ENVIRONMENTAL SCIENCES Vol. 2, No. 2, 115~122
Bulletin of the Korean Environmental Sciences Society

Development of Optimal Treatment Process Train of Leachate from Industrial Waste Disposal Site

Gee Baek Han, Kwang Soo Choi*, Man Gi Min, Young Hwan Han, Jung Hoon Im*, Hae Goon Lee*, Myung Won Choi*, Chang Won Kim* and Dong Keun Park*****

Department of Environmental Engineering, Sorabol College, Kyongju, 780-250, Korea
**Department of Environmental Engineering, Pusan National University, Pusan, 609-735, Korea*
***Department of Biology, Dongguk University, Kyongju, 780-714, Korea*
****Department of Environmental Engineering, Dongseo University, Pusan, 617-716, Korea*

(Manuscript received on 8 November 1998)

Train of chemical and biological processes was investigated to treat leachate from industrial waste landfill. Organics and nitrogen concentrations of landfill leachate studied in this research were high and their BOD/COD ratio was 0.3. Biological process should be combined with chemical process for optimum treatment of leachate. PAC(Polyaluminium chloride) was the best coagulant among three chemicals tested, and the optimum condition of PAC coagulation was pH 6 and 1,250 mg/L of dosage. When SBR was operated for simultaneous removal of organics and nitrogen, removal efficiency of COD and T-N reached over 82%, 71%, respectively and time distribution of 2/4/2/1 was most effective for one cycle of anoxic/aerobic/anoxic/aerobic.

Key words : Leachate, Process train, Sequencing Batch Reactor, Cycle time

1. INTRODUCTION

Quantitative and qualitative characteristics of leachate are dependent on the environmental conditions of landfill sites and therefore its prediction and treatment are quite difficult(Chian, 1976; Keenan, 1984; Pohland, 1988; Levine, 1989). Furthermore leachate characteristics change dramatically by landfill age and the formal type of treatment processes can not be applied to the landfill treatment plant. Hence it should be considered that the combination of various treatment processes including physicochemical and biological treatment processes for optimum treatment of leachate(Lu, 1985; Christensen, 1992).

BOD/COD ratio can be used as a evaluation parameter for biological treatability as well as respiration rate. It is reported that when it is lower than 0.4~0.5, biological treatment efficiency decreases dramatically(Forgie, 1988). In general, since leachate includes high concentration of nonbiodegradable matter and ammonium nitrogen, a reasonable combination of several treatment processes is recommended for simultaneous removal of pollutants.

In this research, characteristics of leachate from industrial waste landfill was surveyed and optimum combination of its treatment processes in which biological process was coupled with the pre-chemical treatment process for simultaneous removal of nonbiodegradable matter, organic and nitrogen compounds.

2. Materials and methods

2.1. Leachate characteristics survey

Pollutant concentration from the landfill site reaches its maximum value under 2~3 years of landfill age, and it decreases later on(Christensen, 1992). COD concentration of young leachate usually is high and BOD/COD ratio is 0.4~0.8 and anaerobic biological treatment is effective. On the other hand, when BOD/COD ratio is 0.1~0.4 and NH_4^+-N concentration is high, physico-chemical treatment and aerobic biological treatment are effective(Forgie, 1988). Hence in order to select and/or combine treatment processes for landfill leachate reasonably, raw leachate from industrial waste landfill was tested within 15 items for 1 year.

2.2. Evaluation of chemical pretreatment process

COD/BOD ratio of leachate studied in this research was 0.3, and therefore biological treatment process is not sufficient and hence pre-chemical treatment process is required(Forgie, 1988). So in order to enhance the efficiency of biological treatment process, pre-chemical treatment using coagulant was introduced. PAC, $FeCl_3$ and LAS(Liquid Aluminium Sulfate) were tested as coagulant. COD and SS removal efficiency were tested after 3 minutes of rapid mixing and 20 minutes of slow mixing followed by 30 minutes of stagnation period. Using each coagulant, 6 beaker was fed by 1,000 mL of leachate and 1,000 mL of coagulant and then optimum pH was selected through jar-test (pH 4~9). With each optimum pH, optimum coagulant dosage was selected under various dosage; 500~1,750 mgPAC/L, 500~3,000 mg$FeCl_3$/L and 500~3,000 mgLAS/L. And leachate treated under optimum pH and dosage was fed to the biological basin.

2.3. Development of biological treatment process

SBR(Sequencing Batch Reactor) was operated with leachate pretreated in the chemical process to estimate the biological treatability. Two sets of experimental devices are in Fig. 1 and effective volume of SBR was manipulated between 6 L for reaction mode and 3 L for decantation mode. Peristaltic pumps and mixers were automatically controlled by using a timer as shown in Table 1. In order to control SRT, 600 mℓ/day and 300 mℓ/day of mixed liquor was removed from each SBR just before settling mode. Analysis of the samples followed Standard Method(APHA, 1989) and NH_4^+-N, NO_3^--N and NO_2^--N were analysed by Ion chromatography(model No : Waters 431)

3. Results and discussion

3.1. Characteristics of leachate

One year of analysis data for leachate from industrial waste landfill are shown in Table 2. Average BOD_5 and CODcr concentration was 4,850 mg/L and 16,170 mg/L, respectively and BOD/COD ratio was 0.3. TKN, NH_4^+-N concentration was 842 mg/L, 722 mg/L, respectively, and NH_4^+-N/TKN ratio was 0.86 and it means that NH_4^+-N was a dominant type of nitrogen. Even if it was leachate from industrial waste landfill, phosphate and heavy metals concentrations were similar with that from the municipal waste landfill.

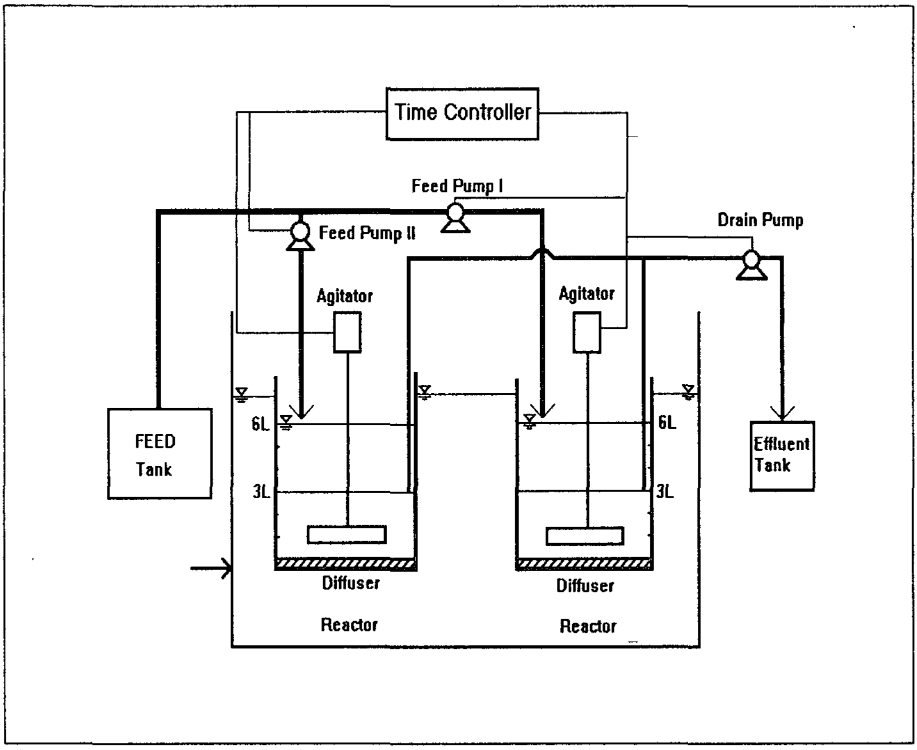

Fig. 1. Schematic diagram of lab-scale SBR.

Table 1. Operational strategies for SBR systems in one cycle.

RUN No.	SRT	Time(hrs)							Cycle time	Cycle frequency
		Fill	1st Anoxic	1st Aerobic	2nd Anoxic	2nd Aerobic	Settle	Draw		
RUN-1	10	0.25	3	3	3	1	1.5	0.25	12hrs /cycle	2cycles /day
RUN-2	20	0.25	2	5	2	1	1.5	0.25		

Table 2. Characteristics of industrial waste landfill leachate.

Constituent	Range(mg/L)	Average(mg/L)	Constituent	Range(mg/L)	Average(mg/L)
pH	7.4 ~ 8.5	7.8	T-P	33.8 ~ 52.4	45.2
TSS	847 ~ 1,126	945	As	0.015 ~ 0.229	0.084
VSS	654 ~ 976	733	Cd	ND ~ 0.057	0.025
COD	14,276 ~ 18,475	16,168	Cr	0.156 ~ 0.763	0.432
BOD	4,075 ~ 6,657	4,849	Cu	0.404 ~ 4.637	2.835
TKN	635 ~ 1,047	842	Hg	ND ~ 0.027	0.005
NH_4^+-N	557 ~ 934	722	Pb	0.341 ~ 3.975	2.145
NO_2^--N	-	-	Zn	3.120 ~ 11.700	5.246
NO_3^--N	-	-			

3.2. Coagulation characteristics of leachate

3.2.1. Optimum pH decision and SS and COD removal

A. Ferric chloride($FeCl_3$)

In order to select optimum pH, ferric chloride dosage was fixed and pH was changed from 4 to 9 by unit. As shown in Fig. 2, SS and COD removal efficiency was maximum at pH 5, 23.7%, 18.3%, respectively. Based on this result, optimum ferric chloride dosage was selected. When ferric chloride dosage was changed from 500 to 3,000 mg/L, SS and COD removal efficiency was 27.2%, 25.9%, respectively at 2,000 mg$FeCl_3$/L(Fig. 3). And even though dosage was higher, they did not increased. Therefore 2,000 mg/L of ferric chloride was decided as an optimum dosage.

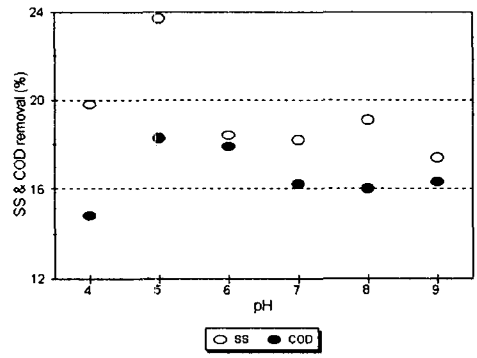

Fig. 2. Profile of SS and COD removal efficiency at varying pHs($FeCl_3$).

B. Aluminium sulfate(LAS)

Test of SS and COD removal efficiency according to the pH variation with constant LAS concentration showed that pH 7 was the optimum value for LAS coagulation in which SS and COD removal efficiency was 25.7%, 20.1%, respectively. pH 7 was also recommended as an optimum condition for LAS coagulation by other researchers(AWWA, 1990) .and it meant that no pH conditioning was required. Based on this result, the optimum LAS dosage was also selected by the same way with ferric chloride. Similarly with chloride test, when LAS dosage was 2,000 mg/L, SS and COD removal efficiency was highest, 15~29%, 16~27%, respectively(Fig. 5).

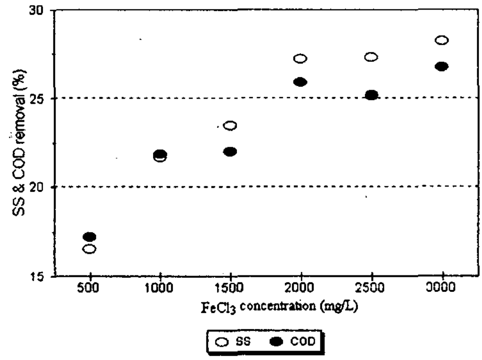

Fig. 3. Profile of SS and COD removal efficiency at varying concentrations of $FeCl_3$.

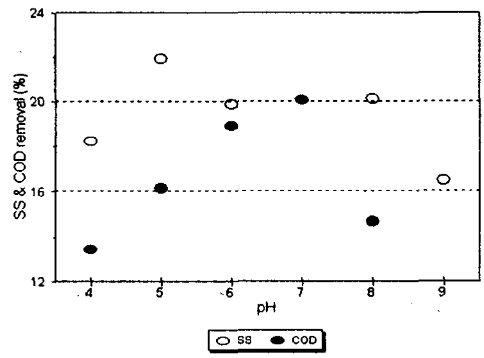

Fig. 4. Profile of SS and COD removal efficiency at varying pHs(LAS).

C. Polyaluminium chloride(PAC)

Fig. 6 shows the effect of pH on the coagulation of leachate with PAC, and SS and COD removal efficiency was 35.1%, 30.9%, respectively at pH 6. These values were slightly higher than that of both ferric chloride and LAS in the range of pH 4~9. When PAC dosage increased from 500 to 1,750 mg/L under pH 6, SS and COD removal efficiency also increased. Both efficiencies increased faster up to 1,250 mgPAC/L, and later its increasing rate was slower. Hence it was concluded that the optimum PAC dosage was 1,250 mg/L, and SS, COD removal efficiency was 43.1%, 36.7%, respectively with this dosage.

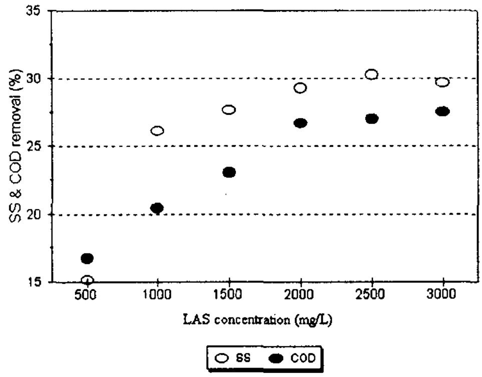

Fig. 5. Profile of SS and COD removal efficiency at varying concentrations of LAS.

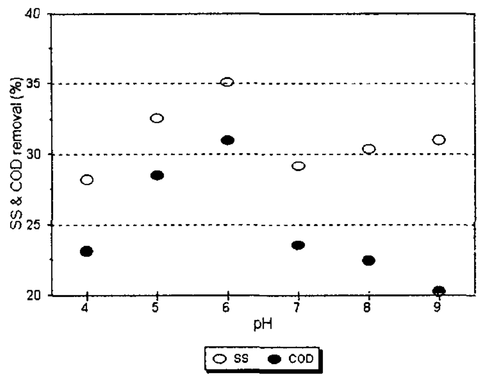

Fig. 6. Profile of SS and COD removal efficiency at varying pHs(PAC).

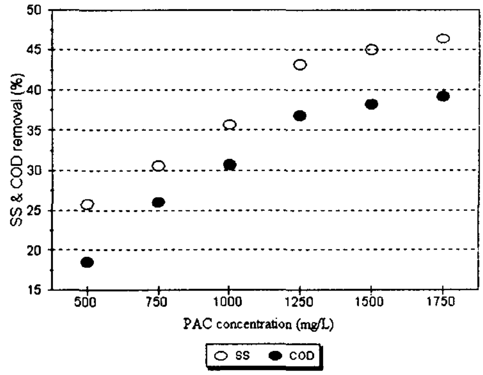

Fig. 7. Profile of SS and COD removal efficiency at varying concentrations of PAC.

3.3. Biological leachate treatment with SBR

3.3.1. Operation of SBR

In this research PAC was the most proper coagulant for leachate pre-treatment and its optimum dosage was 1,250 mg/L. Biological treatment of the effluent from pre-chemical coagulation basin using PAC was investigated with 2 sets of bench-scale SBR. Return sludge from a sewage treatment plant was acclimated to SBRs for 1 month. Through 2 months of operating, organics and nitrogen removal was observed. As soon as one cycle was started, 3 liters of raw leachate was injected, and the reactor was operated under 1st anoxic-1st aerobic-2nd anoxic-2nd aerobic modes in series. Initial average CODcr, TKN and NH_4^+-N concentration in the reactor was 6,120 mg/L, 390 mg/L and 320 mg/L, respectively and average MLSS concentration was 4,430 mg/L and 6,520 mg/L in RUN-1 and RUN-2.

3.3.2. Removal of COD

As shown in Fig. 8, COD removal efficiency was 82 % and 88 % in RUN-1 and RUN-2, and when SRT was increased, removal efficiency also increased. In each run effluent COD concentration was 750 ~1,120 mg/L and these were suspected as nonbiodegradable COD(Ekama, 1986; Bortone, 1992).

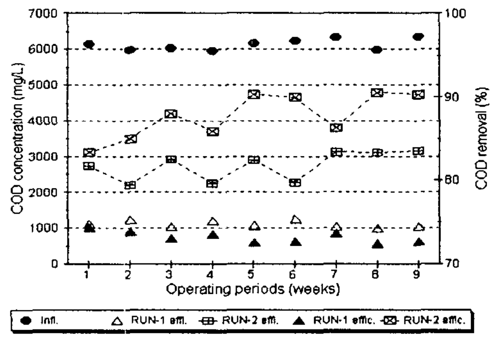

Fig. 8. Temporal profile of COD removal efficiency in a cycle.

3.3.3. Removal of nitrogen

During the 9 weeks of SBR operating period, average nitrogen removal efficiency was 71% in RUN-1(SRT 10 days) and 81% in RUN-2(SRT 20 days) as shown in Fig. 9. The longer aerobic period and SRT, the higher nitrogen removal efficiency, and then it was concluded that the proper time distribution of aerobic mode must be an important operating condition for treatment of leachate containing high concentration of nitrogen and nonbiodegradable matters(Han, 1998).

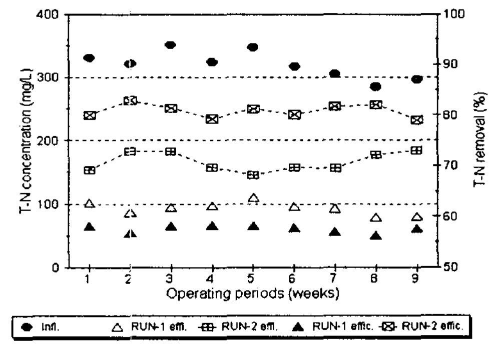

Fig. 9. Temporal profile of nitrogen removal efficiency in a cycle.

3.3.4. Nitrification and denitrification

Fig. 10. shows the specific nitrification rate (SNR) under various aerobic time distribution in one cycle. When aerobic mode was 3 hours(RUN-1) or 5 hours(RUN-2), SNR was 5.87 mgN/gMLSS · hr, 4.63mgN/gMLSS · hr, respectively, and RUN-2 showed lower SNR but higher T-N removal efficiency than RUN-1. Therefore, the longer aerobic period and SRT, the higher nitrification. In case of RUN-2, NOx-N concentration increased proportionally to aerobic period, but its increasing rate decreased after 4 hours of aerobic period, so it was concluded that 4 hours was the optimum aerobic period for nitrification of leachate studied in this research.

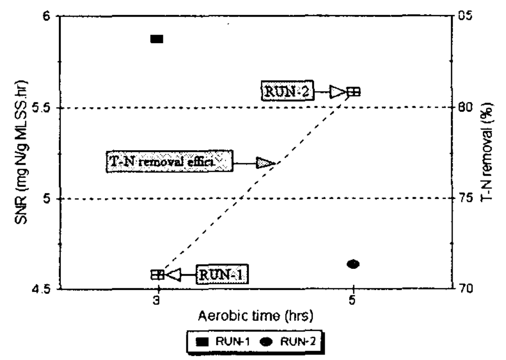

Fig. 10. Effect of aerobic time on specific nitrification rate(SNR) in a cycle.

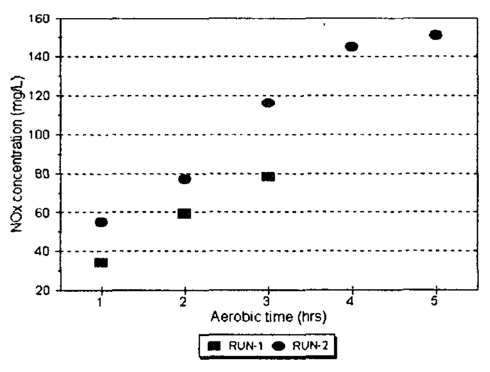

Fig. 11. Temporal variation of NOx-N concentration in a aerobic time.

Fig. 12 shows the effect of anoxic time distribution on the specific denitrification rate (SDNR), and it was 4.21 mgN/gMLSS · hr in RUN-1 and 11.46 mgN/gMLSS · hr in RUN-2. This result might be derived by the fact that portion of denitrification biomass in RUN-1 was higher than that in RUN-2, caused by longer SRT. Finally, when the effluent from chemical process was treated in the SBR process for simultaneous removal of organics and nitrogen, the optimum anoxic/aerobic time distribution was 2/4 hours.

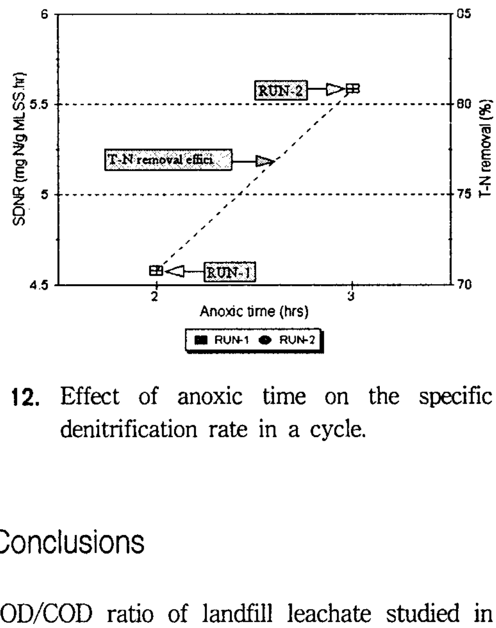

Fig. 12. Effect of anoxic time on the specific denitrification rate in a cycle.

4. Conclusions

1. BOD/COD ratio of landfill leachate studied in this research was 0.3. Its NH_4^+-N concentration was high and NH_4^+-N/TKN ratio was 0.86.
2. Optimum coagulant for pre-chemical treatment of the leachate was PAC and its optimum operating condition was 1,250 mg/L of dosage and pH 6.
3. When leachate pretreated in chemical process was treated with the SBR process, COD and nitrogen removal efficiency was over than 82%, 71%, respectively. Hence it was concluded that the process train between chemical process and biological process should be introduced for treatment of leachate containing high concentration of nonbiodegradable matters.
4. In case of SBR process for simultaneous removal of organics and nitrogen from leachate, optimum anoxic/aerobic time distribution was 2/4 hours and 2 times of anoxic/aerobic mode were required for effective denitrification.

Acknowledgements

Authors greatly appreciate for supporting by Korea Research Foundation(Research No. 1997-004-E00267).

REFERENCES

APHA, AWWA and WPCF, 1989, *Standard methods for the examination of water and wastewater*, 17th Ed.

Bortone G., S. Gemelli, A. Rambaldi and A. Tilche, 1992, *Wat. Sci. Tech.*, 26(5/6), 977-985.

Chian E. S. K and F. B. Dewalle, 1976, *JEE, ASCE*, 102, 411

Christensen T. H., R. Cossu and R. Stegmann, 1992, *Landfilling of waste*, London, Elsevier Science Publishers Ltd.

Forgie D. J .L., 1988, *Wat. Poll. Res., J. Canada*, 23(2), 341-355.

Han G. B., D. K. Park, H. G. Lee, C.W. Kim, 1997, *J. Korean Environ. Sci. Society*, 6(5), 521-529.

Keenan J. D., R. L. Steiner and A. A. Fungaroli, 1984, *JWPCF*, 56(1), 27-33.

Levine A. D. and L. R. Rear, 1989, 43rd Purdue Industrial Waste Conference Proceedings, 173-183.

Lu, J. C. S., B. Einchenberger and R. J. Stearns, 1985, *Leachate from municipal landfills -and management -*, *Noyes Pub.*, 453.

Pohland F. G. and S. R. Harper, 1988, *Civil Eng.*, 66.