

*Today, the implementation of membrane bioreactor (MBR) systems for wastewater treatment is growing at an annual rate of approximately 15% to 20%. By 2010, MBR technology for industrial and municipal wastewater treatment will have a global market value of more than \$360 million.*

By Dr. Peter Aerts

There are three distinct drivers to support this growth and use of MBR technology. First, global water reuse practices are influenced by freshwater availability and affordability. Growing population and urbanization, improving living standards in developing countries and the expansion of intensive water-consuming industries are causing local imbalances between water supply and demand. Second, specific market drivers demand technological solutions for municipal and industrial wastewater treatment. Finally, several economic and operational factors at the system level favor the use of MBR technology.

greater resistance to temperature and as such, are very suitable for industrial and wastewater applications.

**Technical Challenges**

Technical challenges of a submerged membrane module are focused around module characteristics and design. The key to the success of submerged MBR technology offerings is mechanical strength of the fiber and fiber integrity. Biofouling and frequent recovery cleanings reduce the membrane lifetime; therefore, cost dedicated to purchase and replacement of membranes is a relatively high fraction of the capital and operating cost.

The key to market acceptance and operational excellence of MBR is the reduction of membrane fouling and clogging, thus increasing the operational effectiveness of this type of system. Fouling control is mainly achieved by smart operational control schemes of the membranes' permeability and the operation at subcritical flux. Clogging of the membrane area produces heterogeneous air-flow distribution and flux differential over the length of the membrane. This will increase local flux and thus the fouling rate. In real operation, clogging of MBR modules is a major problem because it causes irreversible fouling and downtime for chemical cleaning.

Operational excellence of the biological wastewater treatment is key to consistent operation and minimal fouling of the membranes over time. More automation is required not only in design and startup but also in ensuring daily operation is optimized to capture the throughput advantages. Additional technology advances are under investigation (i.e., the optimization of bubble size for submerged hollow-fiber, improved bubble distribution for submerged flat sheet and supplement air scour with mechanical vibrations). Other strategies involve controlling the condition or nature of the biomass or new designs, including microbial fuel cells and biofilm MBR or the combination of anaerobic processing with MBR.

Efficient energy use is critical in today's MBR market. Air scouring is the main consumer of energy, amounting to 40% of the operational cost of a hollow-fiber MBR today. Needless to say, for a submerged ultrafiltration membrane bundle, the fiber length, diameter and overall module design will ultimately determine the water flux/footprint and the energy consumption per cubic meter of water.

**MBR Sustainability**

MBR technologies have advantages over alternative wastewater treatment technologies. Several hybrid MBR technologies are now under evaluation to lower the energy consumption or increase the removal efficiencies of specific contaminants.

Currently, sustainable operation of MBRs is related to the stable long-term control of membrane fouling and efficient reclamation of wastewater to augment natural supplies. Fouling removal is extensively studied in MBRs because of its relation to energy consumption.

In the future, there will be a need for further development of membrane-based reclamation for sustainable water supply because of two main drivers. First, the cost of processing wastewater to the standard for high-quality use or reuse is about 50% of that for seawater desalination. Second, reclamation and reuse can be done locally, which favors decentralized processing; this could avoid long-distance transfers of the product water. Decentralized wastewater treatment systems avoid the cost of new infrastructure, which is the main bottleneck to large-scale water reuse implementation. WWD

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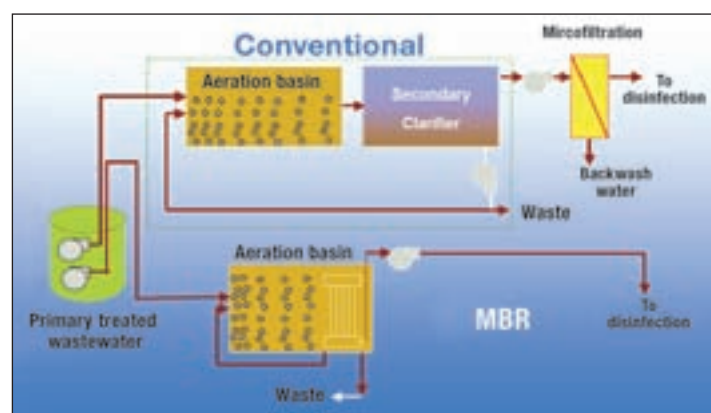
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**Technical Attractiveness**

MBR technology provides advantages over water treatment technology (activated sludge) because of the lower footprint, ease of retrofit, operational flexibility and ability to produce a high-quality reusable effluent. The perceived higher operational cost, coupled with the disruptive nature of the technology and lack of regulations in wastewater treatment, however, creates challenges that currently are slowing the growth rate of MBR implementation.

There are three types of MBR configurations successfully being deployed in wastewater treatment today: external MBR, submerged hollow-fiber MBR and submerged plate/frame MBR.

Today, overall energy consumption and operating cost is lower for a submerged hollow-fiber system than for a flat sheet MBR. This is primarily due to the higher packing density of hollow-fiber module (more active area available), as well as the ability to clean the membranes by several physical methods like air scouring and chemically enhanced backwashing. A plate/frame MBR sheet system is easy to operate and demands low maintenance. The bioreactor volume that is occupied by the membranes is much greater for plate and frame systems compared to hollow fibers; therefore, it is expected that a larger biological tank is needed for a large wastewater treatment plant.



The conventional activated sludge method vs. utilization of MBR technology for treating primary wastewater effluent.

Tubular membranes can be used at higher sludge concentrations, which make them more compact. They are operated at a higher pressure and flux, causing more fouling of the tubular membranes. Due to this fouling, tubular membranes will have more frequent chemical cleaning, and their filtration control scheme makes for easy-to-control membrane cleaning. These membranes are easy to take out of service and use low amounts of chemicals/backwash water. Most tubular membranes have a

An overview of the technology's advantages, drawbacks and sustainability