Membrane Technology

- Membrane separation processes cover an astonishingly wide range of separation, using different types of membranes.

- There are five types of membrane separation processes, for water purification:

  1. Microfiltration
  2. Ultra-filtration
  3. Nano-filtration
  4. Reverse osmosis
  5. Electrochemical separation

- All the separation processes separate solute from solution based on their molecular size.

- All the membrane technologies are essentially separation technologies depending upon size of the constituent to be separated or on the ionic charge or absence of charge, solution diffusion into the matrix or some such transport phenomenon.

- None of the filtration technologies destroy the pollutants.
1. **Microfiltration** This technology is useful in separating suspended particle up to 0.1 micron or above.

2. **Ultra-filtration** this is the size exclusion based pressure driven membrane separation process range of 10-100 Å.

- Typical rejected species or constituents includes sugar, bio-molecules, polymers, colloidal particles and high molecular weight organic substances depending upon their molecular weight, molecular size and also shape.

- These membrane are classified according to their molecular weight cut off (MWCO), which is usually defined as smallest molecular weight species for which membranes have more than 90% rejection.

- Different available configuration of UF membrane are:
  
  i. Flat membrane in plate and frame structure
  
  ii. Tubular
  
  iii. Spirally wound module
  
  iv. Hollow fibre type

Spirally wound module are the most commonly used.
3. **Nanofiltration** The pore size of this membrane is smaller than Ultra Filtration membrane.

- The organic compounds bearing very low molecular weight linear chain structure are rejected while monovalent cations combined with monovalent anions to form compound or salts pass through the permeate.
- The divalent cations or anions do not pass through the permeate. This property of rejection due to ionic charges is made use in the softening of water for the various applications.
- The molecular weight cut for such types of membranes is lower than that of UF membrane.

**Applications of Nanofiltration**

1. Decoloring of effluents and removal of spent mineral acids used to scavenge organics and heavy metal impurities.

2. Heavy metals are rejected preferentially by Nanofiltration membrane, purification of acid and base has become economically possible due to Nanofiltration.

3. Dye factories effluent contains highly concentrated dye, salts and some acids. Nanofiltration can very effectively separate the dye and concentrate it to. This way of concentration and purification reduces the loss for dye thereby effecting a reduction in ETP load.
4. **Reverse osmosis** reverse osmosis is a membrane technology used for separation.

**osmosis:** when more concentrated solution is separated by semi permeable membrane flow of less concentrated solution towards the more concentrated solution takes place due to difference in osmotic pressure of two solution.

- In a typical RO system the solution is first filtered through a rough filter like sand or active carbon, or dual filter etc.
- If solution contains Ca$^{++}$, Mg salts, iron, carbonates, then acid dosing system is introduced.
- The pH is adjusted and the solution is then filter through micro cartridge filter (5-10 micron).
- The pretreated water is then pumped in to the RO tank with a high pressure pump.
- The membrane separates the pollutants in concentrated form in the reject stream and the pure water is collected as a permeate.

**Applications** RO is more useful to separate salts and organic compounds from textile effluents. Some of the wastewater varieties from textile industry that can be treated by RO for recovery of reusable water such as:

1. Rayon industry process wastewater.
2. Textile dyes house effluent. Up to 80% of warm dye house wastewater can be recovered for recycle by RO membrane.
Criteria for designing reverse osmosis treatment system

- Solution based variables: such as suspended solids, dissolved solids (inorganic and organic), microorganisms, sparingly soluble materials, oxidizing chemicals, organic solvents, temperature and pH.
- Minimum pretreatment requirement: such as acid or alkali dosing for pH adjustment and heat exchange for reducing the higher temperature of the solution.
- Membrane variables: Polymer type and module geometry, pressure, flow rate, pressure loss water recovery and concentration level etc.
- Cleaning requirement: the fouling of membrane depend on the extend of pretreatment and module type chosen.

Thus, it is evident that RO can be advantageously used for the treatment of textile wastewater provided the design, pretreatment stringency, operating parameters are strictly adhered to avoid the fouling of membrane modules.
Electrodialysis

- Electrodialysis is an electrochemical separation process in which electrically charged membranes and electrical potential differences are used to separate ionic species from an aqueous solution and other uncharged components.

- The principle of electrodialysis process is that, the arrangement consists of a series of anion and cation exchange membranes arranged in an alternating pattern between an anode and a cathode. The cation pass easily through the negatively charged anion exchange membrane.

- The overall result is an ion concentration increase in alternate components, while other components simultaneously become depleted of ions.

- Ion exchange membrane should have a high selectivity for oppositely charged ions and a high ion permeability.
Enzymatic decolorization

- Commercial azo, triarylmethane, anthraquinonic and indigoid textile dyes are decolorized with enzyme preparation from pleurotus ostreatus, schizophyllum commune etc.
- The substituents on the dyes-benzene ring influence enzyme activity and hydroxyl and amino groups enhance decolorization.
- The presence of lignin peroxidase and or manganese peroxidase in addition to laccase increases decolorization by up to 25%.
Other technologies

**Chemical treatment:** some organic compounds are attacked by chemical reagent such as potassium permanganate, sodium hydroxide, hydrogen peroxide, ozone etc.

For ex. Ozone oxidizes dissolved organic compounds including toxic substances, because of an oxidation potential higher than that of permanganate, hydrogen peroxide or hypochlorite.

**Adsorption:** organic compounds are adsorbed on activated carbon, synthetic resins, specially prepared silica and activated alumina.

**Chemical precipitation:** heavy metals are removed from aqueous waste stream by precipitation in various form (carbonate, hydroxide, sulphide) at different pH values.
Clay treatment

Clays are hydrous alumina silicated. Bentonite material is used as such or after modification for effluent treatment. Due to isomorphous substitution for $M^{3+}$ by $M^{2-}$ and $M^{2+}$ by $M^+$ in its structure, it has unique nature of cation exchange and adsorption capacity. Applicability of these properties is known for long time in decolorizing edible oils, clarification of alcoholic beverages and removal of grease from raw wools.

The modification done by methods classified in three groups:

1. **Acid treated clay:** Acid treated clays are mainly used for decolorizing various minerals, vegetables and animal oils and as catalysts in the cracking process of petroleum refining.

2. **Pillared clay:** Clays are modified by exchange of interlamellar charge balancing cations with polymerichydroxy metal cations of various metals known as pillared clay.

3. **Organo clay:** The organic clays are widely used for decolorizing edible oils, clarification of alcoholic beverages and removal of grease from raw wools.

   i) **Modification by uncharged polar organic compounds**

   ii) **Modification by negatively charged polar organic compounds**

   iii) **Modification by positively charged polar organic compounds**