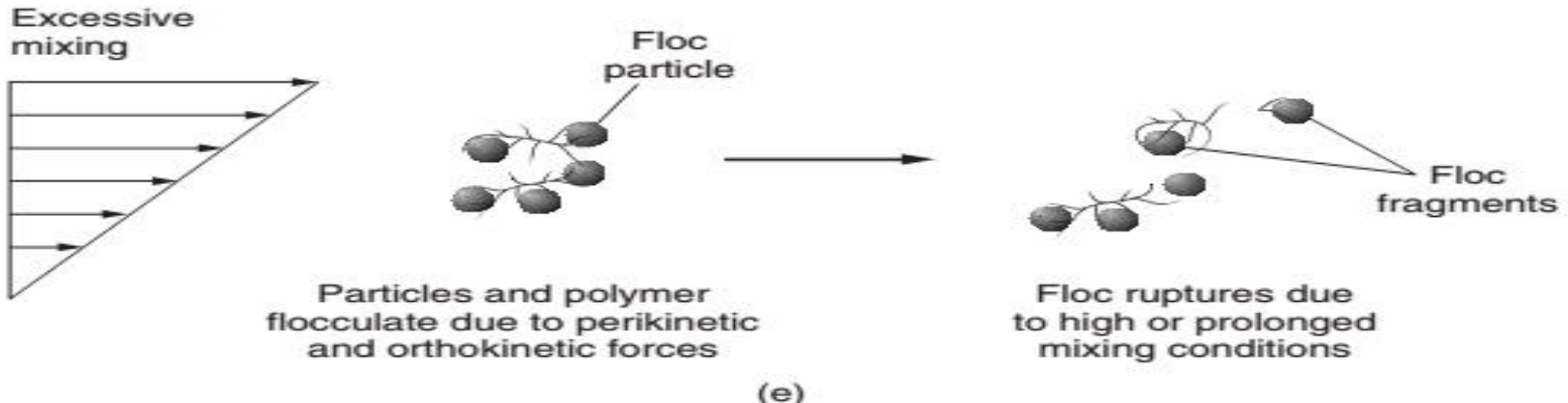


Figure 9-4
Structure of the electrical double layer. The potential measured at the shear plane is known as the zeta potential. The shear plane typically occurs in diffuse layer.


Correct mixing
Polymer
Stable particles
Destabilized particles
Floc particle
Polymer added to particulate suspension at correct dosage
Particle destabilization results from polymer bonding
Particles and polymer flocculate due to perikinetic and orthokinetic forces
(a)
(b)


Particles enmeshed in polymer matrix
Excessive dosage of polymer added
(c)
Secondary adsorption
Inactive particles
Insufficient mixing conditions results in particle restabilization and poor floc formation
(d)


Excessive mixing
Floc particle
Floc fragments
Particles and polymer flocculate due to perikinetic and orthokinetic forces
Floc ruptures due to high or prolonged mixing conditions
(e)

Common inorganic coagulants, coagulant aids, and pH and alkalinity adjusting chemicals used in water treatment

Classification	Chemical Formula	Molecular Weight, g/mol	Application
Coagulants			
Aluminum sulfate	$Al_2(SO_4)_3 \cdot 14H_2O$	594.4	Primary coagulant
Sodium aluminate	$Na_2Al_2O_4$	163.9	Used with alum; provides alkalinity and pH control
Aluminum chloride	$AlCl_3$	160.3	Used in blends with organic polymers
Polyaluminum chloride (PACl)[a]	$Al_a(OH)_b(Cl)_c(SO_4)_d$	Variable	Primary coagulant
Polyaluminum sulfate (PAS)[b]	$Al_a(OH)_b(Cl)_c(SO_4)_d$	Variable	Primary coagulant, produced onsite
Polyiron chloride[c]	$Fe_a(OH)_b(Cl)_c(SO_4)_d$	Variable	Primary coagulant, produced onsite
Ferric chloride	$FeCl_3$	162.2	Primary coagulant
Ferric sulfate	$Fe_2(SO_4)_3$	400.0	Primary coagulant
Coagulant aids			
Activated silica	SiO_2	60.0	Coagulant aid used with alum during cold winter months
Sodium silicate	$Na_2O(SiO_2)_{3-25}$	242–1562	Coagulant aid, produced onsite
Bentonite	$Al_2Si_2O_5(OH)_4$	258	Used to provide nucleation sites for enhanced coagulation
Alkalinity and pH adjustment			
Calcium hydroxide	$Ca(OH)_2$	56.1 as CaO	Used to provide alkalinity and adjust pH
Sodium hydroxide	NaOH	40.0	Used to provide alkalinity and adjust pH
Soda ash	Na_2CO_3	106.0	Used to provide alkalinity and adjust pH

Oxidation and Disinfection

In water treatment, chemical oxidation and reduction processes are used for the treatment of specific inorganic or organic species found in water. For organic compounds, the purpose is to convert compounds into harmless or non-objectionable forms.

For example, it is desirable to oxidize toxic organic compounds into carbon dioxide and mineral acids (e.g., HCl) or taste and odor compounds into non-odorous compounds.
Inorganic metal species (e.g., iron or manganese) are oxidized to insoluble forms and are removed by precipitation. Other inorganic species such as hydrogen sulfide, an odorous gas, is oxidized to non-odorous sulfate.

The oxidants are usually added at the beginning (e.g., pre-oxidation) or end (e.g., disinfection) of the water treatment process; however, oxidants are also added at a variety of intermediate points depending on the treatment objectives.

Application of Conventional Oxidants in Water Treatment
The principal applications of chemical oxidation are for

1. **Taste and odor control**
2. **Hydrogen sulfide removal**
3. **Color removal**
4. **Iron and manganese removal**
5. **Disinfection**

Oxidants and their applications in water treatment

Purpose	Oxidants	Applications
Oxidation of reduced inorganic species	Chlorine, hydrogen peroxide, permanganate, chlorine dioxide	Convert soluble metals such as Fe(II) and Mn(II) to insoluble forms; oxidize odorous sulfide; destroy metal organic complexes
Oxidation of organics	Ozone, AOPs, ultraviolet light, permanganate, chlorine dioxide	Destroy taste- and odor-causing compounds; destroy toxic organics [e.g., pesticides, benzene, trichloroethene, methyl tertiary-butyl ether (MTBE)]; eliminate color; reduce natural organic matter and disinfection by-product precursors
Coagulation aids	Ozone	Reduce amount of coagulant and/or improve coagulation process
Biocidal agents	Ozone, chlorine, iodine, ultraviolet light	Control nuisance growths such as algae in pretreatment basins or reservoirs; as primary disinfectants to meet *Ct*[a] regulations (discussed in Chap. 13)

[a] *Ct* = product of oxidant residual concentration (mg/L) and contact time (min).

In the water treatment process , reducing microbiological contaminants is accomplished by two basic strategies, removing them from the water or inactivating them.

Inactivated microorganisms, although still present in the water, are no longer able to cause disease in the consuming . Processes that use inactivation as their strategy are traditionally referred to as disinfection

Disinfection is used to refer to two activities:

(1) primary disinfection—the inactivation of microorganisms in the Water

(2) secondary disinfection—maintaining a disinfectant residual in the treated-water distribution system.

-The most significant taste and odor problem in surface waters is from naturally occurring organic compounds (NOM's) that are produced by algal blooms and bacteria.

The three principal organic compounds,

- geosmin ,
- 2-methylisoborneol (MIB) ,
- cyclocitral

are thought to be produced and released into the water by actinomycetes and cyanobacteria.

disinfection with chlorine had become a world water treatment standard and, even today, many water supplies are treated with chlorination alone The presence of a free chlorine residual in water at the tap was generally taken as a guarantee of microbiological safety by health officials and the public.

Removal of geosmin and methylisoborneol (MIB) that were spiked into filtered water at initial concentration of 100 ng/L

Chemical	Chemical Feed Rate, mg/L	Removal, %	
		Geosmin	MIB
Powdered activated carbon	10	40	62
	25	52	65
Potassium permanganate	0.8	42	28
Chlorine	2	45	33
Hydrogen peroxide	1	50	72
Ozone	2.5	94	77
Ozone and hydrogen peroxide	2.5, 0.5	97	95

Source: Adapted from Kawamura (2000).

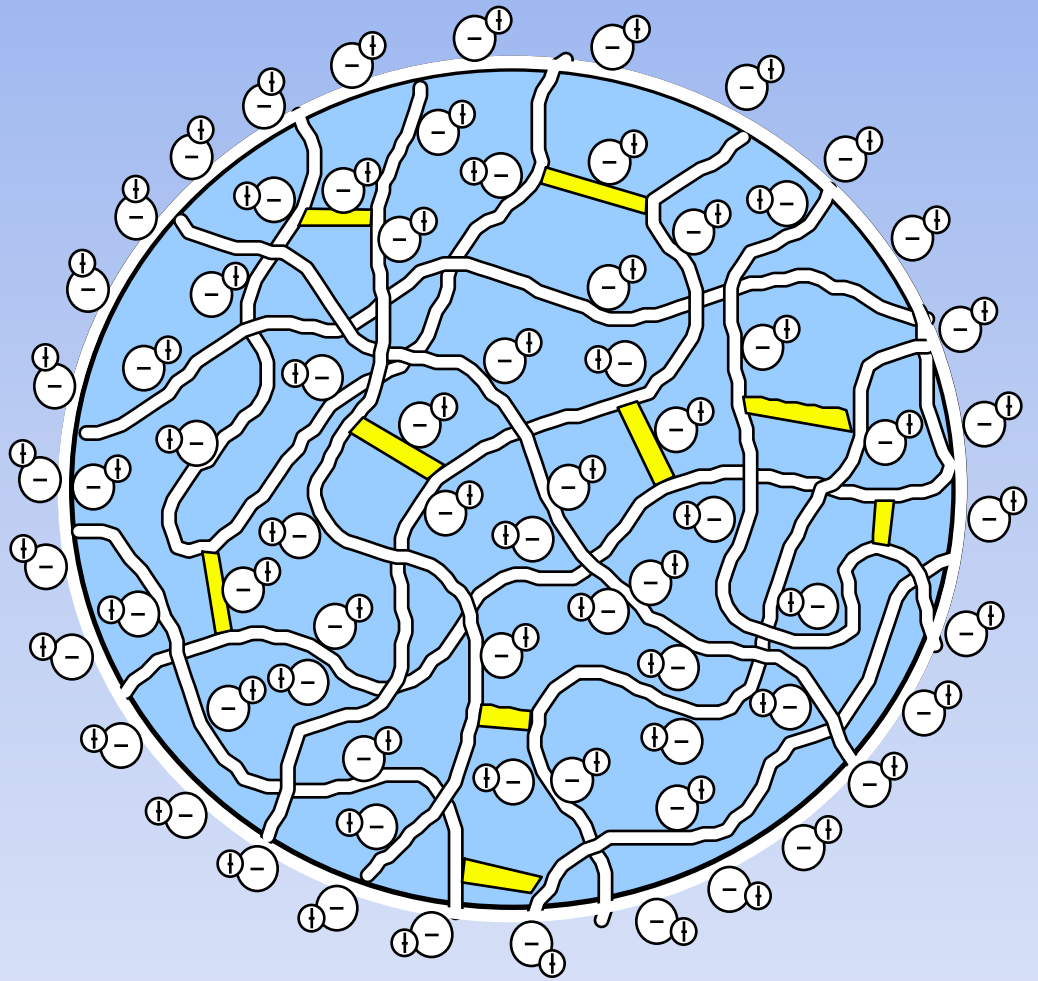
Ion Exchange

Ion exchange resins are polymers that are capable of exchanging particular ions within the polymer with ions in the solution that is passed through them.

This synthetic resins are used mainly in water treatment and the aim is usually either to soften the water or demineralizd it.

Ion-Exchange Resin Bead model

- Fixed Anion
- Counter Cation
- Styrene
- Cross linking Agent (DVB)
- Hydrating Water



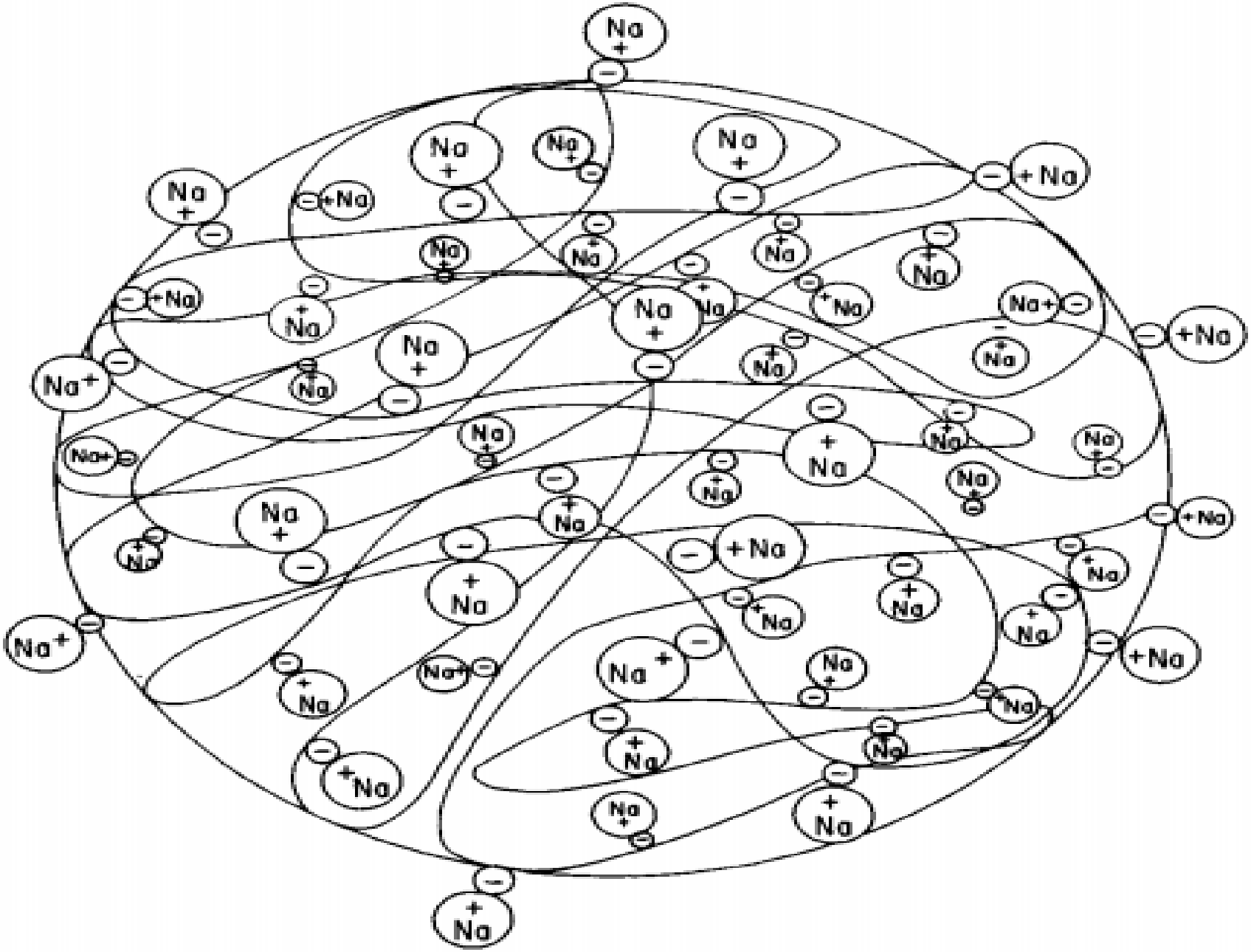
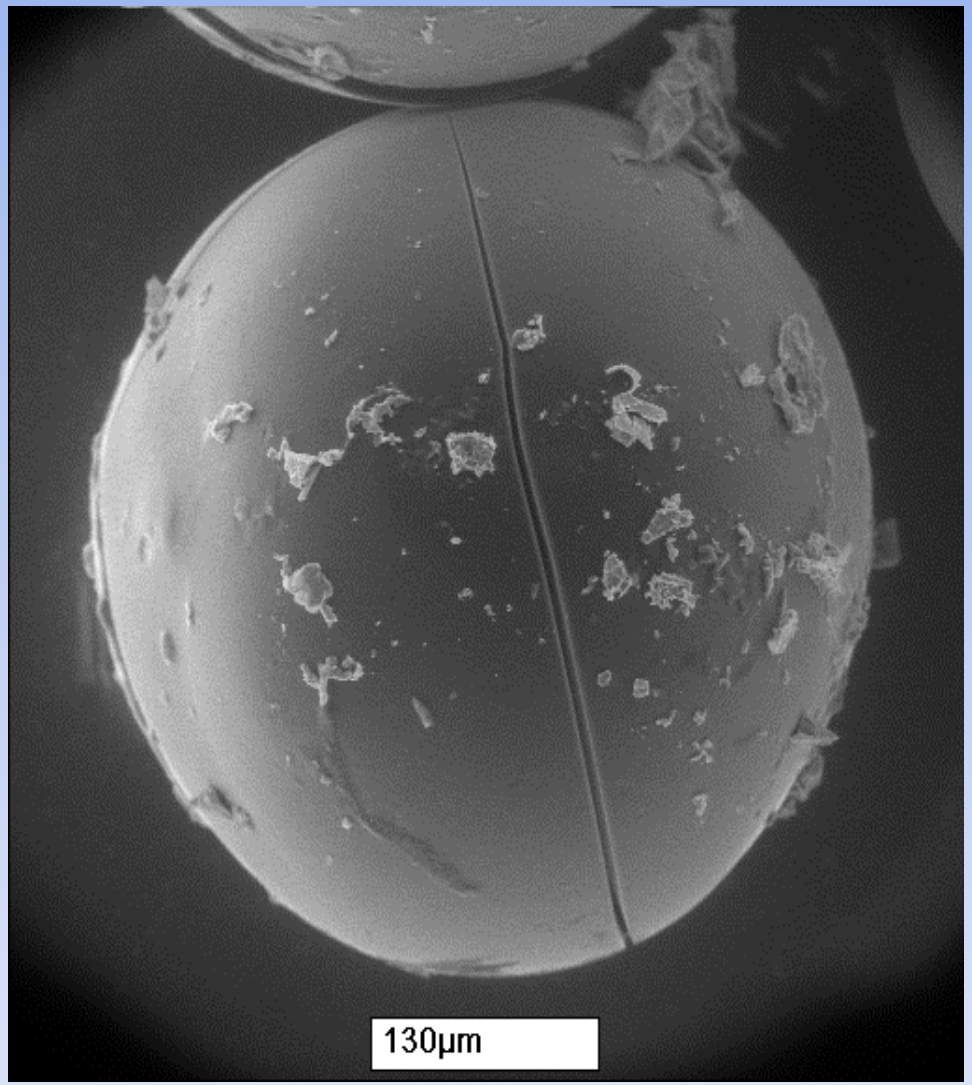


FIG. 12.1 Model of a cation exchanger, showing negatively charged exchange sites on the skeleton holding sodium ions like grapes on a vine.

SEM of Ion-Exchange Resin Bead



Bead diameter:
300 to 1200 µm
(0.3 to 1.2 mm)

Beads pores:
1 to 100 nm
(0.001 to 0.1 µm)

Bead dry weight
40 to 60%

FIG. 12.2 Typical commercial exchangers are of two general structures, gel type *(left)* and macroporous type *(right)*. These are magnifications.

➢softener resin

the resin containing Na+ cations but which binds Ca++ and Mg++ more strongly than Na+. As the water passes through the resin the resin take up Ca++ and Mg++ and release Na+ making for softer water

➢De-ionizing resins:

If the water needs to have the mineral content entirely removed it is passed through a resin containing H^+ (which replace all cations) and then though a second resin containing OH^- (which replace all anions) , the H^+ and OH^- are then react together to give more water.

Example for Cationic Resin:
Strong acidic Sulphonated polystyrene cation exchange resin
Functional group is $SO_3^-H^+$

Example for Anionic Resin :
Strong basic quaternary ammonium anion exchange resin
Functional group is $-CH_2NR_3^+OH^-$

TABLE 12.1 General Order of Ion Selectivity in Water below 1000 mg/L TDS

Cations	Anions
Fe^{3+}	CrO_4^{2-}*
Al^{3+}	SO_4^{2-}*
Pb^{2+}	SO_3^{2-}*
Ba^{2+}	HPO_4^{2-}*
Sr^{2+}	CNS^-
Cd^{2+}	CNO^-
Zn^{2+}	NO_3^-
Cu^{2+}	NO_2^-
Fe^{2+}	Br^-
Mn^{2+}	Cl^-
Ca^{2+}	CN^-
Mg^{2+}	HCO_3^-
K^+	$HSiO_3^-$
NH_4^+	OH^-
Na^+	F^-
H^+	
Li^+	

* These ions may be displaced as they are protonated at low pH to: $HCrO_4^-$, HSO_3^-, $H_2PO_4^-$

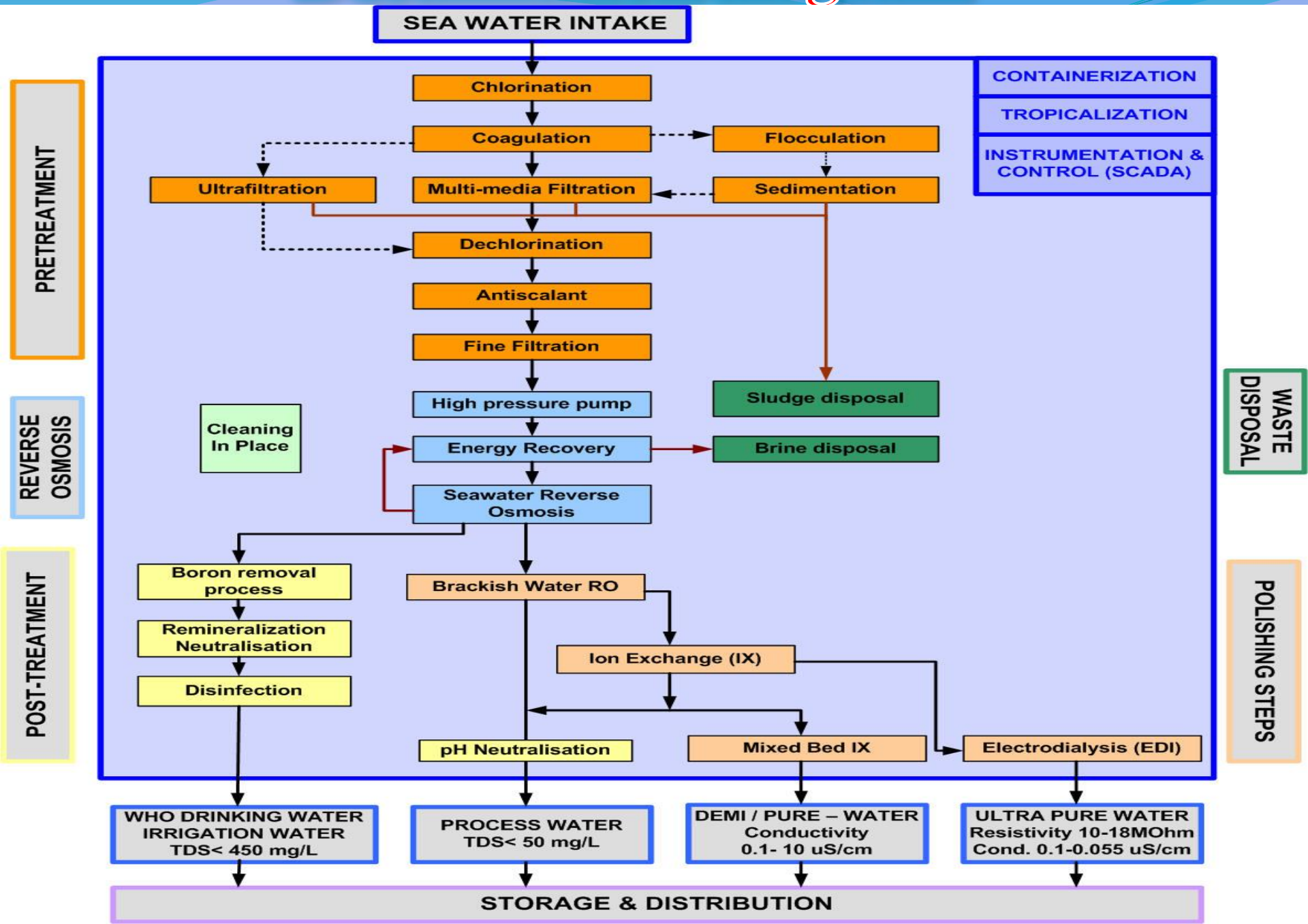
Notes: Changes in position may occur between products of different manufacture or having slightly different skeletons or exchange groups. In general, selectivity is affected by:

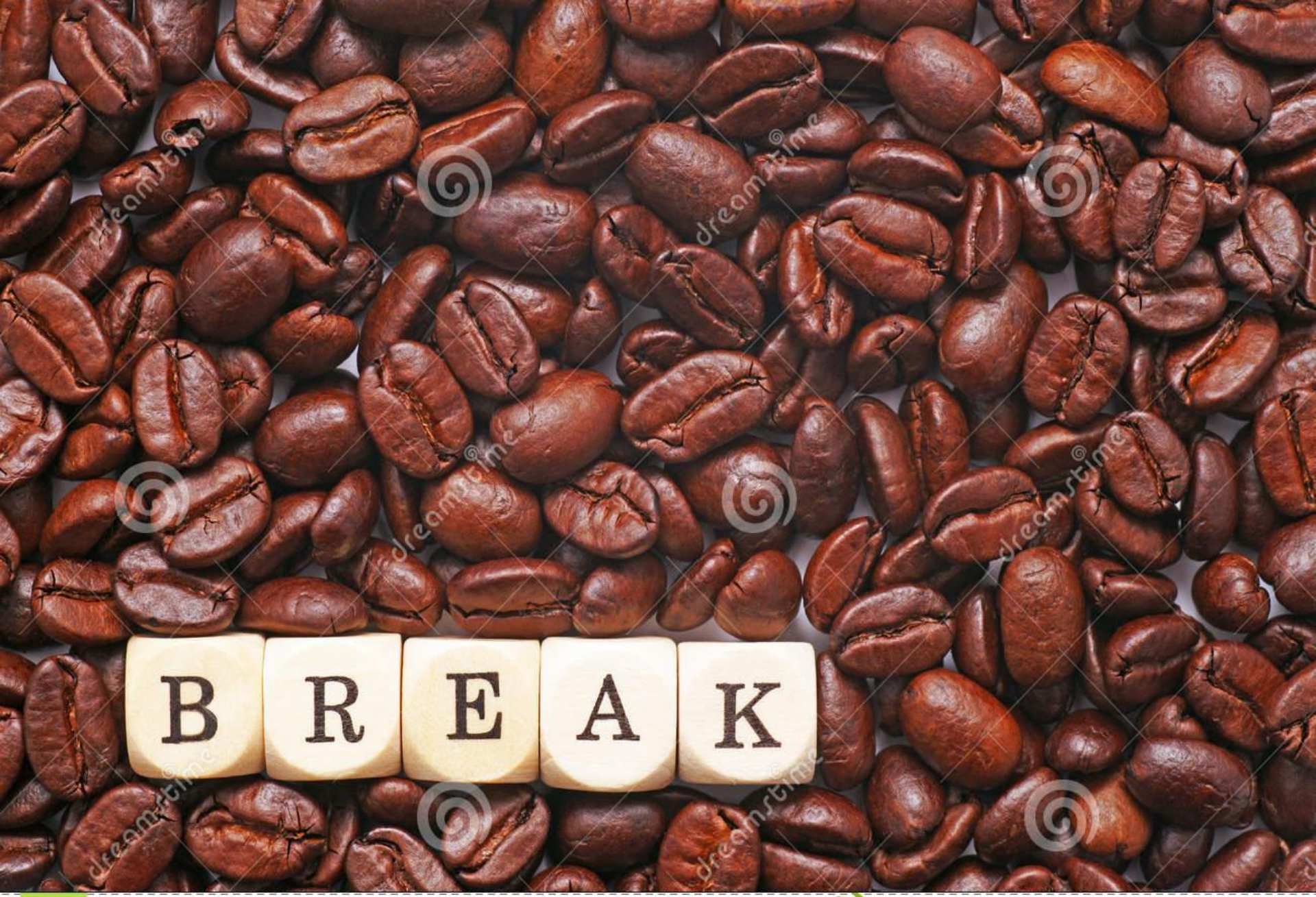
(*a*) Ionic valence: 3 > 2 > 1.

(*b*) Atomic number: Ba > Sr > Ca > Mg in Group IIA.

(*c*) Hydrated ionic radius: the larger the radius, the lower the selectivity and exchange capacity.

Desalination diagram





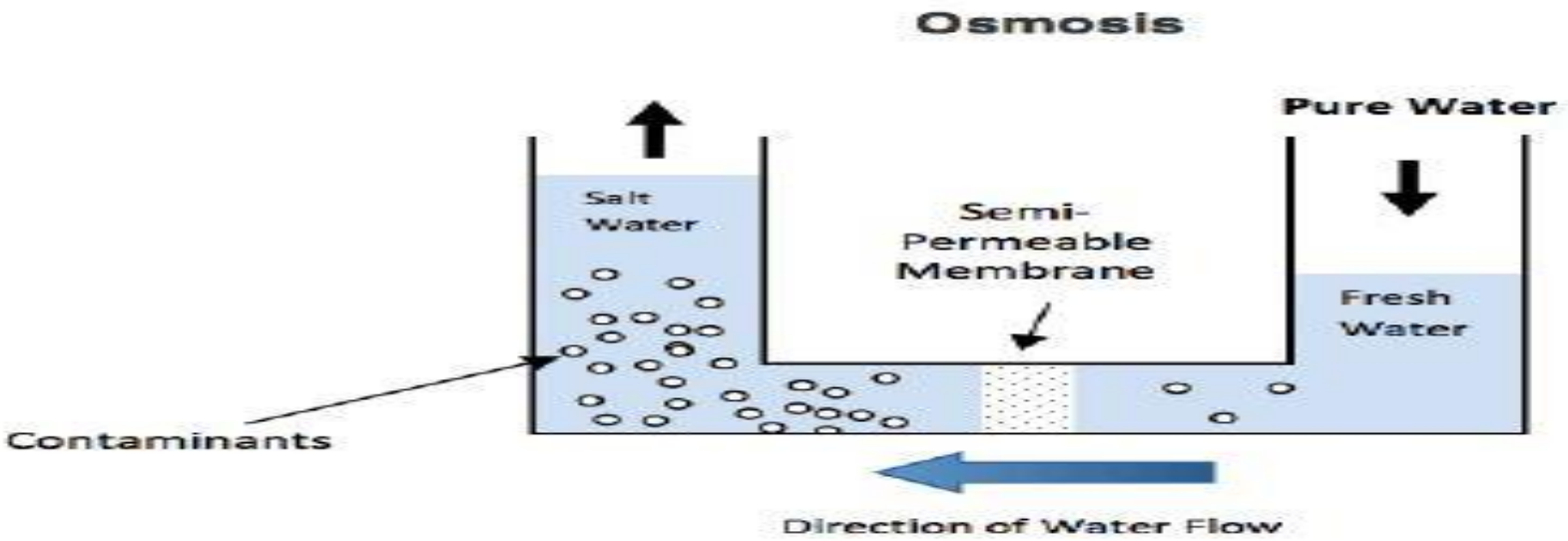
Reverse Osmosis (R.O)

1 – What are we meaning by osmosis ?
2 – What are we meaning by reverse osmosis ?
3 – How does Reverse Osmosis work?
4 – What will Reverse Osmosis remove from water?
5 – What are we mean by the following terms ?

- Permeate
- Concentrate , Reject , Brine
- Recovery %
- Salt rejection %
- Salt passage %
- Concentration Factor
- Flux
- Stage & pass

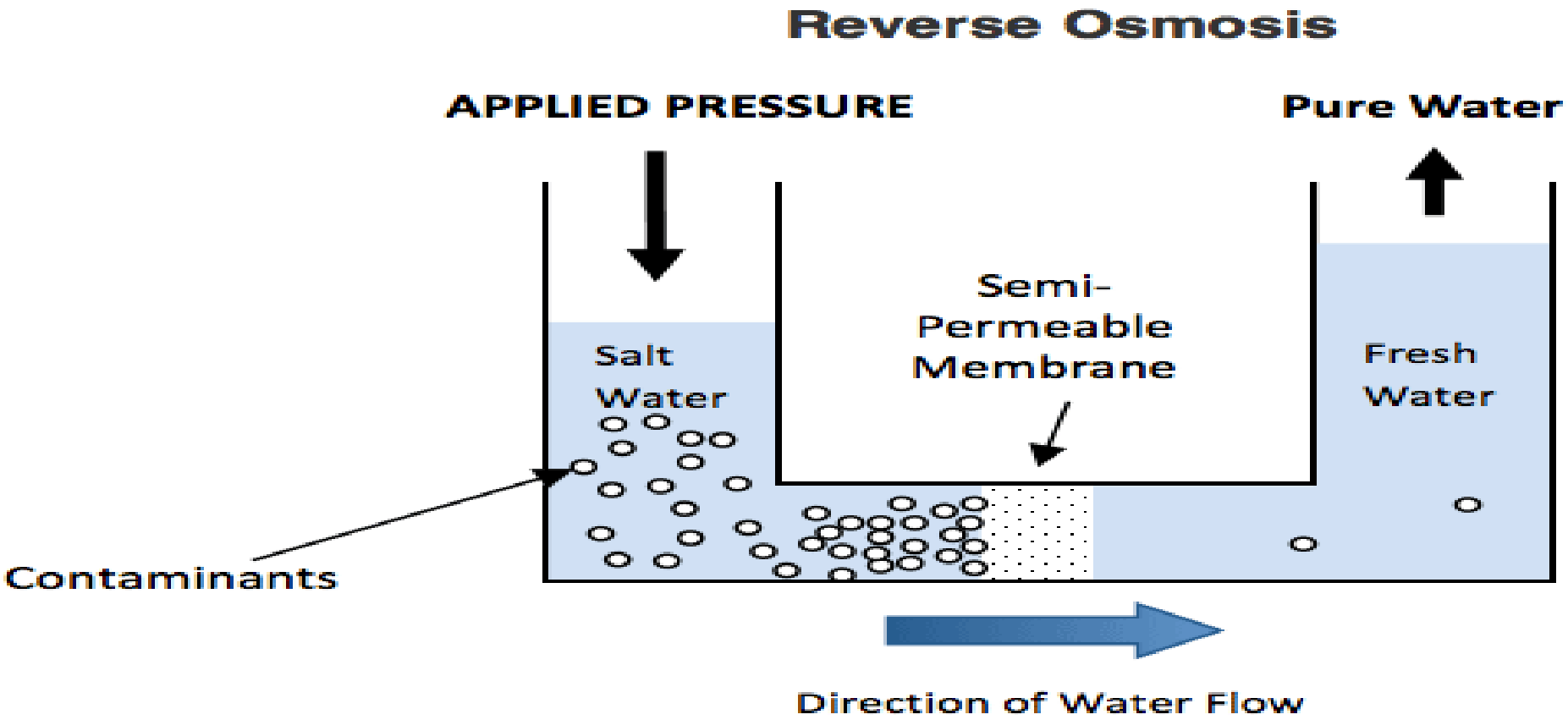
Osmosis:

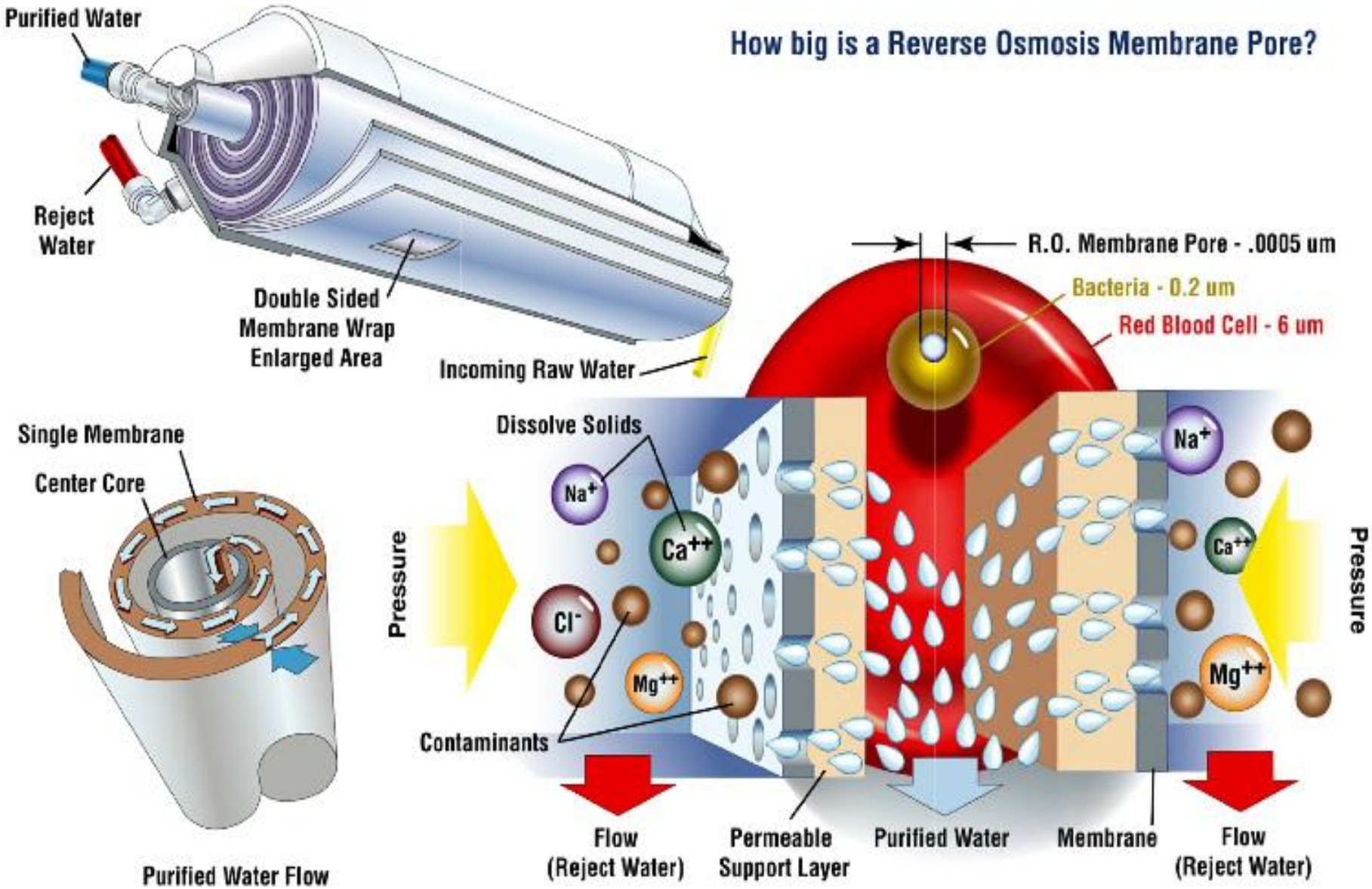
Osmosis is a naturally occurring phenomenon and one of the most important processes in nature. It is a process where a weaker saline solution will tend to migrate to a strong saline solution. Examples of osmosis are when plant roots absorb water from the soil and our kidneys absorb water from our blood.

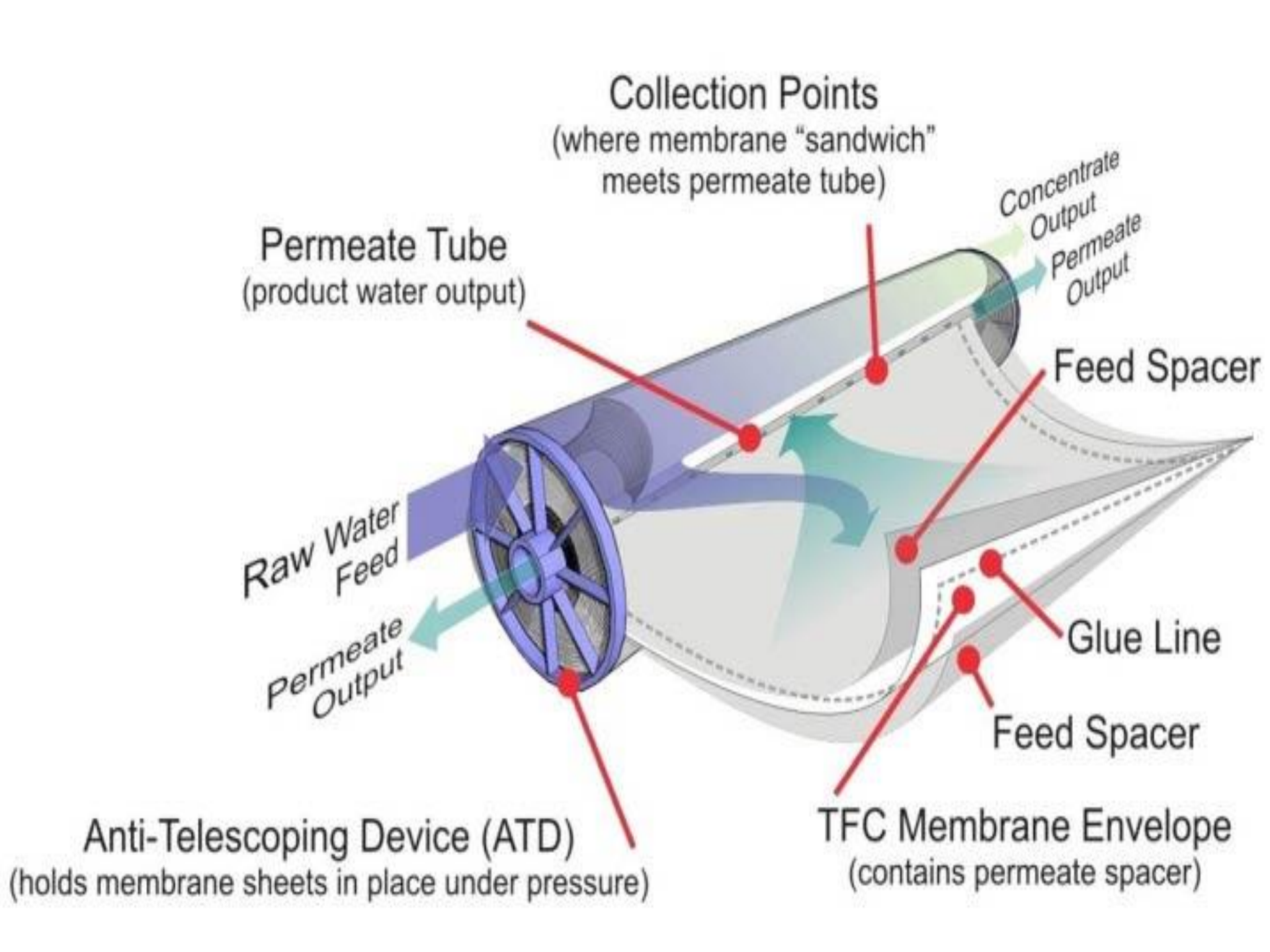


A solution that is less concentrated will have a natural tendency to migrate to a solution with a higher concentration.

Reverse Osmosis is the process of Osmosis in reverse However, you need to 'push' the water through the membrane by applying pressure that is greater than the naturally occurring osmotic pressure in order to desalinate (demineralize or deionize) water in the process, allowing to pass pure water through while holding back a majority of contaminants.



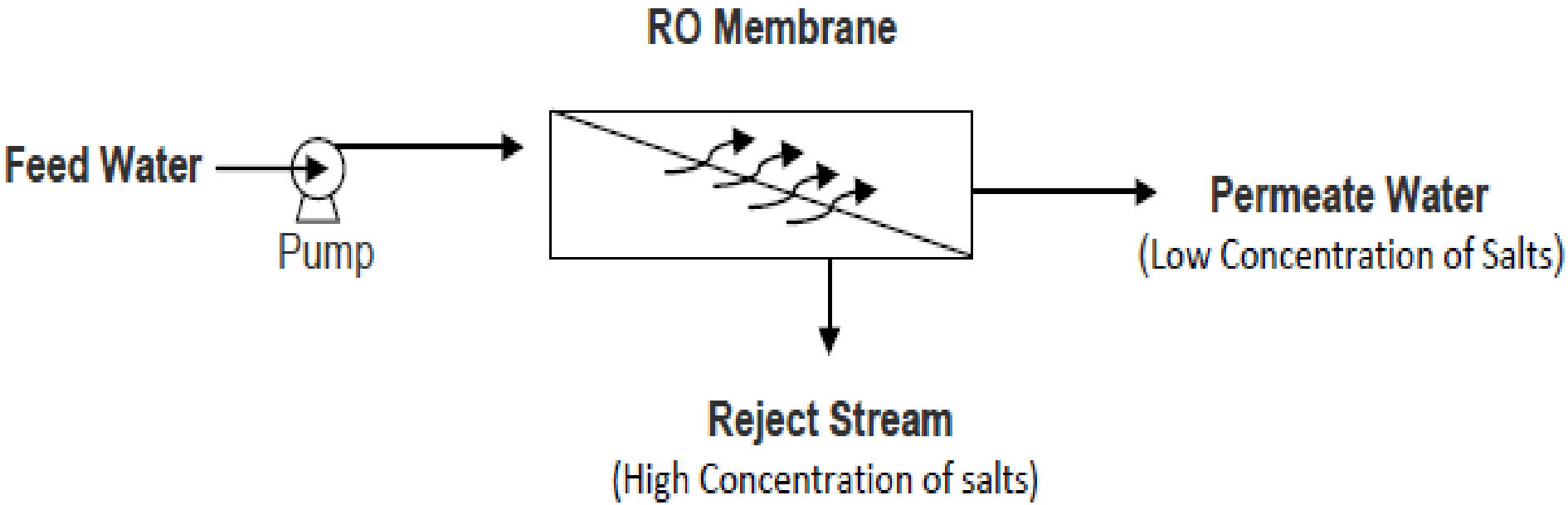

Purified Water
Reject Water
Double Sided Membrane Wrap Enlarged Area
Incoming Raw Water
How big is a Reverse Osmosis Membrane Pore?
R.O. Membrane Pore - .0005 um
Bacteria - 0.2 um
Red Blood Cell - 6 um
Single Membrane
Center Core
Purified Water Flow
Dissolve Solids
Na+
Ca++
Cl-
Mg++
Contaminants
Pressure
Pressure
Flow (Reject Water)
Permeable Support Layer
Purified Water
Membrane
Flow (Reject Water)


Collection Points
(where membrane "sandwich"
meets permeate tube)
Permeate Tube
(product water output)
Concentrate
Output
Permeate
Output
Feed Spacer
Raw Water
Feed
Permeate
Output
Glue Line
Feed Spacer
Anti-Telescoping Device (ATD)
(holds membrane sheets in place under pressure)
TFC Membrane Envelope
(contains permeate spacer)


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

How does Reverse Osmosis work?

Reverse osmosis works by using a high pressure pump to increase the pressure on the salt side of the RO and force the water across the semi---permeable RO membrane, leaving almost all (around 95% to 99%) of dissolved salts behind in the reject stream. The amount of pressure required depends on the salt concentration of the feed water. The more concentrated the feed water, the more pressure is required to overcome the osmotic pressure.



What will Reverse Osmosis remove from water?

Reverse Osmosis is capable of removing up to 99%+ of the dissolved salts (ions), particles, colloids, organics, bacteria and pyrogens from the feed water (although an RO system should not be relied upon to remove 100% of bacteria and viruses). An RO membrane rejects contaminants based on their size and charge. Any contaminant that has a molecular weight greater than 200 is likely rejected by a properly running RO system. Likewise, the greater the ionic charge of the contaminant, the more likely it will be unable to pass through the RO membrane. For example, a sodium ion has only one charge (monovalent) and is not rejected by the RO membrane as well as calcium for example, which has two charges.

Likewise, this is why an RO system does not remove gases such as CO2 very well because they are not highly ionized (charged) while in solution and have a very low molecular weight. Because an RO system does not remove gases, the permeate water can have a slightly lower than normal pH level depending on CO2 levels in the feed water as the CO2 is converted to carbonic acid.

TERMINOLOGY

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.

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

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 %)

Flux :

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

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

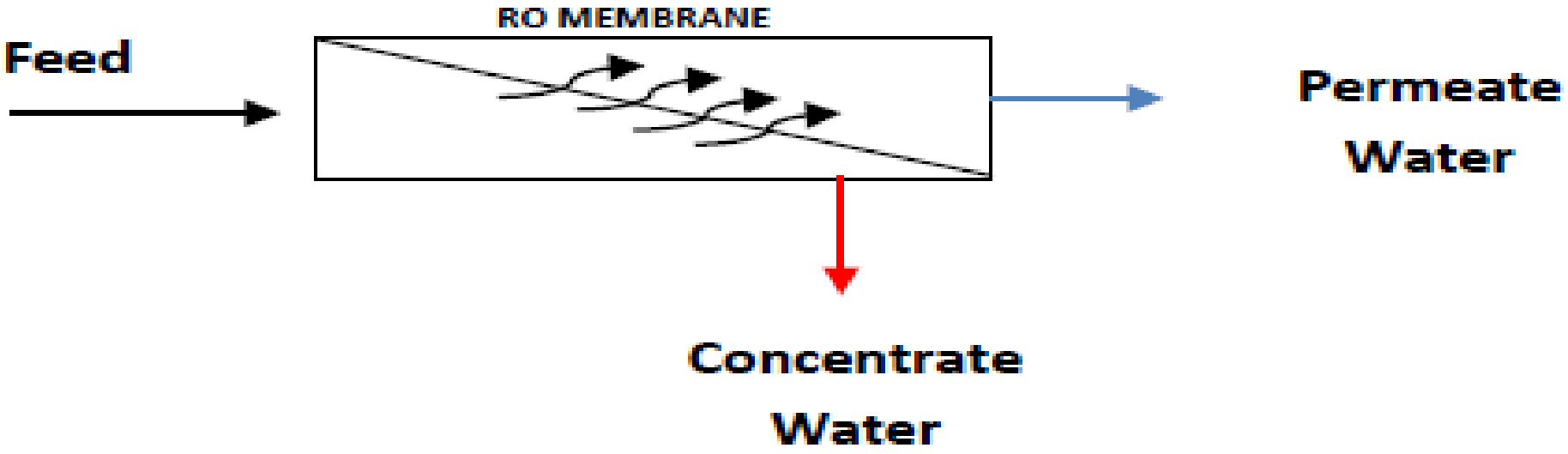
Flux value is Known depending on the source of feed water and type of used membranes for example for DOW filmtec mem. LE---440i

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

passes and stages in a Reverse Osmosis (RO) system

1 stage RO system

- Feed Water
- Permeate Water
- Concentrate Water

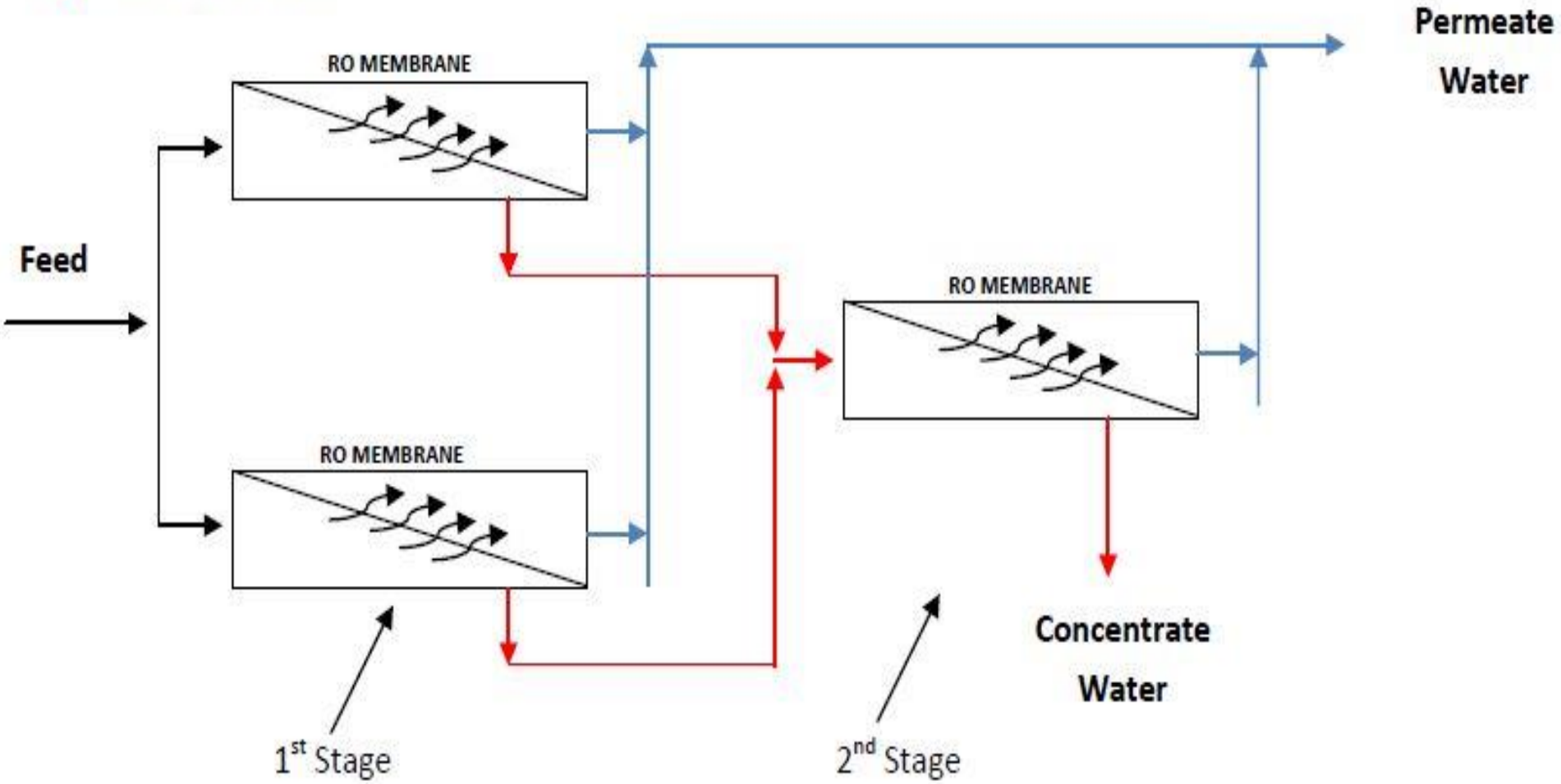


2 stage RO system

→ Feed Water

→ Permeate Water

→ Concentrate Water



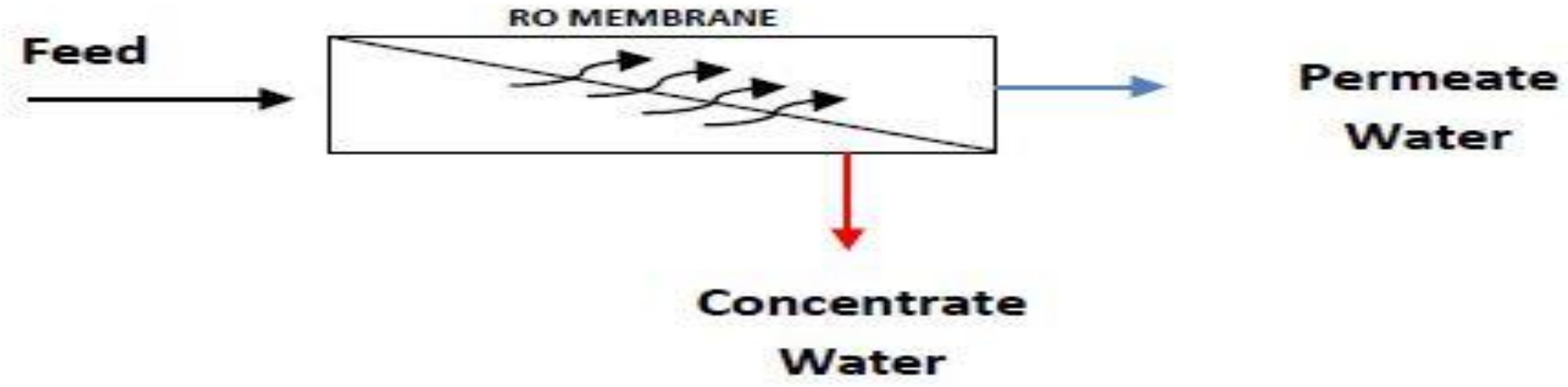
Passes

Single Pass RO

→ Feed Water

→ Permeate Water

→ Concentrate Water

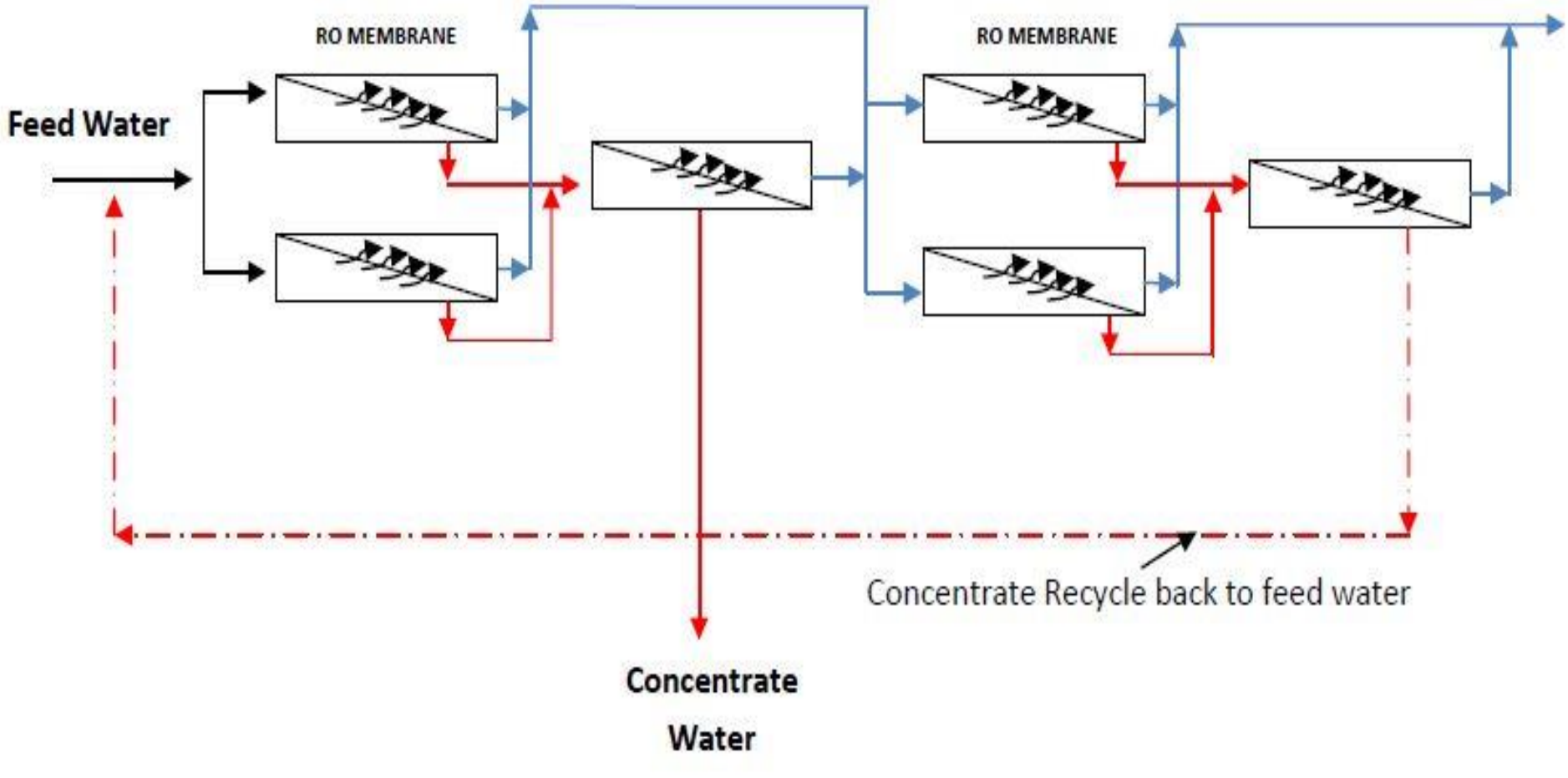


Double Pass RO

→ Feed Water

→ Permeate Water

→ Concentrate Water



Design principles

Firstly You must know exactly the following data:

- **Water source (water type)**
- **Full chemical analysis (to determine the needed technology)**
- **Water consumption**
- **Client need or uses (target quality)**

For filtration media design:

The main factor affect the process is the media surface area which
for sand each cubic foot can filter about 5 gpm.
For GAC each cubic foot can adsorp 8 – 10 gpm.

Which 1 ft3 = 28.3 liter

For sand each liter equal about 1.6 Kg
For GAC each liter equal about 0.5 Kg

Pressure vessel volume calculation :
Due to it is cylindrical in shape

$$V = \pi h r^2$$

Example :
Vessel 10" x 54"
Solution:
r = 10/ 2 = 5 inch = 5 x 2.54 = 12.7 cm = 0.127 m
h = 54 inch = 54 x 2.54 = 137.16 cm = 1.37 m

$$V = \pi (0.127)^2 (1.37) = 0.0695\ m^3 = 69.5\ L^3$$

Ion exchange resin needed volume calculation :

1- Exchange capacity:

Theoretically exchange capacity = 1.45 mg/l
practical exchange capacity = 1.25 mg/l

Real exchange capacity = practical cap. X (Mwt / n)

Due to the hardness represented as $CaCO_3$ which have Mwt = 100
So Real exchange capacity = 1.25 x 100/2 = 62.5 mg/l

2- Calculate ionic load:

Ionic load = hardness value x consumption per day