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Characteristics of Wastewater and Mixed Liquor and their Role in Membrane Fouling

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ABSTRACT

Effects of wastewater characteristics and mixed liquor properties on membrane fouling in a submerged anaerobic membrane bioreactor (SAnMBR) and a thermophilic submerged aerobic membrane bioreactor (TSAMBR) were studied with different types of industrial wastewaters. The differences in wastewater characteristics and mixed liquor were correlated to the differences in membrane filtration behaviour. The results suggest that a full characterization of the feed and mixed liquor may be used as a tool to predict the membrane performance of membrane bioreactors.

1. INTRODUCTION

Membrane bioreactor (MBR) has received considerable attention in recent years. It has been well implemented in treating both municipal (Buisson 1998) and industrial wastewater (Berube 2001). The MBR system has many advantages over the conventional activated sludge process in terms of its excellent effluent quality, high removal efficiency of chemical oxygen demand (COD), small footprint and integration of biological treatment and filtration (Akram 2008). However, the loss of the membrane performances due to membrane fouling remains a major obstacle in the extensive application of MBR.

A number of investigations on the factors affecting membrane fouling have been performed. In a MBR, the fouling behavior is generally considered to be determined by the activated sludge characteristics (Choi 2006), the membrane properties (Peng 2004), their interactions and the chosen operating conditions (Hong 2002). The influence of the three sludge fractions (suspended solids, colloids, and dissolved solutes) on membrane fouling in MBRs was discussed controversially in the literature.

To gain more insight into the optimization of MBRs design, our study focused on the three fractions of the wastewater and mixed liquor and their effects on the membrane fouling. The objective of this study was to investigate the characteristics of four types of industrial wastewater and the mixed liquor properties, providing a systematic research work on the impact of influent on membrane performance and trying to explain their role on the membrane performance of membrane bioreactors.

2. MATERIALS AND METHODS

2.1 Lab-scale membrane bioreactors

The study was based on the investigation of two lab-scale membrane bioreactors for the wastewater treatment studied in our group: mesophilic submerged anaerobic membrane bioreactor (SAnMBR) and thermophilic submerged aerobic membrane bioreactor (TSAMBR). Both systems were equipped with a flat sheet microfiltration membrane module (0.03 m^2). The material of the membrane and the molecular weight cut off (MWCO) were polyvinylidene fluoride (PVDF) and 70,000 Daltons, respectively. The pore size of the membrane is 0.3 μm.

2.2 Types of wastewater and separation of suspended solids, colloids and solutes

All the four types wastewater were collected from a local pulp and paper mill: thermomechanical pulping pressate treated by the SAnMBR (named TMP pressate 1); thermomechanical pulping whitewater treated by the SAnMBR (named TMP whitewater); thermomechanical pulping pressate treated by the TSAMBR (named TMP pressate 2); thermomechanical pulping wastewater treated by the TSAMBR (named TMP wastewater).

2.3 Analytical methods

Chemical oxygen demand (COD) was determined colorimetrically using test vials in the range of 0-1,500 mg/L. Total COD was analyzed for feed water, supernatant and permeate, and soluble COD was measured for feed water and supernatant after the 0.45 μm filtration.

2.4 Determination of membrane fouling

The total fouling resistance (R_t) can be calculated by Darcy's Law with temperature correction to 20 ℃ to account for the dependence of viscosity on temperature:

$$R_t = \frac{\Delta P}{J \cdot \eta T}, \quad \eta_T = \eta_{20℃} \cdot e^{-0.0239\,(T-20)} \tag{1}$$

where R_t is the total resistance (1/m), J is the permeate flux (LMH), ΔP is the trans-membrane pressure difference (Pa), and η_T is the permeate dynamic viscosity (Pa·s).

3. RESULTS AND DISCUSSION

The SAnMBR was operated at a mesophilic temperature of 37 ± 1°C while the TSAMBR was operated at a thermophilic temperature of 51 ± 1°C. The pH in the two bioreactors were maintained around 7.0 by adding 0.1 M NaOH. COD of the influent, supernatant and effluent in the two membrane bioreactors at steady state are listed in Table 1. The total COD removal efficiency in SAnMBR were 87.6 ± 1.0% and 77.5 ± 0.9% for TMP pressate 1 and TMP whitewater, respectively. In the case of TSAMBR, COD removal efficiencies were over 87% for both feed wastewaters.

Table 1. COD of influent, supernatant and effluent in SAnMBR and TSAMBR.

COD (mg/L)	Types of MBR			
	SAnMBR		TSAMBR	
	TMP Pressate 1	TMP whitewater	TMP pressate 2	TMP wastewater
Influent	2499 ± 79	2007 ± 28	3528 ± 101	3770 ± 15
Supernatant	754 ± 77	419 ± 58	817 ± 73	618 ± 28
Effluent	562 ± 25	248 ± 19	429 ± 17	242 ± 39

Fig. 1a displays the total resistance variation of the SAnMBR for TMP pressate 1 and TMP whitewater treatment during the steady state and Fig. 1b presents the total resistance variation of the TSAMBR for TMP pressate 2 and TMP wastewater treatment during the steady state. An abrupt and steep initial rise (Gao 2011) in total resistance was observed in SAnMBR. Despite the lower operating flux in the SAnMBR treating whitewater, the fouling resistance of TMP whitewater was obviously greater than the one of TMP pressate 1. For the TMP whitewater, the initial rise in R_t was followed by a slow 7-days increase in Rt and another steep rise to the maximum of 4.37×10^{14} m^{-1} at day 9. When it comes to the TMP pressate 1, a lower and constant total resistance of $(2.09 \pm 0.20) \times 10^{14}$ after the initial rise presents the better membrane performance. The TMP pressate 2 and the TMP wastewater treated by TSAMBR exhibited similar two-stage total resistance profiles: a very low and steady R_t with negligible fluctuations in the first stage and a rapid R_t jump in the second stage. Compared with the TMP pressate 2, the TMP wastewater caused a much shorter first stage (3 days) and a quicker and steeper Rt jump which took only two days. The maximum total resistance for TMP wastewater was 3.19×10^{13} m^{-1}. However, for the TMP pressate 2, the total resistance stayed relatively stable at a low level of $(3.13 \pm 0.46) \times 10^{12}$ m^{-1} for 22 days and the Rt jump happened in 10 days till the maximum of 2.00×10^{13} m^{-1}.

In the operation of the SAnMBR, the membrane performance of treating TMP whitewater was worse than the performance of treating TMP pressate 1 even under lower flux and organic loading rate (OLR). For the TSAMBR, no operating parameters (e.g. flux, MLSS, OLR) could be accounted for the different fouling behaviour as the operating conditions were kept constant during the operation period (Table 2). Thus, it is assumed that the fractions of the different feed wastewaters and the mixed liquors and their relationship were responsible for the different fouling behaviour.

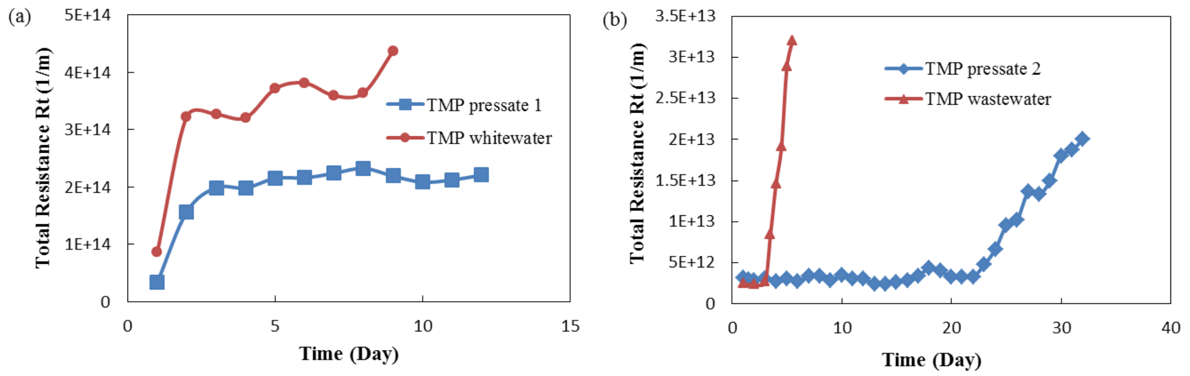

Fig. 1 Typical total filtration resistance (R_t) profiles of (a) SAnMBR and (b) TSAMBR for different types of wastewater.

CONCLUSION

This study investigated the effects of wastewater characteristics and mixed liquor properties on membrane fouling in a SAnMBR and a TSAMBR treating different types of industrial wastewaters. Based on the results presented in this study, the following conclusions can be drawn:

- Wastewater characteristics had significant impact on the performance of MBRs.
- A full characterization of the feed and mixed liquor (including particle size analysis, the quantity of colloids and soluble organic substances analysis) may be used as a tool to predict the membrane performance of membrane bioreactors.

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