What Every Operator Should Know About Reverse Osmosis Systems

Fred Edgecomb

Knowledge	Principle	Practical considerations
Advanced Wastewater Treatment (AWT)	At one time this was considered the same thing as tertiary treatment. The term is currently used to describe advanced processes that provide post-secondary treatment to meet indirect and direct potable reuse quality water. These processes may vary but, in general, they consist of ultrafiltration, reverse osmosis, advanced oxidation and, if necessary, mineral stabilization.	Because most certifications for water treatment and wastewater treatment do not cover AWT, new certifications are being developed by water and wastewater member associations and/or state regulators. Reverse osmosis (RO) is used in most potable and indirect potable reuse systems. Reverse osmosis also can make brackish water suitable for potable use. Operators should become familiar with the RO equipment and processes, which are very different from conventional processes, but not substantially more complex.
Osmosis	Osmosis is the natural flow of water from a less concentrated solution to a more concentrated solution across a semipermeable membrane. The semipermeable membrane allows water molecules to pass through but does not allow larger molecules to pass through. The flow will stop when the concentration is equal on both sides. The difference in concertation is the driving force in this process. The higher the difference in concentration, the greater the flow from the concentrated side to the dilute side.	This principle is very important to the understanding of the operation of the RO process. It effects every operating parameter.
Reverse Osmosis	The application of pressure in excess of the natural osmotic pressure forces water molecules to pass through the semipermeable membrane and the concentrate to remain on the side receiving pressure. As the concentration increases the required pressure also increases.	The amount of pressure required depends on both the osmotic pressure and the membrane material. The required pressure is much higher than conventional particle filtration system and can range from 1,380 to 2,760 kPa (200 to 400 lb/in.^{2}).

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Membrane	RO membranes are thin films that are applied to a backing material. The backing provides support and prevents damage to the thin membrane.	Membranes are made from various polyamide, thin-film composites; cellulose acetate; and cellulose triacetate. The membranes in your system have been designed to provide the best service for your application.
Pressure Vessel	RO membrane modules are inserted into a tube where they interconnect into other modules. The tubes are sealed at each end with penetrations for feed water and permeate.	The pressure vessel is constructed to allow for the easy installation and removal of RO membranes. Pressure vessels are arranged in racks so that multiple pressure vessels are aligned in rows. The feed flow may pass from one rack of vessels into another for a multiple pass system.
Concentrate Seal	At the connection point of individual RO membranes, there is a brine seal that seals the permeate tube connection between membrane modules. Sometimes referred to as an O-Ring or brine seal.	Leaking seals allow concentrate to enter the permeate tube and cause contamination. Troubleshooting with a conductivity probe can locate bad brine seals.
Permeate	The pure water that passes through the membrane is called *permeate*. Permeate collects in the permeate tube.	No membrane is perfect, so some dissolved minerals also pass through the membrane into the permeate. As flow moves through the membrane units the concentration of minerals in the feed water increases and more minerals are introduced into the permeate. The permeate quality in the first membranes and first pass will be of better quality than the downstream modules because of the increased minerals in the concentrate.
Concentrate	The feed water that does not penetrate the membrane is referred to as *concentrate* or *brine*.	There is a direct correlation between the ratio of the permeate and concentrate volume and the pressure applied. The higher the ratio of permeate and concentrate, the greater the required feed pressure. As the concentrate concentration increases and its volume decreases, the pressure required to force water through the membrane increases. This pressure must be controlled to avoid putting too much pressure on the membrane. Too much pressure can damage to the membrane assembly, compact the membrane surface, increase scale build up, and force excessive minerals into the permeate.
Concentration Polarization	As water passes through the membrane the minerals and solids in the water on the concentrate side increase at the membrane surface.	This is important because as the solids increase they begin to foul the surface forming scale or biological fouling. This causes the necessary pressure to increase and will eventually require cleaning of the membrane surface. Most membranes are configured so that flow at the surface is turbulent to help prevent scaling or deposit of solids. Even the best design cannot prevent this indefinetly and eventually the membrane surface will require cleaning

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Differential Pressure	The differential pressure is the difference between the inlet and outlet pressure for each pass of the RO system. Just as inlet and outlet pressures are used to determine backwash cycles in conventional filters, it is important to track and record the difference in inlet and outlet pressures for each pass of the RO system.	An increase in differential pressure indicates that the membrane is getting fouled by contaminants and must be cleaned. Each system will have its own design differential pressure. Operators must monitor the differential pressure and determine the optimal time to perform membrane cleaning.
Flux	Flux is the volume of water that passes through a membrane per unit of time and per unit surface area. Flux is measured either in liters/hour/square meter (lmh) or gallons/day/square foot (gfd).	Flux is a design factor that may effect the operation of the system if the wrong flux rate was used in the design. Although an operator should know what this number is, it will generally not have a critical impact on system operation.
Recovery	Feed water recovery is defined as the percentage of water fed to the membrane unit that actually passes through the membrane as permeate.	This is another factor that will be considered in the system design. While a high recovery rate is desirable it must be balanced against the higher pressure requirement and increased chance of scaling. Higher recovery rates also have a negative effect on permeate quality. Typical recovery rates are 75% to 85%.
Normalization	Normalization refers to the examination of RO process data to account for such factors as changes in feed temperature, conductivity, and recovery to determine if changes in performance are due to problems with the membranes or other factors.	Most RO membrane manufacturers offer free normalization tools in Excel or other formats that do not require any specialized software or hardware. Normalization is used to help determine when the membranes need to be cleaned.
Concentrate Disposal	The concentrate is the waste flow from the RO process. This stream cannot be returned to the treatment facility to be retreated because the process is not designed to deal with increased mineralization.	For facilities with an ocean discharge, local authorities may allow concentrate to be discharged via outfall. For inland facilities, the handling of concentrate is more difficult. Concentrate can be further concentrated by additional RO or other concentrator. Ultimately, there will be a need to dispose of some concentrate. The use of evaporation ponds is a common, economical means of disposal where land is available. Other options are distillation, deep well injection, or irrigation of salt tolerant crops.
Cleaning	As minerals and solids accumulate on the membrane surface it is necessary to take the RO offline and clean the membranes.	Some systems have in-place cleaning systems that are designed to direct a cleaning solution through the system at low pressure. An acidic solution is used most often to clean the minerals from the membrane surface. In other cases, the membrane elements are removed for the pressure vessel and cleaned and tested either on site or at a centralized cleaning facility. Cleaning restores membrane performance and extends membrane life.

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