Journal of Industrial and Engineering Chemistry 22 (2015) 357–367

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

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

Fabrication of alumina/polysulfone nanocomposite membranes with biofouling mitigation approach in membrane bioreactors

Maryam Homayoonfal [1], Mohammad Reza Mehrnia *, Samane Rahmani [1], Yasaman Mohades Mojtahedi [1]

School of Chemical Engineering, College of Engineering, University of Tehran, Tehran 11155-4563, Iran

ARTICLE INFO

Article history:
Received 8 March 2014
Received in revised form 17 July 2014
Accepted 20 July 2014
Available online 25 July 2014

Keywords:
Alumina nanoparticle
Nanocomposite membrane
Biofouling
Biofilm
Membrane bioreactor

ABSTRACT

In this study, polysulfone/alumina nanocomposite membranes were synthesized with the principal aim of reducing biofouling in membrane bioreactors. The filtration experiments indicate that alumina nanoparticles can increase water flux by enhancing membrane hydrophilicity while maintaining the separation efficiency through decreasing porosity. Altogether, as confirmed by AFM images, the development of roughness results in biofilm formation reduction on the membrane surface layer. On the whole, presence of alumina nanoparticles up to the polymer concentration of 0.03 wt.% will result in an augment in separation yield up to 7%, four times higher water flux, and 83% reduction in membrane fouling.

Introduction

Many industries have started to use membrane bioreactors extensively for wastewater treatment purposes in recent years [1]. The most important obstacles against widespread use of membrane bioreactors are the high price of membrane and its fouling during the process [2,3]. In fact, the main operational cost in membrane bioreactor processes originates from exerted pressure distributed across the membrane. Gradually as the process starts, this issue aggravates due to membrane fouling. There are several factors influencing membrane fouling phenomenon. Table 1 presents a general category of different types of membrane fouling and the methods that researchers have utilized to evaluate the factors influencing them.

As shown in Table 1, the factors generating fouling consist of two general categories of parameters related to operational conditions and membrane morphology. Thereupon, methods for reducing fouling in membrane bioreactors can be categorized into two general classes of modifying operational conditions and membrane morphology [2]. Membrane fouling is divided into various parts. The most important and irreversible is the fouling of membrane pores [2,3]. Methods based on modification of operational conditions result in fouling reduction of cake type, whereas those based on modification of membrane morphology will reduce fouling of pores as well. In recent years, the use of hydrophilic particles has been widely studied in order to mitigate the membrane fouling [16–18]. One of the most useful hydrophilic additives which have attracted special attention in recent years that contribute to fouling mitigation in membrane morphology is metal oxide nanoparticles [16,18,19]. Metal oxide nanoparticles can be settled in membrane structure via surface deposition method or method of blending with polymeric matrix. Each of these methods has its own advantages and disadvantages [20]. When nanoparticles settle in the membrane, on the one hand, they offer their intrinsic properties to the membrane and, on the other hand, they will increase or decrease the membrane porosity by changing the rate of membrane formation process. For instance, titanium [21–24] and silver nanoparticles [25,26], in addition to offering their intrinsic hydrophilicity and anti-bacterial properties to the membrane, will increase membrane porosity [21,22] by enhancing the precipitation rate in some cases. They can also decrease membrane porosity by reducing the precipitation rate in some other cases [23,24]. So it influences the behavior and characteristics of membrane filtration in a membrane bioreactor medium.

Alumina nanoparticles, enjoying some intrinsic properties such as mechanical resistance and hydrophilicty, modify the membrane

* Corresponding author. Tel.: +98 2161112184; fax: +98 2166954041.
E-mail addresses: maryam.homayoonfal@gmail.com (M. Homayoonfal), mmehrnia@ut.ac.ir, jtd_mrm@yahoo.com (M.R. Mehrnia), s.rahmani.4667@gmail.com (S. Rahmani), yasaman_mohades@yahoo.com (Y. Mohades Mojtahedi).
[1] Tel.: +98 2161112261; fax: +98 2166954041.

http://dx.doi.org/10.1016/j.jiec.2014.07.031
1226-086X/

Table 1
Different type of membrane fouling and methods used for its mitigation by researchers.

Fouling mitigation route			
Correction in operational condition		Correction in membrane characteristics	
Feed and feeding condition	System hydrodynamics	Membrane structure	Membrane nature
Investigation of the influence of sludge rheological properties on the membrane fouling: Viscosity of activated sludge affects the membrane fouling tendency in an exponential relation [4]	Investigating the influence of hydrodynamics on fouling velocity: high flow rate, low crossflow velocity and high viscosity all favor fouling [7]	Influence of membrane surface properties on fouling in MBR: useful reduction in membrane fouling can be achieved by the control of pore size as well as induction of hydrophilicity on the membrane surface by chemical cross-linking [10]	Using two different membranes (PAN and PVDF) in MBR: Hydrophobic fraction of sludge had the largest fouling propensity for the PAN membrane while neutral hydrophilic fraction demonstrated the strongest fouling potential for the PVDF membrane [13]
Investigation of the influence of dissolved organic carbon and suspension viscosity on membrane fouling: In the lower MLSS concentration (2000–3000 mg/L), irreversible fouling rate of membrane increased with increasing F/M ratio while in the case of higher MLSS concentration (8000–12,000 mg/L), reversible fouling rate of membrane increased with increasing F/M ratio [5]	Controlling fouling in activated sludge submerged hollow fiber membrane bioreactors: permeate flux decline increased with increasing suction pressure and with decreasing air-scouring rate [8]	Investigation of TiO_2 nanoparticle presence in membrane matrix on membrane fouling: membrane fouling was considerably alleviated by the introduction of TiO_2 nanoparticles on the surface of membrane [11]	Comparison of hydrophilic and hydrophobic nature of membrane: hydrophobic membranes (PES and SPES) fouled more significantly than the hydrophilic membrane (CA) [14]
Using variable organic loading rate: TMP increment rate decreased from 3.33 kPa/day to 0.48 kPa/day [6]	Investigating pump shear on membrane fouling: the membrane flux was dropped to about 36 L/(m^2 h) with a centrifugal pump but to only 20 L/(m^2 h) with a rotary pump [9]	Comparison of fouling potential of track-etched and phase-inversed porous membranes in MBR system: The phase inversed membranes showed more rapid resistance increase compared to the track-etched ones due to the rougher surface of the phase inversed membrane [12]	Comparison of the filtration characteristics of organic and inorganic membranes: For the inorganic membranes accumulation inside the membrane pore while for the organic, a thick cake layer formed on the membrane surface, plays a key role in flux decline [15]

morphology in addition to altering the mechanism of membrane formation in the phase inversion process. As a result, they affect the filtration behavior of nanocomposite membranes [27–32]. Thus, in this study alumina nanoparticles were used to reduce the fouling of polymeric membranes. Alumina nanoparticles/polysulfone nanocomposite membrane was synthesized using blending method and phase inversion process. The effect of altering the concentration of alumina nanoparticles was investigated on the morphology, surface properties. Then, the filtration behavior was further analyzed in membrane bioreactors. The effect of nanoparticles on membrane morphology and on biofilm formation on the surface of nanocomposite membranes was investigated as well. Fig. 1 schematically shows the effect of nanoparticle presence on membrane surface roughness and biofilm formation on membrane surface.

Materials and methods

Materials

Polysulfone (M_W: 75000 Da) was supplied by Acros Organics and was used as the main polymer for membrane synthesis

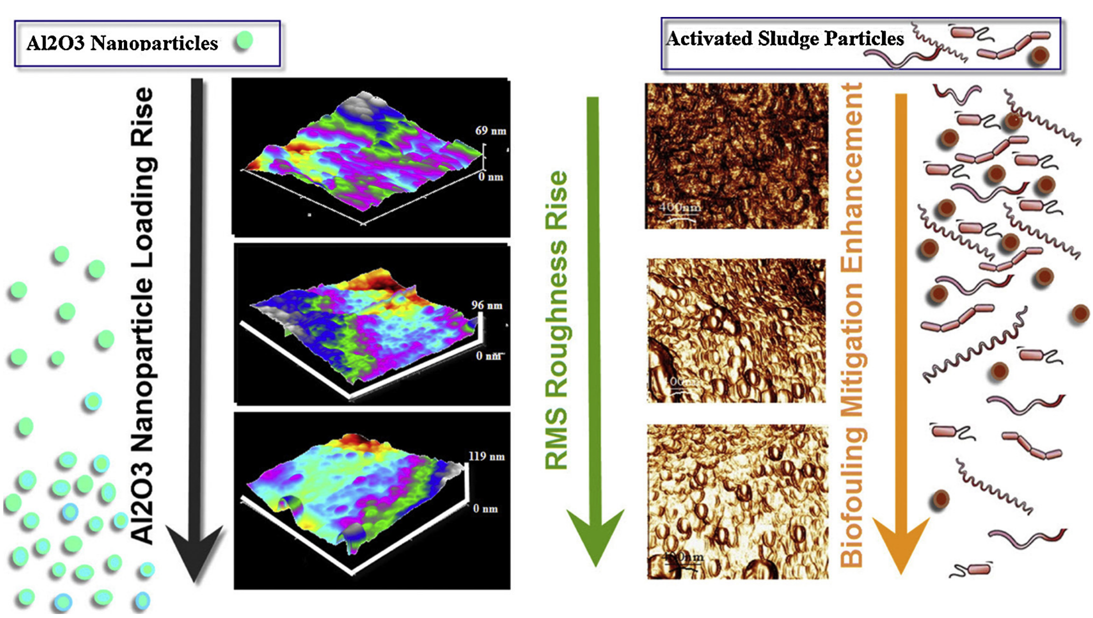

Fig. 1. Schematic illustration of biofouling mitigation enhancement versus Al_2O_3 nanoparticle loading rise.