Membrane technology covers all engineering approaches for the transport of substances between two fractions with the help of permeable membranes. In general, mechanical separation processes for separating gaseous or liquid streams use membrane technology.

Membrane separation processes operate without heating and therefore use less energy than conventional thermal separation processes such as distillation, sublimation or crystallization. The separation process is purely physical and both fractions (permeate and retentate) can be used. Cold separation using membrane technology is widely used in the food technology, biotechnology and pharmaceutical industries. Furthermore, using membranes enables separations to take place that would be impossible using thermal separation methods. Important technical applications include the production of drinking water by reverse osmosis, filtrations in the food industry, the recovery of organic vapours such as petro-chemical vapour, recovery and the electrolysis for chlorine production.

In waste water treatment, membrane technology is becoming increasingly important. With the help of UF and MF (Ultra/Microfiltration) it is possible to remove particles, colloids and macromolecules, so that waste-water can be disinfected in this way. This is needed if waste-water is discharged into sensitive waters especially those designated for contact water-sports and recreation. About half of the market is in medical applications such as use in artificial kidneys to remove toxic substances by hemodialysis and as artificial lung for bubble-free supply of oxygen in the blood.

MEMBRANES

A **membrane** is a thin, film-like structure that separates two fluids. It acts as a selective barrier, allowing some particles or chemicals to pass through, but not others. In some cases, especially in anatomy, membrane may refer to a thin film that is primarily a separating structure rather than a selective barrier.

A membrane is a layer of material which serves as a selective barrier between two phases and is impermeable to specific particles, molecules, or substances when exposed to the action of a driving force. Some components are allowed passage by the membrane into a permeate stream, whereas others are retained by it and accumulate in the retentate stream.

Membranes can be of various thickness, with homogeneous or heterogeneous structure. Membrane can also be classified according to their pore diameter. According to IUPAC, there are three different types of pore size classifications: microporous (dp < 2 nm), mesoporous (2 nm < dp < 50 nm) and macroporous (dp > 50 nm).[3] Membranes can be neutral or charged, and particles transport can be active or passive. The latter can be facilitated by pressure, concentration, chemical or electrical gradients of the membrane process. Membranes can be generally classified into synthetic membranes and biological membranes

SEMIPERMEABLE MEMBRANE

A semipermeable membrane, also termed a selectively permeable membrane, a partially permeable membrane or a differentially permeable membrane, is a membrane that will allow certain molecules or ions to pass through it by diffusion and occasionally specialized "facilitated diffusion".

The rate of passage depends on the pressure, concentration, and temperature of the molecules or solutes on either side, as well as the permeability of the membrane to each solute. Depending on the membrane and the solute, permeability may depend on solute size, solubility, properties, or chemistry. Many natural and synthetic materials thicker than a membrane are also semipermeable. One example of this is the thin film on the inside of an egg.

In the process of reverse osmosis, thin film composite membranes (TFC or TFM) are used. These are semipermeable membranes manufactured principally for use in water purification or desalination systems. They also have use in chemical applications such as batteries and fuel cells. In essence, a TFC material is a molecular sieve constructed in the form of a film from two or more layered materials.

Membranes used in reverse osmosis are, in general, made out of polyamide, chosen primarily for its permeability to water and relative impermeability to various dissolved impurities including salt ions and other small molecules that cannot be filtered. Another example of a semipermeable membrane is dialysis tubing. The diffusion of water through a selectively permeable membrane is called osmosis.

According to driving force of the operation it is possible to distinguish:

Pressure driven operations

- microfiltration
- ultrafiltration
- nanofiltration
- reverse osmosis

FILTRATION

Filtration is a process of removing particulate matter from water by forcing the water through a porous media. This porous media can be natural, in the case of sand, gravel and clay, or it can be a membrane wall made of various materials. Sometimes, large particles are settled before filtration; this is called sedimentation.

MICROFILTRATION

Microfiltration is a membrane technical filtration process which removes contaminants from a fluid (liquid & gas) by passage through a microporous membrane. A typical microfiltration membrane pore size range is 0.1 to 10 micrometres (µm). Microfiltration is fundamentally different from reverse osmosis and nanofiltration because those systems use pressure as a means of forcing water to go from low pressure to high pressure. Microfiltration can use a pressurized system but it does not need to include pressure

ULTRA FILTRATION

An ultrafiltration filter has a pore size around 0.01 micron. A microfiltration filter has a pore size around 0.1 micron, so when water undergoes microfiltration, many microorganisms are removed, but viruses remain in the water. Ultrafiltration would remove these larger particles, and may remove some viruses. Neither microfiltration nor ultrafiltration can remove dissolved substances unless they are first adsorbed (with activated carbon) or coagulated (with alum or iron salts). Ultrafiltration is a selective fractionation process utilizing pressures up to 145 psi (10 bar). It concentrates suspended solids and solutes of molecular weight greater than 1,000. The permeate contains low-molecular-weight organic solutes and salts. UF is widely used in the fractionation of milk and whey, and also finds application in protein fractionation.

NANOFILTRATION

A nanofiltration filter has a pore size around 0.001 micron. Nanofiltration removes most organic molecules, nearly all viruses, most of the natural organic matter and a range of salts. Nanofiltration removes divalent ions, which make water hard, so nanofiltration is often used to soften hard water. Nanofiltration is a special process selected when RO and UF are not the ideal choice for separation. NF can perform separation applications that are not otherwise economically feasible, such as demineralization, color removal, and desalination. In concentration of organic solutes, suspended solids, and polyvalent ions, the permeate contains monovalent ions and low-molecular-weight organic solutions like alcohol.

Some typical applications for Nanofiltration are:

- Desalination of food, dairy and beverage products or byproducts
- Partial Desalination of whey, UF permeate or retentate as required
- Desalination of dyes and optical brighteners
- Purification of spent clean-in-place (CIP) chemicals
- Color reduction or manipulation of food products
- Concentration of food, dairy and beverage products or byproducts
- Fermentation byproduct concentration.

REVERSE OSMOSIS

Reverse osmosis filters have a pore size around 0.0001 micron. After water passes through a reverse osmosis filter, it is essentially pure water. In addition to removing all organic molecules and viruses, reverse osmosis also removes most minerals that are present in the water. Reverse osmosis removes monovalent ions, which means that it desalinates the water. To understand how reverse osmosis works, it is helpful to understand osmosis. Reverse osmosis is a high-pressure, energy-efficient technique for dewatering process streams, concentrating low-molecular-weight substances in solution, or purifying wastewater. It has the ability to concentrate all dissolved and suspended solids. The permeate contains a very low concentration of dissolved solids. RO is widely used in the desalination of seawater.

Osmosis occurs when a semi-permeable membrane separates two salt solutions of different concentrations. The water will migrate from the weaker solution to the stronger solution, until the two solutions are of the same concentration, because the semi-permeable membrane allows the water to pass through, but not the salt. In the following diagram, (A) and (B) illustrate the process of osmosis.

In reverse osmosis, the two solutions are still separated by a semi-permeable membrane, but pressure is applied to reverse the natural flow of the water. This forces the water to move from the more concentrated solution to the weaker. Thus, the contaminants end up on one side of the semi-permeable membrane and the pure water is on the other side. In the diagram below, reverse osmosis is represented in (C).

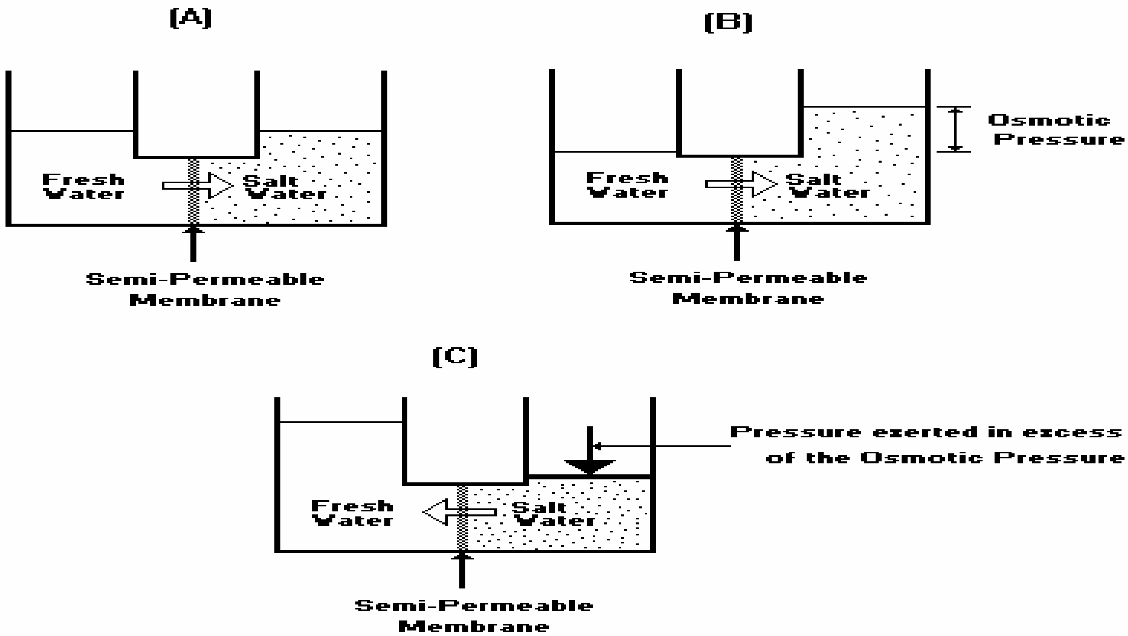
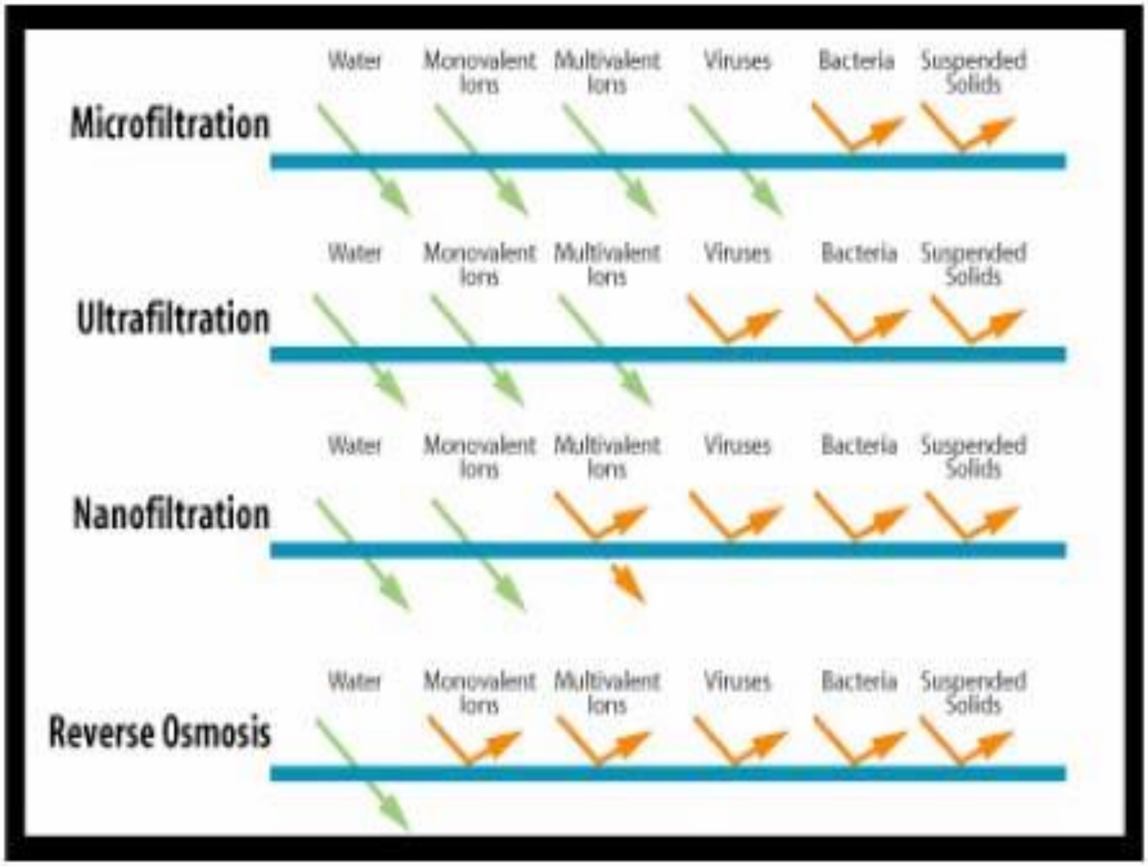


Figure 1 - Osmosis/Reverse Osmosis

WHAT DO THESE PROCESSES REMOVE

Ultrafiltration removes bacteria, protozoa and some viruses from the water. Nanofiltration removes these microbes, as well as most natural organic matter and some natural minerals, especially divalent ions which cause hard water. Nanofiltration, however, does not remove dissolved compounds. Reverse osmosis removes turbidity, including microbes and virtually all dissolved substances. However, while reverse osmosis removes many harmful minerals, such as salt and lead, it also removes some healthy minerals, such as calcium and magnesium. This is why water that is treated by reverse osmosis benefits by going through a magnesium and calcium mineral bed. This adds calcium and magnesium to the water, while also increasing the pH and decreasing the corrosive potential of the water. Corrosive water may leach lead and copper from distribution systems and household water pipes.



Membrane Process Characteristics