AERATION:

Aeration removes odour and tastes due to volatile gases like hydrogen sulphide and due to algae and related organisms. Aeration also oxidise iron and manganese, increases dissolved oxygen content in water, removes CO2 and reduces corrosion and removes methane and other flammable gases.

Principle of treatment underlines on the fact that volatile gases in water escape into atmosphere from the air-water interface and atmospheric oxygen takes their place in water, provided the water body can expose itself over a vast surface to the atmosphere. This process continues until an equilibrium is reached depending on the partial pressure of each specific gas in the atmosphere.

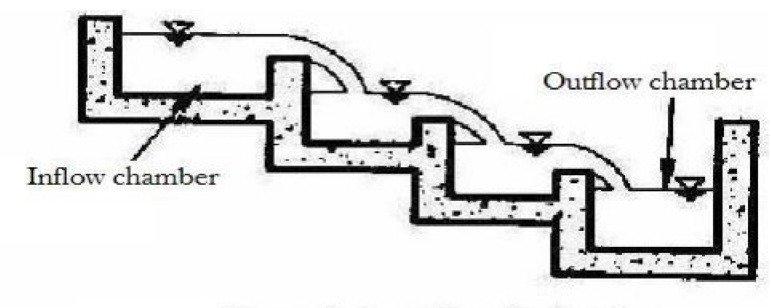
Principle of Aeration

Oxygen uptake depends on the area and duration of contact between water and air. For porous air diffusers this means that the size of the bubbles should be relatively small, since surface area is bigger in proportion to their volume and they rise slower, which gives a longer contact duration.

Types of Aerators

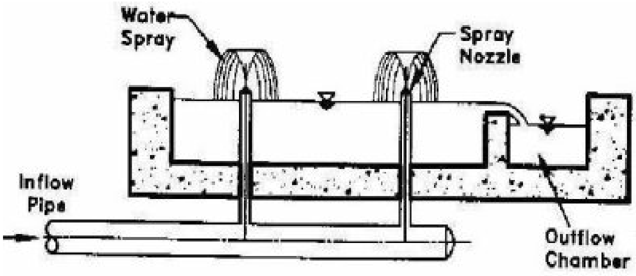
1. Gravity aerators
2. Fountain aerators
3. Diffused aerators
4. Mechanical aerators.

Gr avity Aerators (Cascades): In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by tutbulence.



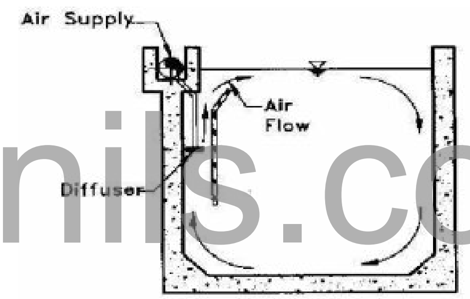
Cascade type Gravity Aerator

Fountain Aerators: These are also known as spray aerators with special nozzles to produce a fine spray. Each nozzle is 2.5 to 4 cm diameter discharging about 18 to 36 l/h. Nozzle spacing should be such that each m3 of water has aerator area of 0.03 to 0.09 m2 for one hour.



Injection or Diffused Aerators :

It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit. The tank depth is kept as 3 to 4 m and tank width is within 1.5 times its depth. If depth is more, the diffusers must be placed at 3 to 4 m depth below water surface. Time of aeration is 10 to 30 min and 0.2 to 0.4 litres of air is required for 1 litre of water.



Mechanical Aerators:

Mixing paddles as in flocculation are used.

Paddles may be either submerged or at the surface.

FUNCTIONS OF AERATORS

1. Aeration brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulfide, and volatile organic chemicals (VOCs). Aeration is often the first major process at the treatment plant. During aeration, constituents are removed or modified before they can interfere with the treatment processes.

2. Aeration brings water and air in close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air (the smaller the bubble, the better) and letting them rise through the water. The scrubbing process caused by the turbulence of aeration physically removes dissolved gases from solution and allows them to escape into the surrounding air.

3. Aeration also helps remove dissolved metals through oxidation, the chemical combination of oxygen from the air with certain undesirable metals in the water. Once oxidized, these chemicals fall out of solution and become particles in the water and can be removed by filtration or flotation.

4. Oxygen is added to water through aeration and can increase the palpability of water by removing the flat taste. The amount of oxygen the water can hold depends primarily on the temperature of the water. (The colder the water, the more oxygen the water can hold).

5. Water that contains excessive amounts of oxygen can become very corrosive. Excessive oxygen can also cause problems in the treatment plant i.e. air binding of filters.

Removal of colour, odour and taste from water:

Aeration:

Aeration is a process in which water is brought in intimate contact with atmospheric air to promote exchange of gases between water and atmospheric air.

(i) oxygen from atmospheric air is absorbed by water thereby oxygen deficiency of water is eliminated and also freshness is imparted to water.

(ii) Carbon dioxide, hydrogen sulphide and other volatile substances imparting taste and odour to water are easily expelled by aeration.

(iii) Iron and manganese present in water are oxidized to certain extent by aeration.

The following four types of aerators are generally adopted for aeration in the treatment of water:

Diffused Air Aerators:

A diffused air aerator consists of a tank or basin in which at the bottom perforated pipes are provided. The water to be aerated is filled in the tank and compressed air is blown through the perforated pipes. The air bubbles emerging from the perforations rise up from the bottom of the tank. While rising up the air bubbles come in close contact with water contained in the tank, and aeration of water is thus achieved. The tanks are generally 3 to 4.5 m deep and 3 to 9 m wide.

Cascade Aerators:

In cascade aerators water is allowed to flow downwards after spreading over inclined thin sheets and the turbulence is created by allowing water to pass through a series of steps or baffles. The number of steps is usually 4 to 6. Water is allowed to fall through a height of about 1 to 3 m. In this case removal of gas varies from 20 to 45 percent of carbon dioxide and about 35 percent of hydrogen sulphide.

Spray Aerators:

In spray aerators water is sprayed through nozzles upwards into atmosphere and broken up into either a mist of droplets. The installation consists of fixed nozzles on a pipe grid and trays for collecting the sprayed water. Nozzles usually have diameters varying from 10 to 40 mm spaced at intervals of 0.5 to 1 m or more. The pressure required at the nozzle head is usually 7m of water but it may vary from 2 to 9 m of water. The discharge rating per nozzle varies from 18to36 m^3/hour.

Multiple Tray Aerators:

A water-fall or multiple tray aerators consists of a number of trays with perforated bottoms, arranged vertically in series. Water flowing through a riser pipe is discharged through perforated pipes into the top most trays and after flowing down through each of the lower trays, it is collected in a basin provided at the base. During the downward flow through trays water comes in contact with atmospheric air and thus aeration takes place. Usually trays about 4 to 9 in number with spacing of 300 to 750 mm are provided. In most aerators coarse media such as coke, stone or ceramic balls ranging from 50 to 150 mm in diameter are placed in the trays to increase the efficiency of aeration.

Treatment by Activated Carbon:

Activated carbon is used to remove colour, taste and odour from water. Activated carbon is produced by heating a carbonaceous material such as coke, charcoal, paper mill waste, saw dust, lignite, etc., in a closed vessel at a high temperature. It is then activated or oxidised by passing air, steam, carbon dioxide, chlorine or flue gases. The activation of the carbonaceous materials removes the hydrocarbons which might interfere with the adsorption of organic matter.

The activated carbon is available in various trade names such as Darco, Nuchar and Minchar. It is available in granular as well as powder form. The grains are of 6 mm size and below. Its weight is 4 kN per m and it is highly porous in structure. Activated carbon removes organic contaminants from water by the process of adsorption. In adsorption high surface area is the prime consideration. Granular activated carbons typically have surface areas of 500- 1400m /gm.

Activated carbon treatment has the following advantages:

(i) It helps the process of coagulation, if adopted before filtration of water.

(ii) It reduces the chlorine demand of treated water.

(iii) It removes tastes, odours and colours caused by the presence of excess chlorine, hydrogen sulphide, phenol, iron, manganese, etc.

(iv) It removes organic matter present in water.

(v) It is effective in preventing or retarding the decomposition of sludge in settling basins.

(vi) Its overdose is harmless.

Use of Copper Sulphate:

Copper sulphate $CuSO_4$ is used to serve the following two purposes:

(i) Removal of colour, odour and taste from water.

(ii) Control the growth of algae, bacteria and some types of aquatic weeds.

Water softening:

Water softening is the process of removing hardness. Hardness is defined as the water"s ability to consume soap. Besides making water more pleasing for washing purposes, softening water can also provide benefits of preventing encrustation and scaling inside boilers, water heaters, hot-water lines, as well as some industrial processes. Hardness is usually expressed in terms of "ppm as CaCO3", or ppm as calcium carbonate.
The home water softener industry usually measures hardness in the form of grains per gallon, of which 1 gpg equals about 17 ppm hardness. The terms, "hard water" and "soft water" are used loosely, as there are no accepted standards or "measuring scale" to determine if water is soft or hard.
The primary constituents in water that cause hardness are calcium (Ca) and magnesium (Mg), especially calcium. Iron (Fe) and manganese (Mn) can also promote to water hardness, but typically at a much lesser degree. Hardness caused by calcium and manganese is typically carbonate hardness, for the calcium and manganese exists in the water in the form of calcium bicarbonate, Ca(HCO3)2, and magnesium bicarbonate, Mg(HCO3)2. This form of hardness is usually referred to as carbonate hardness, or temporary hardness. On the other hand, the sulfate, chloride and nitrate salts of calcium are usually referred to as permanent hardness, since they cannot be readily precipitated. Water heaters suffer from hard water because when water containing calcium bicarbonate is heated, the insoluble carbonate form of calcium will be precipitated.
It is a property of water, which prevents the lathering of the soap. Hardness is of two types.
1. Temporary hardness: It is caused due to the presence of carbonates and sulphates of calcium and magnesium. It is removed by boiling.
2. Permanent hardness: It is caused due to the presence of chlorides and nitrates of calcium and magnesium. It is removed by zeolite method.
Hardness is usually expressed in gm/liter or p.p.m. of calcium carbonate in water.
Hardness of water is determined by EDTA method. For potable water hardness ranges from 5 to 8 degrees.

Temporary hardness removal methods:

Boiling of Water:
Calcium carbonate – slightly soluble in water – present in the form Calcium bicarbonate because, it easily dissolves in water containing CO2.

Ca(HCO3)2 + Heat CaCO3 + CO2 + H2O

Addition of Lime (CaO):
Hydrated lime [Ca(OH)2] is added to water

$MgCO_3 + Ca(OH)_2\ Mg(OH)_2 + CaCO_3$

$Mg(HCO_3)_2 + Ca(OH)_2\ Ca(HCO_3)_2 + Mg(OH)_2$

$$Ca(HCO_3)_2 + Ca(OH)_2 \ 2CaCO_3 + 2H_2O$$

Suitable only for Temporary hardness removal process.

Permanent hardness removal methods

1. Lime-Soda process
2. Base-Exchange process, generally called *Zeolite process*
3. Demineralization process

1. Lime-Soda process

Lime soda process is a method of softening hard water. This process is now obsolete but was very useful for the treatment of large volumes of hard water. In this process Calcium and Magnesium ions are precipitated by the addition of lime ($Ca(OH)_2$) and soda ash (Na_2CO_3).

Chemistry of Lime Soda Process:

Lime addition removes only magnesium hardness and calcium carbonate hardness. In equation 5 magnesium is precipitated, however, an equivalent amount of calcium is added. The water now contains the original calcium noncarbonate hardness and the calcium non-carbonate hardness produced in equation 5. Soda ash is added to remove calcium non-carbonate hardness:

$Na_2CO_3 + CaSO_4$ -------- $Na_2SO_4 + CaCO_3$

Limitations of Lime Soda Process

Lime soda softening cannot produce a water at completely free of hardness because of minute solubility of $CaCO_3$ and Mg $(OH)_2$. Thus the minimum calcium hardness can be achieved is about 30 mg/L as $CaCO_3$, and the magnesium hardness is about 10 mg/L as $CaCO_3$.

We normally tolerate a final total hardness on the order of 75 to 120 mg/L as $CaCO_3$, but the magnesium content should not exceed 40 mg/L as $CaCO_3$.

2. Base-Exchange process, generally called *Zeolite process*

Zeolite or Base-Exchange or Cation exchange process

Zeolites are of two types:

1. Natural zeolite : Natural zeolite are non-porous. for example,natrolite ,$Na_2O.Al_2O_3.xSiO_2.yH_2O$.
2. Synthtic zeolite : Synthtic zeolite are porous and posses get structure. They are prepared by heating together china clay,feldspar and soda ash. Such zeolites possess higher exchange capacity per unit weight than natural zeolites.

Zeolite – termed as *Green sand* – $Na_2O\ Al_2O_3\ x.SiO_2\ y.H_2O$

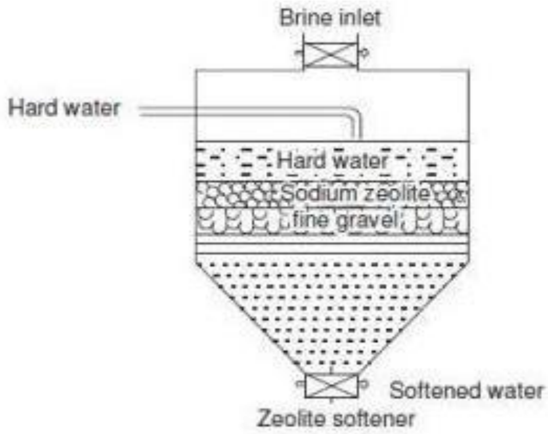
Zeolite or Resins have excellent property of exchanging their cations and hence during softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard water.

Used as filter media in sand filter (Zeolite sand bed)

• When Sodium is replaced by Calcium & Magnesium – backwashing is done – Again brine is added to regenerated the filter bed – excess brine is removed by back washing with water

• Filters – Gravity or Pressure (more common)

• Rate of filtration: 300 l/m2/min



• Zeolite process results in *Zero hardness* – not suitable for public supplies – small amount is processed and mixed with un softened water to obtain standard limits.

Iron and manganese removal:

Iron and manganese control is the most common type of municipal water treatment. Iron and manganese occur naturally in groundwater. These elements are in fact, essential to the human diet. Water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a"rusty" taste and look to the water. Surface water generally does not contain large amounts of iron or manganese, but iron and manganese are found frequently in water systems that use ground water. Iron In drinking water is 0.3 parts per million (ppm) and 0.05 ppm for manganese.

• Iron and manganese minerals are found in soil and rock.

• Iron and manganese can dissolve into groundwater as it percolates through the soil and rock.

• more than 0.3 mg/l of iron will cause yellow to reddish-brown stains of plumbing fixtures or almost anything that it contacts.

• Manganese even at levels as low as 0.1 mg/l, will cause blackish staining of fixtures and anything else it contacts.

• If the water contains both iron and manganese, staining could vary from dark brown to black.

• Iron and manganese in well waters occur as soluble ferrous and manganous bicarbonate.

IRON AND MANGANESE REMOVAL BY AERATION:

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Iron and Manganese Removal by Filtration:

Removing iron and manganese from drinking water instead of sequestration it is recommended if the water contains over 0.3 ppm of iron or 0.05 ppm of manganese. These elements can be removed during softening with lime, but most commonly iron and manganese is removed by filtration after oxidation (with air, potassium permanganate, or chlorine).

Gravity and pressure filters are both used, with pressure filters being the more popular.

The operator should frequently check to see that all the iron in the water entering the filter has been converted to the ferric (or insoluble particulate) state. The operator collects a water sample, passes it through a filter paper, and runs an iron test on the clean, filtered water (filtrate).

If no iron is present, it has all been oxidized and is being removed in the filtration process. If iron is found in the filtrate, oxidation has not been complete and some of the iron will pass through the filter and end up in the treated water. In this case, the operator should consider adjustments to the oxidation process.

Most iron removal filters are designed so that the filters are backwashed based on head-loss on the filter. If iron breakthrough is a problem, the filters will have to be backwashed more frequently. Accurate records will reveal when breakthrough is expected so that the operator can backwash before it is likely to occur.

Desalination:

Desalination is a process that extracts minerals from saline water. More generally, desalination refers to the removal of salts and minerals from a target substance, as in soil desalination, which is an issue for agriculture. Water is one of the earth's most abundant resources, covering about three-quarters of the planet's surface. The reason for this apparent contradiction is, of course, that 97.5% of the earth's water is salt water in the oceans and only 2.5% is fresh water in groundwater, lakes and rivers and this supplies most human and animal needs. The process of removing dissolved salts from water, thus producing fresh water from seawater or brackish water.

Methods of Desalination

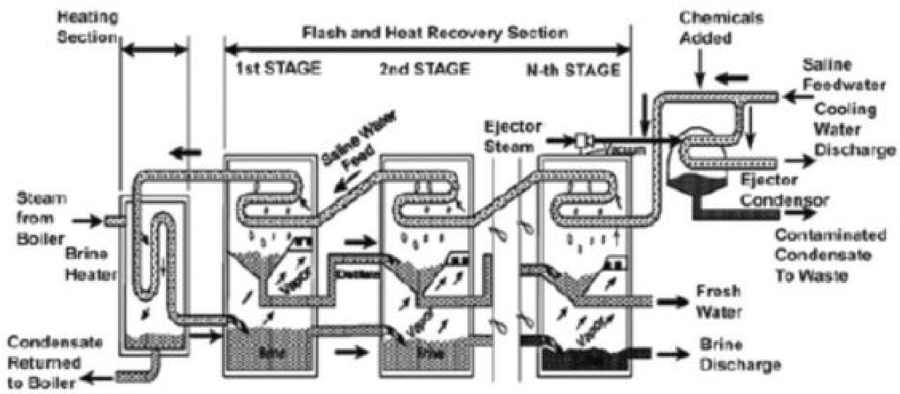
1. Desalination by evaporation & distillation
2. Electro dialysis method
3. Reverse Osmosis method
4. Freezing process
5. Solar distillation method

1. Desalination by evaporation & distillation:

Thermal desalination, often called distillation, is one of the most Thermal most ancient ways of treating seawater and brackish water to convert them ancient them into potable water. It is based on the principles of boiling or into or evaporation and condensation. Water is heated until it reaches the evaporation the evaporation state. The salt is left behind while the vapor is evaporation condensed to produce fresh water.

In this process, the liquids are separated by evaporating and capturing them at various points in their cooling cycle, and then immediately channeled into a condenser.

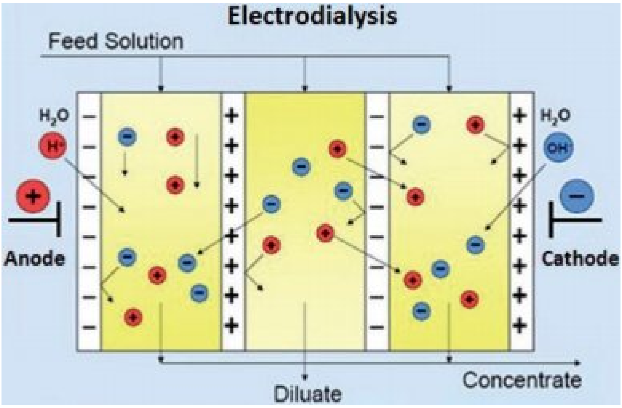
•Simple distillation is used for a mixture in which the boiling point of the components differ by at least 158°F (70°C).



•It is also followed for the mixtures contaminated with nonvolatile particles (solid or oil), and those that are nearly pure with less than 10 percent contamination.

2. Electro dialysis method:

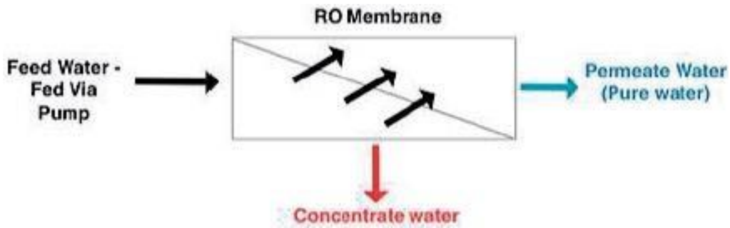
Electrodialysis desalination process is in some way similar to "ion exchange"treatment process, but it differs in utilizing both cation and anion selective membranes to separate charged ions.
Electrodialysis (ED) is used to transport salt ions from one solution through ion-exchange membranes to another solution under the influence of an applied electric potential difference.



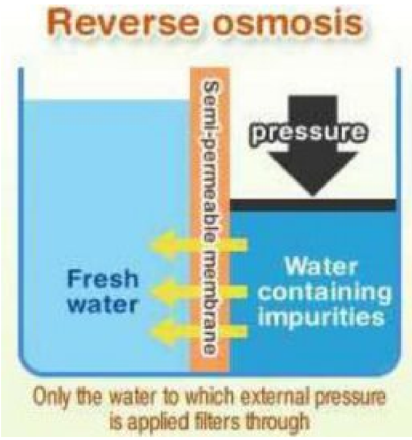
Water is handed between a negative electrode and a high-quality electrode. Ion exchange membranes permit solely high-quality ions to transfer toward the negative electrode from the feed water and negative ions to the positive electrode.

3. Reverse Osmosis method:

Reverse osmosis (RO) membrane is known as hyper filtration and is the supreme filtration known. Reverse osmosis allows the removal of small particles and dissolved organic matter. It is also employed to purify different fluids including glycol and ethanol, rejecting other ions and contaminants preventing them from passing through the membrane. Reverse osmosis is commonly used in water treatment.



Reverse osmosis membrane is a semipermeable membrane allowing fluid that is to be purified to permit through the membrane and rejecting contaminants in the reject stream. Most reverse osmosis systems use cross flow mechanism to decrease membrane cleaning periods. As the fluid flows through the reverse osmosis membranes, the downstream, remove the reject away from in concentrated reject water (brine).



When a semipermeable membrane is used to separate two water (or other solvent) volumes, water is going to flow from the low solute concentration side to the high solute concentration side. By applying an external pressure on the higher concentration side, the flow could be stopped or reversed. In such a case, the phenomenon is called "reverse osmosis." If there are solute molecules only on one side of the system, then the pressure that stops the flow is called the osmotic pressure. The movement of a "solute molecule" within a solvent is over damped by the solvent molecules that surround it.

4. Freezing process:

The basic principles of freezing desalination are simple. During the process of freezing, dissolved salts are excluded during the formation of ice crystals. Seawater can be desalinated by cooling the water to form crystals under controlled conditions. Before the entire mass of water has been frozen, the mixture is usually washed and rinsed to remove the salts in the remaining water or adhering to the ice crystals. The ice is then melted to produce fresh water.

Advantages and disadvantages:

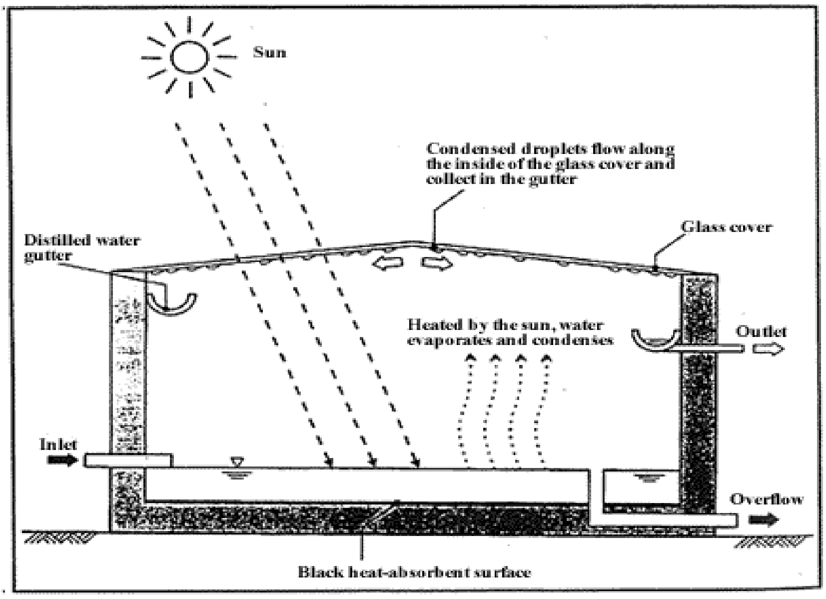
The advantages include a lower theoretical energy requirement, minimal potential for corrosion and little scaling or salt precipitation.

It can produce very pure potable water, and it has special advantages to produce water for irrigation.

The disadvantage is that it involves handling ice and water mixtures that are mechanically complicated to move and process

5. Solar distillation method:

Solar desalination using humidification and dehumidification is a promising technique for producing fresh water, especially in remote and sunny regions. It has the potential to make a significant contribution to providing humans with fresh water using a renewable, free and environmentally friendly energy source.Solar energy can be used to convert saline water into fresh water with simple, low cost and economical technology and thus it is suitable for small communities, rural areas and areas where the income level is very low.


Sun
Condensed droplets flow along the inside of the glass cover and collect in the gutter
Glass cover
Distilled water gutter
Heated by the sun, water evaporates and condenses
Outlet
Inlet
Overflow
Black heat-absorbent surface

Membrane Processes:

Membrane Processes are becoming popular because they are considered "Green" technology - no chemicals are used in the process. A membrane is a selective barrier that permits the separation of certain species in a fluid by combination of sieving and diffusion mechanisms. Membranes can separate particles and molecules and over a wide particle size range and molecular weights.

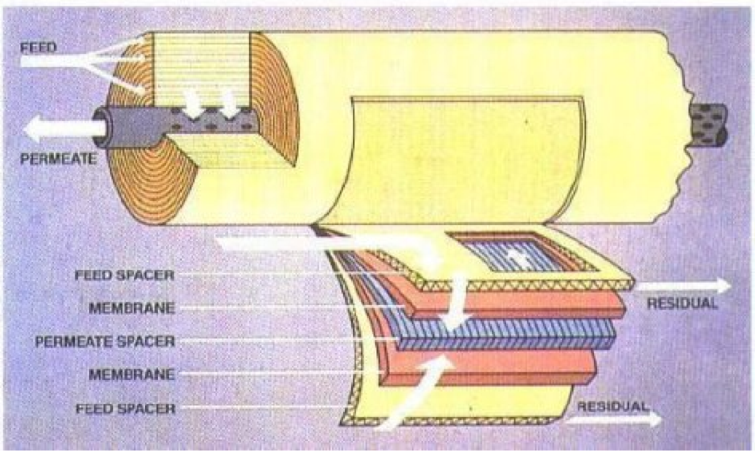
Four common types of membranes:
•Reverse Osmosis
•Nano filtration
•Ultra filtration
•Micro filtration

The R.O. membrane is semi-permeable with thin layer of annealed material supported on a more porous sub-structure.
• The thin skin is about 0.25 micron thick and has pore size in the 5 – 10 Angstrom range.
•The porous sub-structure is primarily to support the thin skin. The pore size of the skin limits transport to certain size molecules.
•Dissolved ions such as Na and Cl are about the same size as water molecules.

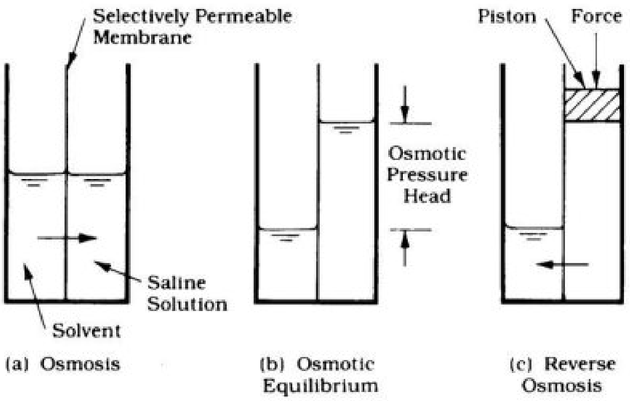
However, the charged ions seem to be repelled by the active portion of the membrane and water is attracted to it.
•So adsorbed water will block the passage and exclude ions.
• Under pressure attached water will be transferred through the pores.

Nanofiltration is a complementary process to reverse osmosis, where divalent cations and anions are preferentially rejected over the monovalent cations and anions.
•Some organics with MW > 100 -500 are removed There is an osmotic pressure developed but it is less than that of the R.O. process.
•Microfiltration and Ultrafiltration are essentially membrane processes that rely on pure straining through porosity in the membranes.
•Pressure required is lower than R.O. and due entirely to frictional headloss

Spiral-Wound Membrane Element



If clean water and water with some concentration of solute are separated by a semi-permeable membrane (permeable to only water) water will be transported across the membrane until increases hydrostatic pressure on the solute side will force the proces to stop.



The osmotic pressure head (at equilibrium) can be calculated from thermodynamics.The chemical potential (Gibbs frees energy per mole) of the solvent and the solute(s) in any phase can be described as:

Applications of Micro- and Ultrafiltration Conventional water treatment (replace all processes except disinfection).
•Pretreat water for R.O and nanofiltration.
•Iron/Manganese removal (after oxidation).
Applications for R.O. and nanofiltration:
•R.O. application mostly desalination.
•Nanofiltration first developed to remove hardness.

Comparison of Membrane process:

Ultrafiltration	Reverse Osmosis	Microfiltration
Operates on difficult colloidal water	Requires extensive pre-treatment of colloids	Rapidly fouled by colloids giving high replacement costs
Low pressure (2-6 bar)	High pressure (10-30 bar)	Low pressure (2-4 bar)
Low energy consumption	High energy	Low energy
High recovery (up to 95%)	Low recovery (50-80%)	100% recovery
Chemical tolerance pH 1-13	pH 2-11	pH 1-13
High temperature up to 80°C	45°C max.	High temperatures possible
High resistance to oxidising agents	Limited resistance to oxidising agents	High resistance to oxidising agents
Stream sterilisable membranes available	Stream sterilisation not possible	Stream sterilisation possible
Hygienic module designs available	Modules not as hygienic	Hygienic designs available

Construction, Operation and Maintenance Aspects of water treatment plant:

Construction aspect:

- Must follow building code of practice when installing
- Use of materials is also need to followed as per standards
- Proper material and workmanship
- Pipe diameter, threads, wall thickness, pressure class, corrosion protection, hoop stress, buried depth, surge protection, thrust restraint, pipe bedding, and jointing should all be considered.

O & M aspect:

Tasks can be broken down into daily, weekly, monthly, and seasonal repeats.

Daily Tasks:

- Check water meter readings and record water use.
- Check and record water level indicators in reservoir/storage tanks.
- Check and record chlorine level in the distribution system.
- Inspect chemical feed pumps for proper operation.
- Inspect well pumps, motors, pressure gauges, and controls. Record well pump running times and pump cycle starts.
- Record and investigate customer complaints.
- Inspect heater operation during winter months.

Weekly Tasks

- Inspect chlorine testing equipment.
- Check chemical solution tanks and record use.
- Clean pump house and grounds.
- Make sure fire hydrants are accessible.
- Record pumping rate for each well or source water pump.
- Inspect pump house plumbing for leaks.
- Take bacteriological sample in for testing
  (required testing frequency may vary -- check with your local health authority).

Monthly, Seasonal, or Annual Tasks

- Take and record electrical meter readings at pump house.
- Inspect well head or intake structure.
- Inspect reservoir.