

Application of Membrane-Bio-Reactor in Waste-Water Treatment: A Review

Jain Jyoti, Dubey Alka and Singh Jitendra Kumar

Department of Chemical Engineering, MNIT, Jaipur, Rajasthan.

Abstract

In the near future, the availability of fresh clean water will become increasingly limited in many areas of the world. Salinity intrusion into ground water supplies, nutrient eutrophication, endocrine disruptors, and heavy metals are just a few source of contamination that may be encountered in water supplies. One possible solution to these problems is the application of membrane bioreactor for wastewater treatment and reuse. The recycling or reuse of wastewater is one way of supplementing available water supplies. The recent developments in membrane technology have made the recycling of wastewater a realistic possibility since the costs involved have reduced by 80% over the past 20 years. The membrane separation of microorganisms from the treated wastewater is discussed in detail. Problems of membrane fouling and membrane washing and regeneration, linked to activated sludge characteristics, are examined. This paper provides a literature review with special focus on comparing the principle, operation and performance of these four types of MBRs with respect to industrial effluent treatment elaborately. In conclusion, MBR represents an efficient and cost effective process that copes excellently with the growing needs for transforming wastewater into clean water that can be returned to the hydrological cycle without detrimental effects.

Keywords: Membrane Bioreactor, Industrial Wastewater, Performance, Fouling.

1. Introduction

The availability of fresh clean water is becoming increasingly limited in many areas of the world, at the same time an increasing quantity and quality of water is required to

maintain and support the growing population. Many under developed areas of the world already face a shortage of clean drinking water and irrigation water for food production, while in industrialized nations, the quality of available water for public and industrial use will be a larger issue in next years.

Portions of Africa, Asia, India, China, Australia, Europe, Mexico, the Middle East and southeast United States are identified as areas having a great water scarcity. It defines as a supply less than 200 m³/person/year (Howell, 2004). Areas with adequate supplies may face issues with quality. Salinity intrusion into ground water supplies, nutrient eutrophication, endocrine disruptors, and heavy metals are just a few source of contamination that may be encountered in water supplies. One possible solution to these problems is the application of membrane bioreactor for wastewater treatment and reuse.

The recycling or reuse of wastewater is one way of supplementing available water supplies. The recent developments in membrane technology have made the recycling of wastewater a realistic possibility. Effluent from membrane treatment is able to meet or exceed current drinking water regulations. Despite the high quality, the reuse of water faces several hurdles. The perception of recycled water by the public is less than favorable. In areas with greater water scarcity, such as India, Singapore, the acceptance of recycled water is much greater (Howell, 2004). The additional treatment required for reuse comes at an increased cost, which may not be justified in areas with sufficient water supplies. Although once considered economical, membrane technology costs have decreased by 80% over the past 20 years, making the use of membranes and MBR a viable option for the first time (Layson, 2004).

2. Membrane –BIO-Reactors

The technology of membrane separation of activated sludge, commonly referred to as “membrane bioreactor” (MBR), is the combination of two processes viz. activated sludge treatment together with a separation of the biological sludge by micro or ultra-filtration membranes with pore size of typically 10 nm to 0.5µm to produce the particle-free effluent. Membrane Bioreactors are able to provide the benefits of biological treatment with a physical barrier separation. Compared to conventional treatment processes, membranes are able to provide better quality effluent with a similar, automated treatment process.

2.1 History

The idea for coupling the activated sludge process and membrane separation was firstly reported by research conducted at Rensselaer Polytechnic Institute, Troy, New York, and Dorr-Oliver, Inc. Milford, Connecticut, US. The first MBR installation (Membrane Sewage System-MST) commercialized in the 70’s and 80’s were based on what have come to be known as side stream configurations, was made by Dorr-Oliver, Inc., with flat sheet ultra filtration plate and frame membrane. Due to the high energy demand, these technologies targeted only small and niche market applications such as treatment of ship-board sewage, landfill leachate or industrial effluents and hence did

not gain much interest in America but it had considerable success in Japan in the 1970s and 1980s.

2.2 Functions Of Membrane –Bio-Reactors

The physical barrier imposed by the membrane system provides complete disinfection of the treated effluent. It also enables not only recycling of the activated sludge to the bioreactor but also production of a permeate free of suspended matter, bacteria, and viruses and it also enables operation at higher sludge concentrations (typically up to 20 g/L instead of max. 6 g/L with conventional systems), and therefore permits to reduce the required footprint and/or sludge production. The bioreactor and membrane module each have a specific function:

- (i) Biological degradation of organic pollution is carried out in the bioreactor by adapted microorganisms;
- (ii) Separation of microorganisms from the treated wastewater is performed by the membrane module.

2.3 Advantages of MBR over Traditional Processes

When compared to traditional activated sludge systems, the MBR offers many attractive advantages:

- The traditional secondary clarifier is replaced by a membrane module. This module is more compact and the quality of rejected water is independent of the variations of sludge settling velocity.
- The MBR allows the biomass concentrations to be higher than for traditional treatment plants. Jefferson et al. [3] utilized a 20 g _ L⁻¹ in biomass concentration while Yamamoto et al. [4] utilized 30 g _ L⁻¹, whereas conventional processes utilize biomass concentrations less than 5 g _ L⁻¹ in order to avoid problems inherent to settling of concentrated flocs. With poor settling flocs avoided, biological degradation is more complete and treatment efficiency is higher.

Other advantages of this system are as follows:

- The volume of the aeration tank can be also reduced since a higher concentration of biomass can be stored in the bioreactor.
- The production of sludge, the disposal of which is often difficult, is decreased by a factor of 2 to 3 [6], resulting in a reduction of the overall operating costs.
- The membrane bioreactor is perfectly integrated in the industrial process because the wastewater can directly be treated in situ, allowing water reuse and concomitant reduction of the manufacturing costs linked to water consumption.

Unlike the conventional activated sludge system, the membrane bioreactor is characterized by a complete retention of the biomass inside the bioreactor because of the use of membrane separation, which controls and increases the sludge retention time (SRT) independently from the hydraulic retention time (HRT). High SRTs enable one to increase the sludge concentration and the applied organic load, thereby increasing the pollutant degradation.

2.4 MBR Configurations

MBR systems can be classified into two major categories according to the location of the membrane component: **External membrane MBR configuration** which typically involves the use of polymeric organic or inorganic membranes located external to the bioreactor.

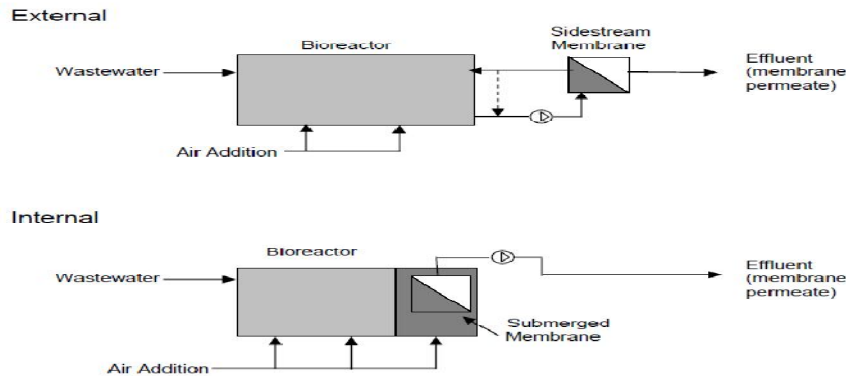


Figure 1: Simplified Schematics Depicting MBR Configurations.

Table 1: Comparison of External and Internal Membrane MBR System Configurations.

S. No.	Comparative Factor	External Membrane MBR	Internal Membrane MBR
1.	Membrane area requirement	Characterized by higher flux and hence lower membrane area requirement.	Lower flux but higher membrane packing density (i.e. membrane area per unit volume).
2.	Space or Footprint Requirement	Higher flux membranes with bioreactor operating at higher VSS concentration and skidded assembly construction results in compact system.	Higher membrane packing density and operation at bioreactor VSS concentration of 10 g/l or greater translates to compact system.
3.	Bioreactor and Membrane Component Design and Operation Dependency	Bioreactor can be designed and operated under optimal conditions including those to achieve biological N and P removal, if required.	Design and operation of bioreactor and membrane compartment or tank are not independent. High membrane tank cycle required (e.g., recycle ratio 4) to limit tank VSS concentration build-up.

4.	Membrane Performance consistency	Less susceptible to changing wastewater and biomass characteristics.	More susceptible to changing wastewater and biomass characteristics requiring alteration in membrane cleaning strategy and/or cleaning frequency.
5.	Recovery of Membrane Performance	Off-line cleaning required every 1 to 2 months. Simple, automated procedure normally requiring less than 4 hours.	Off-line "recovery" cleaning required every 2 to 6 months. A more complex procedure requiring significantly more time and manual activity, at least on occasion may be required (i.e., physical membrane cleaning).
6.	Membrane Life or Replacement Requirements	Results to-date imply an operating life of 7 years or more can be achieved with polymerics prior to irreversible fouling. Operating life of ceramics much longer.	Results to-date imply an operating life of 5 years may be possible prior to irreversible fouling and/or excessive membrane physical damage.
7.	Full Scale Application Status	Conventional membrane based systems have a very long track record.	Full scale application widespread.

3. Advantages of MBR System in Treatment of Industrial Wastewater

Specific advantages of MBR systems in the treatment of industrial wastewaters include the following.

- Slower growing organisms, such as nitrifying bacteria and those capable of degrading Complex organics, can be readily maintained in MBR's.
- Largely unencumbered control of the SRT provides optimum control of the microbial Population and flexibility in operation. A short SRT maximizes biomass production and its organic content which if the biomass is anaerobically processed, maximizes digester gas production and therefore its energy value. A long SRT favors aerobic digestion of bio solids, which may be attractive under certain circumstances.
- High mixed liquor concentrations in the reactor allow wastewater to be treated efficiently at long SRTs, minimizing biomass yield.
- More compact biological reactors are possible.
- Non-biodegradable compounds tend to be discharged with the sludge rather than with treated water.
- Rapid initial process startup due to retention of all microbial seed material.

- Particulate, colloidal and higher molecular weight organics are retained for a period equivalent to the reactor SRT versus the liquid contact time or hydraulic retention time (HRT), providing maximum opportunity for biological degradation of these compounds.
- Eliminates concern for changing biomass settling characteristics (e.g., filamentous growth) and associated cost implications (e.g., polymer addition, chlorine addition to control filaments).
- Can be readily configured to achieve biological nitrogen and phosphorus removal if required. Ideal process configuration to promote removal of certain metals through external chemical addition, and retention of resulting salts and hydroxides.
- MBR systems can operate largely unattended except for occasional routine performance checks and maintenance of mechanical components.
- Represents an attractive technology for upgrading and/or expanding an existing activated sludge system plagued by clarifier performance problems or excessive operational needs, or where site constraints dictate against addition of new structures.
- Ideal first step in producing water for reuse through reverse osmosis.

4. Conclusion

The application of MBR technology is rapidly expanding, with new installation occurring every year. MBR technology is highly suited for the reclamation of wastewater due to the ability to produce drinking water quality effluent. The effluent produced can be reused within industrial processes or discharged to surface waters without degrading streams and rivers. The small footprint and ease of operation of the MBR system makes it ideal for application in remote areas where wastewater can be reused for irrigation or groundwater discharge.

In addition MBR can be adapted to almost any industrial or municipal wastewater, reducing demand on local water supplies, and pollution in local waterbodies.

The following conclusions can be made regarding the use of MBRs for treatment of wastewater.

- The MBR technology has proven optimal for treatment of many industrial wastewaters.
- The external membrane MBR configuration is preferred versus the internal membrane configuration, for a number of technical reasons.
- Recent membrane and system design advances have resulted in comparable economics for external versus internal membrane MBRs over a much broader wastewater flow rate range.
- Future developments are likely to include the emergence of cost-effective anaerobic MBR systems and full scale application of alternative MBR configurations in which membranes are used for other purposes than simply biomass-effluent separation.

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