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Effects of operational parameters on aeration on/off time in an intermittent aeration membrane bioreactor

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Abstract

This study was performed to evaluate the operational parameters on aeration on/off time in an intermittent aeration membrane bioreactor for wastewater treatment. The membrane bioreactor has 5.5 L of effective working volume including a microfiber membrane. The influent wastewater contained 133 mg/L of BOD, 195 mg/L COD, 98 mg/L SS, 30 mg/L total nitrogen, and 3.8 mg/L total phosphorous. Operational conditions related to aeration on/off time were 8.8 h HRT, 10 LMH flux, 10 L/min air flow, and 6300 mg/L MLSS. For 2 h/cycle, aeration on/off time was operated for 12 cycles in three variations: 60/60 min, 50/70 min (I), and 40/80 min. Suction on/off time was 10/2 min, 8/2 min, and 8/2 min, respectively, but also 50/70 min (II) when aeration on/off time was operated at 8300 mg/L MLSS. The BOD removal efficiency rate of this process was higher than 97% regardless of the aeration on/off time distribution. To get higher than 82% total nitrogen removal efficiency rate, aeration off time in the reactor needs to be more than 70 min. The specific denitrification rate was 2.68 mgNO_3-N/gMv/h at 40/80 min on/off aeration times, which was 2.6 times more than at 60/60 min, and 1.4 times more than at 50/70 min (I) for 6300 mg/L MLSS. The specific nitrification rate was 1.96 mgNH_4-N/gMv/h at on/off aeration times of 50/70 min, 1.4 times less than at 40/80 min, but was ineffective for nitrification. Microbial activity was affected only a little by variation in aeration on/off time, though oxygen demand was reduced by aeration off time and allowed microbial concentration to increased. EPS (extracellular polymeric substance) per unit of microorganisms increased with aeration off time.

Keywords: MBR; Aeration on/off time; Extracellular polymeric substance; Specific nitrification rate; Specific denitrification rate

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1. Introduction

The SBR (sequencing batch reactor) process is intented to reduce the plant area and simplify operation. Aerobic and anaerobic reactors occurs in one tank during the fill, reaction, settlement and draw in the process. Advanced treatment of nitrogen and phosphorus is possible using different nitrogen removal characteristics created by changing time distribution and working conditions [1]. Even so, it has problems similar to biological processes, such as sludge bulking, pin-floc, and solid–liquid separation. Solid substances must also be removed from sedimentation tanks and the deterioration of water quality may occur while adapting treatment facilities to higher treatment standards. Recently there has been active study and good progress domestically and abroad using MBR (membrane bioreactor) processes to improve treatment efficiency by increasing microorganism concentration. Using membrane techniques is a core skill often to produce good drinking water, as well as advanced treatment and reuse of wastewater and sewage [2]. Researches are in related on the advanced treatment process of nitrogen and phosphorus through the nitrification/denitrification with optimum time distribution by using SBR merits and MBR process which is submerged the separation membrane inside bioreactor instead of the sedimentation regardless of troubles. Also of interest were solution to the troubles of EPS, cake resistance and rising of permeate pressure generated by use of separation membranes. This study was carried out to investigate the optimum working conditions and to evaluate the effects of operational parameters in an intermittent aeration membrane bioreactor.

2. Methods

2.1. Experimental design of MBR

The experimental MBR set up is shown in Fig. 1 and the specification of the membrane used is presented in Table 1. The membrane bioreactor has 5.5 L of effective working volume including the volume of microfiber, 8.8 h HRT, 0.3 μm pore size, 2 mm diameter, and 0.062 m^2 sectional area of microfiber. The lower section of the reactor has 2 aeration stones to reduce membrane pollution and air feeding is controlled to deliver about 10 L/min. Also, suction is adjusted to control water level during changes in aeration and the working temperature is from 17 to 23°C

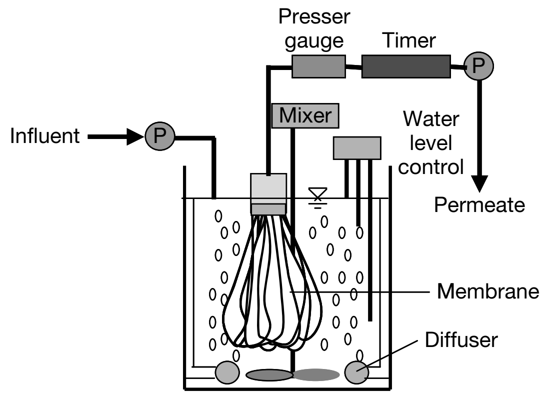


Fig. 1. Schematic diagram of the experimental MBR reactor.

2.2. Experimental method

Wastewater used in this study was taken from P apartment in Daejeon, Korea, and suspended solids of the influent is filtered using a 1mm sieve. The detailed characteristics of the wastewater are presented in Table 2.

Table 1
Specification of membrane

Item	Specification
Pore size	0.3 μm
Total length	55 cm × 18 ea
Thickness	2 mm
Section area	0.062 m^2
Material	Polyacrylether sulfone

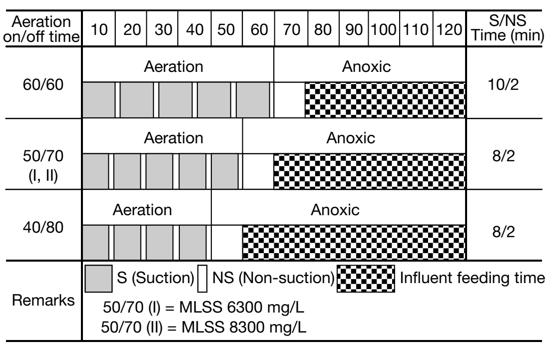
Table 2
Characteristics of influent

Item	Min.	Max.	Avg.	Item	Min.	Max.	Avg.
pH	6.7	7.7	7.0	TKN	23	35	27
TBOD	92	223	133	NH_4-N	17	23	20
TCODcr	142	242	195	TN	24	37	30
SCODcr	53	99	70	TP	2.3	5.2	3.8
TSS	83	117	98	Alkalinity	116	142	125

All units are in mg/L.

Operational conditions according to aeration on/off time are presented in Table 3. DO concentration during aeration changed from 0 to 7 mg/L. After 10 min of aeration off time, DO concentration dropped back to 0. So influent wastewater was supplied to the reactor to reduce impediment of nitrification. BOD, COD, TSS, VSS, TKN, NH_4-N, total nitrogen, total phosphorous and alkalinity were analyzed using the standard method [3]. Carbohydrate was measured according to the Phenol–sulfuric acid method [4] after pre-treat of the sample and protein was analyzed by the Lowry method [5] using the Bicinchoninic acid protein assay.

Table 3
Operation conditions by aeration on/off time



3. Results and discussion

3.1. Organic matter removal

Results of measurement of organic matter during changes in aeration on/off time are presented in Table 4. A COD removal efficiency less than the BOD removal efficiency is caused by multiplication of non-biodegradable matter because of an increase of SMP (soluble microbial product) in the oxic tank [6]. Consequently the removal efficiencies of organics were 97% BOD, 92% COD, and 100% SS regardless of the aeration on/off time and did not vary with

Table 4
Effect on organic matter removal efficiency by aeration on/off time

Condition		Influent (mg/L)			Effluent (mg/L)			Removal efficiency (%)		
MLSS (mg/L)	Time (min)	TBOD	TCOD	SCOD	TBOD	TCOD	SCOD	TBOD	TCOD	SCOD
6300	60/60	115	192	66	1.5	8.3	5.2	98.7	95.7	92.2
	50/70 (I)	121	203	69	3.0	15.6	11.1	97.5	92.3	83.9
	40/80	162	190	73	1.7	13.5	3.0	99.0	92.9	95.9
8300	50/70 (II)	148	210.4	90.7	2.4	9.4	6.8	98.4	95.5	92.5

Table 5
Effects on nitrogen removal efficiency by aeration on/off time

On/off time (min)	Influent (mg/L)		End of aeration (mg/L)	Effluent (mg/L)			Removal efficiency (%)		
	TKN	NH_4-N	NH_4-N	TKN	NH_4-N	NO_3-N	TKN	NH_4-N	TN
60/60	24.5	20.9	0.5	2.9	1.1	8.7	88.2	94.9	60.0
50/70 (I)	29.2	18.3	0.1	1.4	1.1	4.1	95.2	94.0	82.2
40/80	28.1	20.0	0.1	1.1	0.8	4.0	96.1	96.0	82.9
50/70 (II)	30.6	17.4	0.04	1.4	0.6	3.4	95.4	96.9	86.9

increments of microorganism concentration under at the same aeration on/off conditions.

3.2. Nitrogen removal

Results for nitrogen removal efficiency are presented in Table 5. The removal efficiency of total nitrogen was 60.0, 82.2, 82.9, and 86.9% at 60/60 min, 50/70 min (I), 40/80 min, and 50/70 min (II) aeration on/off times, respectively. The longer the aeration off time, the higher was total nitrogen removal efficiency. The maximum removal efficiency of total nitrogen occured at 50/70 min (II). In an intermittent MBR process involving a specific anoxic tank, and a total nitrogen influent concentration of 45.3 mg/L, the maximum removal efficiency reported by Choi [7] was 78.8% at 20/20 min aeration on/off time for 6 h HRT. In that study, the removal efficiency of total nitrogen was 77% at 60/60 min aeration on/off time and 35 mg/L influent NH_4-N concentration [8], but it was more than 82% in this study. Aeration time is needed more than 40 min for suction amount. It took more than 70 min to get complete nitrification and obtain total nitrogen removal efficiency of more than 83%. SCOD removal efficiency during non-aeration was 68.7, 75.0, 78.3 and 78.8% at 60/60 min, 50/70 min (I), 40/80 min, and 50/70 min (II), respectively. That was higher at 50/70 min (II) for 8300 mg/L MLSS than at 40/80 min for 6300 mg/L MLSS because much of the organics was removed at 40/80 min during the anoxic state and high removal efficiency was maintained at 50/70 min (II) by increased in microorganism concentration during long aeration off times. The SNR (specific nitrification rate) and SDNR (specific denitrification rate) according to aeration on/off time are presented in Table 6.

3.3. Phosphorous removal

Removal efficiency of total phosphorous was 31.4, 38.2, 38.6, and 45.9% at 60/60 min, 50/70 min (I), 40/80 min and 50/70 min (II) aeration on/off time, respectively. Randall et al. [9] reported that the TCOD:TP ratio is the important factor to decide the microorganism species by feed distribution and total phosphorous of effluent is able to below 1.0 mg/L at more than 40:1 of the ratio. Even at a TCOD:TP ratio of 62:1 which was insufficient in this study, phosphorous removal efficiency was low because the DO concentration during aeration on time in a single tank was high and influent organics were consumed for cell synthesis and denitrification.

Table 6
Effects on SNR and SDNR by aeration on/off time

On/off time (min)	SNR ($mgNH_4$-N/gVSS/h)	SDNR ($mgNO_3$-N/gVSS/h)
60/60	1.2	1.05
50/70	1.96	1.92
40/80	1.42	2.68

So it is considered important that a specific anaerobic tank be added or that coagulating agents be fed into the MBR process to remove phosphorous more effectively.

3.4. Specific oxygen uptake rate

Specific oxygen uptake rate (SOUR) has decreased with obstruction of microbial activity due to long SRT, high MLVSS concentration and low organics load. SOUR was found to average 9.38 mgO_2/gMv/h regardless of aeration on/off time, so it is low in cases where aeration on/off times are related to microbial activity. It has been reported that oxygen demand was about 2.27 kgO_2/kgBODrm in an intermittent aeration A2/O process [10], about 2.0 kgO_2/kgBODrm in an SBR process [11], and about 1.3 kgO_2/kgBODrm in an MLE process using media [12] respectively. In this study, oxygen demand was measured from 2.7 to 3.3 kgO_2/kgBODrm higher than other processes due to high microbial content and DO concentration. The oxygen demand is reduced during short aeration on time and long aeration off time.

3.5. EPS production

Effects on carbohydrate and protein masses by aeration on/off time are shown in Fig. 2. Carbohydrate and protein masses are essential factors of EPS to control the microbial activity and destruction. EPS amounts differ with changes in microbial state and operating conditions of the bioreactor. EPS is also the source of membrane pollution as it multiplies viscosity and accumulates on the membrane surface. Carbohydrate and protein were found to be 12.3 or 30.4 mg/gMv at 60/60 min, 14.2 or 47.3 mg/gMv at 50/70 min (I) and 27.2 or 80.7 mg/gMv at 40/80 min. They increased in proportion to aeration off time because cell growth exploded as SRT and aeration off time become longer. Therefore the sticky EPS content increased.

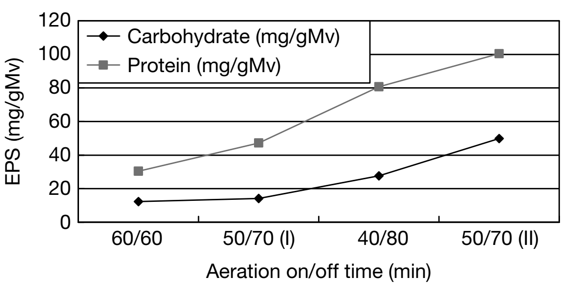


Fig. 2. Variation of EPS by aeration on/off time.

3.6. Transmembrane pressure variation

Changes in transmembrane pressure according to aeration on/off time are shown in Fig. 3. Under the working conditions of 6300 mg/L MLSS, 8.8 h HRT and 10 L/min air supply, the operating periods were 21 days (60/60 min aeration on/off time) and 17 days (40/80 min aeration on/off time). It was difficult to maintain 10 LMH flux once the transmembrane pressure reached 23 kPa. This pressure has elevated at 40/80 min than 60/60 min on a sudden. It is supposed that the working transmembrane pressure is increased due to membrane resistance caused by incremental rise in the EPS content related to aeration on/off time even though mixing was done during aeration off times.

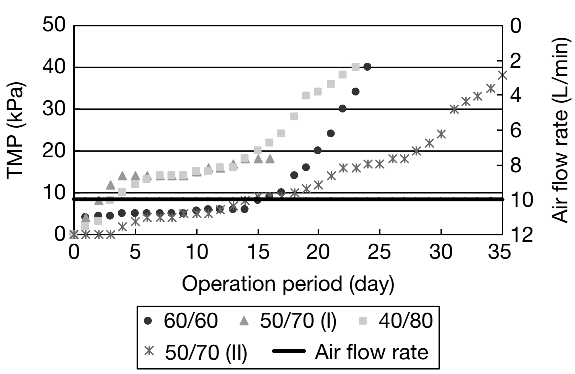


Fig. 3. Variation of transmembrane pressure by aeration on/off time.

4. Conclusion

This study was performed to evaluate parameters such as removal efficiency rate of organics and nitrogen, EPS content, and TMP by aeration on/off time in an intermittent aeration membrane bioreactor for wastewater treatment. The BOD removal efficiency rate of this process was higher than 97% regardless of the aeration on/off time distribution and reached a maximum of 99% at 40/80 min aeration on/off time. Nitrification of more than 99% was attained without relation to the aeration on/off time distribution. To get a rate of total nitrogen removal higher than 82%, aeration off time in the reactor needs to be more than 70 min.

The specific denitrification rate at 40/80 min aeration on/off time was 2.68 $mgNO_3$-N/gMv/h, which was 2.6 times more than at 60/60 min, and 1.4 times more than at 50/70 min (I) for 6300 mg/L MLSS. The specific nitrification rate at 50/70 min aeration on/off time was 1.96 $mgNH_4$-N/gMv/h and 1.4 times less than at 40/80 min, but was no effective for nitrification. Microbial activity was a little more effective according to the aeration on/off time. During aeration off times, oxygen demand was reduced and microbial concentration increased. EPS per unit of microorganisms increased as the aeration off time got longer. The content at 50/70 min and 40/80 min aeration on/off time increased 1.6 times and 2.7 times respectively, compared with 60/60 min.

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