MEMBRANE FILTRATION (MF/UF)

OVERVIEW

Water utilities nationwide are turning to advanced filtration to meet more stringent federal drinking water regulations in order to remove turbidity, precursors, metals, and disinfectant-tolerant microorganisms from both groundwater and surface water supplies.

Low-pressure microfiltration (MF) and ultrafiltration (UF) membrane filtration technology has emerged as a viable option for addressing the current and future drinking water regulations related to the treatment of surface water, groundwater under the influence, and water reuse applications for microbial, organic, and inorganic contaminants and turbidity removal. For more than 20 years, full-scale facilities have demonstrated the efficient performance of both MF and UF as feasible treatment alternatives to conventional granular media processes. Both MF and UF have been shown to exceed the removal efficiencies identified in the US Environmental Protection Agency's (EPA) Surface Water Treatment Rule and related rules, such as those for Cryptosporidium oocyst, Giardia cyst, and turbidity.

MF and UF membrane systems generally use hollow fibers that can be operated in the outside-in or inside-out direction of flow. Pressure (5 to 35 psi) or vacuum (-3 to -12 psi for outside-in membranes only) can be used as the driving force to transport water through the membrane surface.

Figure 1 shows some examples of MF/UF membrane modules and cassettes. At 20 degrees Celsius, typical flux rate for MF and UF ranges between 20 and 80 gallons per square foot per day (gfd). Flux rate is defined as the permeate flow per day per unit membrane surface area. In MF/UF, "permeate" is often referred to as "filtrate".

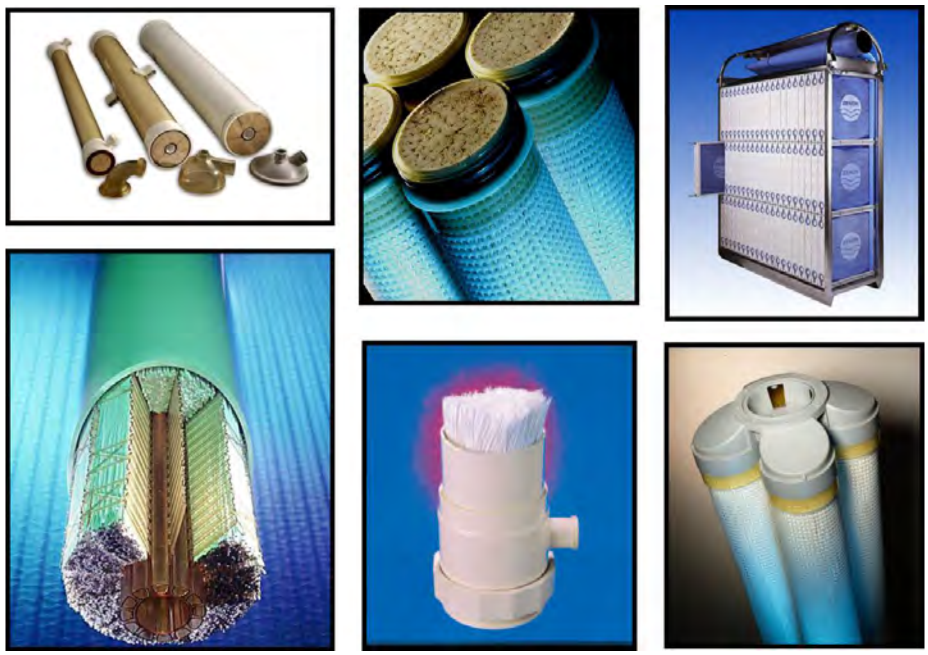

Figure 1: Examples of MF/UF membrane modules and cassettes

Since both processes have relatively small membrane pore sizes, membrane fouling—caused by the deposition of organic and inorganic compounds on the membrane—may occur at unacceptable levels if the system is not properly selected, designed, and/or operated. Automated periodic backwashing and chemical washing processes are used to maintain the rate of membrane fouling within acceptable limits. Chemical cleaning is employed once a maximum transmembrane pressure differential has been reached. Some systems utilize air/ liquid backwash. Typical cleaning agents utilized include acids, caustic, surfactants, enzymes, and certain oxidants, depending upon membrane material and foulants encountered. Chemicals used for cleaning and the method used in the cleaning process must be acceptable to the membrane manufacturer.

Overall treatment requirements and disinfection credits must be discussed with and approved by the reviewing authority. Disinfection is recommended after membrane filtration as a secondary pathogen control barrier and for distribution system protection.

MF and UF membranes are most commonly made from various organic polymers such as different polysulfones and polyvinylidene fluoride (PVDF). Physical configurations include hollow fiber, spiral wound, cartridge, flat plate/ sheet, and tubular. MF membranes are capable of removing particles with sizes down to 0.1-0.2 microns. Some UF processes have a lower cutoff rating of 0.005-0.01 microns. Encased MF/UF modules are manifolded with all valves and instruments on a rack/skid as shown in **Figure 2**. Several racks can then be manifolded together in parallel to construct a large membrane facility, as shown in **Figure 3**.

Ceramic membranes are available for MF/UF separations and are beginning to be used in the United States for potable water applications. They have been used extensively for food and dairy and industrial applications where their robust nature and temperature tolerances are invaluable.

MF/UF membranes can be either encased (pressure) or immersed (submerged), as shown in **Figures 4** and **5**, respectively.

Membrane filtration is also becoming popular for conventional plant retrofits, replacing sand media with submerged membranes, for enhanced water quality and increased capacity. An example is shown in **Figure 6**. Typically, the net water production of the plant can be doubled without major structural modifications.

Figure 2: Example of skid mounted UF modules

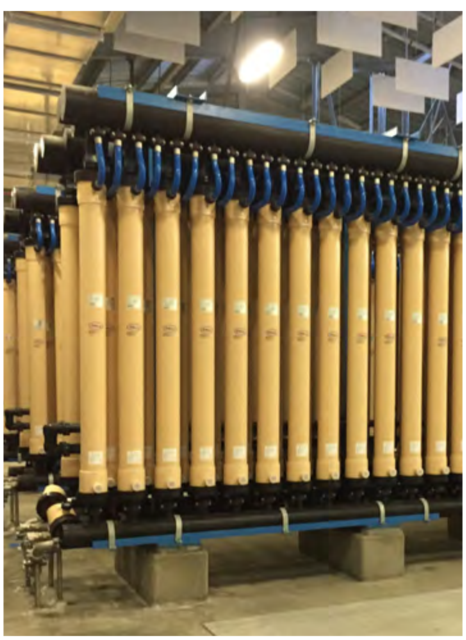

Figure 3: Example of skid mounted MF racks manifolded in a plant

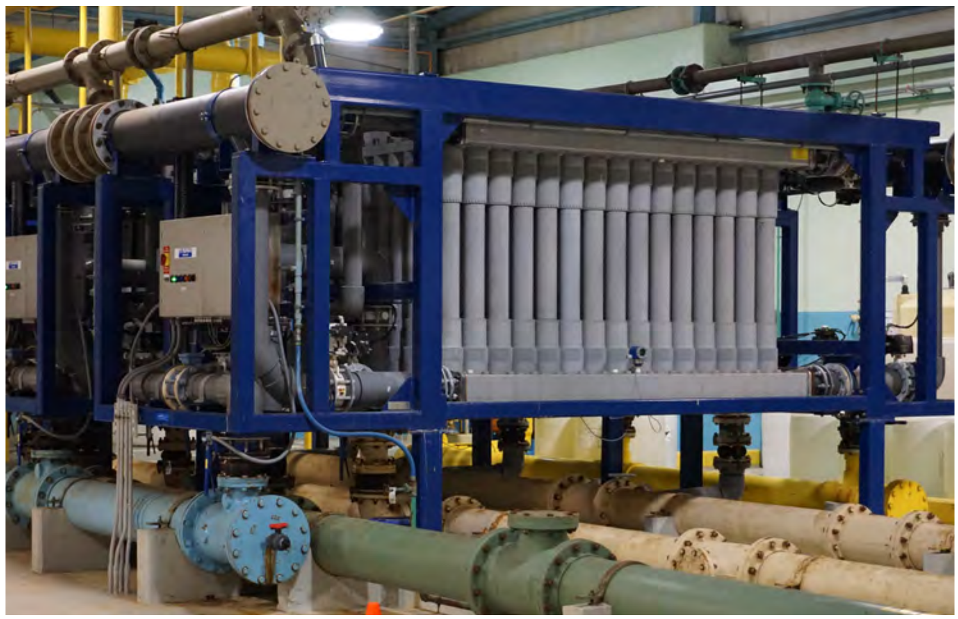

Figure 4: Example of encased (pressure) membranes

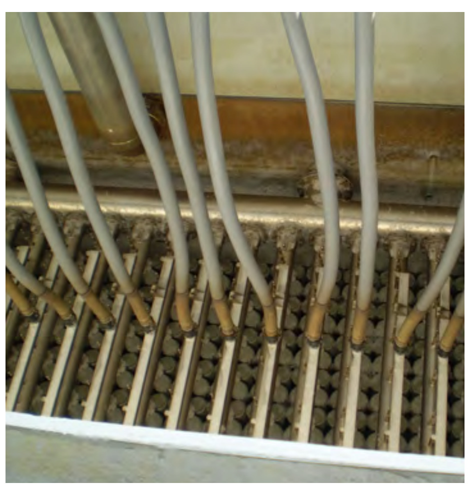

Figure 5: Example of immersed (submerged) membranes

Figure 6: Example of conventional media to submerged membrane plant

SELECTING MF/UF MEMBRANE SYSTEMS

When selecting MF/UF systems, the following should be considered:

1. **Water Quality:** A review of historical source raw water quality and variability data, including turbidity, algae, particle counts, seasonal changes, organic contents, microbial activity, and temperature as well as other inorganic and physical parameters is critical to determine the overall cost of the system and operation. The degree of pretreatment, if any, should also be ascertained. Design considerations and membrane selection at this phase must also address target removal efficiencies and system recovery versus acceptable membrane fouling rate. At a minimum for surface water supplies, pre-screening is required.

2. **Life Expectancy:** The life expectancy of a particular membrane under consideration should be evaluated (typically 7-10 years). Membrane replacement frequency is a significant factor in operation and maintenance cost comparisons in the selection of the process. Warranties offered by manufacturers vary significantly and should be considered closely.

3. **Water Temperature:** The source water temperature can significantly impact the flux of the membrane under consideration, especially the tighter UF membranes. At low water temperatures, the flux can be reduced appreciably (due to higher water viscosity and resistance of membrane to permeate), possibly impacting process economics by the number of membrane units required for a full-scale facility. System capacity must be selected for the expected demand under seasonal (cold and warm water temperature) conditions.

4. **Operational Parameters:** Backwashing waste volumes can range from 4 to 15 percent of the permeate flow, depending upon the source water quality, membrane flux, frequency of backwashing, and the type of potential fouling. Membrane cleaning frequency is directly a function of flux rate and feed water characteristics.

5. **Monitoring:** Membrane systems used for drinking water production should be provided with an appropriate level of finished water monitoring and a direct integrity test feature. Monitoring options may include laser turbidimeters, particle counters, and manual and/or automated integrity testing using pressure decay or air diffusion tests. The EPA has published a membrane filtration guidance manual (EPA 815-R-06-009).

6. **Disinfection By-Product:** Other contaminants of concern, such as color and disinfection by-product (DBP) precursors, should also be addressed. DBPs can be removed to varying degrees by coagulation in front of the membrane system, either with settling or directly removing the coagulated contaminants with the membranes.

7. **Pilot Plant Study:** Prior to initiating the design of a MF or UF treatment facility, contact the state reviewing authority to determine the disinfection credits available for the membrane process, and whether a pilot plant study is required. In most cases, a pilot plant study is necessary to determine the best membrane to use, particulate/organism removal efficiencies, cold and warm water flux, the need for pre-treatment, fouling potential, operating and transmembrane pressure, as well as other design considerations. Contact the state reviewing authority prior to conducting the pilot study to establish the protocol to be followed.

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8. **System Design:** Redundancy of critical components and control features should be considered in the final design. Other post-membrane treatment requirements, such as corrosion control and secondary disinfection, must be evaluated in the final design. Cross-connection control considerations must be incorporated into the system design, particularly with regard to the introduction and discharge of chemicals and waste piping. Membrane systems that use chemical washing processes with harsh chemicals require additional consideration.