



Case Study: Research Leads To Large-Scale Microfiltration Plants – 10/01/1999

What are the advantages of low-pressure membrane treatment processes for surface water supplies? How are the requirements of the Surface Water Treatment and Disinfectants/Disinfection Byproducts Rules addressed using low-pressure membrane filtration?

Conventional water treatment consisting of coagulation, flocculation, sedimentation, filtration, and disinfection has long been the accepted method for protecting public health. With stringent requirements to ensure pathogen removal or inactivation, utilities are turning to low-pressure membrane technologies such as microfiltration (MF). As membrane technologies improve and become a cost-effective alternative for utilities, drinking water regulators must determine appropriate performance criteria to provide the same or better level of public health protection. Issues critical to this decision-making process include the following:

- Do low-pressure membranes effectively remove particles from surface waters?
- Can log removals of microorganisms such as *Giardia* and *Cryptosporidium* be demonstrated?
- What testing protocols can be used to assess membrane integrity?

Role of Water Research Foundation Research

The Water Research Foundation has produced a report that utilities are using to demonstrate the performance of low-pressure membrane treatment plants for compliance with the Surface Water Treatment and Disinfectants/Disinfection Byproducts Rules:

- Jacangelo, J.G., et al. 1997. *Membrane Filtration for Microbial Removal*. Denver, Colo.: AwwaRF and AWWA (Order #90715).

This report provides pilot plant data from a variety of membranes treating water in three different locations. Results of microbial challenge studies conducted using organisms such as *Cryptosporidium parvum*, *Giardia muris*, MS2 virus, and total coliform bacteria demonstrated removal efficiencies of the membranes (MF pore openings are 0.2 μm , and *Cryptosporidium* ranges in sizes from 2-3 μm), under conditions that closely simulated full-scale treatment plants.

For regulatory agencies responsible for permitting membrane treatment plants, membrane integrity is a key concern. Widespread use of membrane systems may ultimately be contingent on reliable testing protocols to demonstrate that membranes are intact. Research examining these protocols provides drinking water regulators with critical information to determine performance standards appropriate for protecting public health.

Utility Application of the Research

A number of utilities, consultants, and regulators have applied Foundation research in designing and permitting low pressure membrane filtration plants for surface water treatment.

First large-scale MF plant. In 1994, San Jose Water Company (SJWC), an investor-owned utility in San Jose, Calif., began operating the 5-mgd Saratoga Microfiltration Plant—the first large-scale MF system in the U.S. The Saratoga plant was designed to replace an obsolete diatomaceous earth filtration system. MF was selected over other treatment options primarily because its compact, modular design would fit in the existing 1,600-ft² building and because it would achieve the necessary 3-log removal of *Giardia* cysts without chemical pretreatment or final disinfection. The California Department of Health Services (CDHS) granted a 3-log removal credit based on the results of the Foundation research project, including a portion of the study conducted at SJWC. See Table 1 for more information about the MF plants discussed in this issue.

The excellent turbidity removal characteristics of MF demonstrated in the Foundation study made the technology even more attractive for SJWC. The use of MF at the Saratoga facility allows the source of supply to be maximized because the plant experiences fewer problems with periods of high-turbidity storm runoff. When turbidity is as high as 100 ntu, the plant produces finished water that is always 0.05 ntu or less.

The MF technology at Saratoga uses an air pressure hold test to monitor membrane integrity. Foundation researchers evaluated seven different membrane monitoring techniques and determined the air pressure hold test to be the most sensitive. The test operates automatically and works on the principle that air pressure must overcome capillary resistance before an intact membrane fiber allows air to pass. Automatic shutdown is selected at a pressure decay level that ensures the required 3-log removal of *Giardia* is achieved. In addition, log removals of intentionally compromised membranes were verified to confirm the results of the on-line integrity test method.

In 1998, SJWC was issued a permit amendment to increase the allowable unit flux rate from 0.5 gpm/m² to 0.7 gpm/m². Data from the Foundation study as well as operational data collected from the Saratoga plant were evaluated by CDHS in consideration of the permit amendment. Of particular importance were data collected during a seeded challenge study that demonstrated greater than 6-log removal of both *Giardia* and *Cryptosporidium* at a flux rate of 0.94 gpm/m².

In May 1999, Manitowoc Public Utilities, Wisc., began operating their MF plant on Lake Michigan, replacing an existing 10-mgd conventional water treatment plant at a cost of \$6.8 million. Because the utility's source of supply is warmed by the nearby electric utility's cooling water, production remains stable year round. The *Cryptosporidium* outbreak in Milwaukee was the primary reason for considering MF technology rather than expanding existing conventional processes. Other factors favoring MF included

- elimination of coagulants
- ability to increase plant capacity in small increments
- lower space requirements
- producing consistent treated water quality (exceeding EPA/Department of Natural Resources requirements) regardless of changing source water quality
- fewer staff night and weekend shifts required

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- more cost-effective than other alternatives

Before selecting MF, the utility conducted a pilot study on ultrafiltration (UF) and MF processes for almost a year. Manitowoc staff also compared water quality results with ozone pilot studies conducted at other facilities on the same Lake Michigan source water. After comparing capital and operations and maintenance costs with ozone, the utility determined MF to be the most cost-effective alternative.

Research helped Manitowoc, Kenosha (next section), and Wisconsin's Department of Natural Resources (DNR) by providing guidance in setting objectives for the pilot study, establishing initial design criteria and performance benchmarks, and demonstrating to DNR the applicability of these processes. Published research and pilot study results allowed DNR to accept 3-log removal of *Giardia* and *Cryptosporidium* without coagulation or disinfection requirements.

In Wisconsin, membrane integrity must be tested every 8 hours by pressure decay, and a pressure loss of 0.68psi/min. triggers automatic shutdown. If this value is exceeded, each membrane module is sonically tested to identify the module that may have a broken fiber. Any broken fibers are repaired immediately to maintain membrane integrity. A change of 0.05 psi/min in two consecutive tests from previous pressure tests also requires sonic testing.

When Manitowoc began investigating MF, little information was available on the characteristics of the plant's backwash wastewater. Concentrate disposal regulations vary by state, and disposal can add substantial costs to membrane processes. Data collected by Manitowoc enabled the utility to obtain a permit to settle and discharge backwash wastewater to the source, resulting in significant cost savings of capital and long-term operation. The permit requires the utility to monitor the discharge and remain within state limits. Manitowoc also has the option of sending waste to the sanitary sewer.

In December 1998, Kenosha Water Utility, Wisc., began operating its 16.3-mgd MF system, replacing a 1916 conventional plant. Like Manitowoc, Milwaukee's experience with *Cryptosporidium* provided an additional incentive to add microfiltration. Although Kenosha had the option of adding ozone to the existing plant, the utility needed to replace the older conventional plant. Since MF consistently produces low turbidities and offers protection from particle excursions, the utility decided on microfiltration.

In addition, within four years, the cost of MF membranes had dropped more than 50 percent, making MF a cost-effective alternative. The Kenosha MF plant cost \$29.5 million, which included installing a new SCADA system and renovating the 1963 rapid sand plant. Integrated on the same site with a 20-mgd conventional rapid-sand system, the design allows for eventual replacement of the 1963 plant within the current site footprint. Both Kenosha and Manitowoc have space to add a third MF train.

During pilot testing, Kenosha found that from 70° to 32° F influent water temperature, the flux rate or production drops by half because of the influent's increased viscosity. Although this may not present a problem where the peak load occurs during summer, it is an important consideration where water demand remains constant year round.

Backwash volume and disposal present another consideration for utilities. Where conventional rapid-sand filters may produce 1.5 percent of capacity as backwash water, MF backwash and concentrate volume average 10-15 percent. Kenosha disposes of backwash water to the city's wastewater treatment plant, but other options may involve increased costs.

Conclusions

In 1994 when SJWC began operating the Saratoga MF plant, it was the largest of its kind in the United States. Since that time, the findings of the Foundation research project have been proven in full-scale treatment. Currently, several large-scale MF plants provide high quality drinking water to communities throughout the United States and abroad. Microfiltration plants, such as those operating in San Jose (5 mgd), Manitowoc (11 mgd) and Kenosha, Wisc. (16 mgd) continue to demonstrate the application of this technology to provide a safe, reliable, and cost-effective alternative to conventional water treatment plants.

Utilities considering MF are encouraged to

- Plan for a long-term pilot investigation (9 to 12 months).
- Retain competent, experienced people to work on the project.
- Visit operating MF plants to learn from their experience.
- Use Water Research Foundation resources for information and guidance that staff can provide.

Foundation General Resources on Membrane Processes

- Hering, J.G. and M. Elimelech. 1996. *Arsenic Removal by Enhanced Coagulation and Membrane Processes*. Denver, Colo.: AwwaRF and AWWA (Order #90706).
- AwwaRF, Lyonnaise des Eaux, Water Research Commission of South Africa. 1996. *Water Treatment Membrane Processes*. J. Mallevaille, P.E. Odendaal, M.R. Wiesner, eds. New York: McGraw-Hill (Order #90716).
- Jacangelo, J.G., et al. 1992. *Low Pressure Membrane Filtration for Particle Removal*. Denver, Colo.: AwwaRF and AWWA (Available in limited quantities to subscribers, order #90603).
- Mickley, M., et al. 1993. *Membrane Concentrate Disposal*. Denver, Colo.: AwwaRF and AWWA (Available in limited quantities to subscribers, order #90637)

Table 1 Microfiltration facts

| Plant | Year | Size (mgd) | Rated Plant Flux (gpm/m ²) | Backwash Disposal Method | Integrity Testing Method | <i>Giardia</i> and <i>Cryptosporidium</i> Log Removal |
|-----------|------|--------------------------------------|--|--------------------------|---------------------------|---|
| Saratoga | 1994 | 5 | 0.7 | Sanitary sewer | Air pressure hold + sonic | 3 (<i>Giardia</i>) |
| Manitowoc | 1999 | 11 14.4 (peaking for 48 hrs.) | 0.56 0.74 (peaking for 48 hrs.) | Source water | Air pressure hold + sonic | 3 |
| Kenosha | 1998 | 16.3 (summer) 9 (winter) | 0.60 (summer) 0.33 (winter, expect to go higher with demonstration) | Sanitary sewer | Air pressure hold + sonic | 3 |