AN ASSESSMENT OF THE INFLUENCES OF SLUDGE RETENTION TIME ON BIOMASS PROPERTIES IN WASTEWATER TREATMENT BY MEMBRANE BIOREACTOR

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TÓM TẮT

NGHIÊN CỨU ĐÁNH GIÁ ẢNH HƯỞNG CỦA THỜI GIAN LƯU BÙN HOẠT TÍNH ĐẾN ĐẶC TRƯNG SINH KHỐI KHI XỬ LÝ NƯỚC THẢI BẰNG HỆ THỐNG XỬ LÝ SINH HỌC KẾT HỢP LỌC MÀNG (MBR)

Bài báo này trình bày các kết quả khảo sát và đánh giá ảnh hưởng của thời gian lưu bùn hoạt tính (SRT) đến đặc trưng sinh khối khi xử lý nước thải sinh hoạt bằng phương pháp sinh học kết hợp lọc màng vi lọc (MBR). Kết quả cho thấy khi tăng SRT từ 10 ngày lên 60 ngày thì nồng độ bùn hoạt tính trong hệ tăng từ 4160 mg/L lên tới 14200 mg/L nhưng tỷ lệ giữa hàm lượng cặn rắn lơ lửng dễ bay hơi và hàm lượng tổng cặn rắn lại giảm từ 83% xuống 76% và sản lượng sinh khối giảm từ 0,25 kg-MLVSS/kg-COD xuống 0,10 kg-MLVSS/kg-COD. Ngoài ra, độ nhớt của bùn hoạt tính cũng tăng tương ứng từ 9,2 lên 72,4 mPa.s. Trong khi đó, chỉ số thể tích bùn hoạt tính (SVI) tăng dần dần khi tăng SRT từ 10 đến 50 ngày, sau đó tốc độ tăng sẽ nhanh hơn nếu tăng SRT trong khoảng 50-60 ngày. Số liệu thực nghiệm về tốc độ hấp thu ôxy đặc trưng cũng chỉ ra rằng hoạt tính sinh học của bùn giảm khi tăng SRT. Nhìn chung, SRT ảnh hưởng đến sự phân bố kích thước hạt bùn hoạt tính. Tuy nhiên, điều này không tác động đến hiệu quả xử lý COD của hệ thống.

1. INTRODUCTION

Membrane filtration which combines with biological treatment, called as membrane bioreactor (MBR), is an alternative to the conventional activated sludge (CAS) process used for wastewater treatment [1]. The MBRs have several advantages over CAS processes. The main advantages of MBRs are summarised as the excellent quality treated water, smaller footprint, longer sludge retention times, and lower sludge production [2, 3]. Normally, MBR is operated with high mixed liquor suspended solids (MLSS) concentration [4]. High MLSS reduces the bioreactor volume for the same organic loads that need to be treated [5]. The MLSS levels in the reactor is controlled by the sludge retention time (SRT). Thus, SRT is an important operational parameter that may affect the performance of the bioreactors. A long SRT is considered as an advantage of the MBR, because it can reduce the amount of sludge generated and then to save the cost for the sludge disposal [6].

In recent years, many researchers have operated MBR with long SRT [2, 6, 7], since a higher biomass concentration, which was derived from longer SRT, gave rise to a higher treatment efficiency. However, at long SRT the accumulation of dead or inactive microorganisms occurs in the MBR, and thus affects the sludge activity [7, 8]. Moreover, long SRT may result in the wasted sludge with poorer thickening characteristics that affect the performance of subsequent sludge treatment [5]. Despite the previous studies, the relationship between SRT, MLSS and the biomass properties in MBR have not been quantified systematically. Therefore, it would be interesting and necessary to conduct an experiment for this lacking information since it can be used to optimize MBR design and operation.

The purpose of this study is to examine the effects of sludge retention time on the biomass characteristics in a lab-scale MBR treating domestic wastewater, including (i) the sludge bioactivity which was characterized by the specific oxygen uptake rate; (ii) sludge particle size distribution; (iii) sludge settling index. In addtion, the organic removal in the system was also evaluated.

2. MATERIAL AND METHODS

2.1. Experimental system

A lab-scale membrane bioreactor (MBR) having an operating volume of 60 L (LxWxH = 450x150x900 mm) was used in this study (Fig. 1). Five flat-sheet membranes were submerged inside the bioreactor. The membranes were made of polyvinyldene fluoride (PVDF, Hyosung Co., Ltd., Korea) with the pore size of 0.22 µm. Total filtration areas of the membranes were 0.5 m^2. Air was provided from an aeration pipe located below the membrane sheets to supply oxygen for biotreatment and to avoid the deposition of activated sludge particles on the membrane surface.

Domestic wastewater was stored in a feeding tank and pumped into the bioreactor. The influent pump was automatically controlled by a water level sensor to maintain hydraulic retention time of 6 hrs. The effluent was filtered through membrane by a suction pump, operated with a mode of 10 min on and 2 min off. The peameation flux was maintained at 20 $L/m^2.h$. The experiment was carried out with several stages with different sludge retention times (SRT) which were changed from 10 to 60 days. In each stage, a certain amount of excess sludge was discharged from the bioreactor to maintain the designed SRT. Bioactivities, settling characteristic, viscosity, particle size distribution, as well as microscopic observation of the activated sludge were monitored frequently to assess the effects of SRT on the biomass characteristics in the system.

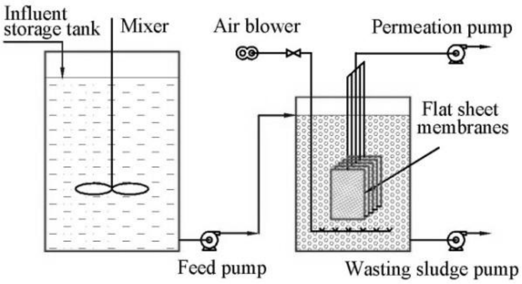

Fig.1.A schematic diagram of the membrane bioreactor used in this study

2.2. Analysis methods

The standard methods [9] were used for the analyses in this study. Mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were measured by using the methods 2540D and 2540E, respectively. Chemical oxygen demand (COD) was determined by the closed reflux, colorimetric method (Method 8000) and measured by a spectrophotometer (Hach DR/2500, Hach Co., USA). These parameters were analyzed two to three times per week. Bioactivities of the activated sludge were characterized by specific oxygen consumption rates (SOUR) which were weekly measured using a specific DO meter (YSI Model 5100, YSI Incorporated, USA). The settling characteristic of sludge was weekly monitored by measurement of sludge settling index (SVI) according to the 2710 D method. Viscosity was weekly measured using a viscosity meter (LVDV-E, Brookfield, USA). Sludge particle size distribution was determined at the end of each experimental stage by a laser beam diffraction using a Mastersizer 2000 (Malvern Instruments Ltd., UK). The microscopic observation of sludge was measured by a Microscope SZX9 (Olympus Optical Co., Japan).

3. RESULTS AND DISSCUTION

3.1. Variation of MLSS and MLVSS at various SRTs

As stated above, one of the advantages of the MBR is to maintain high MLSS [4]. In this study, both MLSS and MLVSS concentrations, which were presented in Fig. 2, increased almost linearly with increasing SRT. In which, MLSS increased from 4160 mg/L to about 14200 mg/L, and MLVSS increased from 3450 mg/L to about 10800 mg/L for SRTs of 10 to 60 days, respectively.

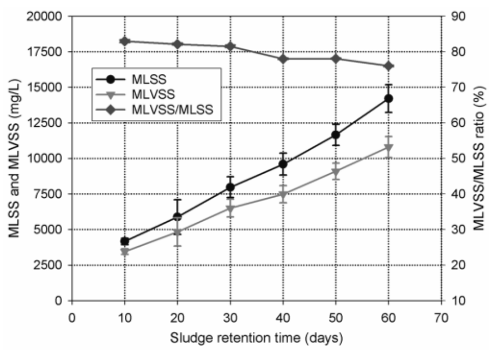

Fig.2.Variation of MLSS, MLVSS and its ratio at various SRTs

These could be easy to explain as the long SRT and membrane retention brought a high sludge concentration in the MBR. However, as showed in the figure, the ratio MLVSS/MLSS was decreased from 83% to about 76% when SRT increased from 10 to 60 days. This is due to the accumulation of inert substances resulted in a decrease of the MLVSS/MLSS in the MBR at longer SRT.

The substrate/biomass (F/M) ratio and the observed yield (Y_{obs}) were also estimated and presented in Fig. 3. As a result, the F/M ratio was varied from 0.13 to 0.35 kg COD/kg MLVSS.d, which was much lower than in the activated sludge process (0.2 to 0.6 kg COD/kg MLVSS.d [10]). Under such a low loading operation, the Yobs were also very low and decreased (from 0.25 to 0.10 kg MLVSS/kg COD) along with the SRT increasing from 10 to 60 days. It was reported that a low F/M ratio would cause a limiting supply of nutrient for microorganism growth, and resulted in a low sludge yield [11].

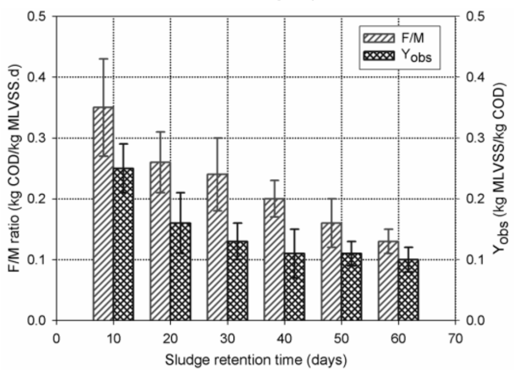

Fig.3. Variation of F/M ratio and observed yield (Y_{obs}) at various SRTs

3.2. Influence of SRT on the sludge bioactivity

The specific oxygen uptake rate (SOUR) can be used as an indicator to evaluate the sludge bioactivity [10]. In this study, the SOUR of sludge at a SRT of 10 days was 23.7 mg O2/g MLVSS.h, whereas it decreased to 10.8 mg O2/g MLVSS.h at the SRT of 60 days (Fig. 4). The observations in this study showed that the SRT has affected the bioactivity of sludge obviously.

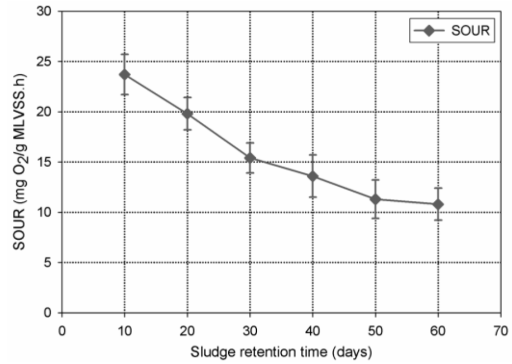

Fig.4. Variations of the specific oxygen uptake rates (SOUR) at different SRTs

The decrease of the sludge bioactivity was consistent with the reduction of the sludge yield. The efficient membrane filtration was another cause resulting in the SOUR decrease, because a large amount of inert biomass was retained in the system. Thus, this indicated that membrane separation played an important role in the accumulation of dead or inert cells. Also, it could be confirmed that the SOUR reduced is correlated with the F/M ratio since a low F/M ratio has resulted in a low sludge yield.

3.3. Influence of SRT on SVI and viscosity

The effect of SRT on the sludge volume index (SVI) and viscosity was presented in the Fig. 5.

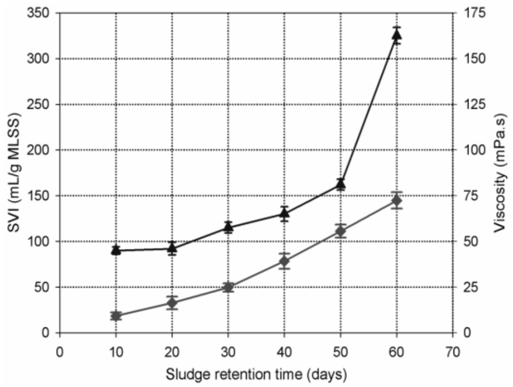

Fig.5.Influence of SRT on SVI and viscosity

In fact, increasing the SRT resulted in higher MLSS which has obvious benefits in terms of increasing the volumetric loading. As showed in the figure, viscosity was increased gradually along with increasing SRT from 10 to 60 days, from 9.2 to 72.4 mPa.s, respectively. It should also be noted that high viscosity may lower a by increasing the rate of air bubble coalescence and thus, reducing the interfacial area for oxygen transfer [12]. It can be seen in Fig. 5 that the SVI was increased only gradually along with increasing SRT from 10 to 50 days, then it was sudden increased when SRT was increased from 50 to 60 days. The increasing in SVI along with SRT is showing that the poorer thickening characteristics of the sludge wasted from the MBR. Actually, the poor settling would not affect the sludge separation in the MBR as the sedimetation process has been replaced by the membrane filtration process. However, poor settling sludge would have the negative impacts on the subsequent sludge disposal and management.

3.4. Influence of SRT on sludge particle size distribution

Another change of the sludge characteristics would be the difference of the sizes of sludge flocs which were affected by the SRT. Fig. 6 presents the sludge particle size distributions at different SRTs. As showed in the figure, all sludge particles were limited within 246.4 µm. The average particle sizes at SRTs of 10, 20, 30, 40, 50, and 60 days were 131.1, 124.8, 83.2, 74.6, 47.1, and 24.9 µm, respectively. The result showed that the sludge particle sizes reduced with SRT and many differences from the large and widely distributed flocs were observed.

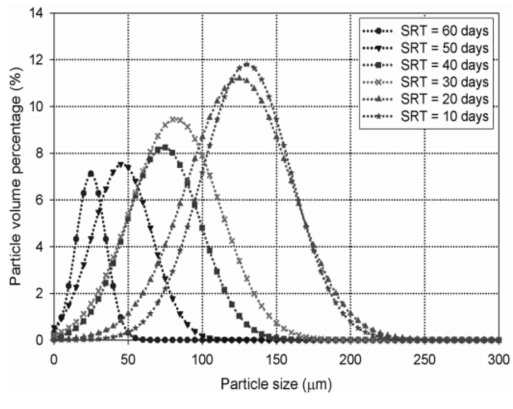

Fig.6.Variations of the sludge particle size distributions at various SRTs

It should be noted that the small sludge particles in the MBR can provide a good environment to improve the mass transfer of dissolved oxygen as well as soluble organic matter into the flocs, thus the system would enhance the organic removal [4].

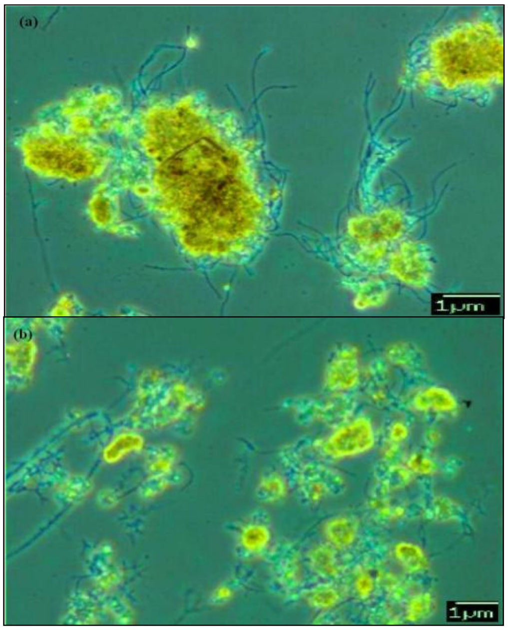

Fig.7. Microscopic observation of sludge at SRTs of 10 days (a: with magnification of 60x) and 60 days (b: with magnification of 20x)

The observations in this study were a little larger than that in a recirculated type of MBR [13]. The difference could be explained that a higher shear stress caused by the recycling pump in the recirculated type of MBR may destroy sludge flocs. A microscopic evaluation of the sludge from MBR was carried out and presented in Fig. 7. Overall, floc-morphologies of sludge at different SRTs were very different.

3.5. Influence of SRT on COD removal in the system

Fig. 8 presents the variation of COD in the influent and efflent of the system at different SRTs. On the average, more than 96% of the COD was removed for all SRTs and the effluent COD were varied in the range of 8 - 15 mg/L. Even, sometimes it was only about 3 mg/L (e.g. on date 219). The observations show that there was no significant differences in the average COD percent removal for all studied SRTs.

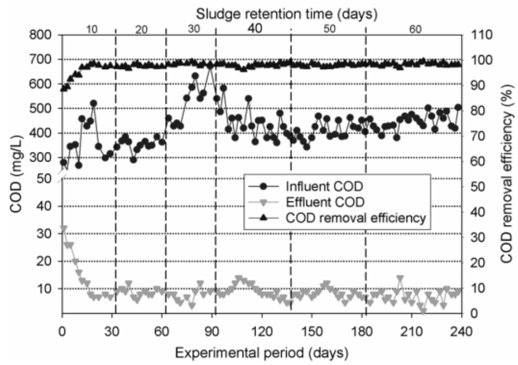

Fig.8.Variation of COD removal at different SRTs

4. CONCLUSIONS

The following specific conclusions were withdrawn from the present study:

- With increasing SRT from 10 to 60 days, the sludge concentrations in the MBR were increased, whereas the ratio of volatile suspended solid to the total solid was decreased.
- Under a low loading operation, the Yobs were decreased along with the SRT increasing from 10 to 60 days.
- The SRT has affected the bioactivity of sludge obviously. The SOUR was reduced significantly along with the increasing SRT.
- Viscosity were increased gradually along with increasing SRT. The SVI were increased only gradually along with increasing SRT from 10 to 50 days, then it was sudden increased when SRT was increased from 50 to 60 days.

- The sludge particle sizes varied with SRT and floc morphology of sludge at different SRTs were very different.
- However, the COD removals was not significantly affected by the SRTs.

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