Improving Drinking Water Quality
Microfiltration and Ultrafiltration Membranes Increasingly Meet Cost and Quality Demands

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In recent years, microfiltration (MF) and ultrafiltration (UF) membranes have become a viable alternative to conventional filtration in water treatment facilities. This can be attributed to a significant reduction in costs as well as the need for improved water quality to meet more stringent regulations and replace aging infrastructure. Not only are membrane systems becoming cost-competitive and proving reliable, they can also provide a more consistent finished water quality than conventional filtration.

Advances in Membrane Processes
MF/UF membrane processes use hollow fiber membranes with pore sizes ranging from 0.02 to 0.2 μm. These hollow fiber membranes have relatively low operating pressures (~7-40 psi) and a high surface area to volume ratio. The fibers are made of polymeric materials that are tolerant to low/high pH and oxidants, which allows for aggressive chemical cleaning of the membranes and provides flexibility in operation.

Advances in membrane processes over the past decade have resulted in the following benefits:
• Consistent finished water quality
• Positive barrier to waterborne pathogens (including Giardia lambia and Cryptosporidium)
• Highly automated operation
• Cost-competitive when compared to conventional filtration
• Long-term compliance with regulations
• Smaller footprint than conventional treatment

The consistency of the finished water quality in a typical membrane plant is shown in Figure 1. Turbidity, which provides a measure of the clarity of water, can fluctuate substantially in water treated by a conventional treatment plant based on the raw water quality and effectiveness of pretreatment. However, with membrane technologies, the finished water turbidity will remain relatively constant.

Membrane System Configurations
The most common configurations for MF/UF membranes in drinking water treatment are pressure and immersed membrane systems. While the configurations of the membrane systems vary, the operation is relatively similar, with routine backwashing and chemical cleaning being conducted at specified intervals. The hollow fibers in a pressure system are contained in a pressure vessel, and the water is forced through the membrane. This can be advantageous in situations where the feed water is already under pressure. In an immersed (or submerged) system, the membranes are submerged in a water tank or filter basin and water is drawn through the membrane fibers by a vacuum.

Figure 1: Membrane processes provide consistency in finished water quality despite fluctuating raw water turbidity.
This configuration typically requires a smaller footprint than a pressure system. Therefore, both of these system configurations have distinct advantages in certain applications and both should be considered for specific projects.

**Optimizing the Design and Operation**

To provide the most cost-effective and operator-friendly design, optimization of the membrane system design is critical. Constituents that cause membrane fouling (or blockage of the membrane pores) must be managed by optimizing the operation, and if necessary, pretreatment should be included in the design. To optimize both the design and operation, pilot testing is highly recommended.

**Membrane Pretreatment**

Since the primary purpose of MF/UF membranes is particulate removal, chemical addition prior to the membranes is generally required to achieve removal of specific contaminants. Pretreatment using rapid mix, flocculation and sedimentation can increase the capacity of a membrane system and improve membrane performance by significantly reducing organic and/or inorganic fouling constituents in the membrane influent. Specifically, these performance enhancements include increases in membrane flux and recovery, as well as lengthened cleaning intervals and extended membrane life.

As a result of these performance enhancements, municipalities implementing pretreatment with membrane technologies often realize a significant reduction in the capital cost of the membrane equipment, as well as a reduction in operation and maintenance costs. The reduction in membrane capital cost is due to the increased membrane flux and recovery since fewer membranes are required to achieve the same capacity. Likewise, the reduced operation and maintenance costs are a result of chemical and labor savings associated with lengthened cleaning intervals. At several of the membrane facilities recently completed by Burns & McDonnell, the savings in membrane costs were greater than the cost of adding pretreatment, making pretreatment the economically preferred option.

**Pilot Testing**

A properly conducted pilot testing program can provide valuable information regarding the performance and operation of a membrane system, and can allow for a side-by-side comparison of several membrane systems. This information can be used to calculate life cycle costs and provide a fair and competitive procurement environment.

The pilot testing program for the MF/UF systems should be developed to optimize and demonstrate the performance and operation of each system tested. It should provide information that can be used to determine the design criteria for the full-scale plant. Therefore, the pilot testing should be conducted in conditions similar to those expected in the full-scale plant. Both cold and warm water operating conditions should be determined and tested if feasible.

Although various methods can be used for pilot optimization, typically membrane flux is held fairly constant, while the transmembrane pressures (TMPs), percent recovery, frequency of reverse filtration/backpulse and other operational parameters are adjusted to optimize operation and performance of each system.

Specific tasks that should be included in a pilot program include turbidity spiking, optimization of performance, performance demonstration phases, verification of integrity testing, monitoring of cleaning efficiency, a detailed monitoring and sampling protocol, monitoring of finished water quality, and quality assurance/quality control measures. Evaluation of various coagulants and cleaning chemicals can

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also be incorporated into the program to further improve membrane performance and reduce operational costs.

Retrofitting Existing Facilities
For many existing facilities, the retrofitting of membranes into existing filter basins can be a cost-effective solution for meeting new microbial and turbidity removal requirements while simultaneously upgrading plant equipment. (See Figure 2.) Capacity of the plant can often be increased without building entirely new facilities. Although there is a potential for cost savings over constructing new facilities, there are several issues to address that should not be overlooked in the predesign phase of a retrofit project. These include modifications to the filter basins to accommodate membranes and placement of the required ancillary equipment. Depending on the membrane system implemented, ancillary equipment could include blowers, air compressors, vacuum pumps, automated strainers, raw water pumps and permeate pumps. In addition, since chemicals are required for cleaning of the membranes, additional chemical feed and storage facilities are typically required.

Optimization of the design through a detailed pilot program and the design of effective pretreatment can reduce overall project costs and provide the best value to the owner.