NO-BREAK FIBER SOLVES MEMBRANE INTEGRITY PROBLEMS AT FIVE WATER TREATMENT PLANTS

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Abstract

Fiber breakage continues to be a problem for low-pressure membrane systems in drinking water plants. Not only do membrane integrity issues increase the risk of pathogens in the potable water supply, but integrity test failures mean less capacity, solids in the backwash water – which could cause irreversible fouling – and higher disinfection costs. In addition, repairing the fiber breaks requires a considerable amount of time and money, with some plants paying over 20% of the equipment cost to make the repairs needed during the plant's 20-year life [Freeman, 2012]. Many plants have created a "pinning station" to make the repairs, some even hiring a person whose sole job is to pin fibers!

To combat this problem, one manufacturer – inge, now part of Dupont – developed a fiber containing seven feed channels arranged in a honeycomb-like structure, which gives the fiber strength that single-bore fibers lack. This membrane is now used in over 250 installations, including several facilities in the U.S. This presentation looks at five of those installations, ranging from 0.15 to 3.75 million gallons per day (MGD). These plants had several things in common: they all had single-bore membranes that they were pinning frequently, treated surface water (or groundwater under the influence), and they were able to convince their states to accept the new membranes by operating them in parallel with their existing systems. As a result, one site elected to replace their entire membrane trains, while the other facilities were able to retrofit the new membrane modules onto their existing membrane skids.

This paper details the existing systems and their integrity issues and defines how the selected membrane has been able to resolve those issues, meet the USEPA's Long Term 2 (LT2) Enhanced Surface Water Treatment Rule, and outperform the existing modules.

The Problem

The above-referenced study conducted by Black & Veatch looked at sixteen water treatment plants using low-pressure membranes and found that the plants made an average of twelve fiber repairs per MGD of water treated (the maximum was 81!), resulting in an average labor cost amounting to 6.5% of the equipment cost over 20 years (the maximum was 22%!) [Freeman, 2012]. And this value doesn't include the costs associated with capacity loss and increased disinfection requirements. Though there have been improvements in membrane materials and construction over the last decade, the problem still persists: in the November 2021 issue of the Global Water Intelligence magazine, it was estimated that 10-15% of plants are currently having integrity issues with their polymeric membranes [Pankratz, 2021]. Because the solids that pass through a single fiber break are often not detectable on the effluent turbidimeter, pathogens get into the treated water until the next integrity test shuts the train down, which could be as long as

24 hours, posing a significant risk to public health. Failure of several fibers at a time – such as can occur during a water hammer event – could fill the backwash tank with high-solids water before the train shuts down on high turbidity; these solids could irreversibly foul the clean side of the membranes during the next backwash event.

The Alternatives

Existing membrane plants that are experiencing membrane integrity issues have several options, with the four major alternatives being: replace the membranes with the same membrane, replace the membranes with a different membrane, replace the membrane trains with an open (universal) platform, or replace the entire membrane trains with different trains. The option that is often the simplest and least capital is to replace the membrane modules themselves with modules that are the same model number from the same manufacturer; this allows reuse of the existing module racks, valves, pumps, tanks, chemical cleaning systems, etc. In addition, the membrane manufacturer will often give a good price to keep from losing their client to a competitor. The obvious downside, however, is that eventually the membrane integrity issues will reoccur, and the membranes will require frequent pinning and premature replacement (again).

Replacing the membrane modules with those from a different manufacturer may result in lower operating costs, provided the new membranes have less integrity issues and comparable power and chemical requirements. In addition, plants can often reuse much of the existing ancillary equipment, depending on how similar the operating parameters for the new membranes are to those of the failed membranes. However, the cost of the new modules will likely be more than the original modules, and the plant will probably have to purchase additional equipment because the new modules will require different backwash, air, and chemical flows. Also, the new modules will typically require some piping/skid modifications as they will often have different dimensions and connection locations than the existing modules.

Switching to an open (universal) platform has also become a popular option. This is a system that is designed to use modules from more than one manufacturer. That way, when it comes time to replace the membranes, the plant can either replace them with the same membrane model, a new-and-improved module from the same manufacturer (if applicable), or a membrane from a different manufacturer, with no major changes to the rest of the system. The downside of this alternative is that all of the equipment in the system has to be able to handle the highest backwash and chemical flows that will be required by the different membrane manufacturers; therefore, the plant may have to replace much of the ancillary equipment in addition to the membrane skids, which can result in a significant capital cost. Because the equipment must be designed for the module with the highest flows/pressures, using one of the other modules will result in a more inefficient system, resulting in higher operating costs.

The last option is similar to the universal option, except that the system is designed for a specific membrane model. Like the universal alternative, the entire membrane trains are replaced, not just the modules. If the new modules use the same or lower backwash and chemical flows than the original modules, it's likely the rest of the existing equipment can be reused, though some efficiency may be sacrificed. Unlike the universal option, the plant will not be able to easily replace the modules with those of a different manufacturer so they will have to choose from the above alternatives once again.

The five sites discussed in this paper all initially went with the first option – replacing the membranes with the same membrane – because it was the easiest and least-capital alternative; however, the membranes continued to fail, indicating that this was not a sustainable solution. As a result, the sites eventually replaced their membranes with the inge multi-bore membrane. Four of the sites went with the second alternative, replacing only the modules because inge modules could easily be fitted into the existing membrane racks with only minor piping changes. The fifth site, however, had to go with the last option - replacing the entire membrane trains with different trains – because the inge modules would not easily fit into the existing membrane racks.

A Better Membrane

There were several reasons the plants selected the inge membrane, now sold as the Aqua MultiBore® P-Series Polymeric Membrane: robust fibers, better warranty, low power usage, small footprint, and good track record.

Robust Fibers
The primary reason the plants made the switch to these membranes was because of their unique honeycomb-like construction, as illustrated in Figure 1. While almost all other hollow-fiber membranes use fibers with single-bores, this fiber is made with seven bores such that it's essentially seven fibers in one. This gives the fiber strength that a single-bore fiber doesn't have. In addition, the multi-bore fiber is made from a single material with different porosities throughout the membrane structure. Many membranes made of two materials – with the membrane material layered on the outside of a support structure – are very strong, but the outer membrane layer has a tendency to pull away from the support layer over time (delaminate) under the stresses caused by repeated air scours.

Figure 1. Multi-bore Fibers

Better Warranty
Because of the fiber's strength, the membrane manufacturer offers a very unique warranty: if a single fiber breaks within the first five years of operation, the manufacturer will replace the

entire module at no charge to the owner. In contrast, other manufacturers won't replace the modules until the effluent turbidity is out of compliance or a certain percentage of fibers break, typically 0.1-1%. While this seems like a small percentage, it amounts to 14-140 fibers in a typical 14,000-fiber module. In addition, the warranty is now extended to 10 years, with any modules with fiber breaks being replaced during the final five years at a reduced, prorated cost.

Low Power Usage

The best indicator of membrane performance is its permeability, which is the flow divided by the membrane area – also known as the membrane flux – and then divided by the trans-membrane pressure (TMP). The reason the P-Series membrane gets higher permeability is two-fold. First, the membrane material is polyethersulphone (PES), which allows for the creation of more-uniform pores than the material used by most other manufacturers, polyvinylidene difluoride (PVDF). As a result, PES membranes typically have more pores in the same area, which lowers the TMP and increases the permeability. Second, the multi-bore membrane is produced in such a way that the separation layer of very fine 0.02 µm pores – which performs the actual filtration – is very thin, with the rest of the membrane structure consisting of much larger pores (refer to Figure 2).

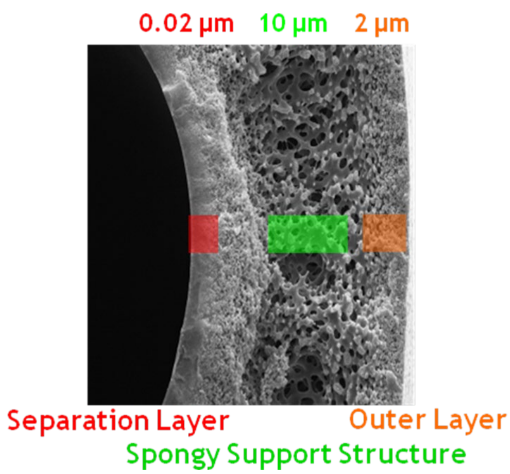

Figure 2. Fiber Bore (left) with Surrounding Membrane Material

With this membrane structure, nearly all of the TMP is occurring at the thin separation layer; once the flow gets past this layer, it moves freely past the other bores and to the outside of the fiber, with very little further pressure loss. The consequence is a lower TMP and higher permeability than other polymeric membranes. This means that it takes less feed pressure to achieve the same flow, resulting in lower feed pump power usage.

Low feed pressure is only one reason for the lower power usage seen with the P-Series membrane. Another reason is that the system doesn't require the air for backwashing that most other membranes require. The membrane uses an inside-to-outside filtration flow path that keeps all of the solids inside the fiber bores (feed channels), where they can be flushed to drain by reversing the filtrate flow, as shown in Figure 3. In contrast, membranes that use an outside-to-inside filtration flow path tend to collect solids in-between the fibers, which can only be removed completely using both water and air.

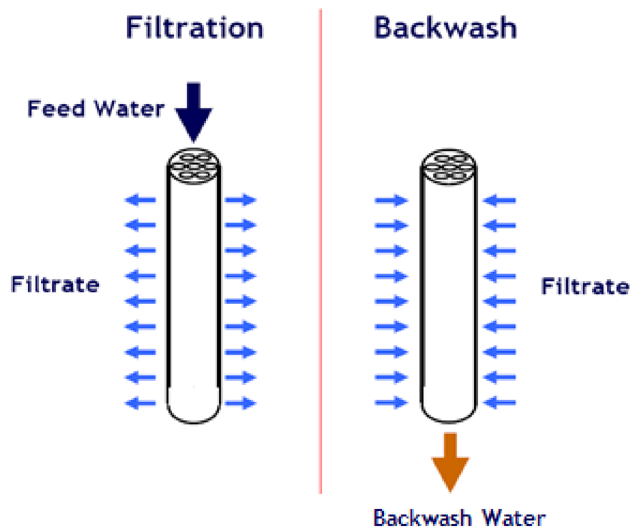

Figure 3. Multi-bore Membrane Filtration and Backwash Flow Patterns

In addition, the PES material is more hydrophilic (water-loving) than PVDF, which means solids are less likely to adhere to the membrane surface. The combination of low feed pressure, no air scour, and hydrophilic material results in a very low power usage, typically less than 0.025 kilowatt-hours (kwh) per cubic meter (m^3) of water treated, or 0.09 kwh per 1,000 gallons (kgal).

Small Footprint

Because air scouring is not used to clean the membranes, the footprint needed for the compressed air system is greatly reduced and can be eliminated altogether if electric valves are used in place of pneumatic valves. In addition, the high permeability minimizes the membrane area needed, resulting in additional footprint savings. Each 10-inch diameter module contains 80 m^2 (861 ft^2) of membrane area, and up to four 15-module rows are assembled on a single skid. With two of these skids connected to the same valve skid, a single membrane train with a footprint of 19 m^2 (205 ft^2) can treat 5.5 MGD (21 million liters per day, MLD) of pretreated surface water at a flux of 55 gallons per square foot per day (gfd), or 93 liters per square meter per hour (lmh).

Figure 4. Typical Multi-bore Membrane Assembly

Good Track Record
The manufacturer is able to offer the 5-year no-break warranty because their membrane has a very high success rate. Over the last twenty years, the same membrane had been installed at over 250 plants with nearly 50,000 total modules treating in excess of 1.3 billion gallons per day (BGD), and only a handful of modules have had broken fibers. As an example, a drinking water installation in Jachenhausen, Germany contains over 54,000 fibers, and they went 11 years without a single fiber break.

Case Studies

Module Replacements
As noted earlier, four of the plants elected to replace just the modules in lieu of the complete membrane trains. The main reason for this was that the new modules have dimensions nearly identical to the existing modules, requiring only minor modifications to the filtrate piping. Other factors in the decision were: the rest of the existing equipment was still in good shape, the same operating modes and steps could be used (no major controls changes), and the existing pumps are capable of attaining the flows and pressures required by the new modules. In all four cases, state regulators waived the requirement for a pilot provided the modules in one train were replaced and then operated in parallel with the modules in the other train(s). During this demonstration test, the performance of the new modules was compared with that of the existing modules, specifically the air integrity test (AIT) results and effluent turbidities; following a successful demonstration period, the modules in the other train(s) were replaced.

Butler, MO
The City of Butler, MO is on the far west side of the state, as shown in Figure 5, a one-hour drive south of Kansas City. The town presently has about 4,100 residents, over 1,600 small businesses (less than ten employees), nearly 400 larger enterprises, and four schools. The City owns and operates the water treatment plant, where water from a surface water impoundment is treated and distributed to the community as well as to four other Public Water Supply Districts (PWSDs). The impoundment is fed from three sources: Butler Lake, Maris de Cygenes River, and Miami Creek.

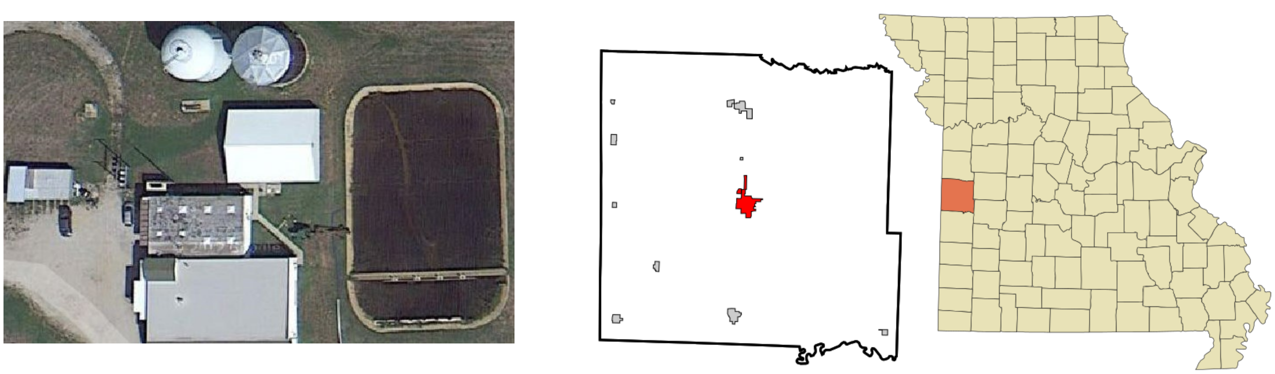

Figure 5. Location of Butler, MO Water Treatment Plant

The original plant was commissioned in 1967. As shown in Figure 6, the treatment process consisted of oxidation, coagulation, pH adjustment, carbon addition, clarification/settling, dual-media filtration, and disinfection.   Waste solids from the clarifiers and filters were sent to a settling pond, which overflowed back to Miami Creek.

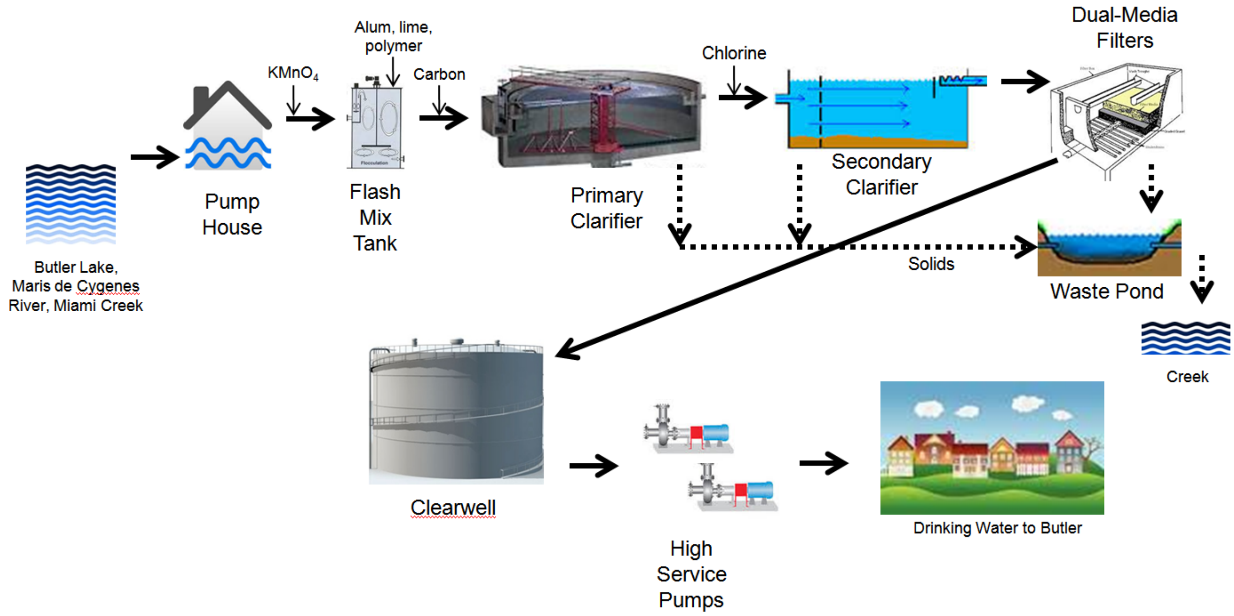

Figure 6. Original Plant Layout at Butler, MO

Over the course of the next 35 years, the system was maintained and parts were replaced as needed, but the treatment process remained basically the same. By 2002, the filters were in desperate need of replacement, and the decision was made to replace them with low-pressure hollow-fiber ultrafiltration (UF) membranes, which promised even better water quality than the filters and with less maintenance. The new membrane system was installed, consisting of:

- (4) disk-type 100-micron strainers to remove the larger particles that could damage the membranes,
- (4) membrane trains, each with (27) modules,
- (2) backwash pumps (one operating and one standby), and
- (1) clean-in-place (CIP) chemical cleaning system.

The membrane system was commissioned in 2003, rated with a design capacity of 3 MGD. To detect any fiber breaks or other breaches in membrane integrity, the system was set up to perform periodic AITs. During each test, air at 15-16 psig was applied to the upper feed header on each membrane train, and the filtrate drain valve was opened to allow the air to push the water through the fibers and into the filtrate line, as shown in Figure 7.

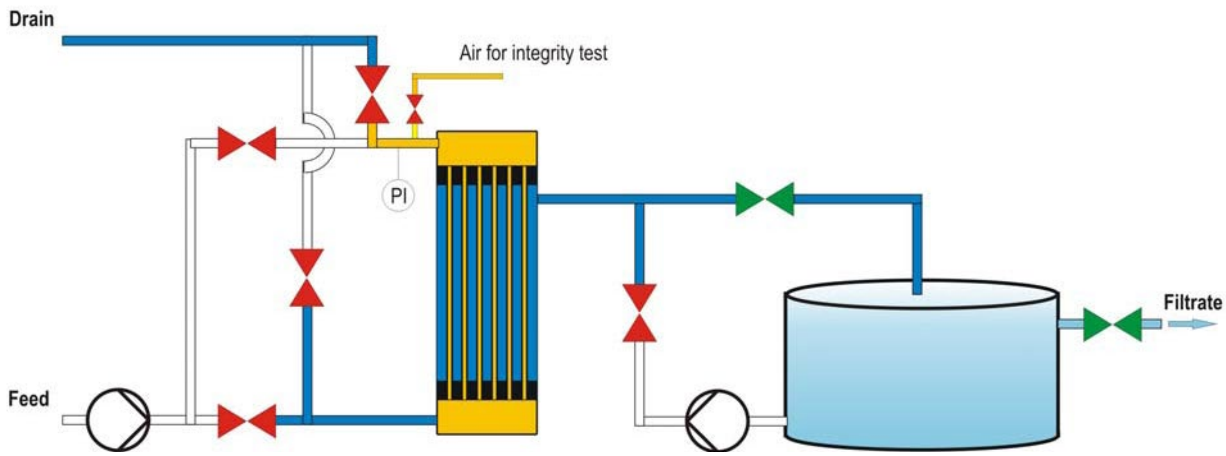

Figure 7. Air Integrity Test (AIT)

The air pressure applied is too low to overcome the surface tension of the water inside the tiny pores of the membrane; therefore, only the very fine air bubbles entrapped in the water should go through the membrane. Once all of the water was displaced from the membrane fibers, the air was turned off and the pressure loss was measured and recorded. A fiber break or any other opening larger than 3 micron - the size of the smallest *cryptosporidium* oocyst – would result in a rapid pressure decay; this prevented the train from being returned to service until the breach was corrected and the train passed a subsequent AIT. In order to determine exactly where in the train the breach had occurred, each module was provided with a clear section of piping in its filtrate line (refer to Figure 8); a breach was evidenced by a steady stream of air bubbles.

Figure 8. Original Butler Membrane Modules with Clear Filtrate Piping

Since being placed in operation, AIT failures steadily increased as membrane fibers broke or pulled away from their potting. Eventually, none of the four membrane trains could pass an AIT without multiple fiber repairs. Since trains with fiber breaks couldn't be used to treat water, the plant often struggled to meet the water demand placed on it by the City and other users.

To combat the ongoing integrity issues, the City of Butler decided in 2012 to replace the modules in three of their four trains. The original membrane manufacturer had recently introduced a new membrane that they felt would have much fewer integrity issues, but would not easily retrofit into the existing module racks; in addition, it would take extra time (and money) to build the racks. To correct the problem as quickly as possible, the City went with the original model instead. Shortly after being placed in service, the new modules began to fail their AITs, and the City knew they would have to go a different route.

After a thorough evaluation, the City decided in June of 2013 to replace the modules with Aqua MultiBore® P-Series Polymeric Membranes, primarily because of the 5-year no-break warranty. It also helped that the operation of the new modules was almost identical to that of the original modules, which meant that the original membrane racks, backwash pumps, CIP system, and PLC program could be reused. In addition, the module dimensions and connection locations were the same, with the exception of the filtrate piping, which had to be rerouted, as shown in Figure 9. Because each new module contained 646 ft^2 (60 m^2) of membrane area in contrast to the 500 ft^2 (46 m^2) in the original modules, only (21) multi-bore modules were needed per membrane train; the train connections vacated by the remaining (6) modules would have to be plugged.

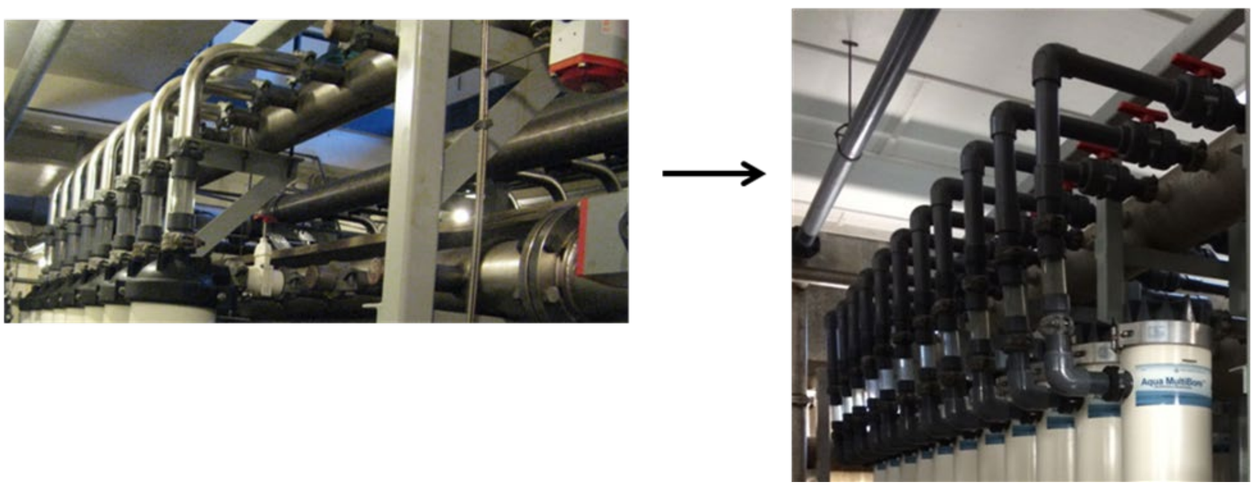

Figure 9. Rerouting the Original Filtrate Piping (left) to Accommodate the New Modules (right)

Because the membrane material remained the same (PES), as did the membrane area per train, the new modules would be able to use the same chemical types, quantities, and cleaning protocol; therefore, chemical costs for the new modules would be identical to that of the original modules.

After discussions with the Missouri Department of Natural Resources (MDNR), the City's consultant engineer, Allgeier, Martin and Associates, proposed to the State a demonstration period whereby the modules on one of the plant's four UF trains would be replaced and operated for nine months to verify their ability to meet the LT2 rule. The MDNR approved the proposal, and the modules were purchased, installed, and started up in April of 2014.

Since commissioning, the effluent turbidity produced by the train with the new modules (Train 2) has consistently been at or below 0.03 NTU, as shown in Figure 10. During the final three months of the 9-month demonstration, the new modules achieved 10-33% lower effluent turbidities than the existing trains.

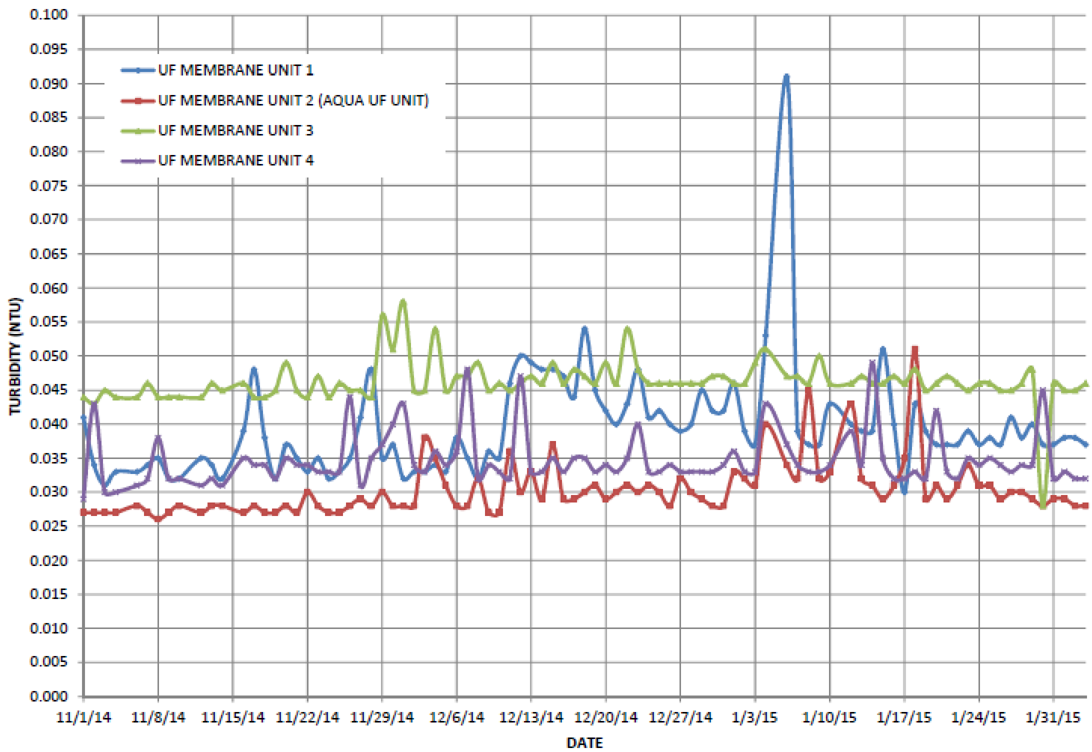

Figure 10. Effluent Turbidities for the Final Three Months of the Butler Demonstration

The permeabilties for each train are given in Figure 11 for the first two months of the demonstration, normalized to 20°C. The average value for the new modules (Train 2) during these months is approximately 24 gfd/psi, while the permeabilities of the existing trains averaged about 17 gfd/psi during the same time period. This represents an improvement of over 40%.

The demonstration proved successful, and the modules in the other four trains were replaced later in 2015 and in 2016, one train at a time. Each of the remaining trains was put through a similar demonstration, only the demonstration period was reduced from nine months to one month. Since the modules were placed into operation, there have been only four modules that required replacement due to fiber breakage, and two of these were due to severe water hammer during a manual CIP sequence.

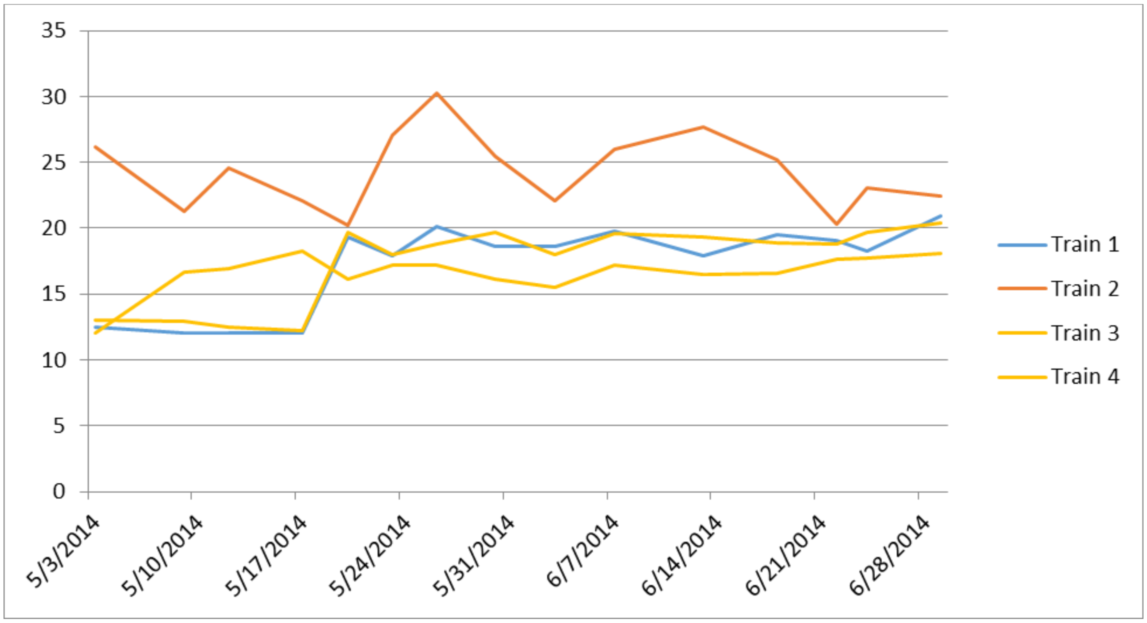

Figure 11. Train Permeabilities in gfd/psi for the Final Four Months of the Butler Demonstration

Garden City, MO

The City of Garden City, MO was the second of three Missouri cities that replaced their failing modules with the Aqua MultiBore P-Series modules. Garden City is about 30 miles northeast of Butler, but is considerably smaller, with a population of only about 1,600. The City owns and operates the water treatment plant, where water from Garden City Lake is treated and distributed to the community.

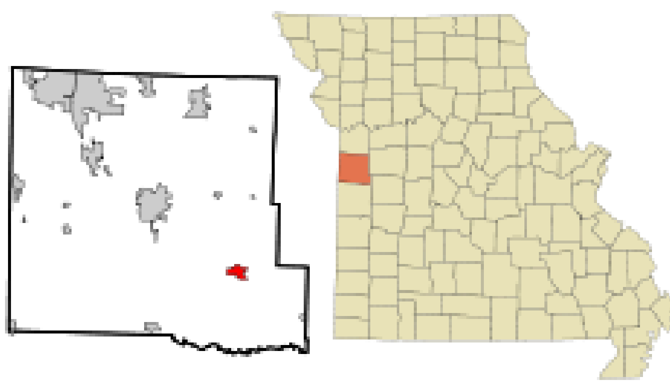

Figure 12. Location of Garden City, MO

The plant had the same treatment technologies as the Butler plant (shown earlier in Figure 6): oxidation, coagulation, pH adjustment, carbon addition, clarification/settling, dual-media filtration, and disinfection. And, like Butler, the dual-media filtration was replaced in the early 2000s with low-pressure hollow-fiber UF membranes, the same brand as those used at Butler. The new 0.15 mgd membrane system was installed, consisting of:

- (2) 100-micron strainers to remove the larger particles that could damage the membranes,
- (2) membrane trains, each with (8) modules,

- (2) backwash pumps (one operating and one standby), and
- (1) clean-in-place (CIP) chemical cleaning system.

Like the Butler system, the Garden City system was set to automatically perform a daily air integrity test (AIT) to verify that there were no broken fibers; the AIT system was set up as shown earlier in Figure 7. Each module was provided with a clear section of piping in its filtrate line (refer to Figure 8); a broken fiber was evidenced by a steady stream of air bubbles in the clear section during an AIT.

Because the modules were the same ones used in the original membrane system at the Butler plant, they experienced some of the same integrity issues. However, the problem was more serious at the Garden City plant since they only had two membrane trains and were forced to stop the flow entirely whenever they had integrity issues in both trains at the same time. Therefore, when they saw that the Butler plant had successfully replaced their modules with the multi-bore fibers, they were interested in doing the same. So in 2014, the eight modules in one train were replaced with seven Aqua MultiBore® P-Series Polymeric Membrane modules, leaving in operation the second train as well as the original membrane racks, backwash pumps, CIP system, and PLC program. The filtrate connection to each module was moved from the top of the module to its upper sidesheet, as shown in Figure 13. Because the new modules contained 30% more filtration area than the original modules, (7) of the new modules provided 14% more area than the (8) original modules; the train connections for the eighth module were plugged.

Figure 13. The New Garden City Modules with Rerouted Filtrate Piping

Because the membrane material remained the same (PES), the new modules would be able to use the same chemical types and cleaning protocol; therefore, no changes to the controls were needed.

The MDNR agreed to a 3-month demonstration period whereby the train of new modules would be operated in parallel with the train of original modules to verify the ability of the new modules to meet the LT2 rule. Since commissioning, the effluent turbidity produced by the train with the new modules (Train 1) has consistently been 0.02 NTU, as shown in Figure 14, compared with 0.03 NTU for the train containing the original modules (Train 2).

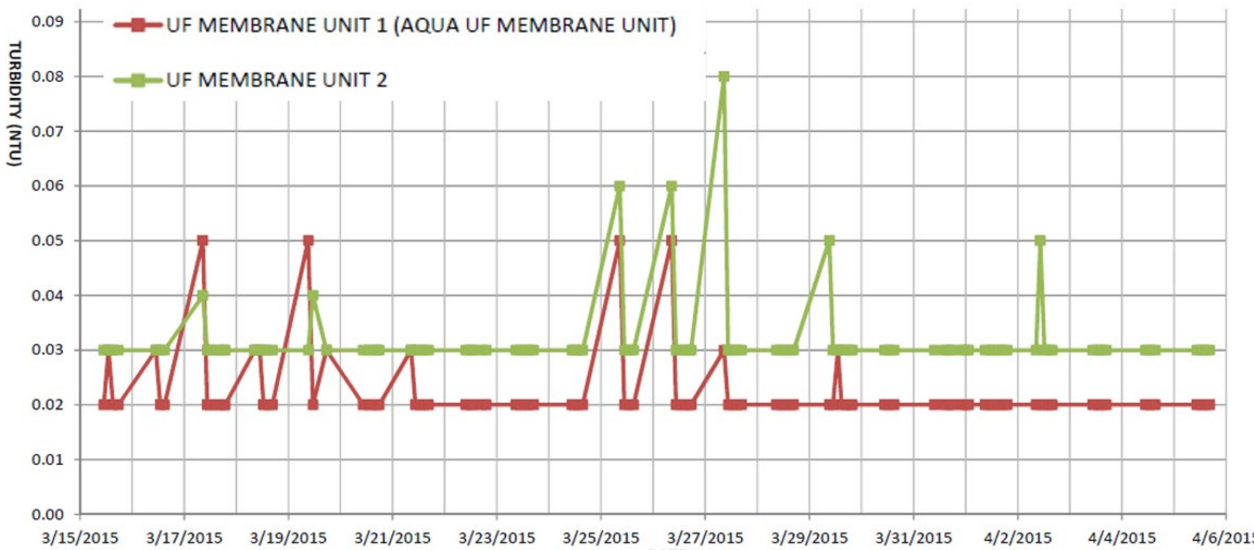

Figure 14. Effluent Turbidities for the Final Month of the Garden City Demonstration

The demonstration proved successful, and the modules in the other train were replaced later in 2015. This second train was put through a similar demonstration, only the demonstration period was reduced from three months to one month. Since the modules were placed into operation, no modules have been replaced due to fiber breakage.

Two Rivers, WI

The City of Two Rivers, WI was the third site to replace their failing modules with the Aqua MultiBore P-Series modules. Two Rivers is located on Lake Michigan between Green Bay and Milwaukee, as shown in Figure 15, with its water treatment plant near where the Mishicot and Neshota Rives meet. The plant provides the drinking water for over 11,000 residents, 80 small businesses, and 6 schools. Water is drawn from Lake Michigan, with the intake about 6,300 feet offshore and 33 feet below the water surface.

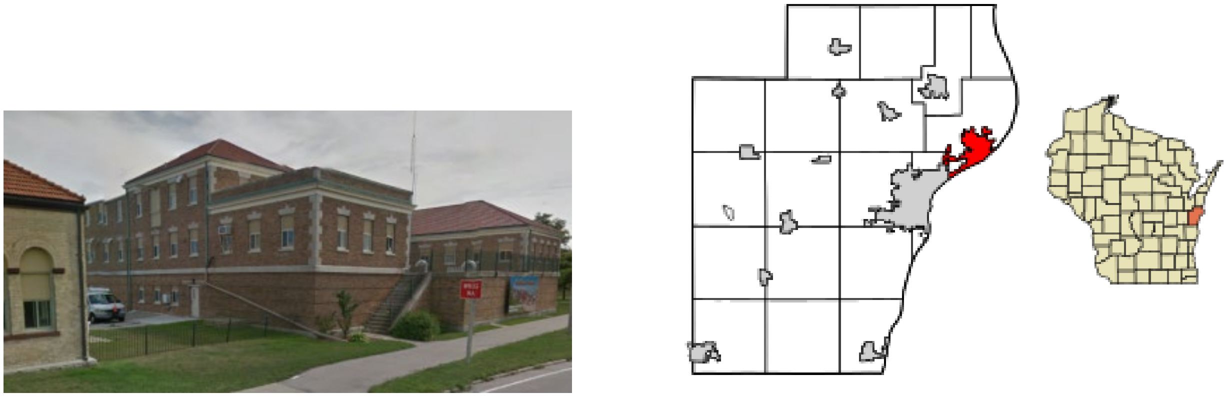

Figure 15. Location of Two Rivers, WI Water Treatment Plant

The plant installed a UF system in 2003 and 2004, which filters water directly from Lake Michigan, pretreated only with chlorine for mussel control and 200-micron strainers for membrane protection. The 3.75 mgd membrane system consisted of:

- (2) 200-micron strainers to remove the larger particles that could damage the membranes,
- (5) membrane trains, each with (45) modules and (1) recycle pump,
- (2) backwash pumps (one operating and one standby), and
- (1) clean-in-place (CIP) chemical cleaning system.

Like the other systems, the Two Rivers systems was set to automatically perform a daily air integrity test (AIT) to verify that there were no broken fibers; the AIT system was set up as shown earlier in Figure 7. While the Butler and Garden City systems performed the AITs on one train at a time, the larger Two Rivers system used pneumatic valves to divide each train into two sections – one with (23) modules and one with (22) modules – and set up the controls so that each section would perform its AIT separately.

The original Two Rivers modules were the same ones used in the original membrane systems at the Butler and Garden City plants; therefore, they experienced some of the same integrity issues shortly after commissioning. When they heard that this same membrane was replaced successfully at the other facilities, they proposed to the Wisconsin Department of Natural Resources (WDNR) that the modules in one of their trains be replaced with the multi-bore membranes. The WDNR agreed under the stipulation that an AIT first be performed on a single module with an intentionally-cut fiber to verify that the module would fail the test. This test was performed successfully in late 2016, and the modules in Train 5 were replaced in 2017. Only 35 of the new modules were needed because these had the same total area as the 45 original modules; the train connections for the other 10 modules were plugged. Because the train area remained the same, the original membrane racks, backwash pumps, CIP system, and PLC program could be used for the new modules. As with the other retrofits, the filtrate connection to each module was moved from the top of the module to its upper sidesheet, as shown in Figure 16. Note that the configuration is slightly different as each Two Rivers train contains four rows in lieu of the two-row trains at Butler and the one-row trains at Garden City.

Figure 16. The New Two Rivers Modules with Rerouted Filtrate Piping

Because the membrane material remained the same (PES), as did the membrane area per train, the new modules would be able to use the same chemical types, quantities, and cleaning protocol; therefore, chemical costs for the new modules would be identical to that of the original modules.

The WDNR agreed to a 1-month demonstration period whereby the train of new modules would be operated in parallel with the four trains of original modules to verify the ability of the new modules to meet the LT2 rule. Upon commissioning in mid-June 2017, the turbidity of the combined filtrate dropped considerably as a result of the lower turbidity produced by the new modules – refer to Figure 17.

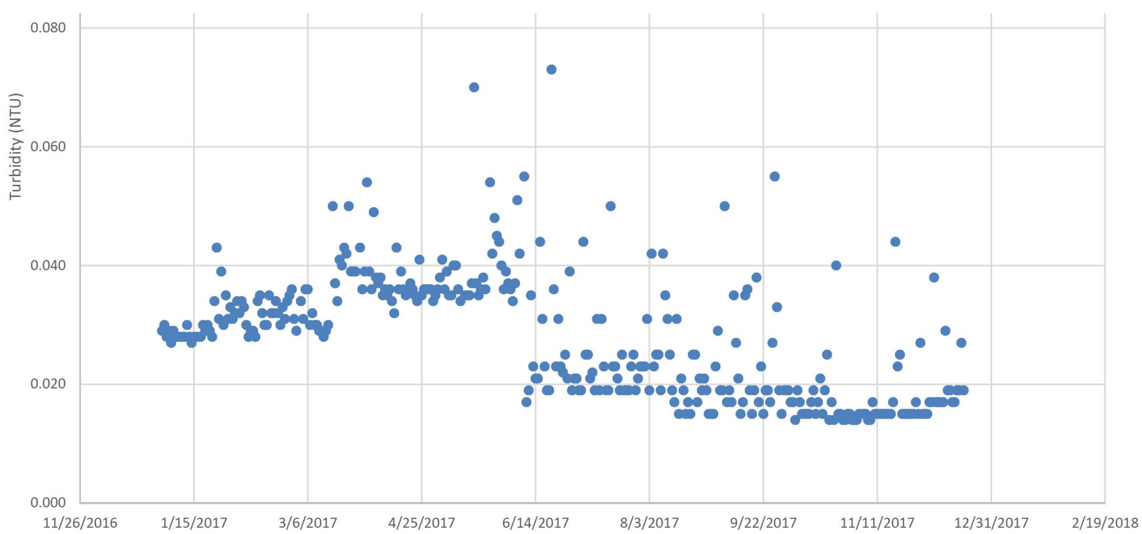

Figure 17. Combined Effluent Turbidities at Two Rivers, WI

Figure 18 shows the minimum, maximum, and average *Cryptosporidium* log removal values (LRVs) for the five system trains. Note that the maximum and average values increased significantly once the new modules were placed in service; this was because the new modules were consistently achieving LRVs of 6 even though the required LRV is only 4.

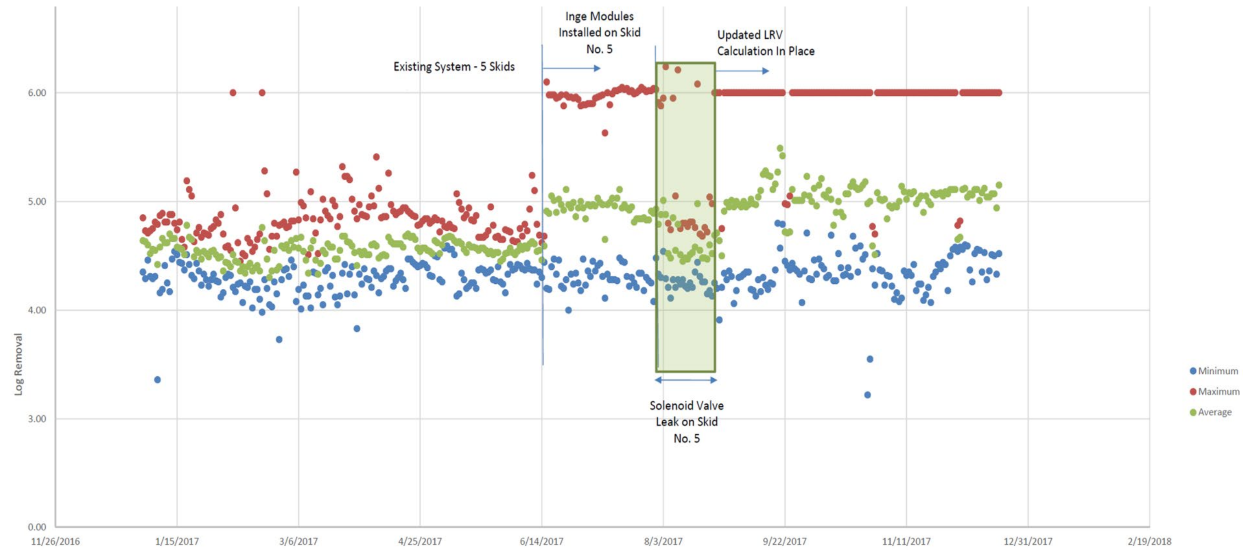

Figure 18. Combined *Cryptosporidium* Log Removal Values (LRVs) at Two Rivers, WI

The demonstration proved successful, and the modules in the other four trains were replaced in subsequent years, one train each year. Each new train of modules was put through a similar demonstration. Since the modules were placed into operation, only two modules have been replaced due to fiber breakage, both under warranty.

Amsterdam, MO

The City of Amsterdam, MO was the third Missouri city to replace their failing modules with the Aqua MultiBore P-Series modules. Amsterdam is about 20 miles northwest of Butler, very close to the Missouri/Kansas border. The city itself has only about 200 residents, but the plant is one of several in the Bates County PWSD. The County owns and operates the water treatment plant, where water from Miami Creek is treated and distributed to the nearby communities.

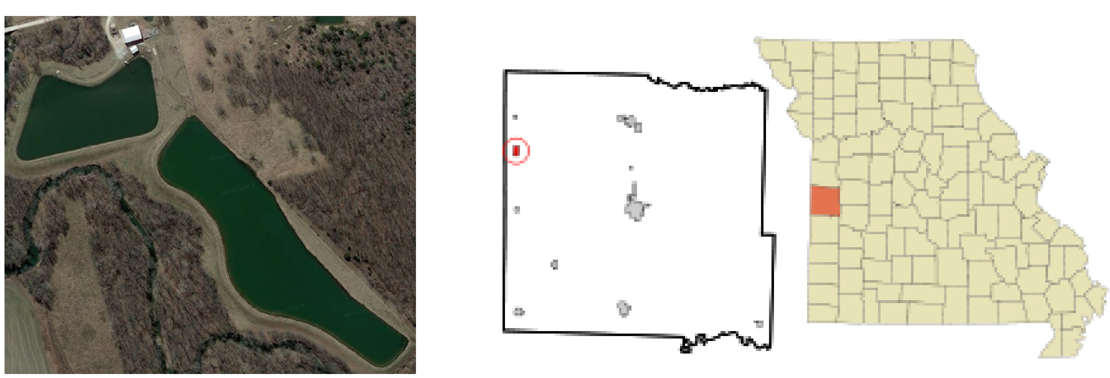

Figure 19. Location of the Water Treatment Plant in Amsterdam, MO

The plant had the same treatment technologies as the Butler and Garden City plants (shown earlier in Figure 6): oxidation, coagulation, pH adjustment, carbon addition, clarification/settling, dual-media filtration, and disinfection. And, like these other sites, the dual-media filtration was replaced in the early 2000s with low-pressure hollow-fiber UF membranes, the same brand as those used at both Butler and Garden City. The new 0.2 mgd membrane system consisted of:

- (2) 100-micron strainers to remove the larger particles that could damage the membranes,
- (2) membrane trains, each with (8) modules,
- (2) backwash pumps (one operating and one standby), and
- (1) clean-in-place (CIP) chemical cleaning system.

Like the other systems, the Amsterdam system was set to automatically perform a daily air integrity test (AIT) to verify that there were no broken fibers; the AIT system was set up as shown earlier in Figure 7. Another similarity was that the membrane fibers began breaking shortly after the system was commissioned, requiring frequent repair. And like the Garden City plant, the fiber breakage was especially troublesome since they only had two membrane trains and were forced to stop the flow entirely whenever they had integrity issues in both trains at the same time.

Once they learned of the successes at the Butler and Garden City plants with the multi-bore fibers, they began working with Aqua-Aerobic Systems to retrofit their modules. Since the MDNR had already approved the membrane for the other two plants, and the plants had been using the membranes for several years, the State allowed the plant to replace all of the modules at one time such that the 1-month demonstration was performed on both trains. So in 2018, the sixteen modules in both trains were replaced with fourteen Aqua MultiBore® P-Series Polymeric Membrane modules, leaving in operation the original membrane racks, backwash pumps, CIP system, and PLC program. The filtrate connection to each module was moved from the top of the module to its upper sidesheet, as shown in Figure 20, and plugs were provided for the connections at the empty module location on each train.

Figure 20. The New Amsterdam Modules with Rerouted Filtrate Piping

Because the membrane material remained the same, the new modules would be able to use the same chemical types and cleaning protocol; therefore, no changes to the controls were needed.

Since commissioning, the permeabilities and effluent turbidities have been equal to or better than those achieved by the original modules only with no fiber breaks.

Byesville, OH

The Village of Byesville, OH was the only of the five sites to replace the entire membrane trains in lieu of just the membrane modules. Byesville is located on the east side of the state approximately 80 miles due east of Columbus. The plant provides the drinking water for over 2,200 residents, 2 schools, and 435 businesses. Water is drawn from three wells within and adjacent to an abandoned underground coal mine; this wellfield is currently considered a ground water source under the influence of surface water.

Figure 21. Location of the Byesville, OH Water Treatment Plant

The original microfiltration (MF) plant was commissioned in 2004. As shown in Figure 22, the treatment process consisted of chlorination and aeration for iron/manganese oxidation, media filtration for iron/manganese removal, microfiltration for pathogen removal, and chlorination for disinfection. Waste solids from the filters and membranes were sent to a settling pond.

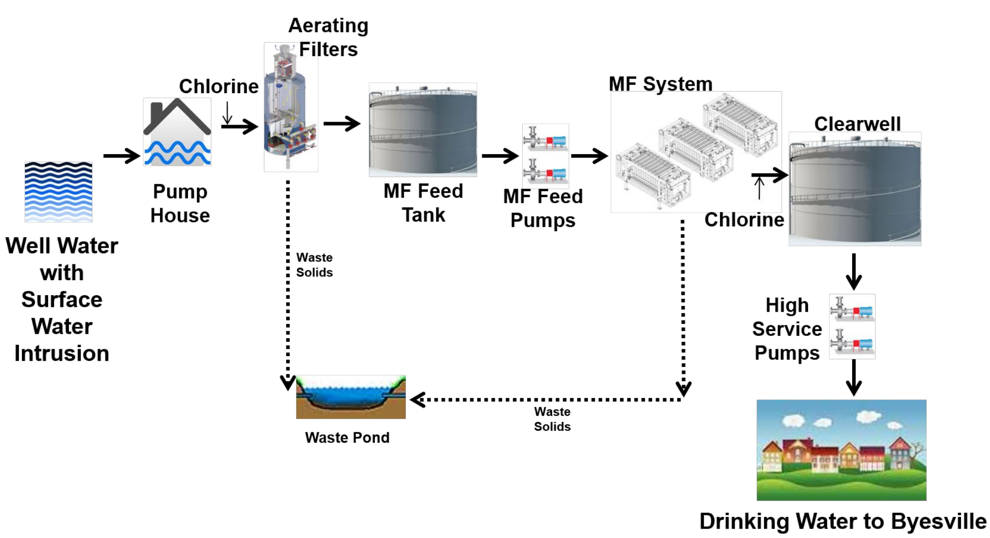

Figure 22. Original Membrane Plant Layout at Byesville, OH

The 2.25 mgd membrane system consisted of:

- (2) feed pumps (one operating and one standby),
- (3) membrane trains,
- (2) backwash pumps (one operating and one standby),
- (1) compressed air system, and
- (1) clean-in-place (CIP) chemical cleaning system.

Like the other systems, the Byesville system was set to automatically perform a daily air integrity test (AIT) to verify that there were no broken fibers. Similar to the Missouri systems, AITs were performed on one train at a time. Though the existing Byesville membranes were different than the original membranes at the other sites, they also began to fail shortly after startup, though the failures at Byesville were likely caused by the agitation during the air scour, a step that the other sites didn't use. And like the other sites, the modules were first replaced with the same model because of the low cost and simplicity of this option; however, this turned out to be only a temporary fix as the membrane fibers continued to break and require frequent pinning.

To help them find a better membrane, the Village hired URS Engineers (now part of AECOM), who suggested they look at several other membranes, including the inge multi-bore membrane. The State regulators approved a 2,000-hour demonstration during which the new system would operate in parallel with the existing system to verify the new system could achieve the desired effluent quality with no fiber breaks. The project was competitively bid in 2013, and the Village decided to go with the Aqua MultiBore P-Series system because of its demonstrated integrity and 5-year no-break warranty. The new system – consisting of (3) 30-module trains – was placed in operation in 2014; instead of running in parallel with the existing system, however, the new system quickly became the only operating system because the plant was unable to keep the existing trains in service due to the frequency and magnitude of fiber repairs.

Figure 23. One of the New Byesville Membrane Trains

Since commissioning, the filtrate turbidity of the new system has consistently averaged 0.03 NTU, as shown in Figure 24.

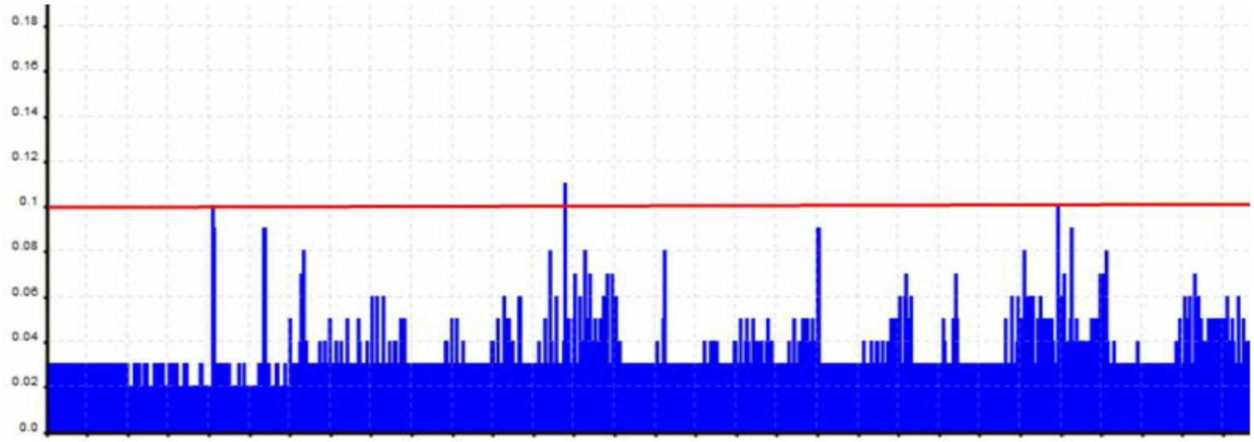

Figure 24. Filtrate Turbidity of the New System at Byesville, OH for One Month, in NTU

The permeabilties for the new system are given in Figure 25 for a typical 30-day period. As seen, the average permeability is approximately 400 lmh/bar (16 gfd/psi).

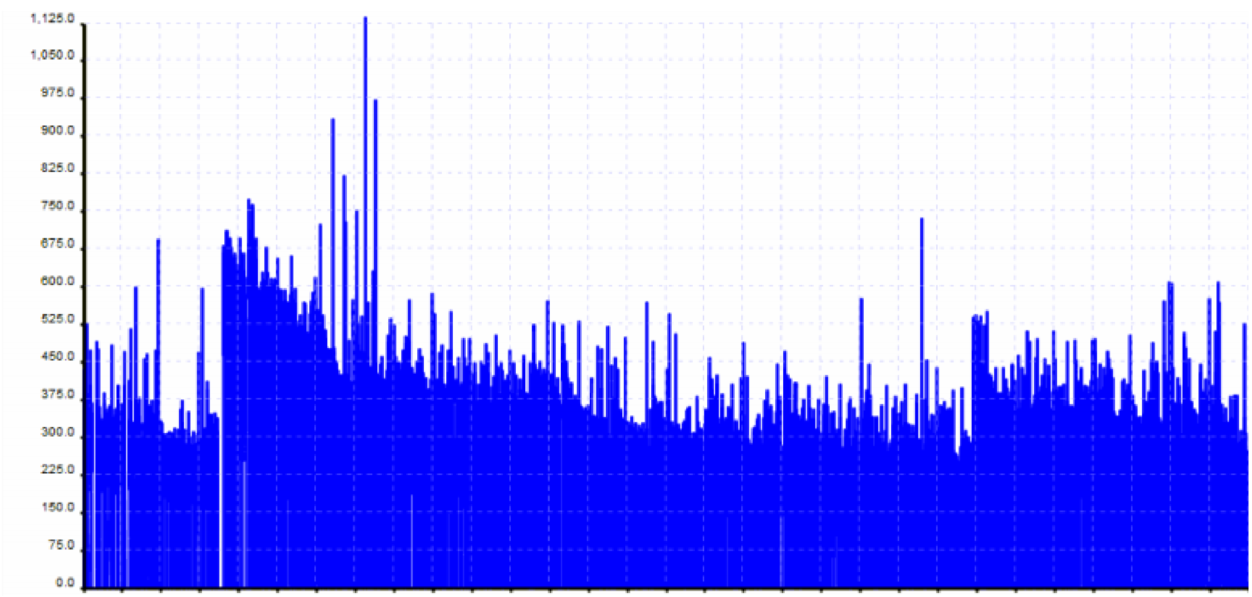

Figure 25. Permeability of the New System at Byesville, OH for One Month, in lmh/bar

Since the new system was placed into operation, only three modules have been replaced due to fiber breakage, all under warranty. The plant expanded in 2019, adding two additional 30-module trains to double the flow through the plant in order to supply water to a new power plant.

Conclusions

Based on the performance of both the original membranes and the new multi-bore modules, there are several conclusions that can be derived from the retrofits at the five drinking water plants:

1. Frequent fiber breaks kept plants from passing integrity tests, restricting plant capacity and resulting in costly repairs.
2. Aqua MultiBore® P-Series Polymeric Membranes were chosen to replace the failing membranes, mostly because of their strength and no-break warranty.
3. At three of the sites, quick State approval was achieved by operating one train of the new modules in parallel with the other train(s) containing the existing modules.
4. At the site where the entire membrane trains were replaced with new membrane trains, quick State approval was achieved by operating the (3) new trains in parallel with the (3) existing trains, though operation of the existing trains had to be discontinued at the start of the demonstration period.
5. The new membranes have consistently passed integrity tests (they have had very few fiber breaks).
6. Turbidities are lower and permeabilities are higher with the new membranes.

References

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