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SBR 활성슬러지 공정을 이용한 질소 및 인의 동시제거 연구

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SIMULTANEOUS REMOVAL OF NITROGEN AND PHOSPHORUS USING THE SEQUENCING BATCH REACTORS PROCESS

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Abstract

이 연구에서는 SBR 공법을 이용하여 질소, 인 동시제거기장에 대해 관찰하고, BOD-SS loading변화에 따른 오염물질 제거효율에 대해 검토하였다.

BOD, TN 및 TP 제거율은 20℃에서 95%, 74% and 81%로 나타났으며, Phosphorus luxury uptake는 호기성이 시작된후 1, 2시간후에 각각 67% 및 84%를 흡수 하는 것으로 관찰 되었으며, 호기성 말기의 농도는 0.9mg/ℓ 이하를 유지 하였다. 80% 및 85% 이상의 안정된 질소 제거효율을 유지하기 위해서는 BOD - SS loading 값을 0.15 및 0.08 kg-BOD/kg-SS.day 이하로 유지 하여야 하는 것 으로 나타났다. 또한 1회 방류수량의 변화에 따른 관찰에서, 반응조 유효용량의 30%, 40% 및 50%를, 유출할 경우 TN은 각각 78%, 72% 및 58%를 TP는 각각 81%, 77% 및 66%의 제거효율을 보였다.

I. INTRODUCTION

The volume of wastewater in Korea has been increasing at a rate of 7% per year in sewage and 20% per year in industrial wastewater. Increased understanding of the problems associated with nutrients, such as nitrogen and phosphorus which cause eutrophication, necessiate their removal. A SBR is a fill - and - draw activated sludge treatment system. As such, SBRs are capable of handling all wastewaters commonly treated by conventional activated sludge process plants. A SBR has shown many advantages including reduced operating costs, improved nitrogen and phosphorus removal and less bulking[1)2)].

This laboratory experiment was operated to recomand optimal operating condition for small scale domestic and industrial wastewater plants to remove of organic matter and nutrients in a single reactor.

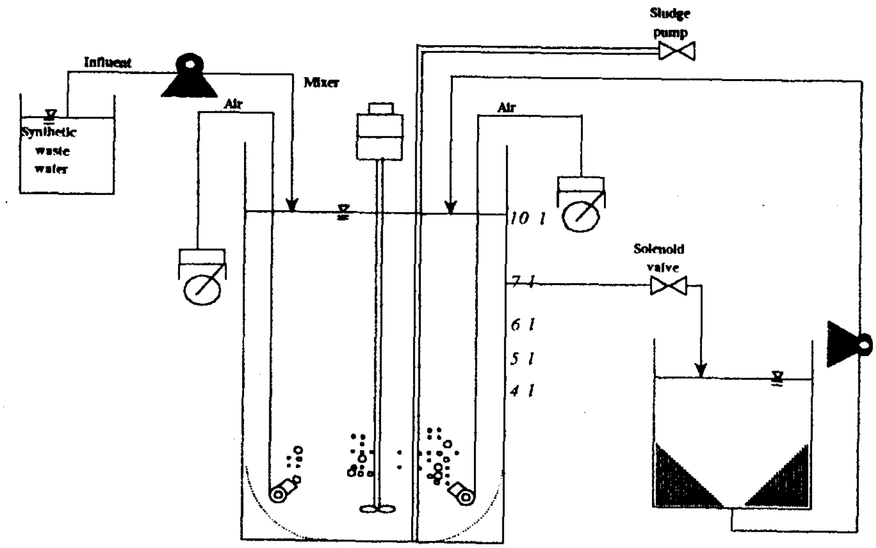

Fig. 1. Schematic diagram of the laboratory apparatus for SBR

II. MATERIALS AND METHODS

1. Experimental Set up

Schematic diagram of the laboratory apparatus for SBR is shown in Figure 1. Volume of SBR is 10 liters and decant volume was various as 3, 4, 5 and 6 liters that are 30%, 40%, 50% and 60% of the effective size. An electric solenoid valve was attached to the reactor to draw the supernatant. Operating conditions were regulated to cope with the variation of influent volume by adjusting the operating time using a timer, and effluent volume.

Submerged mixer was opera'ted to make homogenized activated sludge during the anaerobic condition. The aeration apparatus consisted of two 20 inches long, 0.35 inch diameter glass tubes ending in two diffuser stones.

2. Operating Conditions

The reactor was operated at 20℃ on 8, 12 and 24 hour periodic cycle. The reactor had a cycle consisting of a 30 minute FILL, 340 minute REACT(90 minute anaerobic, 250 minute aerobic), 50 minute SETTLE, 50 minute DRAW and 10 minute IDLE. Submerged mixer was operated during Fill and React period.

3. The Composition of Synthetic Wastewater

The synthetic wastewater, consisting of 1,998mg/ℓ of NaCl, 139mg/ℓ of $MgSO_4 \cdot 7H_2O$, 93mg/ℓ of KCl, 5,550mg/ℓ of $NaHCO_3$, 123mg/ℓ of $CaCl_2 \cdot 2H_2O$, 559mg/ℓ of $Na_2HPO_4 \cdot 12H_2O$, 3,996mg/ℓ of Peptone, 2,664mg/ℓ of Meat extract dilute to 20ℓ distilled water, feed with peristaltic pump automatically.

III. RESULT AND DISCUSSION

1. Evaluation of treatment performance

Table 1 shows average concentration of influent and effluent, and removal efficiency. This SBR system achieved 94.7% of BOD, 90.0% of SS, 74.2% of TN and 81.3% of TP. Applying anaerobic process, especially, nitrogen and phosphorus removal efficiency was much greater than that of conventional activated sludge processes. This results indicate that electrical

Table 1. Influent, Effluent Quality and Removal Efficiencies

terms	BOD(mg/ℓ)	SS(mg/ℓ)	TN(mg/ℓ)	TP(mg/ℓ)	pH
influent	189	125	45	4.8	–
effluent	9.8	12.5	11.6	0.9	7.5
removal eff.(%)	94.7	90.0	74.2	81.3	–

cost could be lowered with the intermittent aeration process.

2. The effects on removal efficiency by operating cycles and decant volume

The removal efficiency of pollutant under variance operating cycles a day is shown in Table 2. BOD is not influenced by change of cycle, it was stable quality as nearly 95%. SS was getting little worse at 2-cycle/day because of destruction of sludge floc by longer aeration and its removal efficiency was below 80% when decant volume was more than 5ℓ.

Ammonium nitrogen removal efficiency was around 92% not depend on influent quantity but in the case of total phosphorus, removal efficiency was reduced by the prolongation of a operating time a cycle. It was due to increasing SS by eruption and floc destruction with endogenous reproduction of microorganisms[3].

The effect of variation of decant volume on removal efficiency at 3-cycle/day is shown in Table 2. Effluent quality was getting better in accordance with lower flowrate. In case of 50% of valid capacity was decanted, SS removal efficiency was around 81%, some SS existed in the effluent, but BOD removal efficiency was more than 90%. To have stable effluent quality and to achieve more than 70% of nitrogen and phosphorus, less than 50% of valid capacity of effluent should be decanted.

3. BOD removal

BOD removal efficiency was always nearly 95% in spite of different operating conditions. This process, therefore, were very efficiency with no influenced by loading of organic matter if there is no operational problems such as machine trouble and power stop-page[1)2)3)]. 70% of BOD was removed, 60% in the first half 10% in the latter half, during anaerobic condition and 25% of the remainder was removed during aerobic condition for 4 cycle/day.

4. Removal characteristics of nitrogen

Denitrification was completed after 1.5 hrs during anaerobic condition at 20℃[3)5)6)]. TN was removed relatively well, more than 70%, when effluent volume was less than 4ℓ/cycle(40% of effective tank volume) in the system. Initially the removal efficiencies of nitrogen and SS were good, but some sludge was

Table 2. The Effects on Removal rate by Operating cycle and decant volume (unit : %)

cycle/d	decant vol.(%)	BOD	SS	TN	NH_4N	PO_4-P	TP
2−cycle/d	30	92.8	84.9	67.3	91.4	72.1	87.8
3−cycle/d	30	94.8	90.0	77.5	91.8	81.3	90.2
	40	95.1	89.2	75.5	91.2	76.2	90.0
	50	92.3	81.8	57.8	88.3	69.8	89.1
	60	88.6	78.2	50.7	84.1	61.3	84.8
4−cycle/d	30	95.1	81.4	61.2	92.6	69.4	79.1

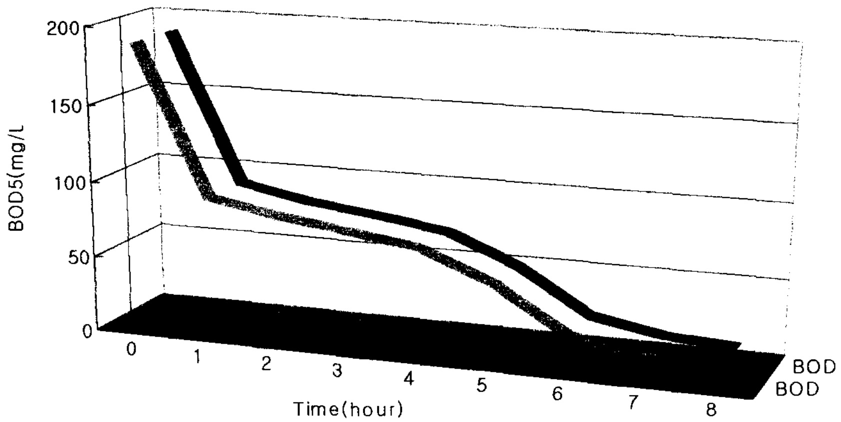

Fig. 2. Variations of BOD Concentration by Operating time

showen in effluent because of greater velocity and decant volume. Nitrogen removal rate was around 70% with heavy fluctuations.

Aerobic conditions were kept 90 minute only, but nitrogen concentration was improved in effluent. Ammonium nitrogen was removed more than 91% and TN removal efficiency was 71%, when 4 ℓ is drawed. Figure 3 shows a variations of nitrogen concentration for 8hrs/cycle. Ammonium nitrogen was constant under anaerobic condition, on the other hand, it was declined almost to zero at the end of aerobic period with nitrification.

The denitrifying organisms consume a portion of the available in fluent under oxygen limited condition (<0.1gm/l)

Nitrate nitrogen was almost denitrified in early anaerobic condition and was removed over 90% in 1 hour and was finished in 1.5 hour. The work in this paper concentrates on the nitrification/denitrification phase for which a typical operating cycle is shown in Table 3.

Table 3. The SBR cycle used to Achieve Nitrification/Denitrification

Period	Duration (min.)	Sequence (min.)	Mixing	Aeration	Description
Fill	30	1.00	off	off	Anoxic/Anaerobic
React					
Aerobic	90		on	on	Oxic period
Anaerobic	250		on	off	Anaerobic period
Settle	50		off	off	Quiescent conditions
Draw	50		off	off	Effluent decanting
Idle	10		off	off	Anaerobic period

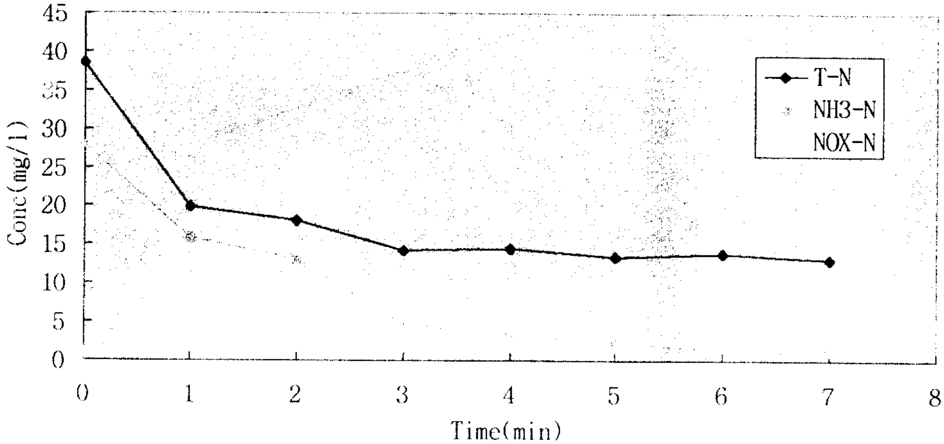

Fig. 3. Variation of T-N, NH_3-N and NO_X-N Concentration by time

5. Phosphorus removal

Phosphorus concentration in the effluent was as low as 0.9mg/ℓ, relatively good, and average removal efficiency of TP was around 80%. Heavy fluctuations of removal efficiency was influenced by decant volume and F/M ratio, and BOD/TP ratio was constant in this study. It is terms advantageous to reveal phosphorus luxury uptake with longer SRT by keeping high MLSS concentration. In the observation of TP/PO_4-P ratio of treated water, 90% of TP in treated water is existed as PO_4-P and others were released from SS. It shows a phosphorus release for 2 hours and luxary uptake for 4 hours. In the observation of phosphorus release from sludge, phosphorus concentration is increased rapidly as 18.5mg/ℓ in 1 hour, 21.1mg/ℓ in 1.5 hour and 23.3mg/ℓ in 2 hours after aeration off. Phosphorus was released from the biomass prohibited if oxygen or nitrate were present, upon subjecting the sludge to anaerobic conditions [7,9,10,11,12]. Rensink[13] conducted study where 50g/m3 of nitrate-nitrogen was added to the feed and noted the decrease in phosphorus removal efficiency over a period of six weeks.

The phosphorus organisms expend energy to transport and process the available fatty acids[8,10].And phosphorus luxury uptake, 67%, 84% and 96% removal efficiency in 1, 2 and 3hours after aeration on, were occurred. Fill period was relatively short, 30min., to reduce oxidized nitrogen as early as possible in this study.

6. Treatment efficiency by variations of BOD-SS loading

BOD-SS loading, estimated by aeration time rate, decant volume, BOD concentration and MLSS, is observed to define relationship with removal efficiency is shown as follows.

BOD - SS loading(kg-BOD/kg-SS.day)

$$= \frac{1}{e} \cdot \frac{n}{m} \cdot \frac{C_S}{C_A}$$

Where, e : aeration time rate

n : number of cycles a day

m : dillution rate of influent

C_S : BOD_{evg}(mg/l)

C_A : MLSS concentration

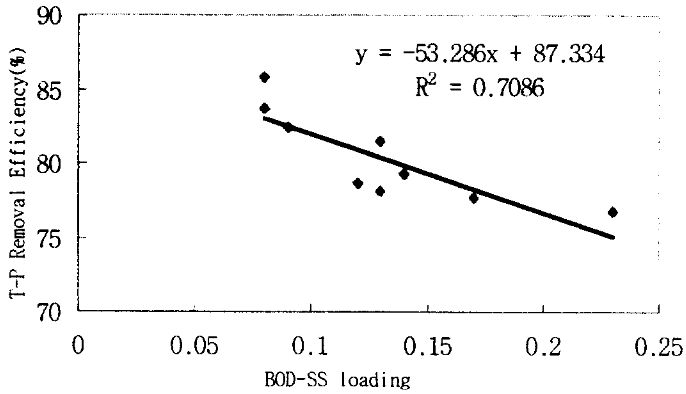

Fig. 4. Variations of TP Removal Efficiency by BOD-SS loading

Figure 4. shows variations of TP removal efficiency by BOD - SS loading. It was shown that these removal efficiencies were inverse porportion to BOD - SS loading clearly. 75% of TP were removed with less than 0.16 of BOD - SS loading. To have stable effluent quality and to achieve more than 80% of phosphorus, not more than 0.13 of BOD - SS loading should be kept.

7. Aspect of microcyte

The propagation of filamentous organisms, cause poor sludge settling and bulking, were not appeared in this SBR systems. During this period a restricted range of protozoa and metazoa were observed and their populations fluctuated considerably. During the start - up period, the reactor demonstrated a healthy protozoan population of free - swimming, crawling and attached ciliate species that is agreed with other research report[4].

IV. CONCLUSION

The results from this bench-scale test using the SBR activated sludge process were follows:

1. Influent(effluent) quality were 189mg/l(9.8mg/l) BOD, 125mg/l(12.5mg/l) SS, 45mg/l(11.6mg/l) TN and 4.8mg/l(0.9mg/l) TP. The removal efficiencies were 95%, 74% and 81%, respectively.
2. Phosphorus luxury uptake that are 67%, 84% and 96% were removed in 1, 2 and 3hours during aerobic condition were occurred, and phosphorus was decreased as low as 0.9mg/l by *Acinetobacter* and its content rate in the sludge was as much as 5.3wt%.
3. In the observation of removal rate by BOD-SS loading, It was known that to have stable effluent quality and to achieve more than 80% and 85% of nitrogen, less than 0.08 and 0.15 of BOD - SS loading should be kept.
4. During the start - up period, the reactor demonstrated a healthy protozoan population of free - swimming, crawling and attached ciliate species.

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