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Membrane bioreactor operation–past achievements and future challenges

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Abstract

The river water association, Erftverband looks back on two decades of experience in design and operation of municipal membrane bioreactors (MBR) in the Erft river catchment in Germany. During that time MBR operations have been monitored scientifically and process optimizations have taken place. For example between 2010 and 2015 the specific energy consumption of Nordkanal MBR (80,000 population equivalents) was cut down from 0.94 kWh/m³ to 0.63 kWh/m³ wastewater treated (see figure 1) while membrane filters remain in continuous operation since 2004. With that background, Erftverband sees a promising potential of MBR in the future development of wastewater treatment not only in the Erft river catchment but the energy consumption at Nordkanal MBR will be further reduced. Construction works for primary clarification and anaerobic sludge treatment started in February, 2017. Membrane bioreactor (MBR) technology for wastewater treatment has been developed for over three decades. Our latest survey shows that MBR applications for wastewater treatment are still in rapid growth today. This review summarizes the pros, cons and progress in full-scale MBR applications. Critical statistics on the capital cost, operating cost, footprint, energy consumption and chemical consumption of full-scale MBRs are provided, and are compared to those of conventional activated sludge (CAS) processes with/without tertiary treatment. The efficiencies in full-scale treatment of ordinary pollutants (C, N and P), pathogens (bacteria and viruses) and emerging pollutants (e.g., trace organic pollutants) are reviewed. The long-term operation stability of full-scale MBRs is also discussed with several examples provided, with special attention placed on the seasonal variation of membrane fouling. Finally, the future challenges of MBR application are outlined from the perspectives of fouling control, pollutant removal, cost-effectiveness and competitiveness in specific fields of application. Osmotic membrane bioreactor (OMBR) is an emerging technology that integrating a forward osmosis (FO) process into a membrane bioreactor (MBR). This technology has been gaining increasing popularity in wastewater treatment and reclamation due to its excellent product water quality, low fouling tendency and high fouling reversibility over conventional MBRs. In past decade especially the last 3 years, novel insights and significant advancements have been achieved in many aspects of OMBR accompanied with greatly increased number of published papers. This paper attempts to critically review the recent developments in OMBRs and to present a clear outline for further studies. Firstly, OMBR fundamentals including its configuration and FO process are presented. Subsequently, performance of OMBRs is summarized and compared to conventional MBRs. In this article, membrane bioreactor principles and applications will be discussed. In particular, the properties and applications of bioartificial hybrid membrane systems used in biotechnological and medical fields will be emphasized. In the first part, we focus on general aspects of membrane bioreactors, including some highlights on membrane properties, functions, and transport as well as on kinetics of biocatalysts immobilized in membranes. Afterwards, membrane bioreactors using immobilized biocatalysts such as enzymes, microorganisms, and cells for the production and separation of bioactive pharmaceutical products are discussed. Membrane bioreactors using isolated mammalian cells (i.e., liver cells and pancreatic cells) as bioartificial organs in temporary or continuous substitution of injured organ are illustrated as well. The properties of membranes to be used in these devices are reported including morphological and physicochemical properties that influence their performance. A brief description of membrane bioreactor (MBR) historical evolution has been presented with emphasis on continual decline of treatment costs and energy requirements. Although MBR can operate at biomass (MLSS) concentrations 5 to 10 times higher than activated sludge these concentrations are limited in practice by increasing biomass suspension viscosity that in turn increases "reversible" membrane fouling and decreases oxygen transfer rates. "Irreversible" fouling is a major operational challenge since it depends on subtle interactions of membranes with various fractions of soluble microbial products resulting from microbial metabolism. 'Most of the municipal solid wastes (MSW) produced daily in the world are being buried in landfilling sites without any prior treatment particularly in developing countries. These landfills yield leachate which is a highly contaminated wastewater. Thus, a proper treatment of leachate is highly recommended before the final discharge. Recently, the use of membrane separation technology alongside bioreactors have opened a new gateway in treating refractory wastewater such as landfill leachate. Anaerobic membrane bioreactor (AnMBR) is a promising technique for leachate treatment due its substantial benefits over other conventional anaerobic and aerobic technologies.

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