By Terry Gellner

The Ins & Outs of MBRs

An introduction to membranes, their surrounding systems and future

A membrane bioreactor (MBR) is a combination of suspended-growth activated sludge biological treatment and membrane filtration equipment performing the critical solids/liquid separation function. This is accomplished by submerging the membranes into the basin of the activated sludge treatment process. The effluent from the MBR (permeate), is of a quality typically exceeding the effluent from a tertiary treatment plant. The MBR performs the solids/liquid separation function that is traditionally accomplished using conventional secondary clarifiers and tertiary filters.

Initially used in smaller wastewater treatment plants, membranes in the activated sludge tank were submerged so that the solids separation process took care of itself as the permeate was drawn through the membrane and a high-quality effluent was achieved. This may have been the situation in smaller plants, but as membrane technology is considered in larger plants, the variation in application is becoming more extreme, process efficiency more critical and the design more focused on biology. Benefits from the use of MBR technology can be seen in nearly every plant upgrade or expansion.

Selecting a System

Engineers and manufacturers have an obligation to educate owners and operators of membrane systems on the following:

Permit requirements. Conventional National Pollutant Discharge Elimination System (NPDES) permit requirements typically do not require the use of membrane technology. Conventional activated sludge processes can treat wastewater to meet final effluent requirements. Membrane technology should be considered when nutrient requirements are stricter; antidegradation is an issue; effluent reuse is a consideration; conventional improvements require new tank construction or the addition of tertiary treatment; limited site development is a goal; and technology updates are considered. Both the hollow-fiber and flat-plate MBR systems by leading manufacturers can treat wastewater to or near nondetectable limits.

Membrane design flux. Membranes are hydraulically restrictive. The ability to permeate flow through the membrane varies between manufacturers and membrane materials because the characteristics of the membranes are different and process the permeate in different manners. Specific details for the membrane flux rate and influences on permeate operation should be discussed with each membrane manufacturer to obtain the design flux rates.

Sizing of the membranes should include low-flow, average-flow, maximum-day and peak-instantaneous flow rates, including necessary sustainable flow periods. Temperature also impacts the ability to permeate. Historical low wastewater temperatures should be provided to the manufacturer to obtain normalized flux rates between manufacturers for the site-specific conditions. Be certain to maintain design flux rates within manufacturers' typical flux operating ranges.

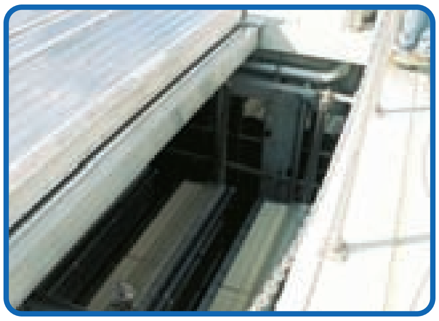
Systems surrounding membranes. Many systems are used to support the membrane process and they differ significantly between membrane manufacturers. Similar to a conventional treatment plant, preliminary treatment is needed for screening and to remove the grit and grease that protects downstream equipment during the treatment process. Membranes are very susceptible to damage from abrasive and sharp materials in the flow and blockages due to larger pieces of materials bridging or matting within or around the membranes.

Membrane manufacturers recommend the use of fine screening. Two-dimension screening such as perforated plates is desired over slotted screens or one-dimensional screening, but either can be used. Hollow-fiber membranes typically require more stringent screening requirements than flat-plate membranes.

In simpler MBR facilities, both may require equalization and provide anoxic basins followed by the aeration basin, then the MBR reactor basin. The activated sludge process basins have similar total volumes, although the aeration basin and MBR basin sizes will differ. A hollow-fiber system has a smaller MBR basin and larger aeration basin when compared with a flat-plate system. The sum total volume of the aeration basin and membrane basin (activated sludge process) is nearly equal between manufacturers.

The air system for the aeration basin prior to the MBR basin can be compared to a conventional treatment plant aeration basin air system. While the MBR air system differs between membrane systems, the total air system is similar in size and connected horsepower. Manufacturers focus on energy conservation within the MBR air system because this is a large source of power consumption. The hollow-fiber system accomplishes this by pulsing or cycling air between membrane cassettes; this is accomplished by cycling pneumatic valves operated by a compressed air system every 10 to 30 seconds. The flat-plate air system, unlike the hollow-fiber, utilizes variable speed drives and meters flow to the MBR basins to adjust air flow and power usage.

Permeate and flux maintenance systems also differ considerably between the two leading manufacturers. The hollow-fiber permeate system is usually a pumped system due to a higher operating transmembrane pressure (TMP) and includes back-pulsing and chemical addition for continuous and regular flux maintenance. Also included are an aspirating tank to capture dissolved air in the pump suction and sometimes reversing



Above: Membrane basin pipe gallery.

Top right: Flat-plate membrane cassettes within basin at time of startup.

multifunctional permeate pumps as opposed to separate permeate and back-pulse pump systems. Flux maintenance is achieved in the hollow-fiber system by relaxing, air pulsing, regular back-pulsing or chemical back-pulsing, regular chemical maintenance cleaning and periodic recovery cleaning. The surrounding systems include onsite chemical pump systems, chemical storage, back-pulse pumps, back-pulse tanks and tank-drain pumping capabilities for higher strength chemical recovery cleaning.

The flat-plate permeate system can be pumped or accomplished by gravity via control valves. Flat-plate membranes can be single stacked or double stacked, each stack having its own permeate system, which is necessary due to low-operating TMPs. Flux maintenance is achieved by relaxation of the membranes, air scouring to maintain an optimum biofilm and clean-in-place (CIP) chemical cleaning when TMPs become higher than desirable and permeability needs to be recovered. CIP cleaning usually occurs three to four times per year and is typically more regular in colder climates where wastewater temperature is lower.

Other equipment common to the two membrane systems consists of monitoring and control systems.

Site conditions. When selecting a new plant site or retrofitting an existing one, the site may lend itself to a certain membrane system due to its hydraulic configurations. Plant design considerations include the method of influent flow and recycle, the method of permeating and the membrane placement. The configuration of the membrane basins varies between manufacturers and installed membranes. The amount of side water depth above the membrane cassette is dependent on the mode of permeate operation.

A common method of permeating membranes is using pumps. A system of permeate pumps creates a slight vacuum on the membranes to assist in drawing permeate through. When site conditions permit, flat-plate systems can be permeated by gravity or gravity-assisted by pumping, regardless of the membrane cassette stack (provided the hydraulic gradient is sufficient to overcome the TMP). Approximately 50% of the flat-plate systems in operation use gravity permeate systems.

Sludge. To date, there appears to be no limit on the sludge processes available due to the sludge produced by the membrane process. What has been realized is a reduction in sludge production from MBR facilities.

Membranes are being incorporated into sludge processes to further increase volatile destruction and reduce the liquid volume, which has resulted in smaller stabilization reactors, more solids in the sludge to be processed and fewer pounds of solids requiring disposal.

Procurement. The advantages outweigh the disadvantages to prenegotiate and select a membrane system prior to final design, as systems vary considerably. Membrane systems are typically procured by prequalification or preselection. First, membrane suppliers are prequalified by the owner based on the credentials of the membrane systems and visits to different facilities. Next, formal site-specific design approaches and price proposals are requested from the prequalified suppliers for use in a best-value evaluation. Understanding that the prequalified membrane systems can produce effluent to meet the requirements of the NPDES permit, an equal comparison of the manufacturers' standard systems can be made by requesting formal proposals. The price from the preselection system is then included in the bid documents as an allowance.

Future of Membranes

MBR wastewater treatment plants have been successfully constructed and operated while consistently producing exceptional effluent. As the MBR process continues to be utilized in more facilities, the construction of larger-capacity plants with MBR technology will occur.

The primary manufacturers have the capability to produce membranes for these larger plants, but these plants will bring new challenges. The manufacturers are learning the difficulties of applying the technology to larger facilities while addressing the need to improve operating efficiencies and minimize power consumption.

As membrane use increases, applications will become more widespread. A greater variation in application will require manufacturers to focus on biological treatment and improve system efficiency. MT

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