America's Authority in Membrane Treatment

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American Membrane Technology Association

Improving America's Waters Through Membrane Treatment and Desalting

Membrane Bio-Reactors (MBR)

The use of Membrane Bio-Reactors (MBRs) in municipal wastewater treatment has grown widely in the past decade. This is due primarily to more stringent effluent water quality requirements, space constraints, lower operator involvement, modular expansion characteristics and consistent effluent water quality capabilities.

Wastewater treatment plants have historically required a significant amount of land to construct the necessary tanks and infrastructure for the required levels of treatment. MBR provides a cost effective viable alternative to conventional treatment within a considerably reduced footprint. Additionally, there are ever increasing regulations relating to pathogens, viruses and other constituents of concern, which are not typically reduced to desirable levels by conventional treatment processes.

New water is not easily created. However, some communities are doing just that by turning to more advanced processes, such as MBR systems, which make water recovery and reuse possible. MBR technology combines conventional activated sludge treatment with low-pressure membrane filtration, thus eliminating the need for a clarifier or polishing filter. The membrane separation process provides a physical barrier to contain microorganisms and assures consistent high quality reuse water. The ability to cost effectively treat raw sewage for reuse provides a new, reliable, drought-proof supply of water that can benefit communities. By reducing reliance on over stressed existing supplies, increased availability of potable water and improve our environment by decreasing discharges of partially treated wastewater to oceans, lakes, rivers, streams and creeks.

MBR technology is also ideally suited for an array of municipal and industrial wastewater applications such as irrigation, aquifer replenishment, wetlands development, industrial process water, boilers and cooling systems. More recently, MBR technology has pushed satellite treatment plants into the forefront. A satellite plant allows communities to remotely treat wastewater, thereby alleviating the need for expanding centralized sewage systems and long distance pipelines, which can be disruptive and costly. It involves taking raw sewage from existing regional sewer lines and treating it through small wastewater treatment plants utilizing MBR technology). Thus, producing recycled water for local use and allowng the residuals back into the sewer system.

MBR Benefits

MBR systems offer a wide range of benefits, such as:

- ✓ MBR is capable of meeting the most stringent effluent water quality standards.
- ✓ Combining space efficient membrane systems and operations at increased mixed liquor concentrations (commonly 8,000-18,000 mg/l), MBR systems are highly space efficient. Moreover, MBR designs will require only 30-50% of the space required for conventional systems designed to meet the same treatment goals. This improved space efficiency benefits not only new facilities, but allows expansion and upgrade of existing facilities up to 3-5 times existing capacity without additional treatment volume or site footprint.
- ✓ MBR systems provide this high effluent quality in a greatly simplified process. This requires only headworks, biological processes, membrane filtration and disinfection to meet the most stringent water quality standards. In comparison, conventional process requires additional primary treatment, secondary clarifiers, Enhanced Nutrient Removal and media filtration, prior to obtaining the same effluent characteristics. More importantly, the effluent quality is highly consistent with the membrane barrier and a more stable biomass.
- ✓ MBR systems are simpler, with fewer process components and maintenance requirements. Common maintenance is still required on mechanical components, but operators can now avoid difficulties in operation tied to sludge settling and clarifier sludge blankets. MBR systems are easily automated and instrumented to measure performance. It allows systems to be remotely operated and monitored, thus significantly reducing operator attendance.
- ✓ The modular nature of the membrane system allows more efficient phasing of facilities. Membrane modules can be delivered on a "just in time" basis. Therefore, reducing the need for large and costly initial construction to meet long-term projections.

MBR Wastewater Influent Limitation and Pretreatment

The membranes in a MBR system are made from polymeric organics (PVDF, PE or PES) and assembled into units (modules, cassettes, stacks) with high packing density. Raw wastewater pretreatment is important to sustain stable MBR performance and fine screening is an essential operation of any pretreatment system. MBRs have a limited tolerance for abrasive and stringy materials, such as grit, hair and fibrous material. This material, if accumulated in the mixed liquor to a sufficient extent, can cause membrane damage, accumulation of solids and sludge between membrane fibers and plates, or clog membrane tube openings. Therefore a multi-step mechanical process, including coarse screening, grit removal, primary clarification and fine screening, is the most efficient pretreatment for large scale municipal MBRs. For small and medium scale, MBRs course screening, grit removal and primary clarifiers are optional and dependant on the designer's/owner's choice and economic analysis. For very small MBRs, such as those used for communal developments, fine screening is optional.

MBR suppliers normally specify fine screening requirement of <2 mm mesh or hole opening (with <1 mm preferred), while side stream MBRs will typically have tighter requirement for fine screening. Fine screens are sized for peak flow with one screen out of service to prevent overflow or bypass of unscreened wastewater. Washing and compaction of screening solids are recommended, where practical, to reduce water and organic content of screenings. Fine screens in many different configurations are available, each uniquely fitting a particular need and application. Typical fine screen configurations include rotating brush screens, internally-fed rotary drum screens, in-channel rotary drum screens and traveling band screens.

Oil and grease in the concentrations typically found in municipal sewage have little or no impact on the operation of an MBR. However, free oil and grease needs to be removed as this can prematurely foul membranes.

Pretreatment of industrial wastewater varies from case to case because some industrial wastewater may have high COD (>10,000 mg/L), high temperature (> 40°C), high TDS (>20,000 mg/L) or high content of inorganic solids. Without proper pretreatment, these wastewaters may jeopardize MBR applicability or economic feasibility. Most industrial wastewaters do not require fine screening and some may need physical-chemical pretreatment, such as flocculation/coagulation and/or dissolved air flotation (DAF).

MBR Effluent Water Quality Capability

One of the most important advantages of MBRs over conventional biological technologies is the superior quality and consistency of produced effluent. Historical MBR operation has proven that the effluent can exceed the world's most stringent wastewater treatment standards; including California's Title 22 reuse standards, European bathing water standards, US- Coast Guard, United Nation's International convention for prevention of pollution from ships and Alaskan marine discharge standards.

MBRs ensure an effluent free of solids, due to the positive barrier for suspended solids and colloidal materials. They also overcome the operation problems associated with poor sludge settling in conventional activated sludge processes while maintaining a considerably higher MLSS concentration and sludge retention time. Consequently, both soluble and particulate organics in waste streams are effectively oxidized. Nutrient removal can be readily accomplished through biological nitrification, denitrification and chemical or biological phosphorus removal.

MBRs have the capability to consistently achieve the following effluent quality:

BOD_5:	< 3 mg/L
TSS:	< 1 mg/L
NH_3-N:	< 0.5 mg/L
Total Nitrogen:	< 3 mg/L
Total Phosphorus:	< 0.05 mg/L
Turbidity:	< 0.2 NTU

The consistent high quality effluent produced by MBRs is suitable for a variety of municipal, industrial and commercial reuse purposes. It also can be applied in environmentally sensitive areas. MBR effluent is an excellent water source for reverse osmosis applications to produce higher quality water for ground water recharge or industrial pure water reuse.

MBR Capital/O&M Ranges

As a result of widely varying conditions, costs for MBR systems can vary greatly. For both capital and operating costs, numerous factors will impact any particular project including:

- Local construction costs
- Redundancy requirements
- Hydraulic peaking factors
- Local power costs
- Project specific needs for site, including plant buildings and enclosure
- Project size
- Materials of construction

However, to provide general guidelines a few basic assumptions have been made. For smaller facilities (less than 1 MGD), expected equipment costs should be $2.00 - $6.00 per gallon of plant capacity, with complete plant construction from $12.00 - $20.00 per gallon of plant capacity. Operating expenses for the combined biological and membrane systems, including power, chemicals, and membrane replacement, should range from $350 - $550 per million gallons treated.

Facilities greater than 1 MGD, typically see some efficiencies and economies of scale, with equipment costs of $0.75 - $1.50 per gallon of plant capacity and complete plant construction from $5.00 - $12.00 per gallon of plant capacity. Operational costs for these plants generally range from $300 - $500 per million gallons treated. Through improved products and more efficient design and construction, these costs continue to decline globally.

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Other Considerations

For owners and utilities, there are a number of key factors to consider when contemplating selection of an MBR system. Capital costs for a typical MBR system have become more competitive. In many cases, less than conventional tertiary or reuse, but still remain marginally more expensive if only secondary effluent quality is required. However, MBR can compete economically with secondary treatment technology when space for expansion is limited and may require expanding to another site. It is well documented that MBR systems are more energy intensive than their conventional treatment equivalents largely due to the energy required for membrane air scour. However, significant gains in energy efficiency have been achieved in the last decade. This is a major area of research and development. With current available technology for wastewater screening, pre-treatment and membrane cleaning, the predicted life of membrane elements is 10 years and their associated costs need to be considered in any present worth analysis.

The hydraulic capacity of membranes in an MBR process is based on design flow rate criteria and temperature. Typically maximum day or peak hour flows at the expected coldest temperature will dictate the membrane surface area required for a treatment plant. The design flux (unit flow per membrane surface) is the single most important design parameter. It will dictate the surface area of membrane installed, impact membrane air scour requirements, chemical cleaning requirements, membrane replacement and warranty costs. Design flux is very site dependant and needless to say, requires careful consideration.

A number of membrane configurations are commercially available and include hollow fiber (both reinforced and non-reinforced), flat plate or tubular. The differences between each of these types of membranes is significant. They include materials of construction, chemical cleaning, pore size (ultrafilter vs. micofilter), air scour requirements, hydraulic configuration and membrane tank volume. Selecting the appropriate membrane configuration requires careful consideration of robustness, operating flexibility, influent wastewater characteristics and operating costs for a given application.

Like all membrane facilities, periodic cleaning must be performed to remove biological and inorganic foulants. Initially, many MBR systems were submerged in the aeration basin that required removal of membrane elements or units for cleaning. This was very labor intensive, particularly as plant capacities expanded. The current trend allows for the biological process and membrane operating system to be located in separate tanks. This optimizes the performance of both processes and allow the membranes to be cleaned in-situ. Cleaning processes are now fully automated simply requiring the operator to schedule the cleaning time or interval through the plant SCADA system.

Membrane systems are highly automated processes and as such redundancy and reliability need to be evaluated through the design process. There are many approaches to build redundancy into an MBR process. Including specification of redundant trains, influent equalization (relevant for smaller facilities), stand-by power and hot back-up PLCs. The level of redundancy required is site specific and one should consider available storage, overall number of process trains, reliability of power, and type of plant (end of pipe vs. water reuse facility).

Significant flexibility exists with the biological design associated with MBRs. Sound biological design, such as maintaining adequate DO concentrations in aerobic reactors and proper selection of SRT, is critical for overall good membrane performance.

Biological process configuration options are extensive. Systems can be designed for very low total nitrogen applications, as well as biological phosphorus removal in addition to more conventional nitrification/de-nitrification systems.

Future of MBR

Market trends indicate MBR technologies will be increasingly utilized as part of wastewater treatment, water reuse programs, conservation of our natural resources and new water sources. With the support of the federal government, states like California, Florida, Texas and Arizona are taking steps to promote the use of MBR technologies for wastewater treatment. In fact, in California, the Bureau of Reclamation supported the Aqua Research 2000 Project that verified an MBR system can reliably produce high quality effluent suitable for Title 22 application.

This type of support, coupled with industry improvements in the technology, will take MBR to the next level to become "not just an alternative," but "the treatment of choice" in the next few decades.

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.

For more information, please contact:

American Membrane Technology Association (AMTA)
2409 SE Dixie Highway
Stuart, Florida 34996
Phone: (772) 463-0820
Fax: (772) 463-0860
Email: admin@amtaorg.com

or visit our website at:
www.amtaorg.com

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