Biological Characteristics of Bangkok Domestic Wastewater Treatment Using a Pilot Scale Membrane Bioreactor

Maneerat Tiranuntakul

Division of Chemical Engineering, Faculty of Engineering,

Rajamangala University of Technology Krungthep, Bangkok 10120 Thailand

Tel. 02-2869600 Fax 02-2869600 ext. 1210

Abstract

This paper presents the biological performance of a pilot scale membrane bioreactor (MBR). The MBR treated Bangkok domestic wastewater by combining membrane filtration and biological processes in one reactor. The removal efficiency for chemical oxygen demand (COD) and ammonia was around 90 and 99.7% respectively. However, efficiency of nitrate and phosphate removal has not been significantly satisfied yet. The mixed liquor suspended solids (MLSS) was gradually building up from 5,200 mg/L to 6,900 mg/L in the MBR during 45 day period. Measurements of carbohydrate and protein of the extra cellular polymeric substances (EPS) was investigated. Protein was predominant in the soluble EPS and the ratios between protein and carbohydrate was around 1.8 by average. The MLSS and total soluble EPS was found to have a stronger positive potential on membrane fouling than carbohydrate EPS and protein EPS alone.

1. Introduction

Conventional wastewater treatment technologies are no longer responding to new standards, and there is an increasing desire for the development of innovative, more effective and inexpensive techniques for most wastewater treatment [1]. To tackle these conflicting requirements, membrane bioreactors have been introduced to wastewater treatment facilities. Nowadays, membrane bioreactor (MBR) technology is one of the cost-effective and sustainable solutions for new and efficient advanced municipal wastewater treatments.

In comparison with the conventional activated sludge (CAS) process, this MBR technology presents several advantages: (i) the space requirement is greatly reduced due to the absence of settlement tanks and to high biomass concentration (two to five times higher than the one observed with CAS), (ii) the effluent quality is significantly better as the suspended and colloidal materials are removed as well as all the associated pollutants, such as heavy metals, micro-pollutants, bacteria, viruses and color, and (iii) a flexible and phased extension of existing wastewater treatment plants is possible [2]. The MBR has been proved to be used for treating a variety of wastewaters such as tannery wastewater, industrial wastewater and oily wastewater [3].

However, practical application of membrane bioreactors in Bangkok domestic wastewater treatment has not been reported in literature. Therefore, the purpose of this paper was to characterize the biological

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performance of a pilot scale MBR system for Bangkok domestic wastewater treatment. Therefore, the study will show the biological attributes of treatment from raw wastewater to final effluent namely; chemical oxygen demand (COD), ammonia, nitrate, phosphate, mixed liquor suspended solid (MLSS), extracellular soluble polymeric substances (EPS) and membrane performances.

2. Experimental Materials and Method

A pilot scale SMBR used in this study was consisted of a 45 liter aerobic unit fitted with a submerged flat-sheet membranes. The membrane material is chlorinated polyethylene with nominal pore size 0.4 µm. Bangkok domestic wastewater from Chongnonsi cannel was collected and pumped to the bioreactor from the feed tank passing through a fine screen. Effluent was removed through the membrane with a suction pump passing through permeate line. Pressure gauge was also located on the permeate line.

The aeration process was conducted using a blower and controlled using air rota-meter. The coarse bubble aeration was supplied to the membrane tank in order to prevent membrane clogging as well as to provide oxygen for microbial growth. Samples were collected once a week at the following 3 different positions: inlet the system, within the MBR and permeate outlet.

The MLSS concentrations were determined by filtering a known volume of a sample through a pre-weighed and dried 0.2-mm pore membrane. These filters were then dried at 105 ^{0}C for 24 hours, and the increase in weight was measured [4]. Ammonia, nitrate and phosphate were determined by Hach colorimeter. EPS analysis by sodium hydroxide extraction followed Nagaoka's method [5]. Modified Hartree-Lowry and Anthrone assays were applied for assessment of soluble protein and carbohydrate respectively [6-7]. Determination of Chemical oxygen demand (COD) followed the standard methods for the examination of water and wastewater [8].

3. Results and discussion

3.1 Ammonia removal

Nitrifying bacteria convert ammonia nitrogen to nitrate nitrogen in a nitrification reaction. Consequently, the change in ammonia concentration is often used as an indirect measurement in the changes in the nitrification process.

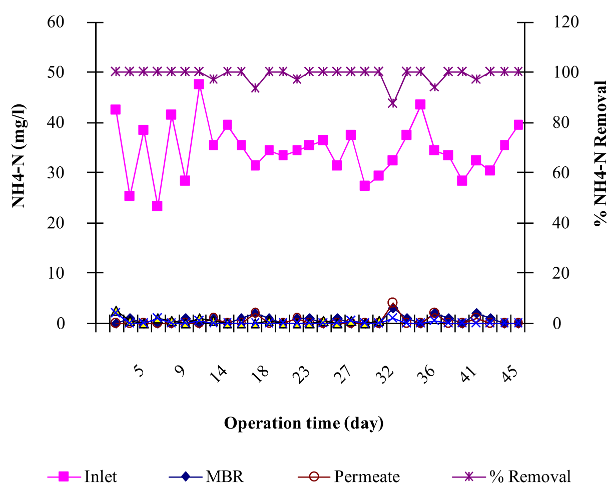

Fig. 1 Variation of ammonia removal in the MBR

In this study, the variations in removal efficiencies of ammonia nitrogen (NH_3-N) concentration in the influent and in the effluent are presented in Fig. 1. The removal efficiency of ammonia began and stabilized at around 98-100%. The excellent performance of the nitrification process during the 45 days of experiment was attributed to the sufficient concentration of nitrifying bacteria to nitrify the ammonium [9]. This reflected the high oxidation rate of ammonia nitrogen in the MBR.

3.2 Nitrate removal

As seen from Fig. 2, nitrate was not removed from the raw wastewater but it increased from nearly zero in the influent to become around 10-45 mg/L in the effluent of the MBR. This is clearly implied that while nitrification has occurred in the system, de-nitrification has not been initiated yet. In theoretical, only the anoxic stage is sufficient to convert most the ammonia (NH_3) to nitrate (NO_3^-) through nitrification process.

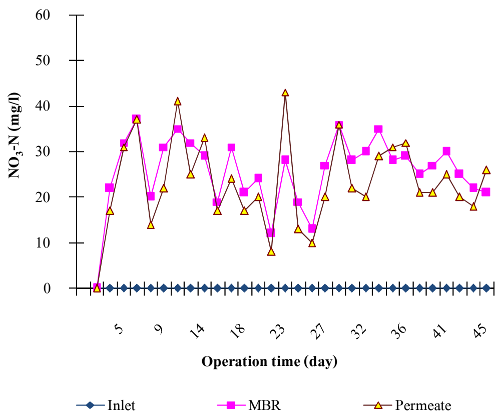

Fig. 2 Variation of nitrate removal in the MBR

From Fig. 2, there was no nitrate concentration presented in the inlet stream of the system. However, nitrate was highly produced in the aerobic-membrane unit because of high DO concentration. This means only nitrification process took place in the MBR system conversing ammonium to nitrite and finally to nitrate by Nitrosomonas and Nitrobactors bacteria, respectively [10]. To remove nitrate, de-nitrification process with deficiency of dissolved oxygen are needed for bacteria to consume nitrate as a terminal electron acceptor and convert it to nitrogen gas [10].

3.3 Phosphorous removal

Fig. 3 showed that the imperfection of the MBR was poor at phosphate-phosphorous removal. It was observed that the phosphorous removal efficiency of the MBR system was not high and fluctuated around 25-45%. In general, improvement of phosphorus removal can happen under sequencing anoxic /anaerobic/aerobic operation modes. Some researchers have demonstrated that in the presence of nitrate, a fraction of phosphorus accumulating organisms (PAOs) can also take up phosphorus using nitrate as the electron acceptor instead of oxygen to oxidize polyhydroxybutyrate (PHB) under anoxic conditions and the so-called denitrifying phosphate-accumulating organisms could exist in the system [11].

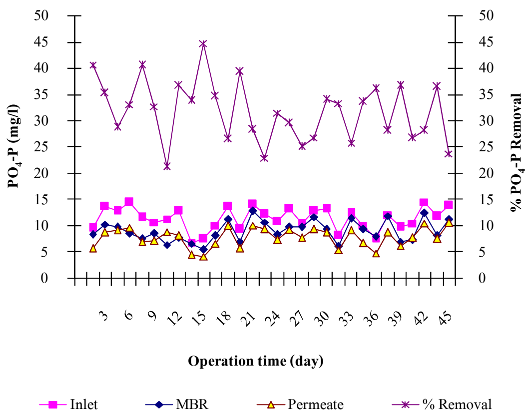

Fig. 3 Variation of phosphorous removal in the MBR

Due to the MBR system achieved low phosphorus removal efficiency on average; it indicated that PAOs would not be the predominant bacteria due to the continuous introduction of nitrate. In addition, the carbon substrate competition between the denitrifying bacteria and PAOs could be more serious. Under that condition, denitrifying bacteria was more superior to PAOs, which grew and moved slowly [12]. Meanwhile, the presence of nitrate could also inhibit the phosphorus release of PAOs. It was clearly evident that these results would influence the removal performance of phosphorus.

3.4 COD removal

The COD concentration of influent and effluent and the removal efficiencies were represented in Fig. 4. During the entire period, the COD concentration of influent was remained between 200–400 mg/L. The COD removal efficiency was slightly fluctuated and the COD concentration of effluent ranged from 5 -70 mg/L. The average COD removal efficiency of the system was about 90%. It indicated that a good performance of organic removal could be obtained in the MBR. It is believed that the high COD removal efficiency was due to the efficient utilization of organic compounds in the system [13]. In addition, it can be implied that a relatively large fraction of COD was degraded by the microorganisms in the MBR.

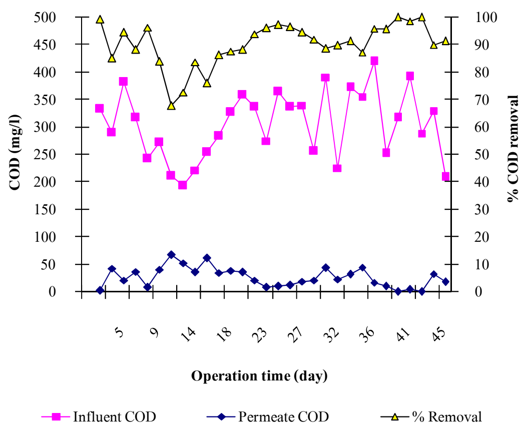

Fig. 4 Variation of COD removal in the MBR

3.6 MLSS, EPS and membrane fouling

Fig. 5 shows the growth of MLSS (mixed liquor suspended solids) in the system. During the first 10 days, at the start-up stage of the MBR system, MLSS had no significantly increase, as a phenomenon for cultivation of the seeding sludge. After 10 days and with the operation time of the system, the MLSS increased from 5,200 to 6,900 mg/L in the MBR.

From Fig. 6, it can be seen that the total soluble EPS in the MBR samples was ranging from 25 to 60 mg/L. From the estimation protocol reported by Stumm and Morgan [14], it can be easily predicted that major components of the EPS are proteins and carbohydrates. The findings are also in agreement with other lab-scale MBR studies, in which carbohydrates and proteins were found to be the major constituents in EPS [14-15]. It has to be pointed out that EPS may also consist other substances such as humic acids, fulvic acids, uronic acids, and nucleic acids, etc [16].

In this study, the protein content in EPS was 1.2–2.4 times higher than that of carbohydrate EPS. The total soluble EPS concentration and corresponding fouling rate variations in the MBR during 45 day operation was shown in Fig. 6 and Fig. 7. It can be observed that total soluble EPS and MLSS have a strong effect on membrane fouling. The great increased in total soluble EPS and MLSS after the first 10 days of operation resulting in the high fouling rate. The findings were in good agreement with other study that significant membrane fouling was caused by EPS and MLSS in lab-scale MBR [17]. The main fouling mechanisms of MLSS and EPS could be deposition, accumulation and consolidation of MLSS and EPS on membrane surfaces and/or reduction the permeability by filling the void spaces among cell particles [18].

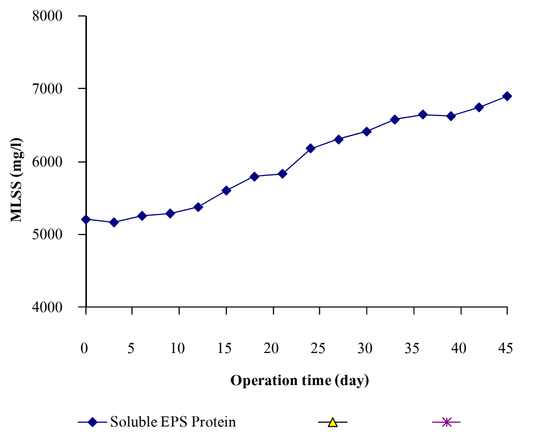

Fig. 5 Variation of MLSS in the MBR

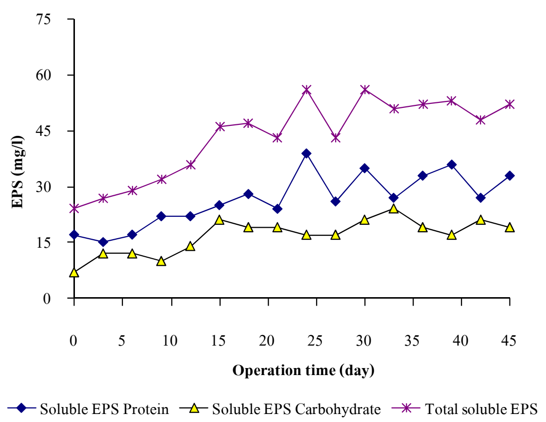

Fig. 6 Variation of EPS content in the MBR

EPS in MBRs are dependent on the balance of their formation, hydrolysis (dissolution), and the part passing through the membrane to enter the effluent. It should be also noted that the concentration of EPS could be influenced by the influent wastewater characteristics (substrate utilization-associated) and various influent wastewater might affect the EPS amount that accumulates by retention and the amount that is consumed or absorbed.

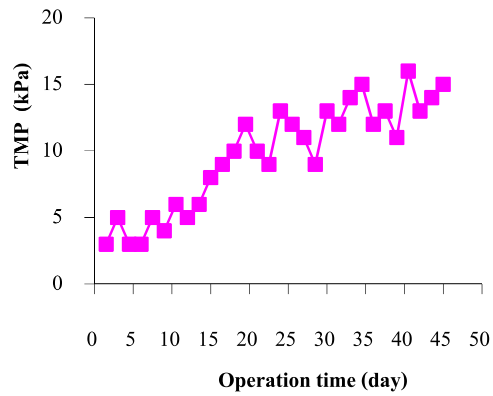

Fig. 7 Variation of TMP in the MBR

4. Conclusions

The performance of the pilot scale MBR was measured for 45 days. The measurement results showed that the average removal efficiencies of COD and ammonia were about 90% and 99.7%, respectively. However, nitrate and phosphate removal has not been significantly realized during this period. Improved anaerobic/anoxic zone was recommended for nitrate and phosphate removal. MLSS increased from 5,200 to 6,900 mg/L over the time of operation. In this study, the protein content in EPS was 1.2–2.4 times higher than that of carbohydrate EPS. MLSS and total soluble EPS was found to have a stronger positive potential on membrane fouling than carbohydrate and protein EPSs.

5. Acknowledgement

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