AMTA
American Membrane Technology Association
America's Authority in Membrane Treatment

Pilot Testing for Membrane Plants

Overview

Although each application and justification is unique, typical goals for conducting a membrane plant pilot study are:

- To address mandates by the state or local primacy regulatory agencies
- To obtain and collect baseline raw-water-quality profiles that can be used to establish a basis of design for the full scale plant
- To obtain adequate operational data to estimate operational and maintenance costs of a full scale plant
- To optimize chemical feed, membrane flux and plant recovery rates and membrane cleaning regimes
- To familiarize the operations staff with membrane technologies and provide hands-on training
- To show compliance with regulatory requirements and confirm that the permeate water quality meets the contractual, regulatory, and site specific needs of the owner and the engineer
- To conduct research for new technology applications or optimize current technologies
- To demonstrate operational protocols and procedures

Two of the most critical needs for designing a membrane plant are delineating the quality of the feed water and predicting the desired quality of the water being produced. Different membranes can produce different permeate water qualities depending on the feed water quality and the type of membrane being used. Additional considerations for design include pretreatment, pumping requirements, process monitoring and flow control, backwash and cleaning cycles, chemical feed equipment, post treatment, and residuals disposal. These components are necessary to provide an estimate of the cost and allow a cost-benefit evaluation to be conducted.

Pilot plant testing offers the best method for evaluating the feasibility of a membrane application for a specific water supply, especially since fouling and scaling sometimes cannot be quantitatively predicted from water quality measurements alone. Fouling indices provide only an estimate of the potential for fouling, but unlike pilot-scale testing, are not predictive of long-term performance. Since most applications are unique, a site-specific understanding is necessary for the proper design of the membrane system, especially for complex raw water qualities. However, the behavior, operation and system designs of membrane filtration technologies - Microfiltration (MF) and Ultrafiltration (UF) - are different from desalting membranes - Reverse Osmosis (RO), Nanofiltration (NF) and Electro Dialysis Reversal (EDR) - requiring system-specific testing for different manufacturers' membranes.

In addition, in many states, pilot testing is required for membrane processes prior to receiving regulatory approvals and applicable permits.

MF and UF Piloting

Important considerations for low pressure MF and UF membrane plants include specific flux, water temperature and associated Trans-Membrane Pressure (TMP), backwash and bleed interval impact on productivity and run time, cleaning frequency and interval, and other system-specific operation, such as Chemically-Enhanced Backwashes (CEB).

Instrument verification and calibration are required for flow meters, pressure and temperature transmitters, online particle counters, and turbidimeters. Test duration is also critical for obtaining pertinent and applicable information from the pilot operation regarding cost and performance of the projected full-scale facility.

For MF and UF plants utilizing ground waters or ground waters under the direct influence of surface waters (GUDI), the design parameters are typically well known and there is not much concern with fouling and cleaning. These membranes are designed for high particulates, turbidity and microorganisms. These systems can be (and have been) designed with success utilizing conservative, but reasonable process design parameters, without the benefit of pilot studies.

For surface waters, including flashy rivers, high organic content reservoirs and lakes as well as tidal waters and seawater, it is a different case. These sources tend to vary in temperature, chemical composition and organic/metal/ solids loading seasonally and during storm events. In most of these situations, but not all, pilot testing will result in a focused and tailored design, minimizing surprises and resulting in a more reliable and efficient facility. During testing, typically a minimum of 30 days of run time should be allowed prior to altering the test conditions or pilot operation set points for any given feed water. If multiple feed waters are to be blended or varied during full scale operating conditions, then worst-case blending scenarios with regard to temperature and water-quality impacts (particularly those related to fouling) must be considered and studied at the pilot scale.

Additional consideration should be given to specific study components of a pilot program, such as challenge tests, integrity testing, and module repair procedures. A side benefit of piloting in these cases could be to obtain guaranteed life cycle costs (power, chemicals, cleaning regime and membrane replacement) from the manufacturers. The bid documents can then be prepared based on a life cycle cost and not just the capital cost. This approach typically requires longer term pilot studies (4 to 6 months) to capture seasonal changes. This approach is typically limited to very large plants due to piloting costs. To capture the peak events and seasonal impacts and decide on optimum piloting periods, the following guidelines could be used.

<u>Spring</u> may result in higher turbidity due to snow melts and late spring rainfalls in some areas and can cause reservoir turnover. Depending on the membrane type and conservatism factor used in design, as well as budget limitations, in most cases spring is not the best time to run a pilot-study.

<u>Summer</u> typically results in a better understanding of taste/odor and algae control for MF/UF systems.

<u>Autumn</u> presents challenges in areas with hardwood cover in the watershed. These areas experience more organics by the decay of leaves. Autumn's cooler air temperatures and wind on the reservoirs will typically produce more organics as well as iron/manganese issues and therefore autumn would be a better piloting period for these locations. Cleaning regimes, coagulation optimization and fouling impacts, as well as taste and odor controls become a major part of the pilot study.

<u>Winter</u> yields the coldest water temperatures for surface water sources and therefore reduction in membrane flux due to the lower viscosity of the water. All membrane manufacturers have accurate membrane specific temperature correction factors which can be used. As long as the extreme cold temperatures are utilized during design and plant sizing, winter is not typically a mandatory season to pilot.

Fouling impacts on process productivity are also best assessed by pilot testing. Evaluation of chemical cleaning is a significant component of MF and UF piloting. Longer run times may be required in order to fully evaluate clean- in-place (CIP) procedures. Also, if CEB is incorporated into the process operation, then the impact on backwash recycle operations with regard to disinfection by-product (DBP) formation potential must be evaluated. If recirculation is to be practiced in the full scale plant then the pilot testing program should incorporate the recirculation. Should citric acid be incorporated into the cleaning regime, then resultant residuals should be disposed of in an acceptable fashion and not recycled back to the front of the process stream, particularly if coagulant is used as part of the pretreatment process train.

Citric acid will interfere with coagulant pretreatment, especially when an iron base is used. Citric acid should not be allowed to come into contact with coagulant upstream of the membrane.

It is important that any problems related to scalability, such as membrane packing density, and analogous pretreatment, be incorporated into the pilot testing program. The MF and UF modules pilot tested must be comparable to anticipated full-scale module configurations. If packing density differences exist between pilot-scale and full-scale systems then inaccuracies in operation evaluations will occur. For MF and UF, the owner and the engineer are thus reliant on the manufacturer to provide a pilot system that mimics the full-scale operation, and therefore must be involved in the technical aspects of the pilot test. Typically 1000-2000 hours of pilot operation is believed to be adequate to obtain the required information for MF and UF systems. Longer periods may be required if the MF/UF system is a pretreatment to seawater RO applications.

NF, RO and EDR Piloting

For most clean ground water sources, such as deep confined aquifers, where dissolved solids such as salts and contaminants (arsenic, radionuclides, nitrate, etc.) are to be removed, the design parameters for RO, NF and EDR membrane systems are well known with significant data from decades of operating these plants. Utilizing these resources, coupled with laboratory testing and computer model projections, typically results in very accurate design parameter estimates. This is especially true if data from other plants using the same aquifer is available. Pilot testing in these situations may not be necessary unless required by local regulatory agencies. However, pilot testing should be done if silica is present in the water at a different level than anticipated as it greatly impacts recovery and scaling.

However, for surface water supplies, such as seawater and tidal brackish sources, problems related to long-term fouling still remain with NF, RO, and EDR, and should be assessed with pilot testing. In these cases longer intervals should be considered to capture seasonal variations and allow for the development of long term fouling assessments, particularly if biological and organic fouling is anticipated. Pretreatment and chemical conditioning of membrane feed systems should be one of the primary targets for such pilot studies.

As of now, most RO and NF elements in use are 20.3 cm (8 in.) in diameter, and it is common that piloting be performed using 10.2 cm (4 in.) diameter elements as they tend to mimic full-scale operating conditions (e.g., feed channel hydraulics). 6.35 cm (2.5 in.) diameter elements, although available for testing, are not recommended to evaluate RO full scale operating conditions, as these elements do not mimic larger-element manufacture. For NF pilot studies requiring a third stage, 6.35 cm (2.5 in.) diameter elements are often used because the need to control velocity in the third stage, despite the inherent limitations of the smaller-diameter element. With the advent of 406.4 mm (16 in.) diameter elements entering the market, the use of 10.2 cm (4 in.) membranes for analogous testing conditions may be questionable for this application. Demonstration-scale testing (on the order of 1900 m3/d (0.5 MGD)) using the large-diameter membrane would be recommended for these cases as these larger diameter elements can be mounted on pilot-scale skids. Instrument calibration of flow meters, pressure and temperature transmitters, online pH and conductivity meters and others is required for NF, RO, and EDR pilot facilities.

Other Considerations

There are no national standards for membrane piloting. Regulations are specific to each state and local jurisdiction. In a few states piloting of membrane plants employing "new technologies" is mandatory. Contact your local regulatory agency early in project planning to get an understanding of their pilot testing requirements. Remember, all leading MF and UF manufacturers have gone through comprehensive national testing protocols such as challenge tests (by EPA/NSF/ Dept. of Health, etc.) multiple times and there is no need to repeat these tests if also inexpensive bench tests are sufficient in establishing rejection properties of membranes for specific contaminants. Share this information and the results of previous studies with your regulatory agency.

If pilot testing is required, it should be a meaningful program tailored for the site conditions. Such comprehensive programs could cost $50,000 to $200,000 for smaller systems with limited pilot program scope to over a million dollars for large mini-plant scale facilities with an extended long term study.

Finally, there will be extensive involvement from the consultant, manufacturers, and facility operators as well as significant laboratory costs, coordination and installation of temporary housing, water, sewer, power, internet and phone for pilot units. If multiple manufacturers are being pilot tested to prequalify manufacturers that will be allowed to bid a project, these requirements are multiple requirements. Remember pilot units are not like vacuum cleaners that you plug in and start collecting data!

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This material has been prepared as an educational tool by the American Membrane Technology Association (AMTA). It is designed for dissemination to the public to further the understanding of the contribution that membrane water treatment technologies can make toward improving the quality of water supplies in the US and throughout the world.

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