ION EXCHANGE METHOD(Demineralization)

PRINCIPLE :

When hard water passes through cation exchange resin, all cations from water are absorbed in exchange of H+ ions of resin, & when this water passes thro' anion exchange resin, all anions are absorbed in exchange of OH-. Finally H+ & OH- ions combine to give soft water .

Structure of cation exchange resin

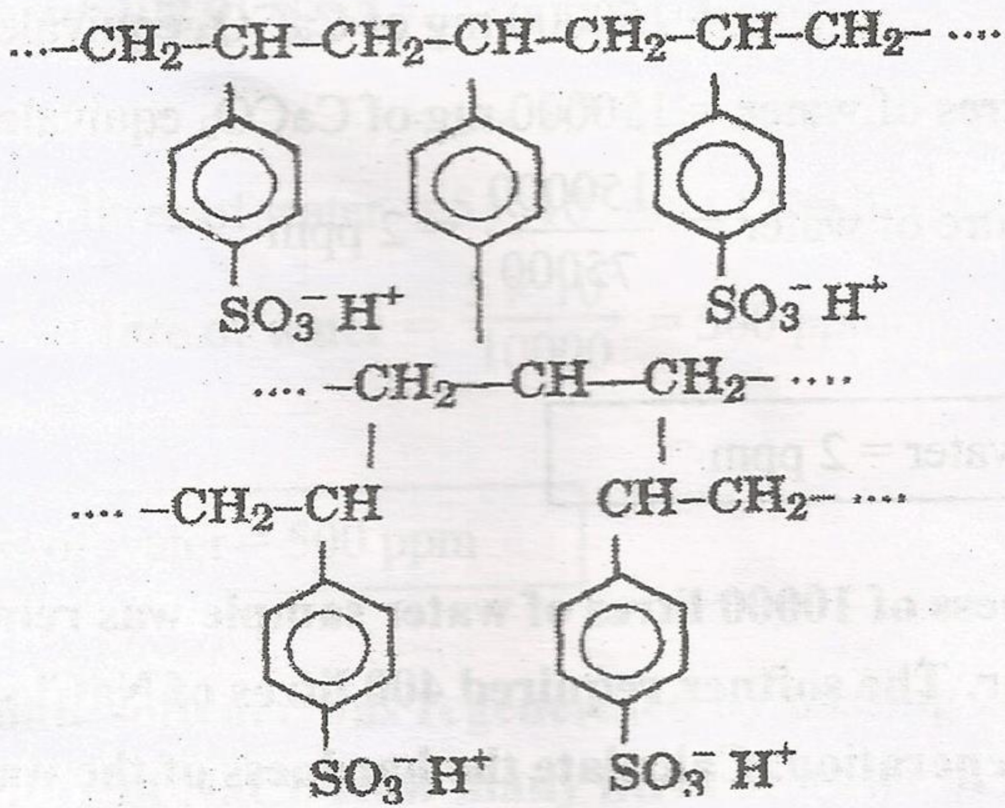


Fig. 1.5 : Cation Exchange Resin

Structure of anion exchange resin

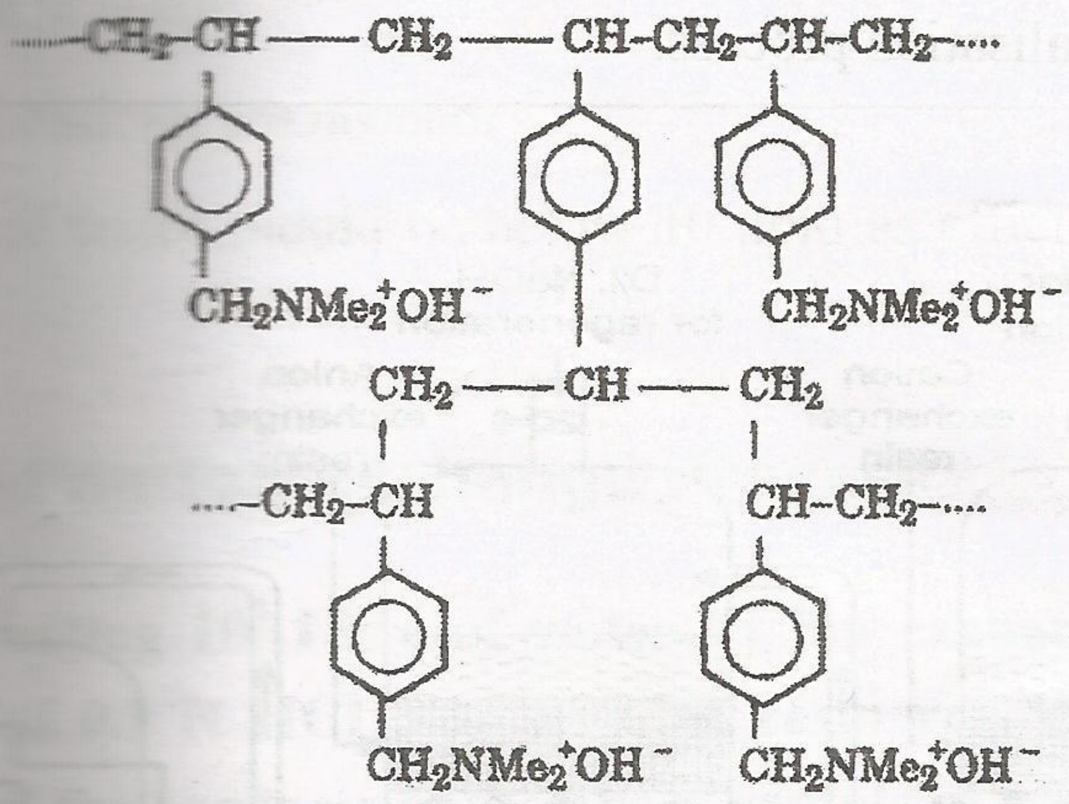


Fig. 1.6 : Anion Exchange Resin

Process

- The hard water is passed thro' cation exchange column, cations of hard water like Ca^{2+}, Mg^{2+} etc. are retained in the column &
- H^+ ions are released from this column to water.

- **When water coming out from cation exchange column is passed thro' anion exchange column, anions like SO_4^{2-} , Cl^- etc are retained in the column & equivalent amount of OH^- ions are released from this column to water.**

Reaction of cation exchange resin

- $2RH^{+} + Ca^{2+} \dashrightarrow R_2Ca^{2+} + 2H^{+}$
- (CaCl2) (2HCl)

- $2RH^{+} + Mg^{2+} \dashrightarrow R_2Mg^{2+} + 2H^{+}$
- $(MgSO_4)$ (H_2SO_4)

Reaction of anion exchange resin

- $R'OH^- + Cl^- \rightarrow R'Cl^- + OH^-$
- (HCl) (H2O)

- $2R'OH^- + SO_4^{2-} \rightarrow R_2'SO_4^{2-} + 2OH^-$
- (H_2SO_4) (H_2O)

Diagram of Ion Exchange method

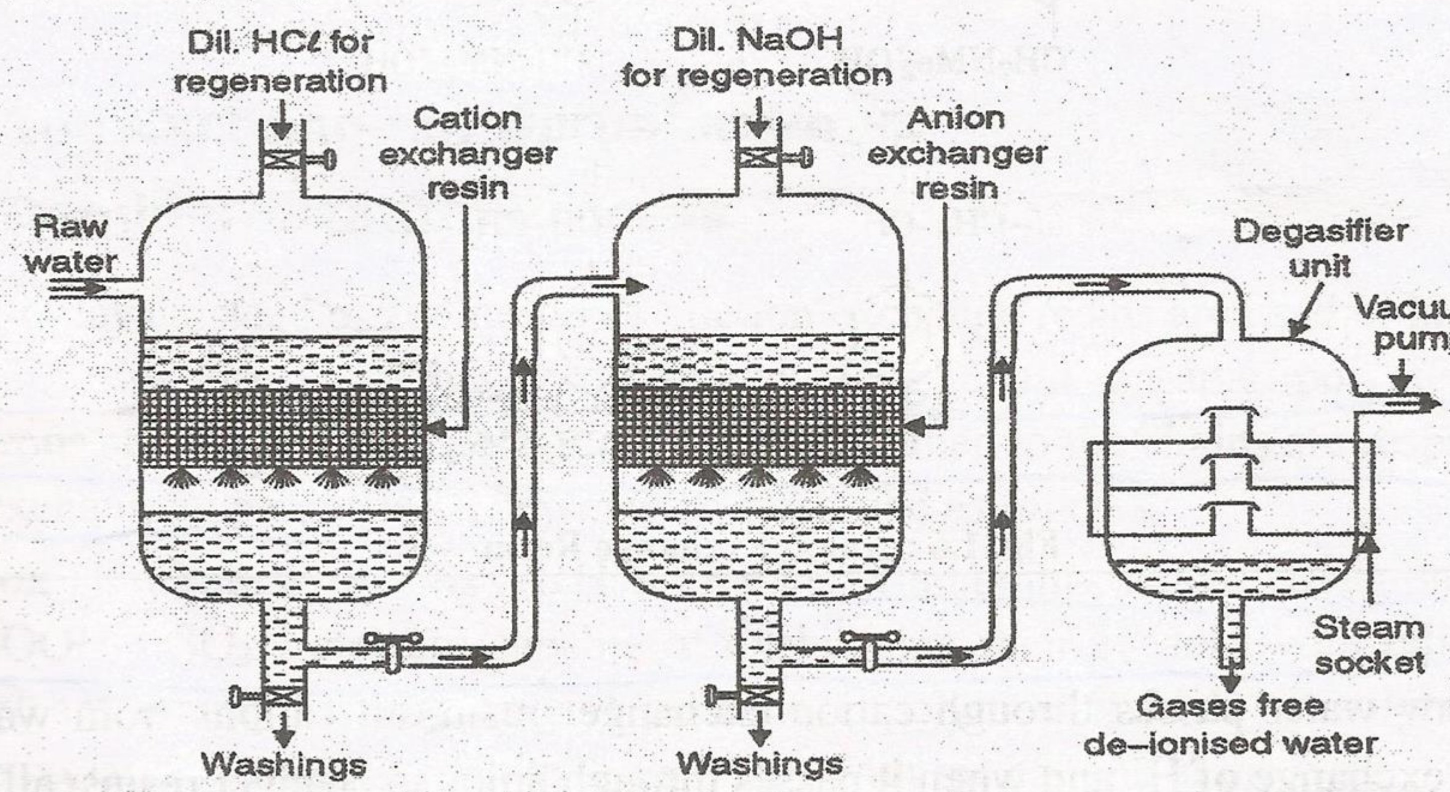


Fig. 1.7 : Demineralization of Water

Regeneration of ion exchange columns

- When cation & anion exchange columns are exhausted (as all H^+ & OH^- ions are exchanged with cations & anions of hard water & they loose capacity to exchange H^+ & OH^- ions), regeneration process is carried out.

- **ION EXCHANGE REGENERATION REACTION**
- **Exhausted cation exchange column is regenerated by passing a solution of dilute HCl or dil H2SO4.**

- $R_2Ca^{2+} + 2H^+ \text{-->} 2RH^+ + Ca^{2+}$

  (HCl)   ($CaCl_2$)
- **Then column is washed with deionised water & washings are sent to sink.**

- Anion exchange column is regenerated by passing dilute NaOH solution

- $R_2SO_4^{2-}$ + $2OH^-$ --> $2R'OH^-$ + SO_4^{2-}

  (NaOH) (Na_2SO_4)

- Then the column is washed with deionised water & washings are sent to sink.

ADVANTAGES

- 1. It produces water of very low hardness (~ 2 ppm).
- 2. Treated water contains negligible amount of solids.
- 3. water obtained can be used in high pressure boilers.
- 4. Highly acidic & alkaline water can be softened.

DISADVANTAGES

- 1. **The equipment is costly.**
- **2. More costly chemicals are needed.**
- **3. Turbidity of water should be below 10 ppm**
- **more turbid water blocks pores of resin.**

ELECTRO DIALYSIS

- **PRINCIPLE**
- The ions present in the saline water migrate towards respective electrodes through ion selective membrane under the influence of applied emf.

- The unit consists of electrodes & ion selective membranes. These membranes are thin & rigid, which are also permeable to either cation or anion. The anode is placed near anion selective membrane while the cathod is placed near the cation selective membrane.

- Under the influence of an applied emf across the electrodes, cations move towards cathode & anions move towards the anode thro’ cation selective & anion selective membranes respectively. There is depletion of ions in the central compartment while it increases in the two side compartments.

- Desalinated water is taken out from the central compartment & brackish water is replaced by fresh saline

- Electrodialysis unit used for practical purpose consists of large numbers of electrode pairs with membranes.
- Fixed positive charge in membrane repel Na+ ions & permit negatively charged ion (Cl-) to pass thro’.
- Similarly fixed negative ions in membrane repel Cl- ions & allow Na+ ions to pass thro’.

ELECTRO DIALYSIS

ode is placed near the cation selective membrane.

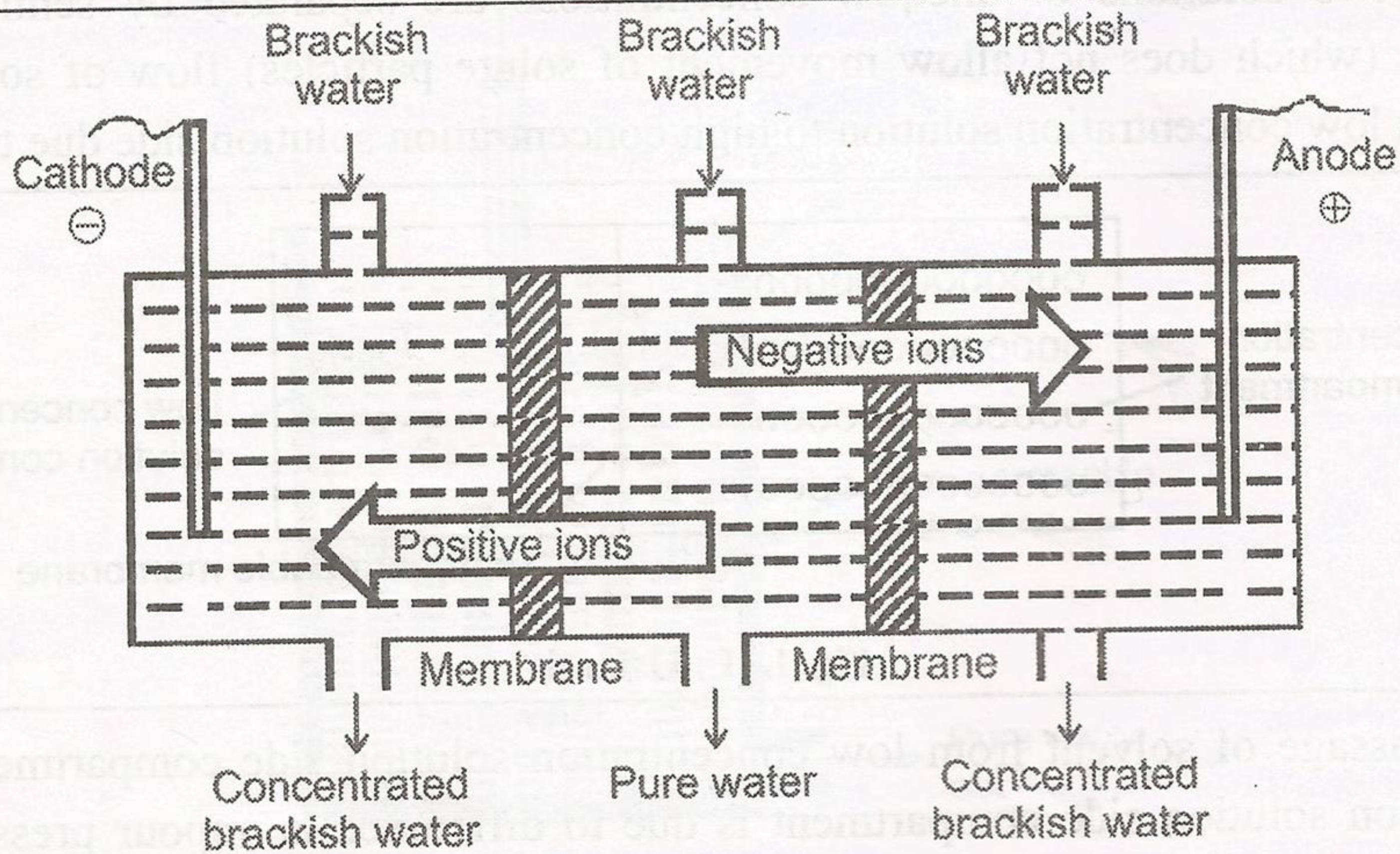


Fig. 1.10 : Electro Dialysis of Brackish Water

ADVANTAGES

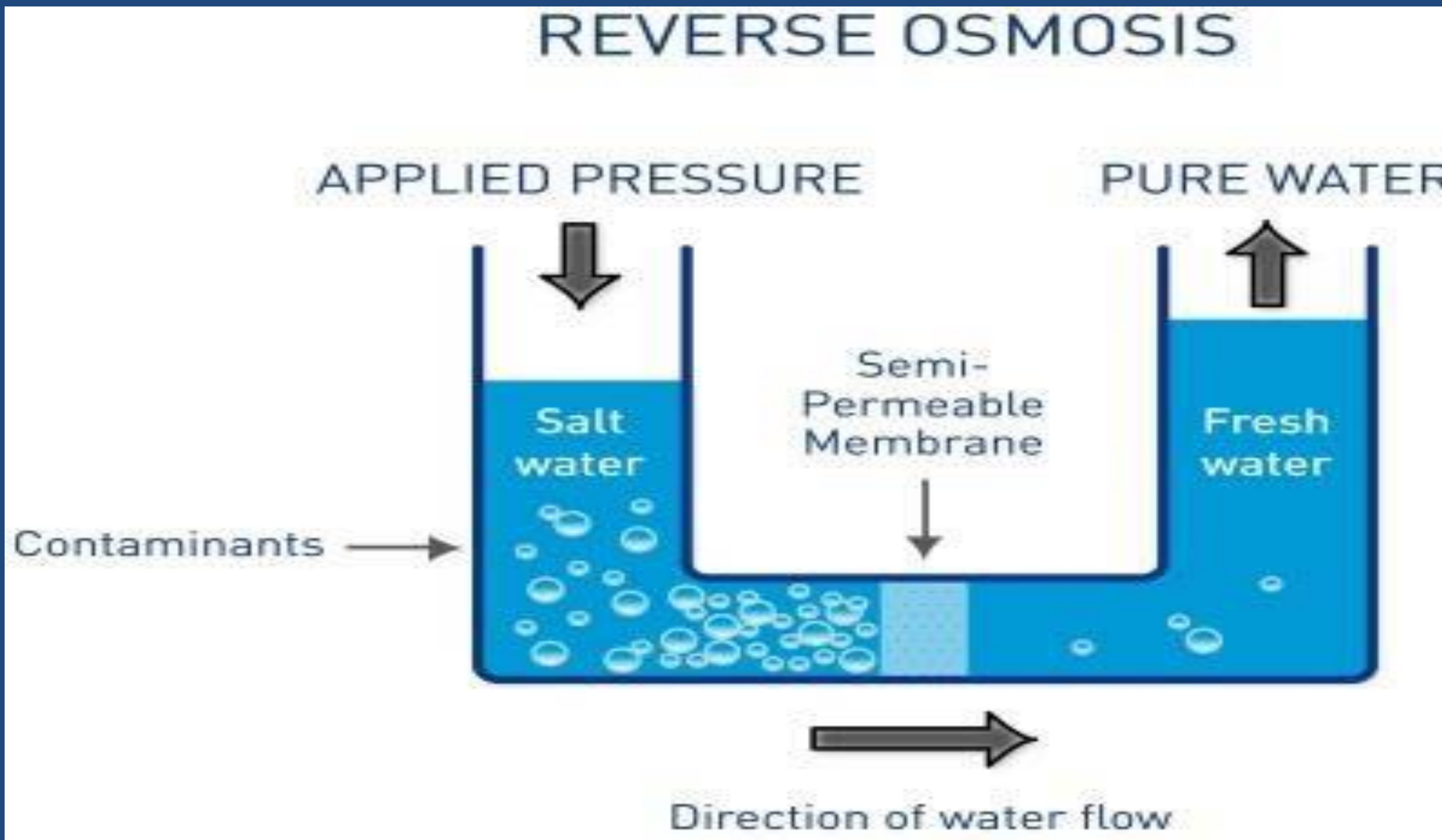
- The unit is compact.
- The process is economical as the cost of installation of the plant & its operational expenses are less.

Reverse Osmosis

- **OSMOSIS** :
- When two solutions of unequal concentrations are separated by semi-permeable membrane flow of solvent takes place from low concentration solution to high concentration solution (due to difference in vapour pressure of two solutions. This process is called osmosis.

REVERSE OSMOSIS

- If a hydrostatic pressure in excess of osmotic pressure is applied on higher concentration solution side, solvent starts moving from higher concentration to lower concentration side through semi-permeable membrane. This process is called reverse osmosis.


REVERSE OSMOSIS
APPLIED PRESSURE
PURE WATER
Salt water
Semi-Permeable Membrane
Fresh water
Contaminants
Direction of water flow

ADVANTAGES

- 1. Reverse osmosis removes ionic, non-ionic & colloidal & high molecular weight organic matter.
- 2. It removes colloidal silica which is not removed by demineralization.
- 3 The maintenance cost is low as only membrane is to be replaced & life time of membrane is two years.

Disadvantages

- 1. It removes all ions (ions which are required for our body.
- 2. Process is slow.
- 3. Efficiency of process is low as after passing 10 gallons of water we get 1 gallon of pure water.

ULTRA FILTRATION

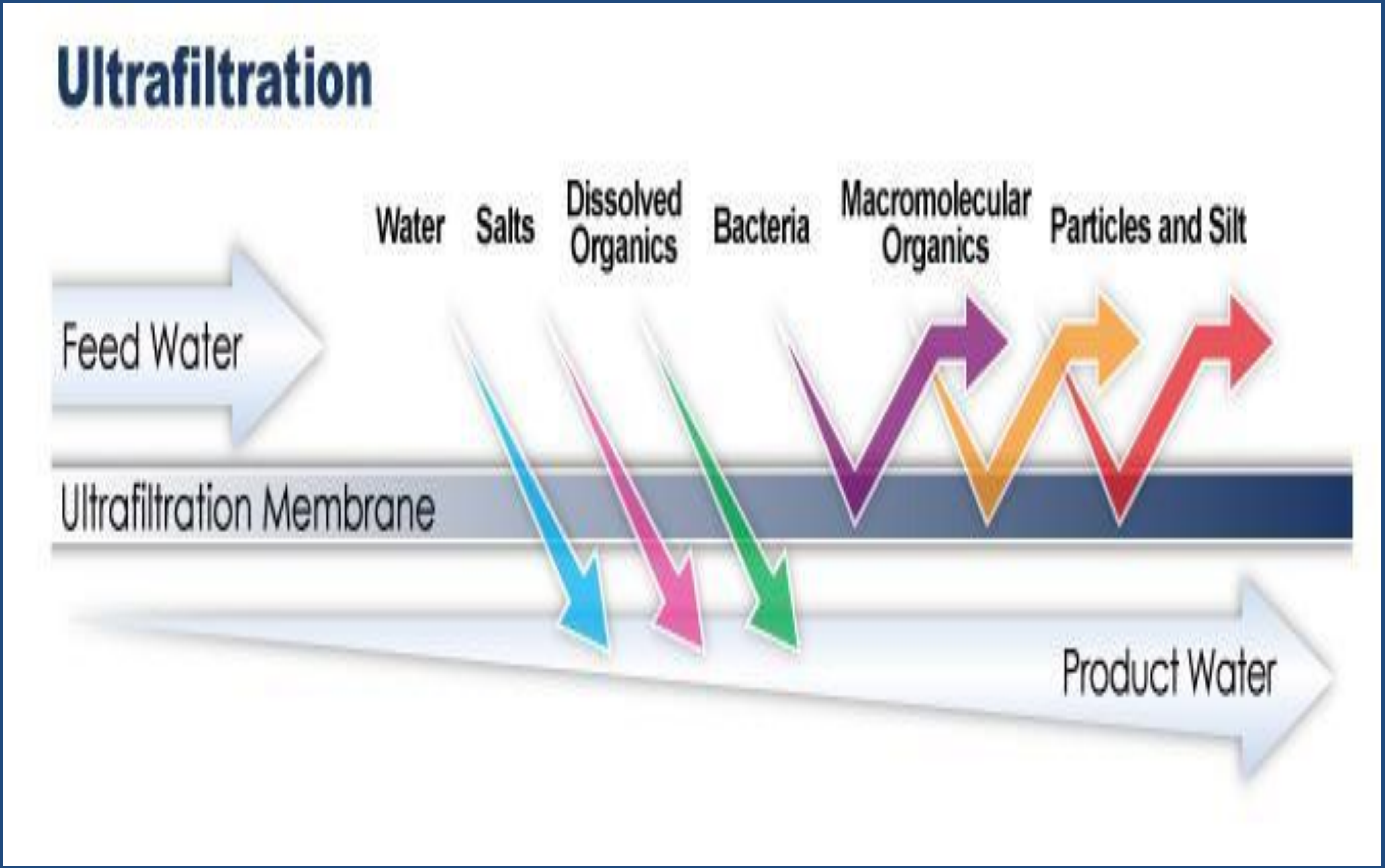
- Cross Flow Ultrafiltration (also known as Tangential Flow Ultrafiltration) is a separation process where the feed stream is in parallel to the membrane surface, which helps to control the formation of the gel layer,.

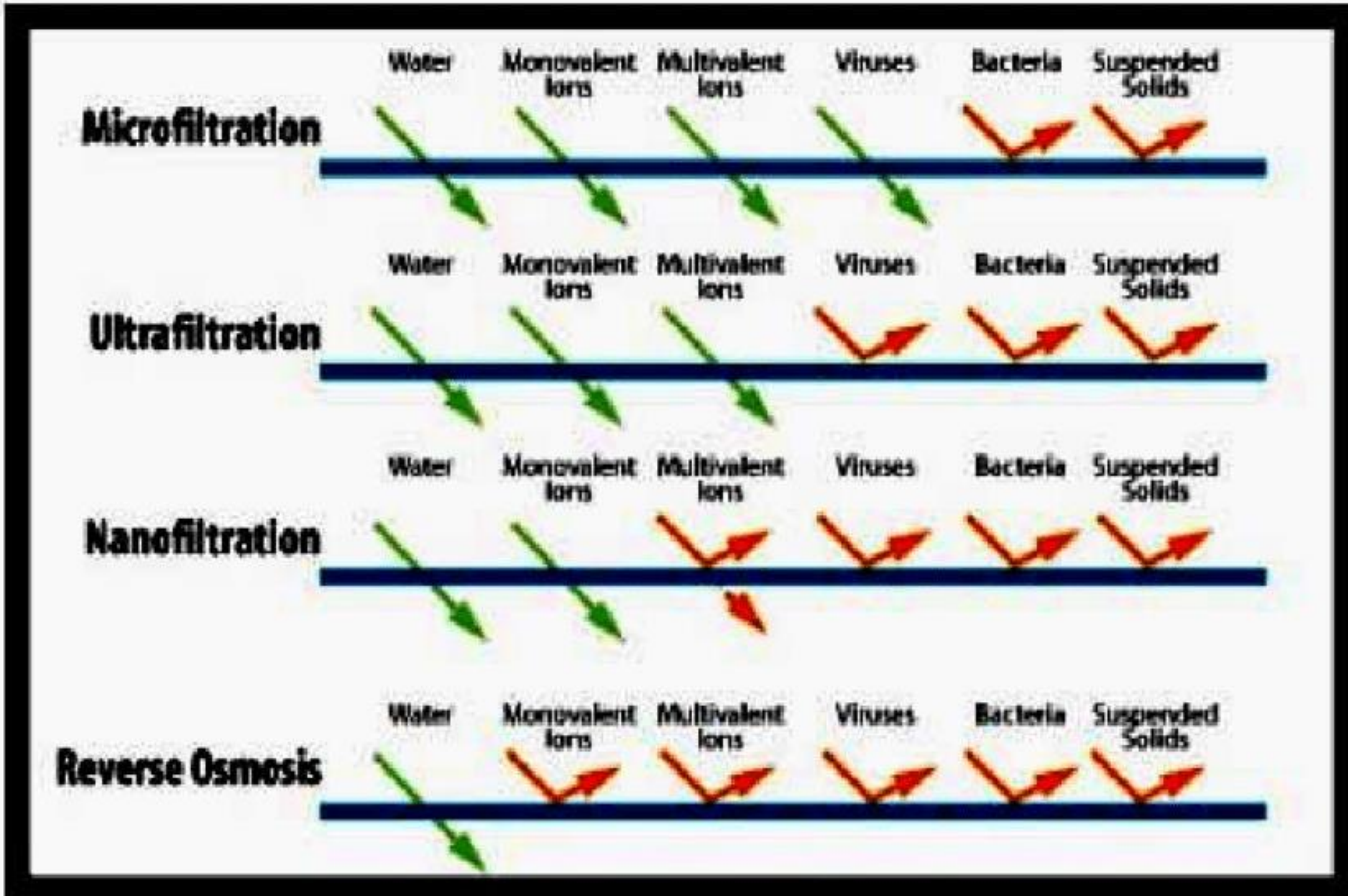
- **greatly improving flux stability and membrane life vs. perpendicular flow system.**

- As opposed to conventional filtration which causes a quick build-up of solids onto the membrane surface, cross flow filtration increases the passage of permeate through the membrane and overall flux efficiency.

- **Ultrafiltration membranes are capable of separating larger materials such as colloids, particulates, fats, bacteria, and proteins, while allowing sugars, and other low molecular weight molecules to pass through the membrane.**

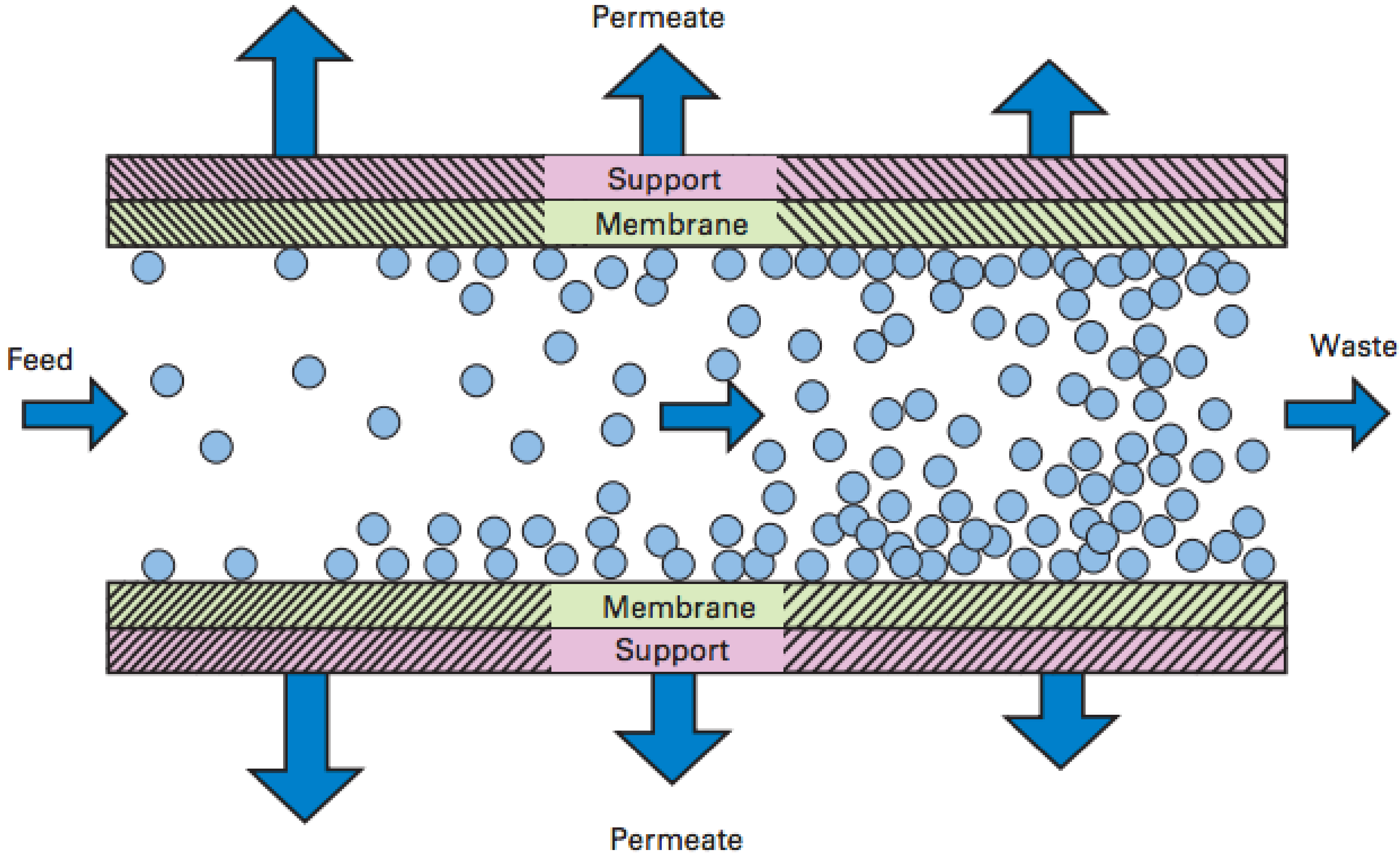
- **With a pore size range between 0.01 to 0.1µm, ultrafiltration membrane pore sizes fall between that of nanofiltration and microfiltration. UF membranes typically operate between 50 – 120 PSI (3.4 – 8.3 bar.**


Ultrafiltration
Water
Salts
Dissolved Organics
Bacteria
Macromolecular Organics
Particles and Silt
Feed Water
Ultrafiltration Membrane
Product Water



Membrane Process Characteristics

Tubular Membrane Filtration Technology.



APPLICATIONS

- 1. In food industry for protein purification, cheese industry for separating milk whey.
- 2. In the automotive industry for paint recovery.
- 3. For removing suspended solids from solution.

- Filtration of effluent from paper pulp mill
- Cheese manufacture, see ultrafiltered milk
- Removal of some bacterias from milk
- Process and waste water treatment
- Enzyme recovery
- Fruit juice concentration and clarification
- Dialysis and other blood treatments
- Desalting and solvent-exchange of proteins .

Biological Oxygen Demand

Biological oxygen demand (**BOD**) is the amount of dissolved **oxygen** (DO) needed (i.e. demanded) by aerobic **biological** organisms to break down organic material present in a given water sample at certain temperature over a specific time period.

Significance of BOD

1) It indicates the pollution level of sewage water or waste water hence it is important in the sewage treatment.
2) BOD values are useful in designing the waste water treatment plants & calculations of waste load.
3) This serves as a measure to assess the quantity of waste which can be safely discharged into the stream.

Chemical Oxygen Demand

The chemical oxygen demand (COD) determines the amount of oxygen required for chemical oxidation of organic matter using a strong chemical oxidant, such as, potassium dichromate under reflux conditions

Significance of COD

This test is widely used to determine:

a) Degree of pollution in water bodies and their self-purification capacity

b) Efficiency of treatment plants

c) Pollution loads, and

d) Provides rough idea of Biochemical oxygen demand (BOD) which can be used to determine sample volume for BOD estimation

COD Process

Most of the organic matters are-destroyed when boiled with a mixture of potassium dichromate and sulphuric acid producing carbon dioxide and water. A sample is refluxed with a known amount of potassium dichromate in sulphuric acid medium and the excess of dichromate is titrated against ferrous ammonium sulphate. The amount of dichromate consumed by organic matter is proportional to the oxygen required to oxidize the oxidizable organic matter.

Chemical Reaction

CnHaObNc+ d $Cr_2O_7{}^{2-}$ + (8d+c) H^+ => nCO_2 +[(a+8d-3c)/2]H_2O+c NH_4 + +2dCr^{3+} (1) Here d= (2n/3) + (a/6)-(b/3)-(c/2)

During experiment, excess dichromate concentration is determined by titrating it with ferrous ammonium sulfate (FAS). The reaction is given by:

$6Fe^{2+} + Cr_2O_7{}^{2-} + 14\ H^+ \Rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$ (2)

DIFFERENCES BETWEEN BOD & COD

BOD	COD
Measures biodegradable organics	Measures biodegradable and non biodegradable organics
Uses oxidizing microorganism	Uses a strong chemical agent
Affected by toxic substance	Not affected
Affected by temperature	Not affected
5 days incubation	2.5 hrs
Accuracy $\pm$ 10%	Accuracy $\pm$ 2%