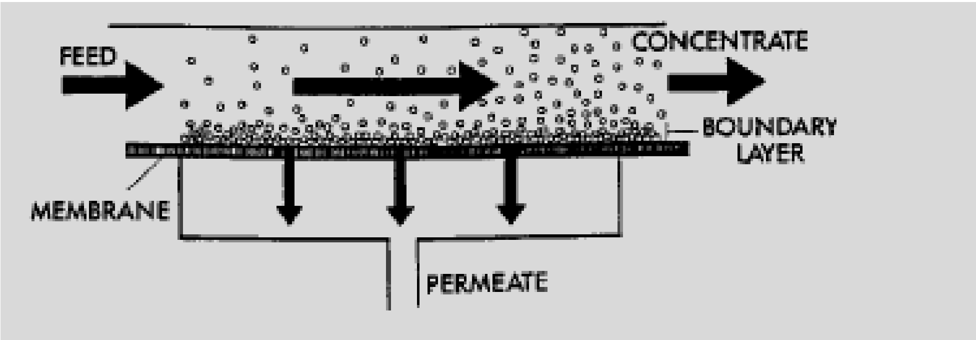
Figure 1.1 Crossflow membrane filtration



There are four general categories of crossflow membrane filtration: microfiltration, ultrafiltration, nanofiltration, and Reverse Osmosis.

Microfiltration (MF) Microfiltration removes particles in the range of approximately 0.1 to 1 micron. In general, suspended particles and large colloids are rejected while macromolecules and dissolved solids pass through the MF membrane. Applications include removal of bacteria, flocculated materials, or TSS (total suspended solids). Transmembrane pressures are typically 10 psi (0.7 bar).

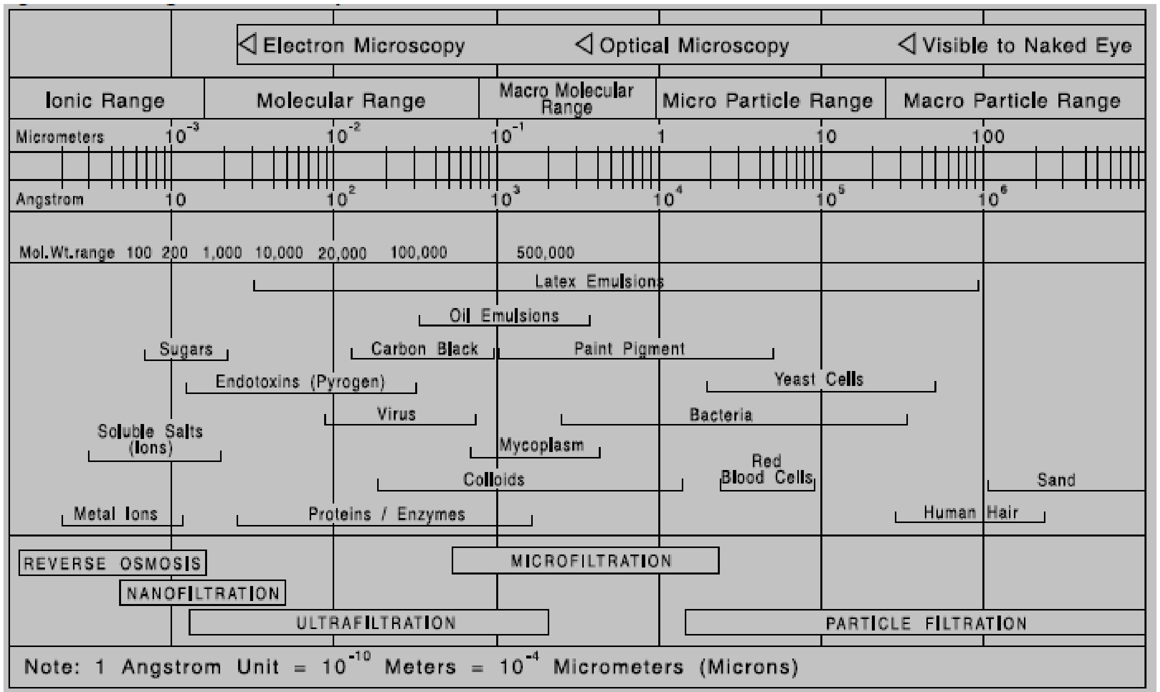
Ultrafiltration (UF) Ultrafiltration provides macro-molecular separation for particles in the 20 to 1,000 Angstrom range (up to 0.1 micron). All dissolved salts and smaller molecules pass through the membrane. Items rejected by the membrane include colloids, proteins, microbiological contaminants, and large organic molecules. Most UF membranes have molecular weight cut-off values between 1,000 and 100,000. Transmembrane pressures are typically 15 to 100 psi (1 to 7 bar).

Nanofiltration (NF) Nanofiltration refers to a speciality membrane process which rejects particles in the approximate size range of 1 nanometer (10 Angstroms), hence the term “nanofiltration.” NF operates in the realm between UF and reverse osmosis. Organic molecules with molecular weights greater than 200-400 are rejected. Also, dissolved salts are rejected in the range of 20- 98%. Salts which have monovalent anions (e.g. sodium chloride or calcium chloride) have rejections of 20-80%, whereas salts with divalent anions (e.g. magnesium sulfate) have higher rejections of 90-98%. Typical applications include removal of color and total organic carbon (TOC) from surface water, removal of hardness or radium from well water, overall reduction of total dissolved solids (TDS), and the separation of organic from inorganic matter in specialty food and wastewater applications. Transmembrane pressures are typically 50 to 225 psi (3.5 to 16 bar).

Reverse Osmosis (RO) Reverse osmosis is the finest level of filtration available. The RO membrane acts as a barrier to all dissolved salts and inorganic molecules, as well as organic molecules with a molecular weight greater than approximately 100. Water molecules, on the other hand, pass freely through the membrane creating a purified product stream. Rejection of dissolved salts is typically 95% to greater than 99%. The applications for RO are numerous and varied, and include desalination of seawater or brackish water for drinking purposes, wastewater recovery, food and beverage processing, biomedical separations, purification of home drinking water and industrial process water. Also, RO is often used in the production of ultrapure water for use in the semiconductor industry, power industry (boiler feed water), and medical/laboratory applications. Utilizing RO prior to ion exchange (IX) dramatically reduces operating costs and regeneration frequency of the IX system. Trans membrane pressures for RO typically range from 75 psig (5 bar) for brackish water to greater than 1,200 psig (84 bar) for seawater.

The normal range of filtration processes is shown in Figure 1.3.

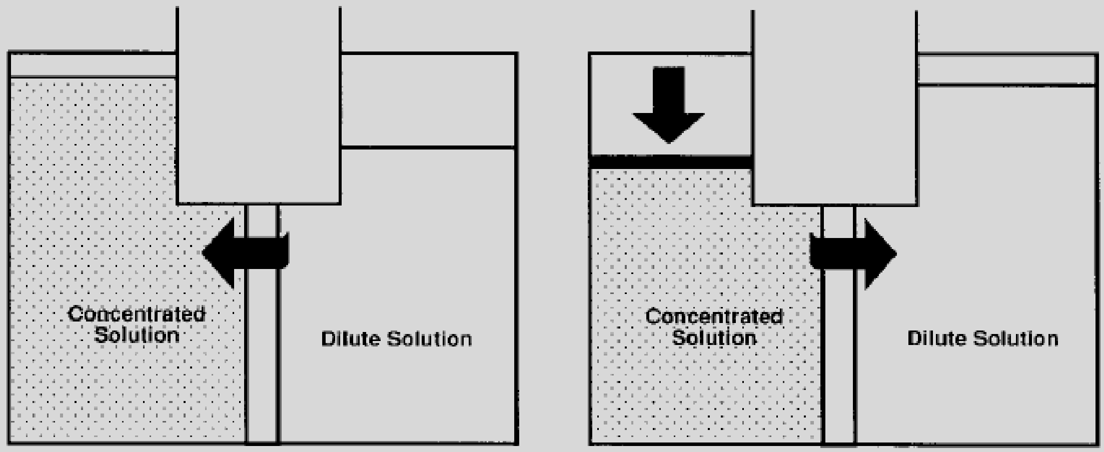
Figure 1.2 Ranges of filtration processes



How Reverse Osmosis Works

The phenomenon of osmosis occurs when pure water flows from a dilute saline solution through a membrane into a higher concentrated saline solution. The phenomenon of osmosis is illustrated in Figure 1.4. A semi-permeable membrane is placed between two compartments. “Semi-permeable” means that the membrane is permeable to some species, and not permeable to others. Assume that this membrane is permeable to water, but not to salt. Then, place a salt solution in one compartment and pure water in the other compartment. The membrane will allow water to permeate through it to either side. But salt cannot pass through the membrane.

Figure 1.3 Overview of osmosis



Osmosis

Water diffuses through a semi-permeable membrane toward region of higher concentration to equalize solution strength. Ultimate height difference between columns is "osmotic" pressure.

Reverse Osmosis

Applied pressure in excess of osmotic pressure reverses water flow direction. Hence the term "reverse osmosis".

How to Use Reverse Osmosis

In practice, reverse osmosis is applied as a crossflow filtration process.
With a high pressure pump, feed water is continuously pumped at elevated pressure to the membrane system. Within the membrane system, the feed water will be split into a low-saline and/or purified product, called permeate, and a high saline or concentrated brine, called concentrate or reject. A flow regulating valve, called a concentrate valve, controls the percentage of feedwater that is going to the concentrate stream and the permeate which will be obtained from the feed. The key terms used in the reverse osmosis / nanofiltration process are defined as follows.

Recovery - the percentage of membrane system feedwater that emerges from the system as product water or "permeate". Membrane system design is based on expected feedwater quality and recovery is defined through initial adjustment of valves on the concentrate stream. Recovery is often fixed at the highest level that maximizes permeate flow while preventing precipitation of super-saturated salts within the membrane system.

Rejection - the percentage of solute concentration removed from system feedwater by the membrane. In reverse osmosis, a high rejection of total dissolved solids (TDS) is important, while in nanofiltration the solutes of interest are specific, e.g. low rejection for hardness and high rejection for organic matter.

Passage - the opposite of “rejection”, passage is the percentage of dissolved constituents (contaminants) in the feedwater allowed to pass through the membrane.

Permeate - the purified product water produced by a membrane system.

Flow - Feed flow is the rate of feedwater introduced to the membrane element or membrane system, usually measured in gallons per minute (gpm) or cubic meters per hour (m3/h). Concentrate flow is the rate of flow of non-permeated feedwater that exits the membrane element or membrane system. This concentrate contains most of the dissolved constituents originally carried into the element or into the system from the feed source. It is usually measured in gallons per minute (gpm) or cubic meters per hour (m3/h).

Flux - the rate of permeate transported per unit of membrane area, usually measured in gallons per square foot per day (gfd) or liters per square meter and hour (l/m2h).

Factors Affecting Reverse Osmosis and Nanofiltration Performance Permeate flux and salt rejection are the key performance parameters of a reverse osmosis or a nanofiltration process. Under specific reference conditions, flux and rejection are intrinsic properties of membrane performance. The flux and rejection of a membrane system are mainly influenced by variable parameters including:

- Pressure
- Temperature
- Recovery
- feed water salt concentration

Aqua Clean Systems Offers complete RO, NF and UF systems with perfect pre filtration according to feed water study.