ELSEVIER

Process Biochemistry 42 (2007) 1641–1648

Process Biochemistry

www.elsevier.com/locate/procbio

Biofouling development and rejection enhancement in long SRT MF membrane bioreactor

Swee Loong Khor [a,*], Darren Delai Sun [a,1], Yajuan Liu [a], James O. Leckie [b]

[a] School of Civil and Environmental Engineering, Nanyang Technological University, Singapore 639798, Singapore

[b] Department of Civil and Environmental Engineering, School of Engineering, Stanford University, Stanford, CA 94305-4020, USA

Received 12 June 2007; received in revised form 13 August 2007; accepted 24 September 2007

Abstract

This study was conducted to investigate the development and extracellular polymeric substances (EPS) distribution in biofouling layer and biofouling effect on permeate quality. The experimental results suggested that formation of biofouling layer was started by the attachment of polysaccharides and formed a biogel like layer on top of membrane surface (adhesive attachment). It further induced the attachment of protein, polysaccharides and bioparticles, and formed cake layer (cohesive attachment). As evidenced in SEM photos and permeates quality, the formed biofouling layer had changed the properties of membrane surface such as the pore and porosity, and hence produce the better permeates quality. A great enhancement of rejection performance occurred at the early filtration period, and followed by a slight enhancement in rejection throughout the entire filtration. This enhancement of rejection performance by biofouling layer can be mathematically expressed by the logarithm function with the degree of membrane fouling.

Keywords: Biofouling; EPS; Membrane morphology; Membrane rejection

1. Introduction

Application of submerged membrane bioreactor (MBR) in wastewater treatment has gained significant attention in recent years. MBR consists of an activated sludge system with a membrane filtration, where a membrane system is used to separate the biomass from the effluent instead of a clarification tank. The submerged MBR provides better treatment efficiency over the conventional biological water treatment, small footprint, sludge reduction and the opportunity for water reuse or reclamation [1]. Currently, MBR tend to be operated with long sludge retention time (SRT) and low food to microorganisms (F/M) ratio for little biological sludge discharge. The excellent long SRT MBR performance in the long-term operation with little or zero biological sludge discharge has been reported by some researchers [2–4]. Nevertheless, biofouling layer on filtration membrane appears as the Archellis heel of the submerged MBR which caused the membrane fouling and hence decreases the water output and increase of maintenance cost [5]. Many studies have been carried out to prevent and reduce the fouling problems, such as membrane modification, low flux operation, backwash, chemical cleaning, coarse bubbles aeration and hydrodynamic conditions [6]. Nevertheless, biofouling on to the membrane surface is inevitable which cause by the nature of biological system, where microorganism and bioparticles are the main component [5].

A superior filtration membrane must have an excellent rejection of pollutants and high membrane flux. However, most of the studies were focused on the filtration membrane fouling prevention as well as its mechanism involved [7,8]; little attention has been put into the rejection performance by the biofouling layer. The formation of biofouling layer on microfiltration membrane could significantly increase the filtration performance; hence increase the effluent quality. Choi et al. [9] reported that fouled MF at cross-flow velocity of less than 1.0 m/s exhibited almost the same rejection efficiency as that of UF membrane. They concluded that biofouling layer was first responsible for dissolved organic carbon (DOC) rejection whereas DOC passing through the biofouling layer was further rejected by fouled membrane pores. Park and Lee

* Corresponding author.

E-mail addresses: khor0002@ntu.edu.sg (S.L. Khor), ddsun@ntu.edu.sg (D.D. Sun).

[1] Fax: +65 67910676.

1359-5113/$ – see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.procbio.2007.09.009

[10] operated a jet loop type MBR with hollow fibre membrane (0.1 μm), and observed the increase of soluble chemical oxygen demand (SCOD) removal during the early stage of filtration run. They suggested that the additional SCOD removal was due to the sieving and adsorption of soluble colloidal and organics by the matrix of biofilm and also the biodegradation by the active microbial communities in the biofilm.

While an effect on extent of solute rejection is expected as a result of membrane fouling, nevertheless, the contribution of biofouling layer to the solute rejection is yet to be fully understood. The formed biofouling layer was highly related with EPS where determine the structure/matrix of biofouling layer. Flemming and Wingender [11] reported that EPS are considered as the key components that determine the structural and functional integrity of microbial aggregates. EPS form a three-dimensional, gel like, highly hydrated and locally charged biofilm matrix, in which the microorganisms are more or less immobilized. In addition, EPS also being reported as the most significant foulant toward the membrane fouling problems [12–14]. Cho and Fane [15] suggested that EPS caused the initial and gradual TMP rise under the constant flux filtration.

Due to the complexity of biological component, it is hardly to obtain a unify or comprehensive understanding on biofouling structural and its effect to the solute rejection. More effort is needed to explore and optimize the use of biofouling layer on the MBR system, which in turn to minimize the operation and membrane cost. This study was aimed to investigate the biofouling development on MF membrane under long SRT condition (300 days), identify the EPS distribution on membrane surface and contribution of biofouling onto the permeate quality.

2. Materials and methods

2.1. Filtration rig

The filtration rig for this study consists of a stabilized MBR system (which had been operated for 380 days and had a constant F/M ratio at 0.2730 kg COD/kg MLVSS day) and MF ceramic membrane as shown in Fig. 1. MF ceramic membrane was immersed into the stabilized MBR system, and operated with filtration flux of 26 L/(m^2 h), aeration intensity of 36 m^3/(m^2 h) (where the aeration intensity was the airflow rate (6 L/min) divided by the cross-sectional area of the riser (100 mm × 100 mm)). Detailed operating conditions of the stabilized MBR are summarized in Table 1. MBR system was fed with industrial wastewater (1000 mg/L COD) which consisted mainly of dairy wastes. The hydraulic retention time (HRT) of stabilized MBR was at 8 h with 300 days SRT condition. DO in the COD- and MBR-tank were kept above 3.0 mg/L; while DO in the N-tank is generally below 0.5 mg/L, due to the intermittent aeration operation in N-tank (1 min of aeration, followed by 10 min of no aeration condition). The pH of the mixed liquor was monitored at the range of 6.5–8.0.

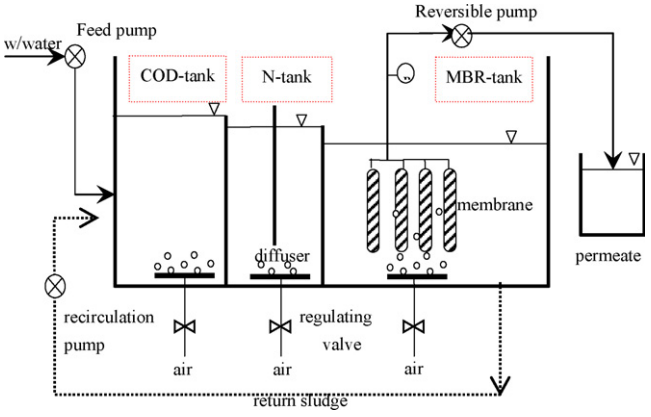

Fig. 1. Schematic diagram of submerged MBR.

Table 1
Operating condition of the submerged MBR

Parameter	Value
Organic loading rate (kg COD/m^3 day)	3
Influent COD (mg/L)	1,000
MBR permeate COD (mg/L)	<20
COD removal (%)	<98
Working volume (L)	20
HRT (h)	8
SRT (day)	300
MLSS (mg/L)	12,500
DO (mg/L)	>3
Temperature (°C)	23–25
pH	6.9–8.0
Airflow rate (L/min)	6

2.2. Membrane

Tubular ceramic MF membrane made by diatomaceous earth material with 0.9 μm was operated with 26 L/(m^2 h) of membrane flux to study the biofouling development. While, polycarbonate track-etched membranes (0.015, 0.4 and 2.0 μm) were used to measure the rejection performance of 0.015, 0.4 and 2.0 μm, subsequently compare the rejection performance with the MF membrane. The polycarbonate membranes are manufactured from high quality polycarbonate film and have sharply defined pore sizes, high flow rates and excellent chemical and thermal resistance.

2.3. EPS extraction method

2.3.1. EPS extraction from MBR's mixed liquor

The EPS extraction method was according to the methods reported by Liu and Fang [16] and Zhang et al. [17]. Ten millilitres of MBR's mixed liquor was centrifuged at 4000 rpm for 10 min; subsequently the supernatant was shifted to another tube. While the microbial pellet was recovered and resuspended in ultra pure water with total volume at 10 mL. For the microbial pellet, 0.012 mL formaldehyde (37%) was added and kept for 1 h at 4 °C, it followed with adding 0.8 mL NaOH (1N) and kept for 4 h at 4 °C. After that, the supernatant of the sample and microbial pellet were centrifuged (13,200 rpm, 20 min and 4 °C) before chemical component analysis.

2.3.2. EPS extraction from biogel layer and cake layer

The fouled membrane was flushed with water, where (i) the washed away loose structure layer was collected as the cake layer, while (ii) the remained layer on the membrane was namely as the biogel layer. Subsequently, cake sample with 10 mL was filled into a vessel, while the biogel on the membrane was cutted into 4 cm^2 (4 cm × 1 cm) surface area, subsequently place into vessel and fill with 10 mL of ultra pure water. Both samples ware added with 0.012 mL formaldehyde (37%) and kept for 1 h at 4 °C; subsequently it followed with adding 0.8 mL NaOH (1N) and kept for 4 h at 4 °C. After that, the samples were centrifuged (13,200 rpm, 20 min and 4 °C) before chemical component analysis.

2.4. Scanning electron microscope (SEM) analysis

The fouled membrane was taken out from the MBR system, and then soaked in 2% glutaraldehyde for 2 h, subsequently, washed in 0.1 M sodium cacodylate