Fundamentals of Reverse Osmosis

By Diego Bonta

An introduction to RO and its applications

This is the first in a series of five articles providing an overview of how point-of-use (POU) reverse osmosis (RO) technology works in residential systems and the critical parameters to keep in mind to optimize its performance.

This article, the first in the series, covers the fundamentals of RO. The second article will look at different feedwater factors that can greatly impact the performance of an RO filter. The third article will provide POU system design guidelines by explaining how the major residential POU components operate with one another. The fourth article will provide guidance on preventing short lifetime failures. The final article will compare RO filter quality and performance.

This series is intended to assist OEMs, dealers, installers and end-users in making better decisions in optimizing a POU RO system and avoiding failures in the field.

Technologies

There are several technologies used to remove impurities from residential drinking water. Each technology focuses on different types of contaminants and can generally be categorized by size. These removal technologies are often used in a series focusing on the larger contaminants first, followed by smaller and smaller impurities. Figure 1 shows the main technologies available for residential systems with the corresponding contaminants they remove.

Out of the list of technologies, particle filtration and ion exchange are the only ones that are not commonly found as membranes. All of the other technologies may exist as flat sheet membranes, hollow fibers or even ceramic candles. If the filter is made up of membranes or hollow fibers, it can be used in two modes of operation: dead-end filtration or cross-flow filtration. The schematic in Figure 2 demonstrates how both modes of filtration work.

Dead-End Filtration

In dead-end filtration, all of the

Figure 1. Contaminant Removal Technologies Available for Residential Systems

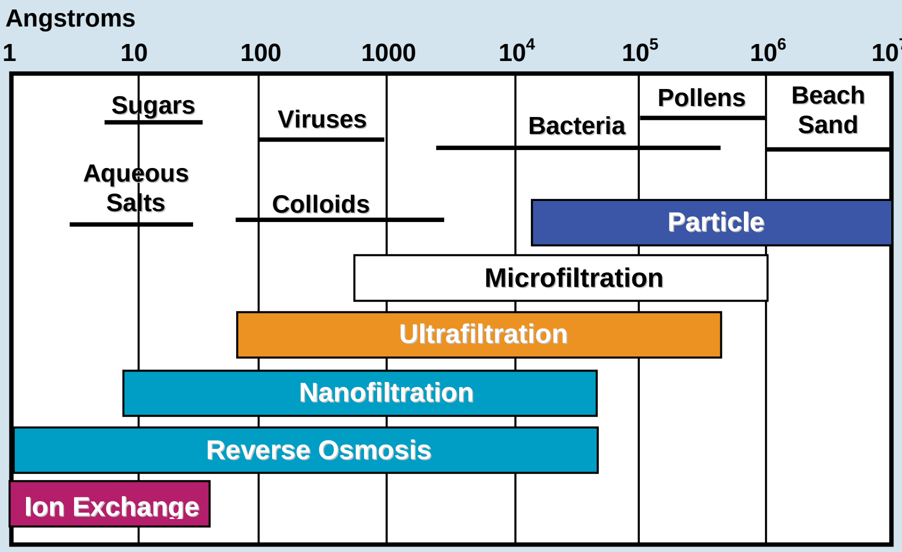


Figure 3. Reverse Osmosis

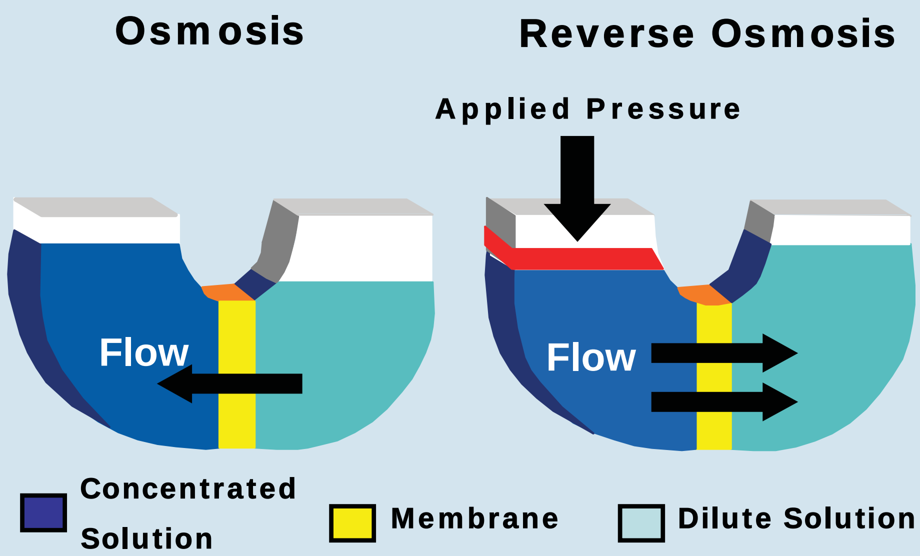


Figure 2. Membrane Operation Modes

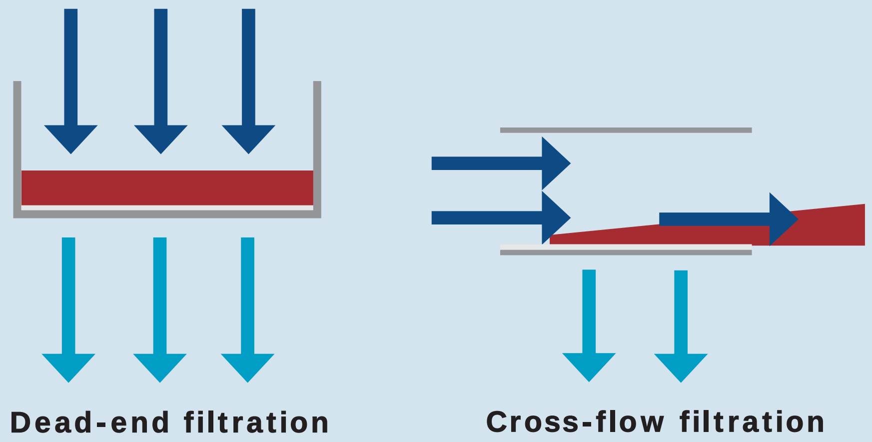
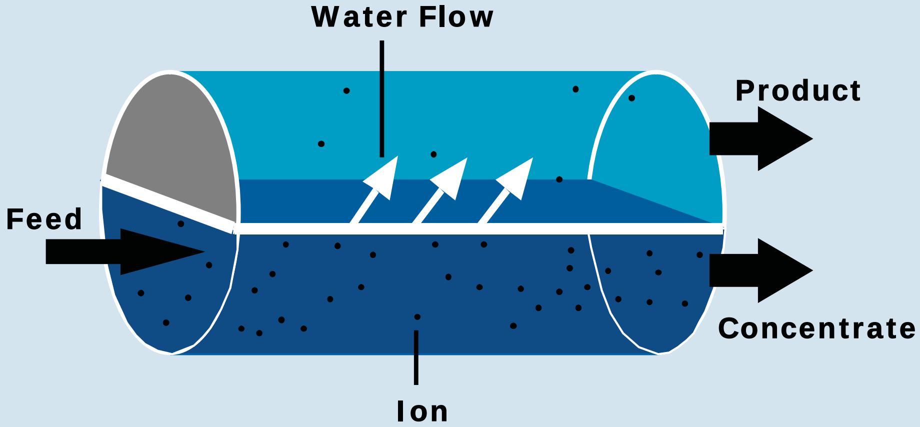


Figure 4. Cross-Flow Filtration



feedwater is pushed through the membrane and becomes produced (permeate) water. The advantage of this mode of operation is that no wastewater is created. The disadvantage is that the impurities build up on the feed side of the membrane, creating a cake layer that decreases performance and can require frequent filter changes. Dead-end filtration is used in microfiltration and ultrafiltration.

Cross-Flow Filtration

Cross-flow filtration means that part of the feedwater is pushed through the membrane while the rest sweeps past the membrane, removing particulates and other foulants to extend the lifetime of the filter. This mode of operation is the most common for RO and nanofiltration.

Along with differences in the mode of operation, filtration technologies also require different feed pressures. In general, the smaller the particles removed by the technology, the higher the operating feed pressure required. The table below shows the general operating pressures required for each technology. Ultrafiltration and microfiltration operate at low pressures compared to RO because they operate independently from the osmotic pressure of the solution they are treating.

Membrane Process	Typical Operating Pressure Range (psi)
Reverse Osmosis Seawater Brackish water	 800 – 1,015 145 – 580
Nanofiltration	50 – 220
Ultrafiltration	30 – 100
Microfiltration	1.5 – 45

Basics of RO

If a semi-permeable membrane separates a concentrated solution from a dilute solution, water will flow from the dilute solution to the concentrated side in order to bring the two solutions into equilibrium through a process called osmosis. However, if sufficient pressure is applied to the concentrated solution, it is possible to force water to flow into the opposite direction. This is the main principle on which RO is based (see Figure 3 on page 12).

A semi-permeable membrane allows water to diffuse through the membrane and only allows a small amount of ions through. RO membrane rejects contaminants by three mechanisms at the surface: repulsion from the ion charge and density; dipolar interactions; and the size of the molecule being larger than the pore size of the membrane.

Companies that specialize in making RO membranes are continually developing new membranes that allow more water and fewer harmful contaminants through. Some membranes are so specialized that they are developed to specifically block ions of interest, such as nitrates, boron or silica.

In summary, the main principle required for RO is the application of sufficient pressure to push water through a semi-permeable membrane.

The membrane allows water to diffuse through the membrane but blocks the majority of the salt. The most common mode of operation is cross-flow (see Figure 4 on page 12) to enable the salt to be swept away from the membrane surface and not build up. *wqp*

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