하수의 고도처리를 위한 저비용 저에너지의 대체 막을 조합한 생물반응기의 개발

Advanced Wastewater Treatment using Bioreactor Combined with Alternative Membrane

김 동 하

Dong-Ha, Kim

Dept. of Civil and Environmental Engineering, Kookmin University, Seoul, Korea

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Abstract

In order to decrease the high costs of membrane process, we have tried to develop two alternatives to membrane; a cartridge type filter and a metal membrane were tested for the high permeation flux with low cost and low energy. This research mainly focused on three points; 1) operation with high permeation flux by using of a cartridge type filter and a metal membrane, 2) removals of the filterable organic materials (FOC) by pretreatments for the membrane fouling control, and 3) advanced wastewater treatment by SMBR process with intermittent aeration and high MLSS.

An Intermittently aerated membrane bioreactor using a submerged micro filter (cartridge type) was applied in laboratory scale for the advanced wastewater treatment. To minimize membrane fouling, intermittent aeration was applied inside of the filter with 3.0 kg_f/cm^2. The experiments was conducted for 6 months with three different HRTs (8, 10, 12 hr) and high MLSS of 6,000 and 10,000mg/L. The filtration process could be operated up to 50 days with permeation flux of 500LMH. Regardless of the operating conditions, more than 95% of COD, BOD and SS were removed. Fast and complete nitrification was accomplished, and denitrification was appeared to be the rate-limiting step. More than 75% T-N could be removed due to the endogenous denitrification. T-P removal efficiency was increased to 80% under the condition of MLSS 10,000mg/L.

Key words: alternative membrane, cartridge type membrane, sieve type membrane, high flux, SMBR, FOC
주제어: 대체 막 개발, 카트리지 타입 막, 메쉬 타입 막, 고 투과유속, SMBR, FOC

*Corresponding author Tel: +82-2-910-4647, FAX : +82-2-910-4939, E-mail: kimdh@kookmin.ac.kr (Kim, D.H.)

1. INTRODUCTION

With the effluent quality standards of wastewater treatment plants getting strict, membrane bioreactor (MBR) has been proposed as an alternative for the conventional activated sludge process. There are several advantages associated with a membrane bioreactor (MBR) that make it a valuable alternative to other treatment techniques. First, the retention of all suspended matter and most soluble compounds (depending on the pore size of the membrane) promotes excellent effluent quality, capable of meeting stringent future discharge limit (Chiemchaisri, 1992). Because suspended solids can be retained in the clarification step, solids retention time (SRT) and hydraulic retention time (HRT) are entirely separated, providing excellent control of microbial population and flexibility in operation (Tronve, 1994).

However, there are several aspects limiting wider use of MBR process for domestic wastewater treatment. Recent researches on domestic wastewater treatment using MBR have focused on how to overcome these limitations; 1) how to control concentration polarization and membrane fouling, 2) simultaneous removal of carbon and nitrogen, and 3) how to decrease the high capital and operation costs. Successful application of membrane technology especially requires efficient control of membrane fouling. Fouling, often associated with accumulation of substances on the membrane surface or within the membrane pore structure, worsens membrane performance and ultimately shortens membrane life. Several remedial actions have been tried to prevent the fouling problem, such as increasing fluid velocity, backwashing, multiphase flowing, and controlling the membrane surface charge (Urbain, 1996; Jong-Oh Kim, 2000).

There have been many investigations about membrane fouling mechanisms, methods to restrict fouling, and methods to enhance the flux. To enhance organic removal and to reduce membrane fouling causing by potential hydrophobic substances, the use of PAC for raw water pretreatment or in combination with the UF system has been practiced. Some studies have indicated that the addition of PAC could increase membrane flux and enhance organic removal (Adham, 1991).

A "submerged membrane bioreactor (SMBR)" in which membranes were directly submerged into an aeration tank was developed by Yamamoto et al. Recently, submerged hollow fiber (HF) membrane with air bubbling around the module has been applied and suggested as a simple and effective solution for both fouling control and space saving(Christophe, 1999). Simultaneous removal of carbon and nitrogen was also tested with single stage SMBR by introducing intermittent aeration (Chiemchaisri, 1992; Kim, 2000).

In order to decrease the high capital and operation costs of membrane process, we have tried to develop two alternative filters to membrane; a cartridge type filter and a metal membrane were tested for the high permeation flux with low cost and low energy.

In this study, the performances of the SMBR with two alternative filters were evaluated for school cafeteria wastewater treatment by laboratory scale experiments. This research mainly focused on three points; 1) operation with high permeation flux by using of a cartridge type filter and a metal membrane, 2) removals of the filterable organic materials (FOC) by pretreatments for the membrane fouling control, and 3) advanced wastewater treatment by SMBR process with intermittent aeration and high MLSS.

2. EXPERIMENTS

For the removal of FOC in feed water, some pretreatments were applied before membrane filtration tests. The additions of powdered activated carbon (PAC), coagulant

Table 1. Experimental conditions for the FOC removal

	Experimental conditions
Run 1	Powdered activated carbon (PAC, 200mg/l)
Run 2	coagulant (27mg/l as alum)
Run 3	PAC (200mg/l) + coagulant (27mg/l as alum)
Run 4	Sedimentation after Run2 + PAC (200mg/l)

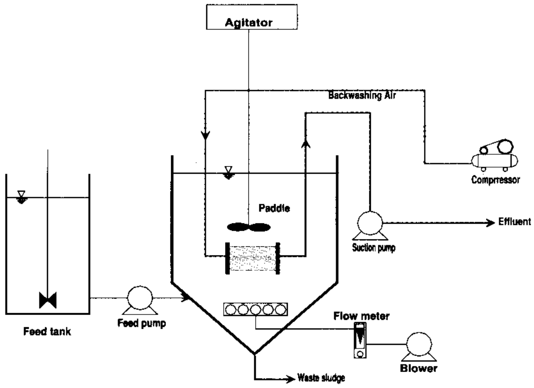

Fig. 1. Schematic diagram of SMBR.

and combination of PAC+coagulant were investigated under some experimental conditions. These conditions were summarized in **Table 1**. For preliminary examination about the removal of FOC of feed water by PAC and coagulant dosages, jar tests were performed at a stirring speed of 150 rpm for 15~30 minutes. Some dead-end filtration test were conducted to investigate the effects of FOC on the permeation flux. The Adventec dead-end filtration cell with 47mm in diameter and an effective filtration area of 17.3cm^2 was used to measure the feed water permeability, which is a fundamental and necessary property in characterizing a membrane.

As shown in **Fig. 1**, the SMBR was consisted of a cylindrical bioreactor(effective volume 30L) and a submerged cartridge filter module(pore size of 0.5 and 1.0μm, surface area of 0.05m^2, ϕ61 × H254mm). The filter was submerged in the reactor and vacuum was applied inside of it for filtration. To minimize membrane fouling, intermittent aeration was applied inside of the filter with 3.0kg$_f$/cm^2. Filtration was occurred after 20 min sedimentation process to take the advantage of low SS concentration for fouling control.

The experiments was conducted for 6 months with three different HRTs(8, 10, 12 hr) and high MLSS of 6,000 and 10,000mg/L. The operating time sequence was as follows; with suspension of aeration, the influent is fed for a given period (70min.) and a submerged pump starts anoxic mixing (50min.), after a given period of reaeration (20min.) and settling (30min.), filtration in suction mode was initiated (10min.). One cycle is consisted of 3 hours. To minimize membrane fouling, air back washing was performed for 10 min. during the first aeration step. The operation of the pumps and valves was automatically controlled. The characteristics of school cafeteria wastewater used in this experiment were summarized in **Table 2**.

Table 2. Characteristics of cafeteria wastewater

Item	Range(mg/L)	Average (mg/L)
BOD_5	102.3~234.0	171.1
COD_{cr}	111.0~352.0	224.0
T-N	16.2~38.9	24.5
NH_3-N	11.1~27.5	20.0
T-P	3.5~8.6	4.3
PO_4-P	2.9~7.3	3.9
pH	6.0~7.5	7.2
SS	51.0~260.0	120.0

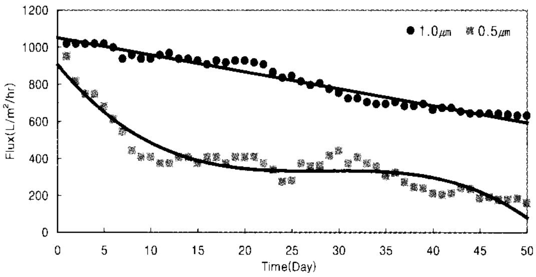

Fig. 2. Variations of permeation flux.

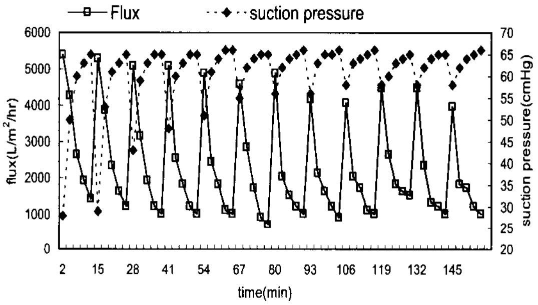

Fig. 3. Variations of suction pressure and permeation flux.

3. RESULTS AND DISCUSSION

3.1. Membrane performance

To investigate the long term permeation ability of cartridge type filter, some tests were conducted under the experiment conditions (influent SS 80mg/L, intermittent operation of 3 min. suction and 0.5 min. air backwashing). The variations of permeation flux were shown in **Fig. 2.** The initial permeation flux of each filter was about 1,000 L/m2/hr (LMH). After 40 days operation, the permeation flux of 1.0μm filter decreased to 600LMH and that of 0.5μm filter to 200LMH. **Fig. 3** shows the effects of backwashing with pressured air, under the sequencing mode of 10 min. suction and 3 min. air backwashing. The filtration process could be operated up to 50 days with permeation flux of 500LMH, which is 10 times high compared to the other's results (Brindle, 1996). This high flux could be obtained by using of cartridge filter with 1μm pore size, which is large pore size compared to the conventional MF membrane, and applying of periodic air backwashing.

3.2. Pretreatment effects on fouling control with PAC

For the removal of organic matters in wastewater, some pretreatments were applied before membrane filtration. The effects of powder activated carbon(PAC), coagulant, and combination of PAC and coagulant on FOC removal were examined under various experimental conditions.

Jar tests were first carried out to estimate the FOC removal efficiencies by different PAC and coagulant dosages. The higher PAC dosage, the more FOC removed. The FOC removal efficiencies increased markedly as PAC dosages increased to 500mg/l. Higher FOC removal efficiencies at increased PAC dosages were due to higher adsorbing surface area. At PAC dosage of 500mg/l, the FOC removal efficiency is about 70% and

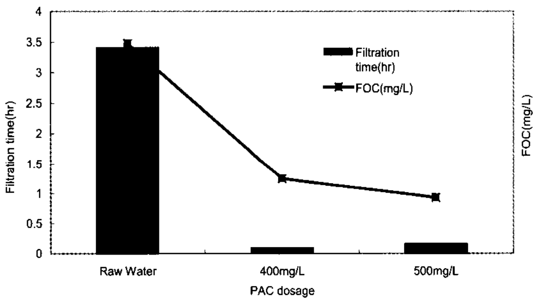

Fig. 4. Effects of PAC dosage on FOC removal.

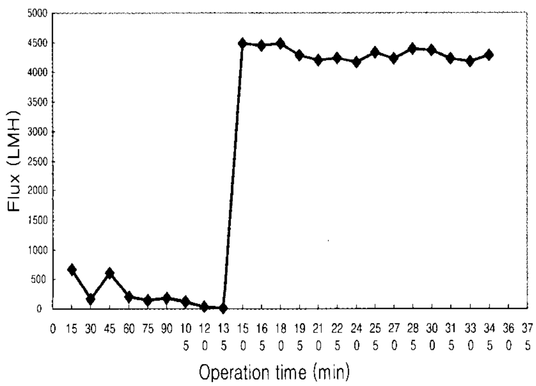

Fig. 5. Effect of PAC addition on MF filtration system.

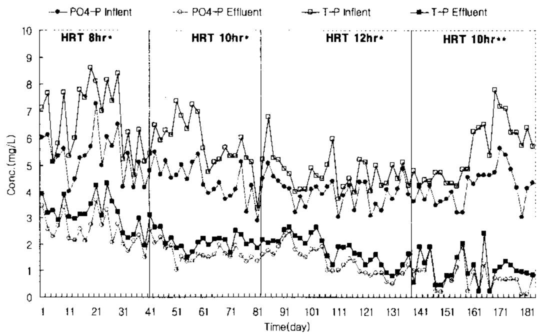

Fig. 6. Variation of phosphorus compounds with different HRTs.

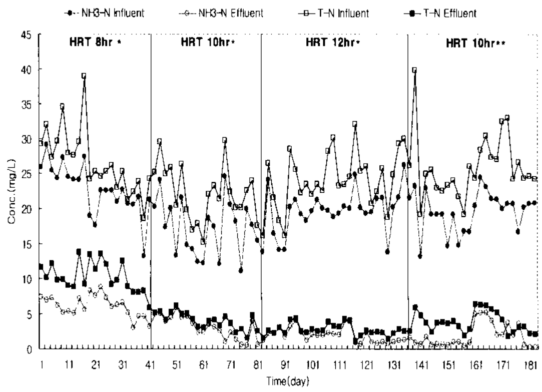

Fig. 7. Variation of nitrogen compounds with different HRTs.

the residual FOC concentration was less than 1.0mg/l (**Fig. 4**).

The normalized permeate flux under several experimental conditions (absence/ presence of PAC addition) as a faction of time is shown in **Fig. 5**. The results are all expected that the flux declines to 50 LMH rapidly in the presence of soluble organic substances, However, with the addition of PAC at a rate of 1g/l, the flux was markedly recovered nearly to the initial permeate flux about 4,500LMH.

3.3. SMBR Performance

It was observed that the influent concentrations of BOD_5, CODcr, T-N and T-P from cafeteria wastewater were 171mg/L, 224mg/L, 24.5mg/L and 4.3mg/L respectively. The treatment efficiencies of organic, nitrogen, and phosphorus compounds during the operations were shown in **Fig. 6** and **Fig. 7**. Regardless of the operating conditions, more than 95% of COD, BOD and SS were removed. By using of 0.5μm pore size filter with 8~12 hour HRT, 95% of BOD and 99% of SS could be removed. Under the conditions of HRT 12 hour, pore size 0.5μm and MLSS 6,000mg/L, the removal efficiency for T-N was 89%, and T-P was 62%.

Those of BOD_5, CODcr, T-N and T-P in the effluents at HRT 12hr were estimated to be below 3mg/L, 4mg/L, 2.8mg/L and 1.8mg/L, respectively. In the case of 1.0μm pore size, the removal efficiencies of organic compounds were over 90%. With HRT 10 hour, pore size 1.0μm, and MLSS 10,000mg/L, the removal efficiency for T-N was 91% and T-P was 78%.

Fast and complete nitrification was accomplished regardless of the operation cycle mode, and denitrification was appeared to be the rate-limiting step. It is shown that NH_4-N and NO_3-N concentrations in the effluent are below 2.0mg/L and 0.8mg/L at HRT 12hr, respectively, which demonstrates that nitrification and denitrification proceed almost completely. When carbon source is not limited, the overall denitrification rate is high and the time required for denitrification is shortened. When carbon source become limited, the nitrate level in the effluent can still be significantly reduced by endogenous denitrification. In both ways, the intermittently aerated SMBR process with high MLSS is likely to be more robust to the fluctuation of influent water quality in terms of nitrogen removal.

Under the experimental conditions of MLSS 10,000 mg/L and HRT 10hrs, T-P was removed about 79%, which was 13% higher compared to the result from run 2 (MLSS 6,000mg/L, HRT 10 hrs). These results could be explained as the effect of biologically mediated precipitation with high MLSS.

4. CONCLUSIONS

An Intermittently aerated membrane bioreactor using a submerged micro filter (cartridge type) was applied in laboratory scale for the advanced wastewater treatment. By using a 1.0μm cartridge type filter with periodic air backwashing, the process could be operated up to 50 days at much higher flux (over 500L/m^2/hr). This high flux could be obtained by using of cartridge filter with 1μm pore size, which is large pore size compared to the conventional MF membrane, and applying of periodic air backwashing.

With 8~12 hour HRT, 95% of BOD and 99% SS could be removed. Under the conditions of HRT 10 hour, pore size 1.0μm, and MLSS 10,000mg/L, the removal efficiency for T-N was 91%, and T-P was 78%. With HRT 10 hour, pore size 1.0μm, and MLSS 10,000mg/L, the removal efficiency for T-N was 91% and T-P was 78%. Fast and complete nitrification was accomplished regardless of the operation cycle mode, and denitrification was appeared to be the rate-limiting step. NH_4-N and NO_3-N concentrations in the effluent were below 2.0mg/L and 0.8mg/L at HRT 12hr, respectively, which demonstrates that nitrification and denitrification proceed almost completely. Regardless of BOD_5/N ratio in the influent, more than 75% T-N could be removed because of the endogenous denitrification. Maintaining high MLSS in the intermittently aerated SMBR process appears to enhance denitrification as well as nitrification.

Especially T-P removal efficiency was increased to 80% under the condition of MLSS 10,000mg/L. It was assumed that T-P was removed highly by the biosorption mechanism with high MLSS concentration. Intermittently aerated MBR with cartridge type micro filter appears to have advantages compared to other biological N and P removal processes. Denitrification and T-P removal could be enhanced under high MLSS condition.

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