Membrane Bioreactors – Lessons Learned

Gordon Culp, Smith Culp Consulting, Las Vegas, NV

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When compared to a conventional wastewater treatment system that produces a high quality filtered effluent, a membrane bioreactor (MBR) system eliminates the need for a secondary clarifier and effluent filter and, in some cases, effluent disinfection (See Figure One). Space savings can be significant because membranes occupy much less space than a secondary clarifier and effluent filter. The size of the aeration tank is also reduced because the MBR can operate with significantly higher mixed liquor suspended solids (MLSS). An MBR produces a better effluent quality because all flow passes through a membrane with a pore size of 0.04 micron. The MBR's compact size and high-quality effluent are appealing but there have been some lessons learned.

Carefully select the membrane flux rate – The required membrane area and related cost will be determined by the flux rate that can be achieved at peak flow at minimum influent temperature. Seasonal variations in filterability of mixed liquor suspended solids (MLSS) have resulted in significant decreases in achievable winter flux rates at some MBR locations. Achievable winter peak flux rates have been as low as 10-14 gallons per square foot per day (gfd) at some plants while peak design rates are often 25-30 gfd. If you design for 25 gfd but membrane throughput is at times limited to 10 gfd, you obviously have a problem – the proverbial dilemma of trying to fit 25 gallons of stuff into a 10-gallon bucket. New plants that startup with wastewater flow that is a small percentage of design flow may not realize that they have a capacity issue for several years. Some MBR plants that have started up with flows near design flows have experienced a capacity problem. More on this in last section of this paper. Lower influent temperatures in the winter contribute to lower flux rates but the decreases have been larger than can be accounted for by temperature as also discussed later. The causes of and cures for poor MLSS filterability are not fully understood. So, it is a good idea to….

Run Pilot Test – Ideally the pilot test would be conducted for at least a full year to test the effects of seasonal variations. At a minimum, it should include the five months with the lowest influent temperatures. Coeur d'Alene Idaho recently completed a 20-month 50,000 gpd MBR pilot study.

Balance increased mixed liquor with membrane limitations – MBR's compactness comes partly from the ability to operate at much higher mixed MLSS than a conventional plant. Early researchers tested MLSS as high as 30,000 mg/L but practical considerations (including some membrane manufacturer warranties) limit MLSS to 7,500-10,000 mg/L. There is a practical limit to the amount of aeration basin that can be eliminated by increasing MLSS.

Consider temperature effects – Adjustments in flux rates for changes in temperature are typically based on relative viscosity at differing temperatures. Complicating this issue is the fact that the filterability of the MLSS in addition to viscosity can also change with temperature. Filterability is a lot harder to predict than viscosity and the filterability can have a major impact. For example, for an influent temperature decrease from 21 degrees C to 12 degrees C, the viscosity change would be expected to decrease the achievable flux by 29 percent. In a plant with seasonal filterability issues, the achievable flux rate declined by 57 percent when the temperature decreased from 21 degrees C to 12 degrees C. Pilot testing is needed to quantify the effects of seasonal changes in filterability.

Equalize Flow – Membranes (and the plant operators!) are much happier when membranes run at constant flow. The trade-offs involve the cost and space required for flow equalization versus that needed for sizing the membrane system to treat peak flows. For example, consider a hypothetical plant with average design flow of 10 mgd and a peak hour design flow of 16 mgd. One option is to design the membrane system to handle the peak flow. If pilot tests showed a reliable cold weather flux rate of 12 gfd, 1,330,000 square feet of membrane area would be required for the peak flow of 16 mgd. If flow equalization were provided that maintains a constant flow of 10 mgd, 833,000 square feet of membrane area would be needed. Flow equalization of primary effluent not only reduces the membrane area required but also reduces the effect of peak flows on the cost of design and operation of biological treatment. So, the economic evaluation of flow equalization involves determining the saving from 500,000 less square feet of membrane area in this case and the cost saving from eliminating the peak flows and loads to the biological process. The savings would then be compared with the cost to provide flow equalization to determine the cost effectiveness of flow equalization. The volume of flow equalization required for our hypothetical 10 mgd plant will, of course, be a function of the influent flow hydrograph but could be on the order of 1.5 million gallons. The space required for flow equalization will depend on the depth of the equalization basin. At 15 feet of depth, the area would be on the order of 13,000 sq. ft. Flow equalization can be provided in lined basins or in a tank, a 130-foot diameter tank in this example. In one example in Southern California, equalization is provided in a lined basin to maintain a constant 13 gfd flux rate and the 10 mgd plant is reporting excellent results.

Provide the right O&M skills – There are a lot of moving parts in an MBR plant and many are moving every few minutes. Skills to maintain a highly automated and computerized system are critical. If your existing staff doesn't have these skills, it may be a challenge to recruit them because the marketplace demand is higher than the supply in most parts of the country. You may want to consider using the design-build-operate project delivery method that will provide a single source of responsibility to eliminate finger pointing between designer and operator for any shortcomings in MBR performance.

Talk to others using the same membranes – A lot can be learned from talking to others who are using the membranes you are considering (flux rates, cleaning methods, manufacturer support, biological process operation, etc.). Better yet, visit a few installations that are operating the membranes you plan to use. Check flux rates <u>actually experienced</u> and at what influent temperatures for similar MBR installations, not just the design flux rates.

Check State Design Requirements – States may dictate certain aspects of MBR systems. For example, the State of Washington requires that peak hour flux rates must be based on one membrane train being out of service while some other states require this level of redundancy only for flows less than peak hour. The State of Pennsylvania states "influent flow equalization shall be considered for all MBR systems." Many states specify maximum flux rates for flows such as average day, peak month, peak day and peak hour. But don't take it as given that the flux rate limits in state requirements are achievable – run pilot tests to see what you can realistically expect to achieve.

Read the fine print – Example provisions of membrane warranties that can affect your design and operational flexibility include:

- Maximum MLSS concentration in the membrane tanks of 10,000 mg/L. At a 3:1 recycle rate, this corresponds to a MLSS in the bioreactor of 7,500 mg/L.
- Maximum ammonia-nitrogen of 1.0 mg/L.
- Maximum nitrate-nitrogen of 10 mg/L
- Solids retention time of 10-22 days
- Membrane supplier must approve any chemicals added to the wastewater treatment process

Complying with the membrane warranty provisions can affect the overall plant design. The ammonia limitation is an example. Ammonia in itself is not a risk to the membranes. The membrane manufacturers want a well stabilized wastewater applied to the membranes and use ammonia as an indicator of the well stabilized wastewater produced by complete nitrification. Even if you do not have an ammonia limit in your discharge permit or if you have only a seasonal ammonia limit, you must design and operate the plant for full nitrification 12 months per year to avoid voiding your membrane warranty.

Other warranty provisions that if not met may void your warranty are:

- Minimum influent temperature
- Any single influent constituent exceeds its design load
- Flux rate with all membrane trains in service
    - Average day flow
    - Maximum month flow
    - Maximum week flow
    - Peak hour flow
- Flux rate with one membrane train out of service
    - Peak hour flow
    - Maximum day flow

Plan for what happens when the membranes can't keep up – Nobody wants to end up in the situation where the membranes can't process all the incoming flow. But you need to have a plan because you'll be trying to figure out what to do with primary effluent if it happens. Here are a couple of examples in the State of Washington:

- King County's Brightwater MBR is designed to provide treatment for a maximum flow of 44 mgd. They report at times the membrane tests show a capacity as low as 20 mgd. The Brightwater plant has large storm-related flows. Peak storm-related flows greater than the MBR capacity are diverted to parallel chemically-enhanced primary treatment (CEPT) and blended with the MBR effluent for discharge to Puget Sound. If the membranes can't process all the incoming flow, the raw wastewater flow that exceeds the achievable membrane capacity can be diverted to the CEPT facility or to other treatment plants in the regional system for treatment and discharge.

- Spokane County's MBR plant has a max month capacity of 8.5 mgd and peak hour capacity of 13.8 mgd. At times during winter months the plant has been able to treat peak flows of only 6 mgd. The County diverts flow that exceeds membrane capacity to the downstream City of Spokane treatment plant where the County owns capacity. Modifications are underway to enhance the capacity of the County's plant.

Conclusion

The space savings and high degree of treatment offered by MBRs is an attraction much like the siren's call is an attraction to sailors:

> *The Sirens bewitch everybody who approaches them. There is no homecoming for the man who draws near them unawares. For with their high clear song the Sirens bewitch him, as they sit there in a meadow piled high with the moldering skeletons of men, whose withered skin still hangs upon their bones.* (The advice of Circe, *Odyssey*, 12:39-47)

Be aware of the lessons learned so that your good ship MBR lands safely ashore.

Figure One

Conventional Activated Sludge/Filtration vs Membrane Bioreactor

Source: Wikipedia