Ultrafiltration 101

By Larry Zinser

UF membranes provide efficient method for water treatment

Ultrafiltration (UF) offers an efficient and effective opportunity for treatment of extremely small contaminants. Recent developments in the chemistry and assembly of UF membranes make this technology available for a wide range of applications, from residential to commercial to industrial.

Ultrafilters are membranes. They consist of a membrane surface that restricts the passage of suspended solids larger than a rated size. The membrane itself is a thin selective barrier. In nature, membranes are made from lipids and proteins. Manmade membranes are manufactured of plastic, typically polysulfone.

Natural membranes cover the surfaces of the organs in our bodies. Manmade membranes are typically fashioned into hollow fibers—minute straw-like tubes that are open at only one end. The ends of the fibers, however, are not loose; rather, they are held together in a plug called a potting, which is also a plastic material.

Filtration Range

UF removes suspended particles at the sub-micron range. The range of filtration for UF is 0.005 to 0.05 µ. A micron, also called a micrometer, is 0.000039 in. One inch is 25,400 µ long, and a period is 615 µ in diameter.

Although the range of UF is 0.005 to 0.05 µ, a specific UF membrane has a specific micron rating, such as 0.01 or 0.02 µ. It does not filter over the entire range—it only restricts particles in its own suspended solids range.

UF membranes are less restrictive than reverse osmosis (RO) membranes. RO membranes also are made of plastic, usually polyamide, but are made to filter at less than 0.001 µ. The RO filtration range includes dissolved solids in addition to suspended solids. UF does not remove dissolved solids.

Manmade membranes are usually fashioned in the form of hollow fibers held together by a potting.

Flow Rate

The flow rate, or flux, through a UF membrane depends on the physics of the application. As with all membranes, the rate of flow and the loss of pressure depend on the surface area of the membrane, the temperature of the water, the trans-membrane pressure and the total solids in the water. The flow rate is directly proportional to the surface area of the membrane in a linear relationship.

Likewise, the flow is directly proportional to the water temperature, but their relationship is nonlinear and unique to the specific membrane. Membrane manufacturers publish specifications for a water temperature of 77°F, along with a listing of "correction factors" for other water temperatures.

Generally, the flow increases as the temperature increases, with the increase being less of a factor as the temperature increases over 77°F. This flux is due to the ability of water to permeate the membrane surface. Cooler water is denser and cooler membranes become more rigid, with the opposite effects in warmer water.

Trans-Membrane Pressure

Trans-membrane pressure is the net driving pressure of the membrane. Simply stated, it is the difference between the pressure on the feed side of the membrane, less the pressure on the permeate (treated) side of the membrane.

As the trans-membrane pressure increases, so does the flux. Either increasing the feed pressure and/or decreasing the permeate pressure will increase the flow rate.

The use of feed or permeate booster pumps can improve the performance of UF membranes. One of the most common obstacles to flow rate is backpressure on the permeate side of the membrane. This is true of all membranes, from microfiltration to RO.

Solids Concentration

Solids in the water will have an inverse effect on flow. All solids in the water exhibit some obstruction to flow. For RO membranes, the effect of dissolved solids in the water is dramatic, because these are the particles that are being retained on the feed side of the membrane. For UF membranes, the effect is much less.

Suspended solids also have an effect simply due to their collection on the feed side of the membrane. The suspended solids affect both RO and UF membranes. In all cases, the concentration of solids in the water has an inverse relationship to membrane flux.

Particle Diffusion

Diffusion can cause reverse contamination in UF. Diffusion is the natural tendency of particles in water to move from areas of high concentration to areas of low concentration. This phenomenon is familiar to those who use tea bags. The tea tannins tend to disperse throughout the total volume of the enclosure.

The same phenomenon occurs with

membrane surfaces. The only difference between membranes is the ability of the specific particle to penetrate the membrane. For example, a dissolved solid would have some difficulty penetrating an RO membrane, but little difficulty penetrating a UF membrane. This is one of the principles behind the operation of artificial kidneys in dialysis treatment. The result of diffusion is that the small particles may diffuse across a UF surface.

Energy Considerations

All filtration requires energy. As noted previously, the driving force in membrane filtration is trans-membrane pressure. It takes energy to increase the feed pressure. One of the advantages of UF is that at a given trans-membrane pressure, the membrane flux is much higher for UF than RO. This means that less energy is required for a specified flow rate through a UF membrane than it would for an RO membrane of the same surface area. This makes UF a practical alternative for low-pressure applications.

Membrane Cleaning

All membrane surfaces must be cleaned. The cleaning protocol is based, in part, on the filter range of the membrane. Accordingly, an RO membrane that filters at the 0.001-µ range requires a continuous cleaning process. This is the basis for cross-flow filtration and the continuous flow to drain, which are required for RO filtration. For a UF that filters at the 0.01-µ range, however, cross-flow filtration is not necessary.

UF membranes may be placed into the normal flow line without a constant drain flow. Periodically, the UF surface must be cleaned of accumulated particles, however, and the most efficient process for this is a reverse flow—from the treated side of the membrane to the feed side of the membrane. The frequency and duration of these cleaning cycles depends on the amount of particulates that the membrane is capturing. Typically, a small-scale pilot test is used to determine the appropriate cleaning cycle.

Applications

UF has an important role to play in water treatment applications. When the treated water specification includes any qualification other than dissolved solids, UF is a much more efficient choice for treatment. RO removes much smaller particles, including ions, but the energy and wastewater requirements are much more demanding.

For example, if the treated water specification includes the removal of bacteria, cysts and viruses, some UF membranes may accomplish this at a much lower energy and waste cost than RO. *wqp*

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