Treatment of Saline Wastewater by the Activated Sludge with Nonwoven Fabric Separation

Byung-Hyun Moon[1,*], Jong-Soo Heo[2], and Hyoung-Sub Choi[3]

[1]Department of Environmental Emgineering, Chang-Won National University,
[2]Department of Agricultural Chemistry, Kyung-Sang National University,
[3]Provincial Government Institute of Health and Environment, Kyung Sang Nam-Do

Direct membrane separation using nonwoven fabric was applied to saline wastewater treatment by an activated sludge process. A nonwoven fabric module was immersed in an aeration tank. The part of treated was filtered through the module by suction and the rest of that was separated by a settling tank. Various F/M ratios and salt concentrations were applied to investigate stable flux as well as pollutant removal. The pollutant removal efficiencies of nonwoven fabric separation was not affected by F/M ratios and salt concentrations and was higher than that of settling tank separation. The decline in flux was seemed to be caused by the biofilm on nonwoven fabric surface.

Key words: direct membrane separation, saline wastewater treatment, nonwoven fabric

INTRODUCTION

Activated sludge is the most widely used biological wastewater treatment process in Korea, treating saline wastewater. However, it has always been recognized that increased and changed salt concentrations can have significant negative impacts on the activated sludge process. Increased and changed salt concentrations tend to disrupt biological activity, reduce degradation kinetics and cause poor sludge settling characteristics. As results of salt, the process shows the reduced organic removal efficiency, increased effluent suspended solids and decreased microorganisms in reactor [1-3]. Recently, solid-liquid membrane separation for activated sludge process has been applied to variety of wastewater. The complete solid-liquid separation by membrane can reduce effluent suspended solids and increase microorganisms in the reactor [4-5]. By maintaining high concentration of microorganisms in the reactor, organic removal efficiency can be increased. Easier control of food to microorganism (F/M) ratio and microorganism retention time by solid-liquid separation means easier control of biological activities and better effluent quality. But the application of the membrane separation is limited to some special situation due to the high capital and operation cost with lack of enough experiences. The main reason for the high cost is due to membrane price, the recirculation pump energy, and flux decline. In this study, a nonwoven fabric separation of activated sludge process for saline wastewater treatment was investigated. The direct solid liquid separation was applied to an activated sludge process by immersing nonwoven fabric module to aeration tank for reducing energy consumption and membrane cost.

* Corresponding author
Tel: 0551-79-7564 Fax: 0551-81-3011
e-mail: bhmoon@sarim.changwon.ac.kr

MATERIALS AND METHODS

Figure 1 illustrates a schematic diagram of the laboratory reactor. The volume of aeration and settling tank were 6L and 4L, respectively. Two nonwoven fabric module were immersed in the aeration tank. Total surface area of the module was 0.09 m^2. The nonwoven fabric were domestic products, made of polyester with poresize of 50.6 μm, thickness of 0.3 mm, tensile strength of 27.0 kg/5 cm and weight of 100 g/m^2. The part of treated water was obtained by using a suction pump and the rest of treated water was obtained by using settling tank to compare the treated water quality. The intermittent suction, 10 minutes suction/ 10 minutes idle, was applied because intermittent suction showed higher performance than continuous suction regarding to the maintenance of stable flux [5]. The composition of influent synthetic wastewater is shown in Table 1.

The operational conditions for each reactor are summarized in Table 2. The activated sludge sample taken from a full scale activated sludge wastewater plant was used as seeding sludge without salts acclimation for the experiment. Various F/M ratios (kg BOD/ kg MLSS-day) and salt concentrations were applied to investigate pollutant removal efficiencies and flux variation. Permeate flow rate and suction pressure from nonwoven fabric module were monitored together. Analysis of water quality were followed by the Korea Standard Method. Floc size and distribution were measured by Diffraction Particle Sizer (Malvern, MasterSizer E).

RESULTS AND DISCUSSION

Treated Water Quality

Experiments of the nonwoven fabric separation with NaCl concentration of 3000 mg/l and different F/M ratio were conducted. Before the activated sludge was ac-

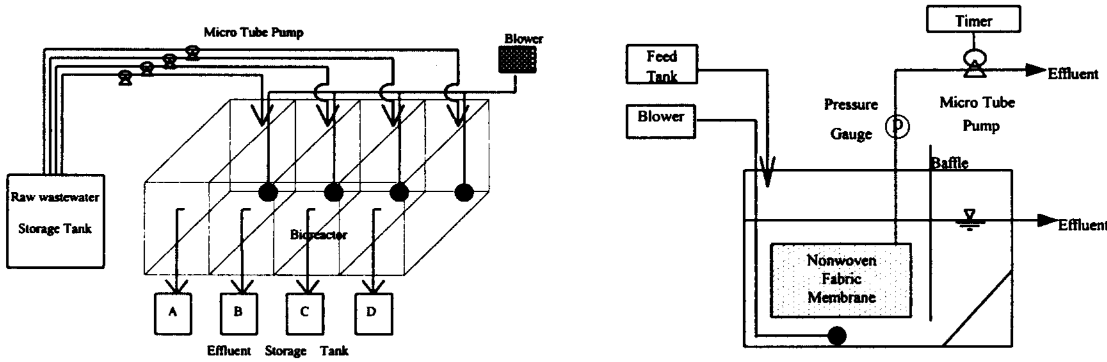

Fig. 1. Schematic diagram of experimental system.

Table 1. Composition of Synthetic Wastewater

Composition	Concentration (mg/l)
Glucose	4,000
Peptone	4,000
Yeast extract	400
$(NH_4)_2SO_4$	3,200
KH_2PO_4	640
$MgSO_4 \cdot 7H_2O$	800
$MnSO_4 \cdot 6H_2O$	72
$FeCl_3 \cdot 6H_2O$	4
$CaCl_2 \cdot 2H_2O$	8

climated to 3000 mg/l NaCl, the water quality treated by nonwoven fabric separation (NFS) and conventional settling tank (CST) were fluctuated as shown in Fig. 2. The magnitude of fluctuation in treated water quality by NFS was smaller than that by CST. As the sludge acclimated, the treated water quality showed the stable removal efficiency. The average BOD, COD and SS effluent concentration by NFS treating wastewater containing 3000 mg/l NaCl were 5.5, 26. 9 and 6.8 mg/l, respectively. Compared to the effluent quality produced by CST, the effluent quality by NFS was more clear and more stable. The water quality by NFS treating wastewater containing 5000 to 15000 mg/l NaCl showed similar quality as shown in Fig. 3. It leads to facts that NFS was not significantly affected by salt concentration and F/M ratio. However, the removal efficiency of CST varied depending on salt concentration. The removal efficiency of CST decreased as the salt concentration and F/M ratio increased.

At the concentration of 15,000 mg/l of salt, foaming on the aeration tank was observed. When foaming appear on the aeration tank surface, the conventional settling tank could not be properly operated. But NFS could be possibly operated. The separation of sludge and liquid by nonwoven fabric produced the better water quality regardless of various F/M ratio and salt concentration. And the formation of deposit layer, consisting of particles of varying sizes, on the nonwoven fabric surface worked as filter and improved effluent quality. Consequently, NFS could be applied for saline wastewater treatment to achieve compliance with current effluent regulation.

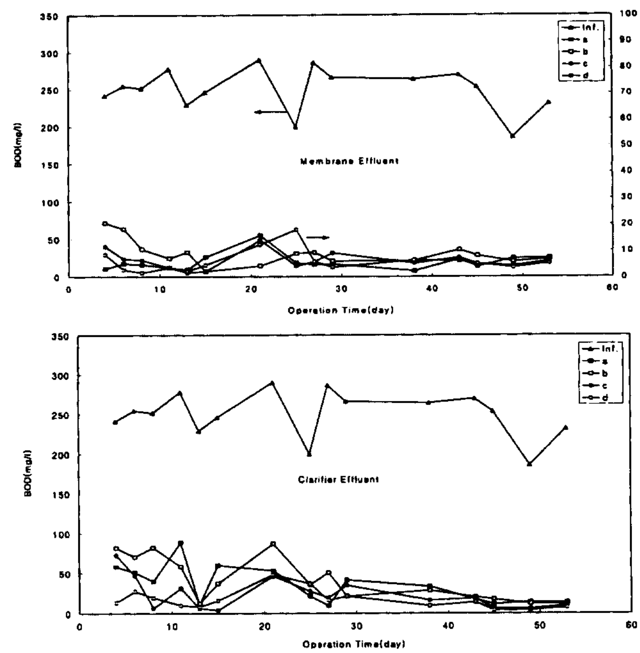

Fig. 2. BOD concentration of membrane and clarifier effluent with operation time (NaCl 3000 mg/l).

Flux and Suction Pressure

The relationship between flux and suction pressure is illustrated in Fig. 4. One suction pump with four channels was used in this experiment so that the equal flux of the four reactors obtained. The higher suction pressure was maintained in the lower flux.

In reactor B and D, average flux of 0.222, 0.225m^3/m^2/day and suction pressure maintained steady operation. However, suction pressure of A reactor increased after

Table 2. Operation condition of activated sludge reactor

Reactor / Items (Avg.)	NaCl 3000 mg/l				NaCl 5000, 10000, 15000 mg/l			
	a	b	c	d	A	b	c	d
F/M*	0.42	0.36	0.26	0.22	0.33	0.25	0.20	0.15
HRT (hr)	7.0	6.5	7.0	6.5	6.2	6.6	6.6	6.1
SRT (day)	10	15	20	30	10	15	20	30
MLSS (mg/l)*	2020	2574	3315	4207	3170	3950	5010	6940

*Total average.

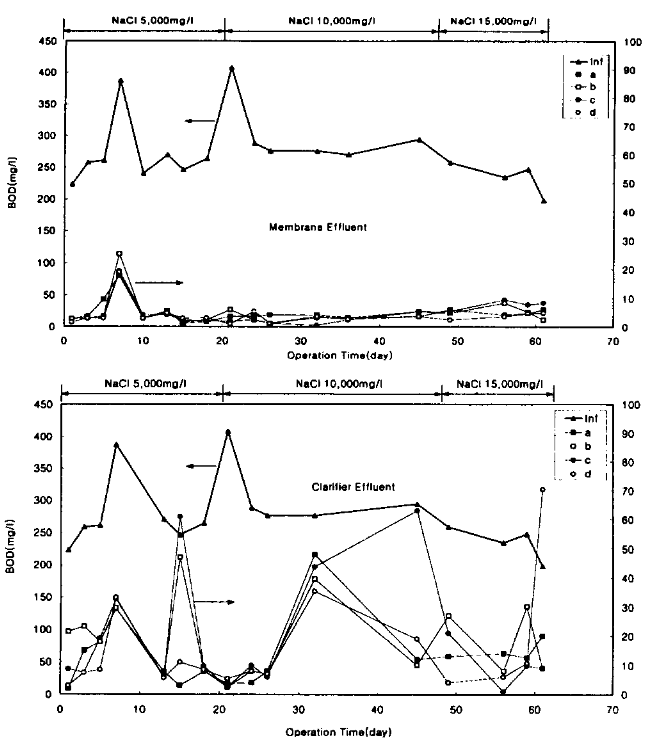

Fig. 3. BOD concentration of membrane and clarifier effluent with operation time (NaCl 5000, 10000, 15000 mg/l).

6 days operation. From then on, suction pressure of reactor A increased rapidly to suction pressure of 51 cmHg and the flux decreased to 0.146 m^3/m^2/day after 50 days operation. The suction pressure of reactor C increased after 23 days operation reached 68 cmHg and showed the flux of 0.11 m^3/m^2/day after 50 days operation. The settling properties of the biological suspension determined by sludge volume index (SVI) shows that A reactor show relatively higher value and C reactor shows lower value than the B and D. The stable flux in reactor B and D was maintained at SVI value of around 110~130. The high SVI of C reactor could be caused by bulking flocs and low SVI of A reactor caused by pin flocs in the system. These imply that the settling properties which is one of biological floc characteristics affects flux. The surface of four nonwoven fabric used for A, B, C and D reactors were pictured and are shown in Fig. 6. As shown in Fig. 6, the microorganisms layer formed on the surface A and C more than B and D. From the above observations, the characteristics of deposit layer on the nonwoven fabric surface affect the flux.

In order to investigate the effects of higher salt concentration, new nonwoven fabric modules were applied. The initial suction pressure and flux was maintained until about 45 days operation as shown in Fig. 5. After increasing the salt concentration to 15,000 mg/l, the flux decreased. The foaming and pin floc caused by cell disruption were observed and might be caused the flux decreasing. The average floc size at NaCl 5000 mg/l were 248.7, 198.1, 158.4 and 184.9 μm. As the salt concentration increased to 10,000 mg/l, the average floc size dereased to 154.9, 164.4, 137. 7 and 175.6 μm. The decreased floc size is another cause of flux reduction. However, as shown in the previous 3000 mg/l concentration case, clogging proceeded at low MLSS and NaCl concentration by applying unacclimated sludge. It leads to the fact that sludge acclimation and deposit layer characteristics are important to obtain stable flux. Once clogging occurs on the nonwoven fabric surface, it increases the pressure difference and suction pressure, in turn, promotes clogging, which ultimately

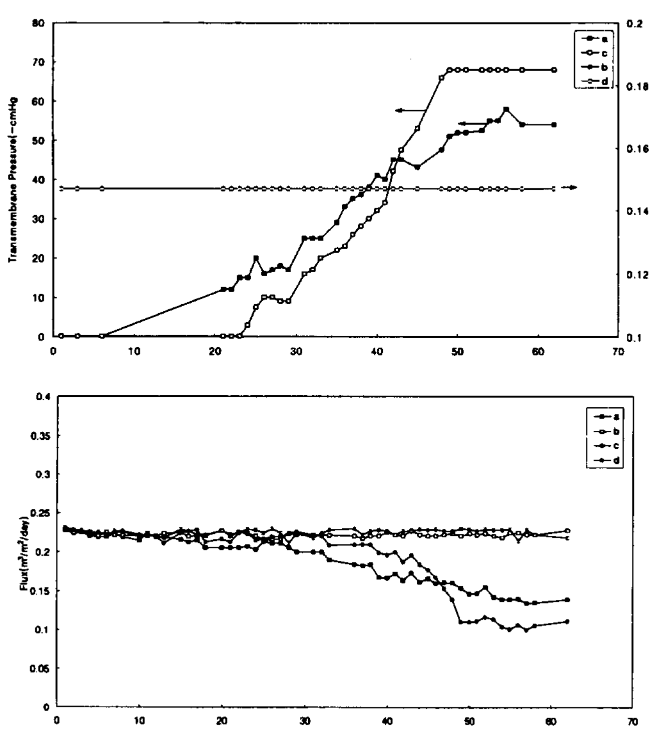

Fig. 4. Variation of MLSS, Pressure, and Permeate Flux at NaCl 3000 mg/l.

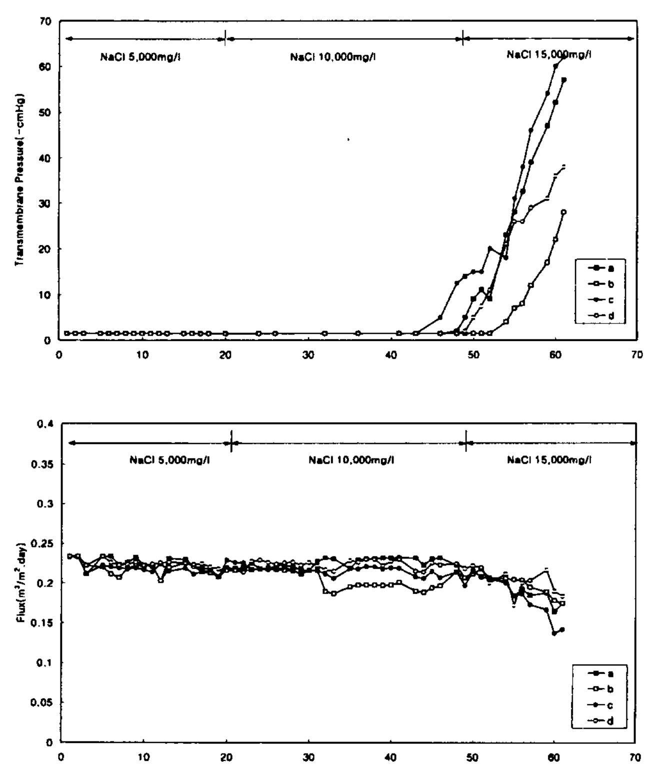

Fig. 5. Variation of MLSS, Pressure, and Permeate Flux at NaCl 5000, 10000, 15000 mg/l).

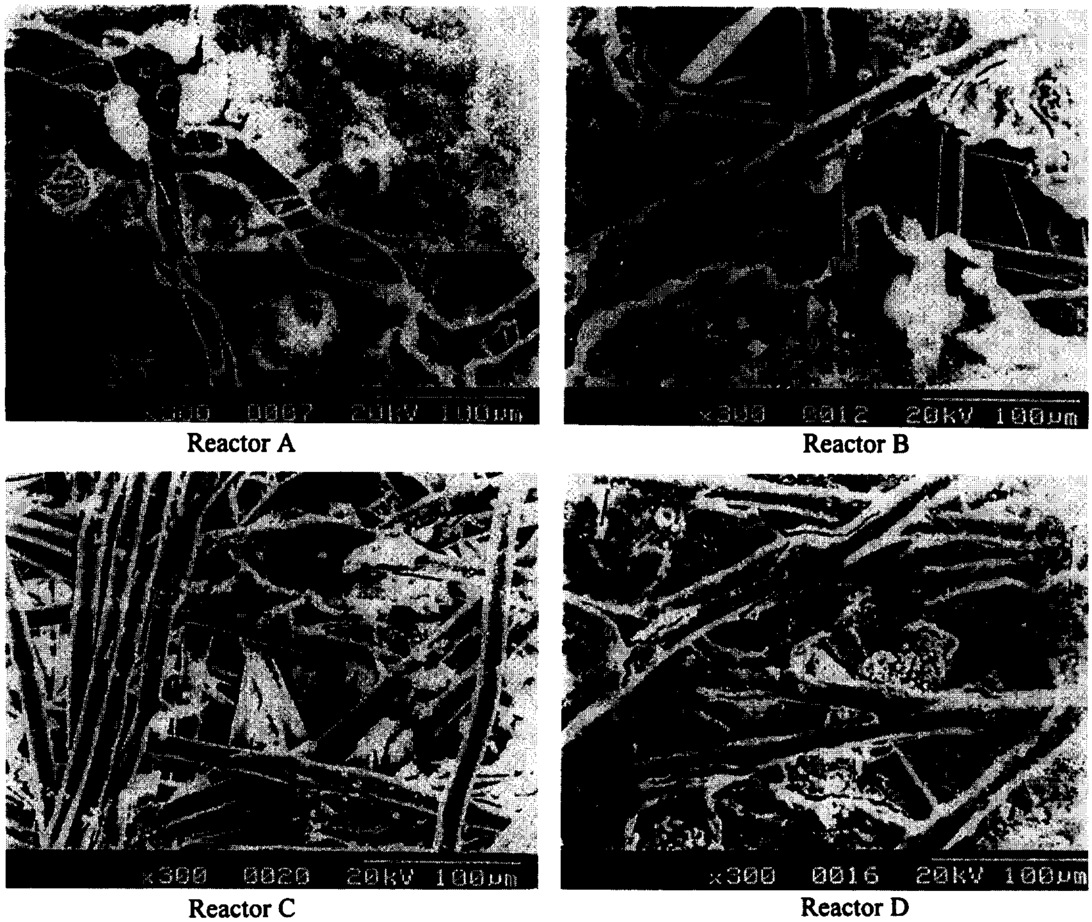

Fig. 6. SEM photography of the fouled surface of nonwoven fabric after filtration (NaCl 3,000 mg/l).

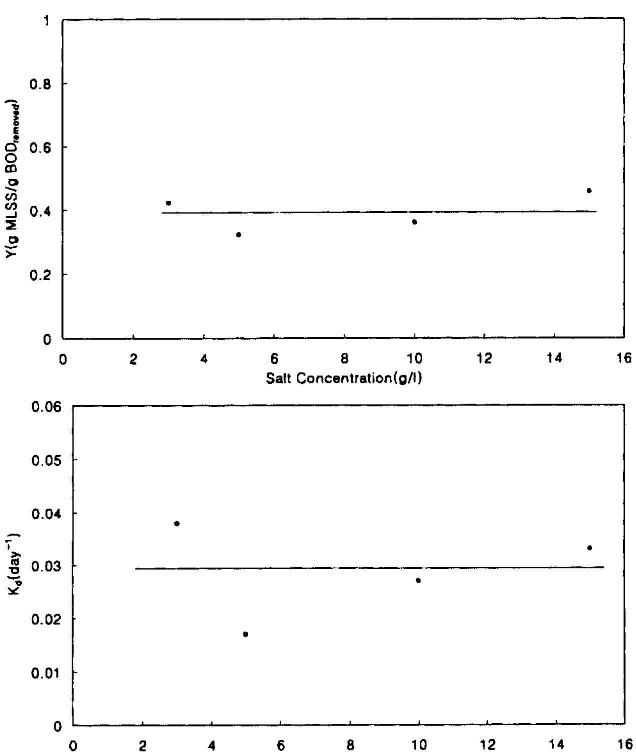

Fig. 7. Biomass yield coefficient (Y) and the decay rate coefficient (K_d).

results in an unrecoverable dead end of operation.

Determination of Kinetic Coefficients

The biological kinetic coefficients of Y and K_d were determined by using following equation.

$$\frac{1}{SRT} = Y\frac{S_0 - S_e}{X \cdot \theta} - K_d$$

Where

Y : is the biomass yield coefficient, g MLSS/g $BOD_{removed}$

K_d : is the decay rate coefficient, (day^{-1})

S_o and S_e : are influent and effluent BOD concentration (mg/l), respectively

θ : is hydraulic resident time (day)

SRT : is sludge resident time (day)

X : is mixed liquor suspended solid (MLSS)

Experimental data of salt concentration of 3,000, 5,000, 10000 and 15,000 mg/l were plotted as (S_o-S_e)/X HRT versus 1/SRT. The variation of the biomass yield coefficient (Y) and the decay rate coefficient (K_d) with salt concentration is presented in Fig. 7.

The yield coefficient and endogenous coefficient varied between 0.322 and 0.458. Since X in equation measured by MLSS, X are the sum of active and inert biomass. If the inert biomass could be subtracted from the MLSS, the values of Y and K_d would increase. In biological wastewater treatment, MLSS are used to represent the biomass in the reactor customary. The values of Y and K_d obtained in this study are smaller than the value determined from salt free wastewater treatment. The values of Y were reported in the range of 0.47-0.56 g MLSS/ g $BOD_{removed}$ in salt free wastewater treatment [6]. And increasing salt concentration did not significant change the biological kinetic coefficients of Y and K_d. Similar results were reported by other researchers [3]. According to their research, the yield coefficient values varied between 0.4 and 0.38 g MLSS/g $COD_{removed}$ and increasing salinity of the feed wastewater did not affected significant change of Y and K_d values in biological treatment of saline wastewater by fed-batch operation.

CONCLUSION

Direct solid liquid separation of activated sludge using nonwoven fabric for saline wastewater treatment was investigated. The better treated water quality by nonwoven fabric separation of liquid and solid was produced. And salt concentration and F/M ratio did not much affected the effluent quality by using nonwoven fabric separation. To obtain stable flux, sludge acclimation and control of deposit layer should be considered. The biomass yield and the decay rate coefficient determined from saline wastewater were smaller than the value determined from salt free wastewater treatment. But increasing salt concentration did not significant change the biological kinetic coefficients of biomass yield and decay.

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