Water Research 114 (2017) 151–180

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Review

Fouling in membrane bioreactors: An updated review

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ARTICLE INFO

Article history:
Received 18 October 2016
Received in revised form
10 January 2017
Accepted 2 February 2017
Available online 4 February 2017

Keywords:
Extracellular polymeric substances (EPS)
Membrane bioreactor (MBR)
Membrane fouling
In-situ fouling control
Wastewater treatment

ABSTRACT

The goal of the current article is to update new findings in membrane fouling and emerging fouling mitigation strategies reported in recent years (post 2010) as a follow-up to our previous review published in Water Research (2009). According to a systematic review of the literature, membrane bioreactors (MBRs) are still actively investigated in the field of wastewater treatment. Notably, membrane fouling remains the most challenging issue in MBR operation and attracts considerable attention in MBR studies. In this review, we summarized the updated information on foulants composition and characteristics in MBRs, which greatly improves our understanding of fouling mechanisms. Furthermore, the emerging fouling control strategies (e.g., mechanically assisted aeration scouring, in-situ chemical cleaning, enzymatic and bacterial degradation of foulants, electrically assisted fouling mitigation, and nanomaterial-based membranes) are comprehensively reviewed. As a result, it is found that the fundamental understanding of dynamic changes in membrane foulants during a long-term operation is essential for the development and implementation of fouling control methods. Recently developed strategies for membrane fouling control denoted that the improvement of membrane performance is not our ultimate and only goal, less energy consumption and more green/sustainable fouling control ways are more promising to be developed and thus applied in the future. Overall, such a literature review not only demonstrates current challenges and research needs for scientists working in the area of MBR technologies, but also can provide more useful recommendations for industrial communities based on the related application cases.

Abbreviations: AAL, Aleuria aurantia lectin; AFM, atomic force microscopy; AHL, N-acyl homoserine lactones; AI-2, autoinducer-2; ATR-FTIR, attenuated total reflection Fourier transform infrared spectroscopy; C_{60}, fullerenes; CA, cellulose acetate; CEB, chemically enhanced backflush; CFD, computational fluid dynamics; CIP, cleaning in place; CLSM, confocal laser scanning microscopy; CNMs, carbon nanomaterial; CNTs, carbon nano-tubes; COD, chemical oxygen demand; Con A, Concanavalin A; DGGE, denaturing gradient gel electrophoresis; DLVO, Derjaguin-Landau-Verwey-Overbeek theory; DO, dissolved oxygen; DSA, Datura stramonium agglutinin; ENMs, engineered nanomaterials; EP, electrophoresis; EPS, extracellular polymeric substances; FNA, free nitrous acid; GAC, granular activated carbon; Gal, galactose; GC, gas chromatography; Glc, glucose; GO, graphene oxide; Gt, graphite; GtO, graphite oxide; HA, humic acid; HRT, hydraulic retention time; LCA, Lens culinaris agglutinin; MBRs, membrane bioreactors; MEC, magnetic enzyme carrier; MF, microfiltration; MFCs, microbial fuel cells; MLSS, mixed liquor suspended solids; MS, mass spectrometry; MW, molecular-weight; MWCNTs, multi-walled carbon nanotubes; NF, nanofiltration; NMR, nuclear magnetic resonance; NOM, natural organic matter; NPs, nanoparticles; PA, polyamide; PCoA, principal coordinates analysis; PE, polyethylene; PEG, polyethylene glycol; PES, polyethersulfone; PET, polyethylene terephthalate; PP, polypropylene; PSf, polysulfone; PT, polyester; PVDF, polyvinylidene fluoride; QCM-D, quartz crystal microbalance with dissipation monitoring; QQ, quorum quenching; QS, quorum sensing; rGO, reduced graphene oxide; Rha, rhamnose; RO, reverse osmosis; ROS, reactive oxygen species; RCA, Ricinus communis agglutinin; SAD_m, specific aeration demand per membrane area; SAD_p, specific aeration demand per permeate volume; SAPO, silico-aluminophosphate; SEM, scanning electron microscopy; SMP, soluble microbial products; SRT, sludge retention time; SWCNTs, single-walled carbon nano-tubes; SWRO, seawater reverse osmosis; TFC, thin film composite; TMP, trans-membrane pressure; T-RFLP, terminal restriction fragment length polymorphism; UF, ultrafiltration; XPS, X-ray photoelectron spectroscopy.

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http://dx.doi.org/10.1016/j.watres.2017.02.006
0043-1354/

Contents

1. Introduction

MBRs are a compact technology that combines an activated sludge process and membrane filtration for wastewater treatment and recycling. MBRs could achieve high nutrient removal efficiency and complete biomass retention without a secondary clarifier. In the past decades, such unique advantages of MBRs have caused this technology to be of increasing interest for practitioners (Xiao et al., 2014). The MBR market in China has been increasing significantly. For instance, the total treatment capacity of large-scale MBRs (>10,000 m^3 d^{-1}) increased from 1.0 to 7.5 million m^3 d^{-1} between 2010 and 2015 in China (Xiao et al., 2014), and this number is expected to increase to ca. 10.0 million $m^3 \cdot d^{-1}$ by 2017. In the coming years, a number of large-scale MBR plants will be installed soon in China. For example, two MBR plants with a treatment capacity of 0.23 and 0.6 million $m^3 \cdot d^{-1}$ will be installed in Beijing. In addition, four conventional wastewater treatment plants in Chengdu will be retrofitted using MBR processes, with a total treatment capacity of 0.75 million m^3 d^{-1}. In recent years, Beijing Origin Water has been the largest membrane supplier in China, with a market share of about 70%. The rapid increasing rate of MBR market in China is mainly promoted by the following: the improved MBR technology, the accumulation of operating experience on MBR plants and particularly the requirement of high-quality treated wastewater by the local government.

In fact, the annual growth rate of MBRs in the global market was assessed to be ca. 15% by a number of research reports (Judd, 2016). In addition to the wide application in China, large-scale MBR plants are also adopted in U.S.A. and Europe Union, as indicted in Fig. 1 (data from http://www.thembrsite.com/). In addition, we noted that the treatment capacity of most MBR plants constructed before 2010 were smaller than 0.1 million m^3 d^{-1}; however, much larger MBR plants were or will be constructed in the world since 2010. Two MBR plants with treatment capacity exceeding 0.2 million