Water Quality Association

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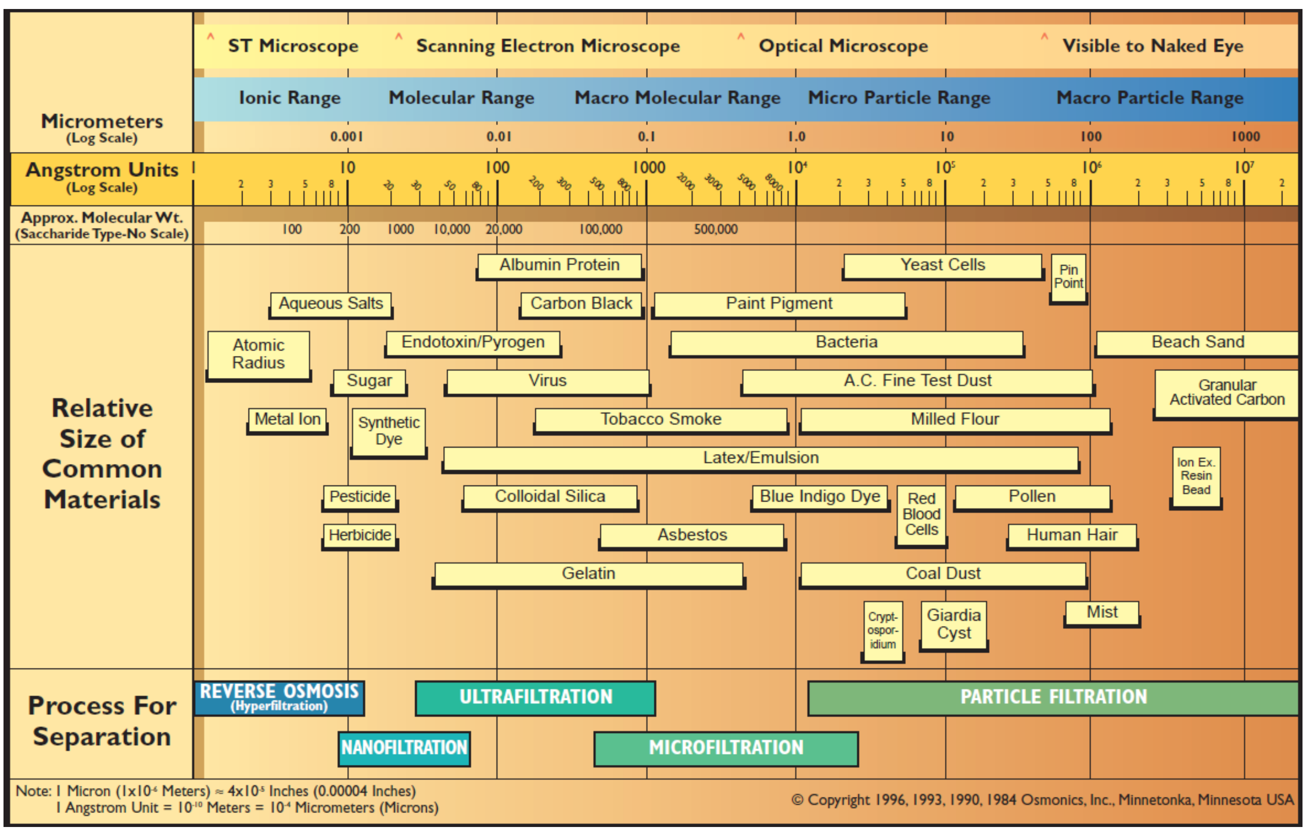
REVERSE OSMOSIS (RO) FACT SHEET

BASICS OF SPIRAL WOUND RO MEMBRANES

Reverse osmosis (RO) water treatment contains a semi-permeable membrane. There are two common types of membranes: cellulose acetate (CA) and thin film composite (TFC). One advantage of the CA membrane is it is more resistant to chlorine than the TFC membrane. However, TFC membranes are much more efficient and superior in performance overall compared to CA membranes.

The RO membrane can remove particles that are Angstrom in size (human hair is ca. 1,000,000 Angstroms in size). Figure 1 below describes capability of reverse osmosis membrane.

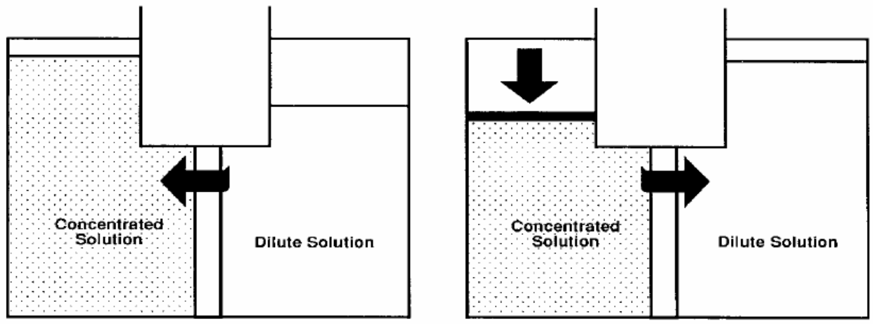
Figure 1:



HOW RO WORKS

The RO membrane is semi-permeable, which means it allows water to pass through the membrane while it is not permeable to other species. The RO membrane is very good at rejecting many species such as viruses, bacteria, salts, but for an RO membrane to work, one has to apply a net driving pressure (i.e. a pressure greater than osmotic pressure that is created by the soluble salts in water).

Figure 2:



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.

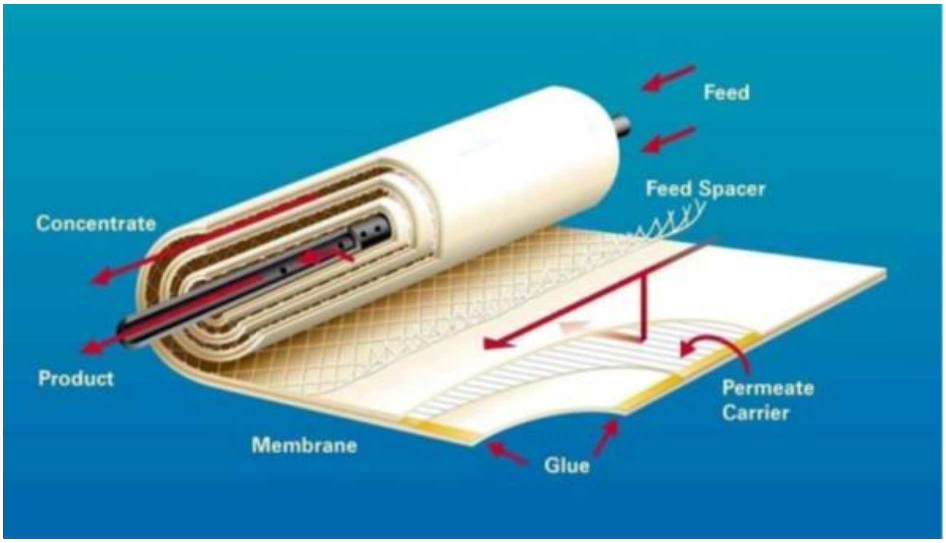
Reverse Osmosis

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

Once the net driving pressure is applied, the RO membrane will begin to produce permeate (product) water. There are mainly 4 different factors (feed water concentration, feed water temperature, operating pressure and % recovery) that affect the performance of RO membranes. We will discuss how these factors can affect the performance of RO later.

The RO membrane can be configured in different ways (such as plate & frame, hollow fiber, spiral wound), but the most efficient and economical configuration is spiral wound configuration (see figure 3).

Figure 3:



One can think of a spiral wound RO membrane element as an envelope analogy. An envelope (outer side of envelope is membrane barrier side) has three sides sealed (urethane glue is applied on three sides of membranes to seal to separate permeate water from feed water) and only one side is open (where permeate water flows out). The spiral wound RO membrane element is an envelope that is wound around the tube with holes where permeate water comes out. The spiral wound RO membrane element works on cross-flow filtration principle. Unlike dead-end filtration where there are only feed and product streams, cross-flow filtration has three streams (feed, permeate and concentrate streams). When sufficient net driving pressure is applied to spiral wound reverse osmosis membranes, feed water enters the spiral wound RO membrane element and permeate water is produced. The third stream is the concentrate or reject stream. Concentrate/reject stream contains whatever is rejected by the RO membrane. Cross flow filtration can never be operated at 100% recovery since it always has to have 3 streams. If it is operated at 100% recovery, then there would only be feed and permeate streams and there would be no concentrate/reject stream.

MAIN COMPONENTS OF SPIRAL WOUND ELEMENTS

The membrane is a polyamide thin film composite (TFC) sheet which is ca. 2,000 Angstroms thick. This is the outside of the envelope in our analogy.

To create turbulent flow and good mixing in the feed water stream, typically a diamond shaped mesh screen (called a feed spacer) is placed in between the membrane sheet and it is spirally wound along with RO membrane.

To efficiently transport permeate water to come out of the spiral wound membrane element, a permeate spacer is placed backside of the RO membrane (i.e. inside the envelope in our envelope analogy). Once permeate water is collected inside the envelope, the permeate spacer carries permeate water to product water tube.

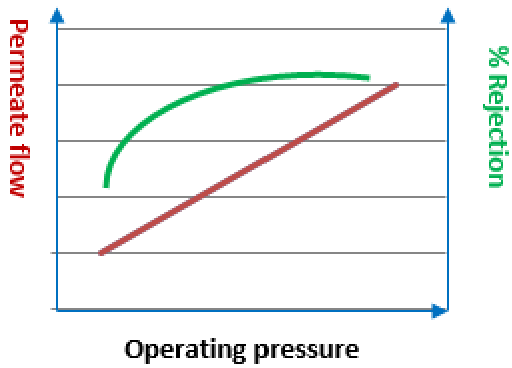
Polyurethane glue is used to seal three sides of membrane so that feed water is isolated/separated from permeate water.

The product water tube has multiple holes in them allowing permeate water to go through these holes and flows out of product water tube.

FACTORS AFFECTING RO MEMBRANE ELEMENT

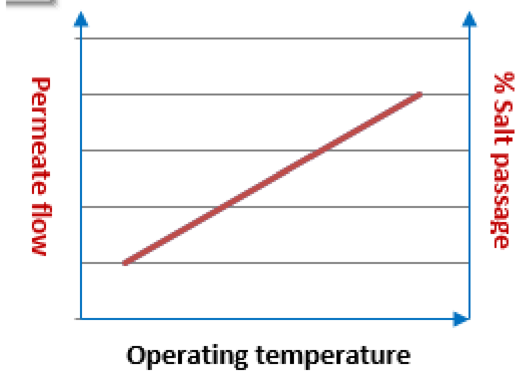
The feed water total dissolved solids (TDS) concentration, operating pressure, temperature and recovery ratio are the four main factors affecting the performance of RO membranes. There are other factors such as pH and types of inorganic ions that also influence the performance, but these four factors are considered here.

Figure 4: Effect of operating pressure



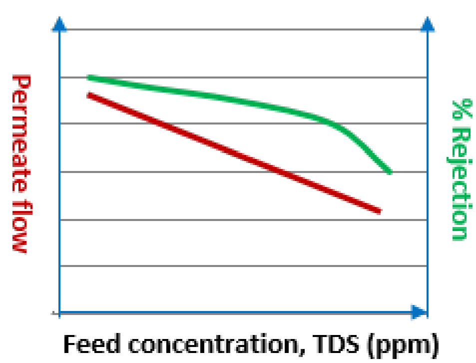
As operating pressure increases, more permeate water is produced and % rejection of the membrane increases if other parameters such as feed water TDS, feed water temperature and % recovery stay the same. But it should be operated according to manufacturer's design guidelines; otherwise, operating at high pressure will prematurely foul or scale the membrane, reducing membrane life prematurely.

Figure 5: Effect of operating temperature



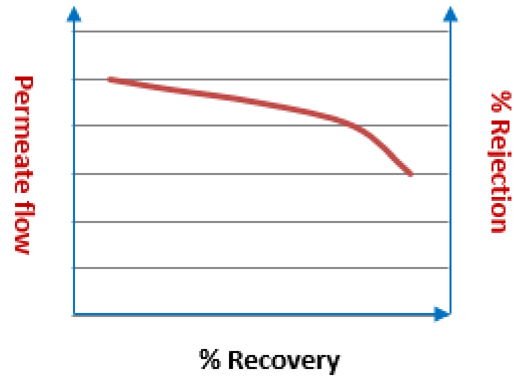
Permeate flow rate and the amount of salt passage is proportional to temperature. As temperature increases, so does permeate flow rate and % salt passage. So, when feed water is colder during winter time, permeate flow rate will be lower and salt passage through RO membranes will be lower (i.e. better water quality) given other parameters such as feed water TDS, operating pressure and % recovery stay the same. On the other hand, during summer time where feed water temperature tends to be warmer, permeate flow rate and % salt passage will increase given other parameters such as feed water TDS, operating pressure and % recovery stay the same. This also means that it will take a bit longer to fill product tank during winter time compared to summer time.

Figure 6: Effect of feed concentration



Typically, feed water TDS concentration is measured in micro Siemens/cm (uS/cm) or in parts per million (ppm) using a conductivity or TDS meter. The higher the feed water concentration, the higher the osmotic pressure will be. As feed water concentration increases, permeate flow and % rejection of RO membrane declines given other parameters such as feed water temperature, operating pressure and % recovery stay the same.

Figure 7: Effect of % recovery



The % recovery is defined as the ratio of permeate flow rate divided by feed flow rate x 100%. The % recovery is inversely proportional to permeate flow rate and % rejection given other parameters such as feed water TDS, operating pressure and feed water temperature stay the same. When % recovery is low, more water is drained and wasted, but your RO membrane performance will be better. Typically, there is a recommended % recovery rate by RO system manufacturers to balance performance and economics. In under the sink RO systems, this is controlled by flow restrictors.

WHAT CAN BE REMOVED WITH RO MEMBRANES?

Generally speaking, an RO membrane can remove bacteria, virus, and organic compounds with molecular weight cut off (MWCO) of greater than 100 as well as most of the inorganic substances. (See figure 1) There are of course some exceptions. The main advantage of using an RO is the fact that it is capable of removing harmful contaminants to our bodies such as bacteria, virus, soluble organic compounds such as pesticides and herbicides, and heavy metals such as arsenic, barium, cadmium, chromium, copper, lead, fluoride, nitrate and others.

Read more about contaminant reduction claims on the Water Quality Association and NSF International's websites:

WQA Technical Fact Sheets: https://www.wqa.org/Programs-Services/Technical-Guidance/Technical-Fact-Sheets

NSF Contaminant Reduction Claims Guide: http://www.nsf.org/consumer-resources/what-is-nsf-certification/water-filters-treatment-certification/contaminant-reduction-claims-guide

WATER/WATER RO SYSTEMS

Figure 8:

The water/water design uses a tank with two adjacent chambers separated by a flexible diaphragm or bladder. One chamber is product water, and the other chamber is squeeze water which comes from the reject water from the membrane. RO product water then gradually fills the chamber, displacing the accumulated reject water to the drain until it occupies all of the tank's volume. When RO water is dispensed, reject water under line pressure squeezes the diaphragm forcing the RO product water out. This type of design offers efficient water usage due to zero back pressure on the membrane.

References:

Figure 1: Omsonics
Figure 2: FilmTec Technical Manual
Figure 3: Hydranautics online
Figure 4: FilmTec Technical Manual
Figure 5: FilmTec Technical Manual
Figure 6: FilmTec Technical Manual
Figure 7: FilmTec Technical Manual
Figure 8: Topper Manufacturing Corporation

ACKNOWLEDGEMENT

WQA wishes to express sincere appreciation for the unselfish contributions of the members of WQA who contributed their time and expertise toward the completion of this bulletin.

Arvind Patil, Ph.D.	Richard Andrew
Gary Hatch, Ph.D.	Shannon Murphy
Charles Michaud, MWS	Steve Ver Strat
Mark Brotman, MWS	Michael Kim, CWS
P. Regunathan, Ph.D.	Bob Kappel
Rebecca Tallon, P.E.	Gary Battenberg

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This reference document is published by:

Water Quality Association

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