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Description	第6回衛生工学シンポジウム（平成10年11月5日（木）-6日（金） 北海道大学学術交流会館） . 2 モデリング・評価 . 2-8
Citation	衛生工学シンポジウム論文集, 6, 66-70
Issue Date	1998-11-01
Doc URL	https://hdl.handle.net/2115/7323
Type	departmental bulletin paper
File Information	6-2-8_p66-70.pdf



SIMULATION ANALYSIS OF UPGRADING THE EXISTING WASTEWATER TREATMENT PLANT FROM A CONVENTIONAL PROCESS TO A MULTI-ANOXIC ZONE PROCESS WITH STEP FEEDING

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ABSTRACT

Simulation analysis was performed to study the effect of total number of anoxic zones on nitrogen removal of a multi-anoxic zone process with step feeding. The mathematical model that included the Activated Sludge Model No.2 was developed for simulating the performance of the full-scale municipal wastewater treatment plant upgraded from the conventional activated process without enlargement of reactor volume. We performed the following experiments to verify our model: (i) Characterization of organic matters in the influent to the reactor with the OUR measurement method; (ii) Lab-scale batch experiments with the multi-anoxic-aerobic phases with sewage step feed. Simulated results showed that there were the optimum number of anoxic zones and the optimum concentration of dissolved oxygen in aerobic zones to maximize the nitrogen removal.

KEYWORDS

Activated sludge model; multi-anoxic zone process; simulation analysis; step feed; upgrading nitrogen removal

INTRODUCTION

In upgrading the existing wastewater treatment plants which were originally designed as conventional activated sludge system to treat nutrients, one of the most cost-effective solutions is to change their operation style to multi-anoxic zone process with step feeding without the extension of reactor volume (Coen et al., 1996). In this upgrade process, the key factor is setting the operating conditions such as number of anoxic zones, allocation of reactor volume to aerobic and anoxic zones, as well as air supply for aerobic zones. The objective of the study presented in this paper is to examine the appropriate operating conditions for upgrading the wastewater treatment plant in Sapporo City by simulation analysis.

METHODS

Simulation model

The performances of biological reaction basin and final clarifier were modeled. We used the

Activated Sludge Model No.2 (Henze et al. 1995) to express the biological reactions. The flow scheme of reaction basin was modeled by series of 60 complete mixing tanks. The performance of final clarifier was described by the empirical formula by Chapman (1984). We set the following conditions in the simulation with reference to the operating condition of the investigated municipal wastewater treatment plant: i) Flow rate of primary effluent was 36,500m³/day; ii) total reactor volume was 15,200m³; iii) flow rate of return sludge was 18,250m³/day; iv) flow rate of excess sludge was 600m³/day; v) surface area of final clarifier was 2300m².

Lab-scale batch experiments

In order to calibrate the simulation model, lab-scale batch experiments were performed with 2L vessel at 20°C. We used primary effluent and return sludge from the municipal wastewater treatment plant. To characterize the primary effluent, the respiration test (Gujer and Kappeler, 1992), COD analysis as well as volatile acid measurement were employed to classify organic matters into the readily biodegradable substrate S_s , volatile acid S_A , slowly biodegradable substrate X_s , heterotrophic biomass X_{H_p} , inert soluble organics S_p , and inert particulate organics X_I . The biomass of phosphorus-accumulating bacteria and nitrifying organisms in the primary effluent were assumed to be negligible. The active heterotrophic biomass in the return sludge was estimated by comparison of simulated results with data from denitrification test using the mixture of the sludge, acetic acid and nitrate nitrogen. Nitrifying bacteria in the sludge was estimated by data from the nitrification test.

Multi-anoxic-zone process was simulated in the batch experiment by the following procedures: i) Anoxic phase. At the beginning of this phase, V_i of the primary effluent and V_r of the return sludge were mixed. Mechanical mixing was adopted. ii) Aerobic phase. Air was supplied through diffuser. iii) Anoxic phase. At the beginning of this phase V_i of the primary effluent was mixed again. iv) Aerobic phase. v) Repeat the procedures iii) and iv).

We set the experimental conditions, V_p , V_r and reaction time, corresponding to the following case: i) the primary effluent was distributed to the anoxic zones uniformly; ii) the sludge recycling rate, 50%; iii) the original reactor had the volume that mean residence time based on the flow rate of the primary effluent was 10hr; iv) in the N-anoxic zones operation, reactor was divided into N equal parts. We performed three batch experiments having two, three and five anoxic zones operations. The reaction times in each experiments are summarized in Table 1.

TABLE 1. Reaction time in the batch experiments

No. of anoxic phase	Reaction time of each phase (hr)										Total time (hr)
	1		2		3		4		5		
	AX*	AR**	AX	AR	AX	AR	AX	AR	AX	AR	
2	2.5	2.5	1.7	1.7	-	-	-	-	-	-	8.3
3	2.0	2.0	1.4	1.4	1.1	1.1	-	-	-	-	9.1
5	1.4	1.4	1.1	1.1	0.9	0.9	0.8	0.8	0.7	0.7	9.8

* AX: Anoxic Zone. ** AR: Aerobic Zone

Analytical methods

COD was analyzed according to Standard Methods(1989). $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, and $\text{NO}_2\text{-N}$ were determined using ion chromatography. Volatile acids concentration was measured using liquid chromatography. All samples except for COD were prefiltered with $0.45\mu\text{m}$ membrane filters.

RESULTS

Comparison of computed results with measured data

The fractions of organic matters in the primary effluent used in the experiment are summarized in Table 2. The denitrification and nitrification test of the return sludge showed that active biomass of heterotrophic and nitrifying bacteria in the return sludge were 3000g-COD/m^3 and 570g-COD/m^3 , respectively. Figure 1 is comparisons of computed results with data from the batch experiments, showing that the model yielded the reasonable simulation results. The observed and computed results showed that denitrification in anoxic zones did not proceed completely and nitrate nitrogen was accumulated. This was due to the low denitrification rate because of the low ratio of readily biodegradable COD to nitrogen (Funamizu *et al.* 1997).

TABLE 2. Character of the primary effluent used in the experiments

S_F^*	S_A^*	S_I^*	X_I^*	X_S^*	X_H^*	$S_{\text{NH}_4}^{**}$	$S_{\text{NO}_x}^{**}$	$S_{\text{PO}_4}^{***}$
7.1	0.0	12.1	26.8	72.1	14.8	29.4	0.0	3.0

*: g-COD/m^3 , **: g-N/m^3 , ***: g-P/m^3

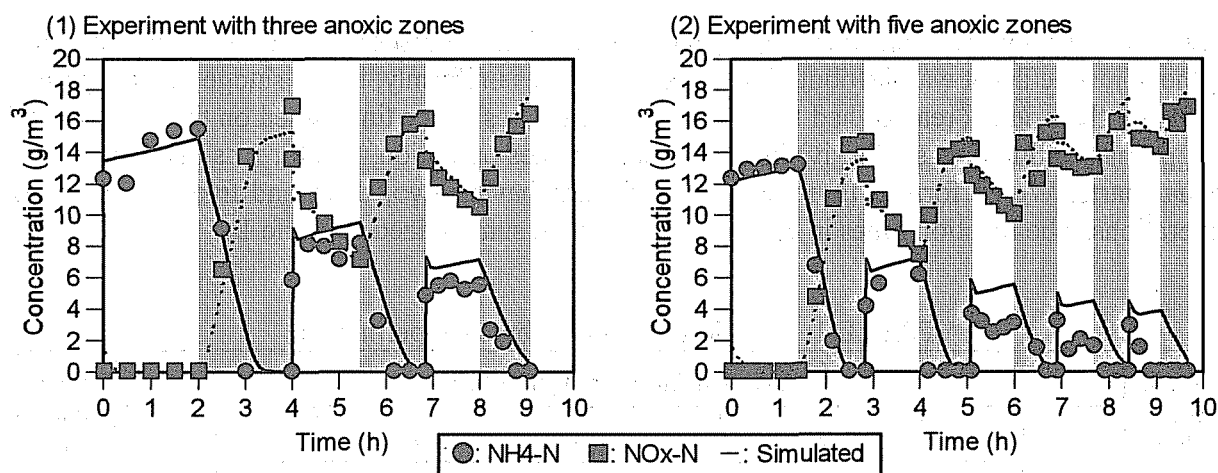


Figure 1. Comparisons of computed results with data from batch experiments

Simulation analysis to improve nitrogen removal

The effect of total number of anoxic zones on nitrogen removal. Figure 2 shows the computed results for the investigated plant, showing the influence of the total number of anoxic zones on the total nitrogen removal. It can be seen from Fig.2 that there is the optimum number of anoxic zones for nitrogen removal. Organic matter is consumed by heterotrophic bacteria

aerobically just after the mixing of the primary effluent and sludge in the anoxic zone, because dissolved oxygen is supplied by the mixed liquor from the previous aerobic zone. Residual organic matter is used for denitrification. Figure 3 gives simulation results, showing that over-repetition of anoxic-aerobic zone causes consumption of organic matter aerobically not for denitrification.

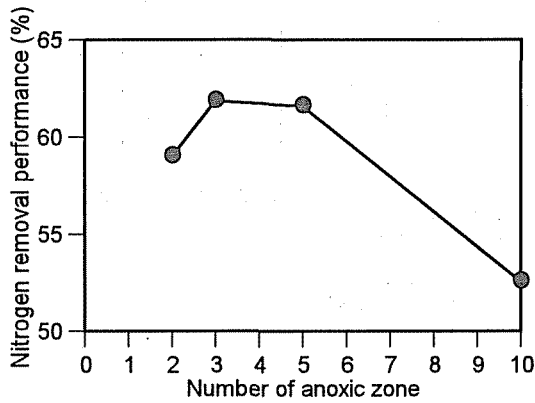


Figure 2. Effect of number of anoxic zone on nitrogen removal.

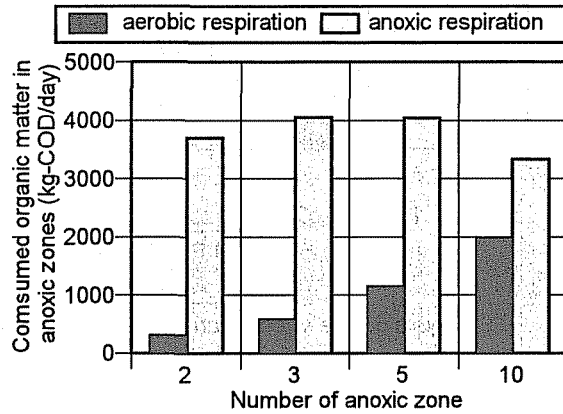


Figure 3. Organic matter consumed in anoxic zone.

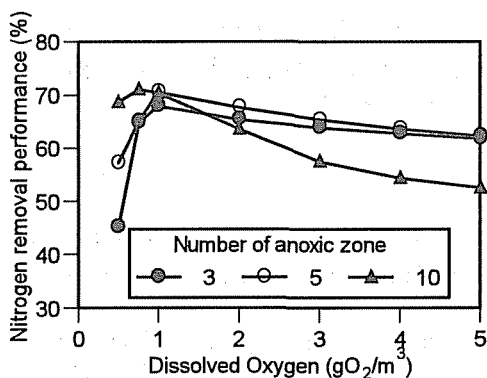


Figure 4. The effect of DO level on nitrogen removal

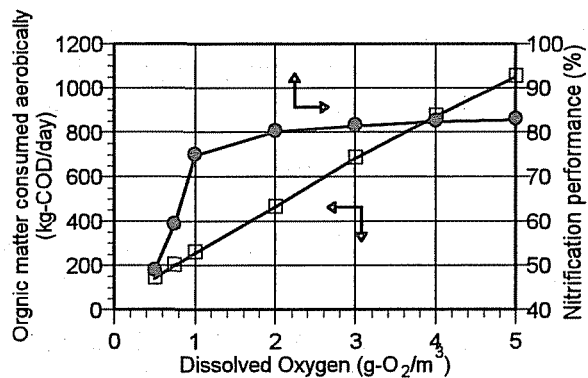


Figure 5. Aerobic consumption of organics and Nitrification performance

The effect of dissolved oxygen concentration on nitrogen removal. Results in Figs.2 and 3 are yielded from simulation under 5 mg/L of DO level in aerobic zones, and they imply the possibility of improving nitrogen removal by reducing DO level in the aerobic zones. Figure 4 gives simulation results of the effect of DO level on nitrogen removal, showing that the optimum DO level is about 1mg/L. This optimum DO level is the result from the trade-off shown in Fig.5 such that nitrification in the aerobic zone decreases rapidly at low DO range and aerobic consumption of organic matter in the anoxic zone increases with DO level.

The effect of volume of anoxic zone.

Since the simulation results in Fig.1 showed that nitrate nitrogen was accumulated in the anoxic zones, we examined the effect of allocation of reactor volume to anoxic and aerobic zones on nitrogen removal. Figure 6 gives simulation results, showing that the extension of anoxic zone improves nitrogen removal.

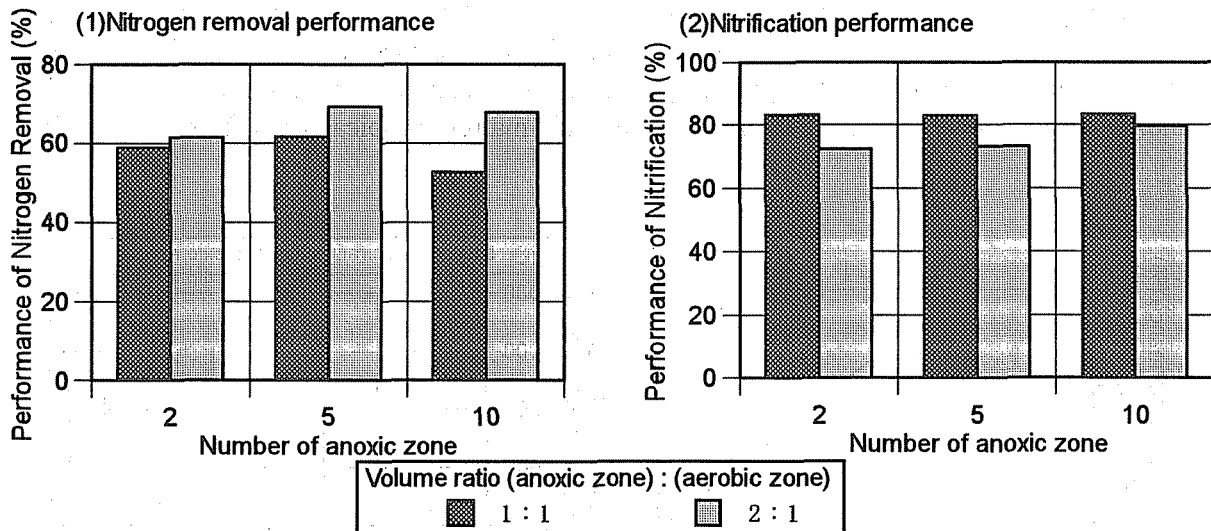


Figure 6. The effect of anoxic zone's volume on nitrogen removal

CONCLUSION

The mathematical model was developed for simulation analysis of operating conditions in upgrading the existing conventional wastewater treatment plant to multi-anoxic zone process with step feeding. The validity of the model was confirmed with data from the lab-scale batch experiments. Simulated results showed that there is the optimum number of anoxic zones which gives the maximum nitrogen removal, and also showed that choice of suitable dissolved oxygen level in aerobic zones improves the performance of nitrogen of removal.

REFERENCES

- APHA, AWWA, and WPCF (1989). *Standard methods for the examination of water and wastewater*, 17th ed. Chapman, D.(1984). The influence of dynamic loads and process variables on the removal of suspended solids from an activated sludge plant. *Ph.D. dissertation*. University of Alberta, Edmonton. (cited in Patry G. and Chapman D. (1989). *Dynamic Modeling and Expert System in Wastewater Engineering*. Lewis Publishers.).
- Coen, F., Vanderhaegen, B., Boonen, I., Vanrolleghem, P.A., Van Eyck, L. and Van Meenen, P.(1996). Nitrogen removal upgrade of a wastewater treatment plant within existing reactor volumes: a simulation supported scenario analysis. *Wat. Sci. Tech.*, 34(3-4), 339-346.
- Funamizu, N., Yamamoto, S., Kitagawa, Y., and Takakuwa, T. (1997). Simulation of the operational conditions of the full-scale municipal wastewater treatment plant to improve the performance of nutrient removal, *Wat. Sci. Tech.* 36(12), 9-18.
- Gujer, W. and Kappeler, J (1992). Estimation of kinetic parameters of heterotrophic biomass under aerobic conditions and characterization of water for activated sludge modeling. *Wat. Sci. Tech.*, 25(6), 125-139.
- Henze, M., Gujer, W., Mino, M., Matsuo, T., Wentzel, M. and Marais, G.(1995). Activated Sludge Model No.2, *IAWQ Scientific and Technical Report No.3*.