ICA2025OSLO
14th IWA Specialised Conference on
Instrumentation, Control and Automation

# Development of Aeration Control Method to Achieve Balancing between Nitrogen Removal and Energy Efficiency

R.Ueda*, W.Yoshida*, Y. Hayashi*, E. Imamura*, I. Kimoto*, J.Hon**

* Advanced Technology R&D Center, Mitsubishi Electric Corporation,8-1-1, Tsukaguchi-Honmachi, Amagasaki City, Hyogo 661-8661, Japan, Ueda.Reo@ap.MitsubishiElectric.co.jp

** Kobe Works, Mitsubishi Electric Corporation, 2-7-3 Marunouchi, Chiyoda-ku, Tokyo 100-8310, Japan, Hon.Jini@bx.MitsubishiElectric.co.jp

**Abstract:** Our research group confirmed that nitrogen removal in A2O system can be maximized at a specific ammonia nitrogen concentration in the aerobic tank outlet (AN-O), which varies with the inflow load. Based on this finding, an automatic control target setting function (ACTSF) was developed to estimate the optimal AN-O as the target value in real-time based on the inflow ammonia load. By controlling the aeration rate to meet this target, the aeration rate and total nitrogen concentration in the treated water (TN-TW) were reduced by approximately 15% and 30%, respectively.

**Keywords**: Aeration control; Nitrogen removal; Advanced treatment; Artificial intelligence

## 1. Introduction

Reducing energy consumption while enhancing water quality to meet stringent discharge standards presents significant challenges for wastewater treatment plants (Yong et al., 2023). In this study, the optimal conditions for maximizing nitrogen removal efficiency were identified by varying the aeration rate of a wastewater treatment plant. Furthermore, we developed an automatic control target setting function (ACTSF) that estimates the optimal target values for aeration control based on real-time inflow load measurements and historical operational data to promote nitrogen removal. The reductions in aeration rate and total nitrogen were verified on-site.

## 2. Methodology

**Figure 1** shows the configuration of Treatment Plant A, which employs the A2O process and served as the test site. **Table 1** shows the conditions of three tests which were conducted in this study.

In the preliminary test, the aeration rate per unit of the inflow rate was changed weekly between 1.9 to 3.5 (approximately 4.2 in the existing operation) over about six months, to explore conditions that increase nitrogen removal.

In the demonstration test, an aeration control system to promote nitrogen removal was developed based on the preliminary test findings. Subsequently, long-term continuous operation was carried out for nine months. **Figure 2** shows a schematic diagram of the developed system. This system consists of the Ammonia Control Function (ACF) and the ACTSF. The ACF controls the aeration rate to maintain ammonia nitrogen concentration in the aerobic tank outlet (AN-O) at a predetermined target value, and the ACTSF updates the target value. Two treatment series with the configuration shown in **Figure 1** were used in the test. One series served as the demonstration system, while the other, with DO control at two points in the aerobic tank, was the comparison system. The reduction rates of aeration rate and total nitrogen concentration in the treated water (TN-TW) were evaluated.

In the sampling test, water samples were collected from the anoxic and aerobic tanks at sampling points (A) to (E), as shown in **Figure 1**. The collected samples were filtrated and analysed for ammonia nitrogen ($NH_4$-N), nitrate nitrogen ($NO_3$-N), and nitrite nitrogen ($NO_2$-N), to elucidate the nitrogen treatment process within the reaction tanks.

## 3. Results and Discussion

### 3.1. Preliminary test

**Figure 3** shows the relationship between nitrogen removal amount and AN-O from the preliminary test. The maximum nitrogen removal was observed around AN-O of 4 mg/L. This suggests that

the optimal conditions for promoting nitrogen removal can be identified by the AN-O. Additionally, it was found that higher $NH_4$-N loads shifted the peak nitrogen removal point to the right on the x-axis. This indicates that the optimal $NH_4$-N concentration for nitrogen removal varies with the influent ammonia load.

Based on these findings, we developed the ACTSF. **Figure 4** shows a schematic diagram of the ACTSF. It clusters historical operational data based on indicators such as influent load and water temperature. Using the closest cluster to current conditions, the ACTSF models the relationship between nitrogen removal amount and AN-O. The ACTSF estimates the target AN-O that can achieve the desired nitrogen removal.

### 3.2. Demonstration test

**Figure 5(a)** shows weekly trends of aeration rates and AN-O for the demonstration and comparison systems. The AN-O in the demonstration system remained between 0.5 and 2 mg/L, preventing complete nitrification, and resulting in lower aeration rates compared to the comparison system. The AN-O in the comparison system was consistently under 0.2 mg/L. **Figure 5(b)** shows TN-TW, with the demonstration system achieving lower TN. **Table 2** shows the reduction rates of aeration rate and TN-TW during the demonstration test. Over about nine months, aeration rate and TN-TW were reduced by approximately 15% and 30%, respectively.

### 3.3. Sampling test

**Figure 6** shows $NH_4$-N, $NO_3$-N, and $NO_2$-N concentrations at sampling points (A) to (E). In the demonstration system, the total concentration of $NH_4$-N, $NO_3$-N, and $NO_2$-N at sampling point (B) and beyond were lower than at sampling point (A), indicating denitrification occurred in the aerobic tanks. This suggests that localized anoxic zones were formed in the aerobic tanks in the demonstration system, which resulted in facilitating both nitrification and denitrification.

## 4. Conclusion

It was observed that the optimal AN-O to maximize nitrogen removal varies by the influent load. The ACTSF was developed to estimate the target AN-O from past operational data. The demonstration test showed that the aeration rate and TN-TW were reduced by approximately 15% and 30%, respectively, implying that the trade-off between water quality and energy efficiency can be overcome. Sampling tests suggested that higher denitrification in the aerobic tanks in the demonstration system contribute to TN-TW reduction.

## 5. REFERENCES

Yong, G., Yu, L. & Qiang, Y. 2023 Optimization and control strategies of aeration in WWTPs: A review. Journal of Cleaner Production 418, 1–21.

**Table 1** Conditions for preliminary, demonstration and sampling test.

| | Preliminary test | Demonstration test (including sample test) |
|---|---|---|
| Period | Dec. 10, 2019 to Feb. 18, 2020<br>Aug. 3, 2020 to Oct. 26, 2020 | May 1, 2022 to Feb. 6, 2023 |
| Aeration control | AR/IR : 1.9 - 3.5 | ACF + ACTSF |
| MLSS | 2107 mg/L | 1800 mg/L |
| Water temperature | 11.7 to 26.3 °C | 13.8 to 26.9 °C |
| HRT | 13.6 hr | 10.9 hr |
| A-SRT | 12 days | 10.5 days |
| Return sludge ratio | 30% | 36% |
| Nitrification liquid recirculation ratio | 36% | 32% |

**Table 2** The reduction rates of aeration rate and T

| | Aeration reduction rate | TN-TW reduction rate | Average Temperature |
|---|---|---|---|
| May 2022 | 16.8 % | 33.1 % | 22.3 °C |
| Jun 2022 | 16.7 % | 29.4 % | 23.3 °C |
| Jul. 2022 | 19.8 % | 43.5 % | 25.3 °C |
| Aug. 2022 | 20.8 % | 46.0 % | 26.1 °C |
| Sep. 2022 | 16.7 % | 30.4 % | 25.6 °C |
| Act. 2022 | 16.3 % | 37.9 % | 23.8 °C |
| Nov. 2022 | 20.2 % | 30.2 % | 22.6 °C |
| Dec. 2022 | 3.6 % | 19.9 % | 20.6 °C |
| Jan. 2023 | 8.0 % | 33.5 % | 19.7 °C |
| Feb. 2023 (until Feb. 6) | 6.6 % | 28.0 % | 19.2 °C |
| Entire period | 15.2 % | 34.7 % | 23.2 °C |

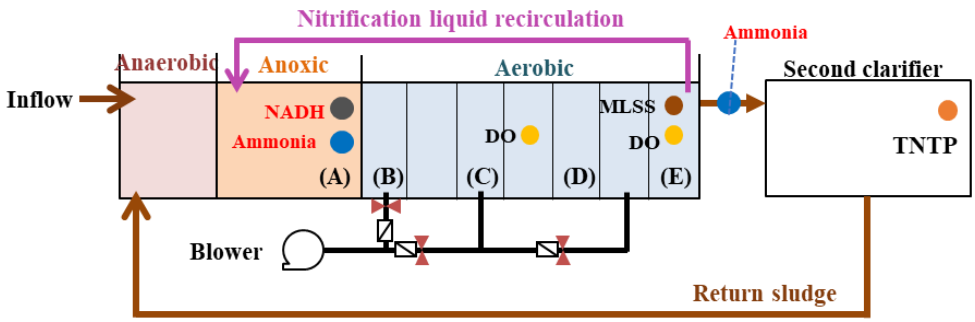


**Figure 1** Configuration diagram of Treatment Plant A.

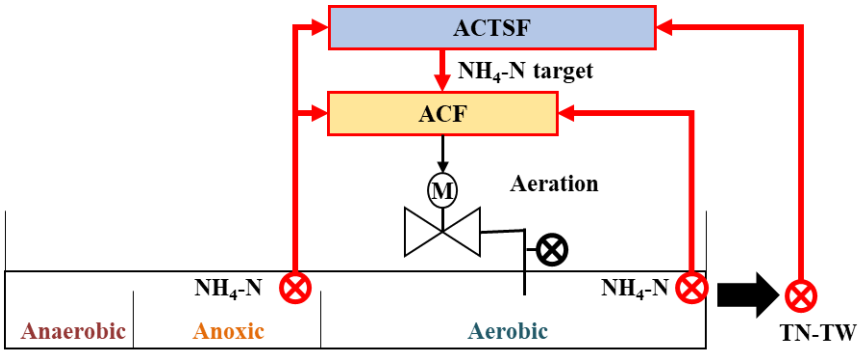


**Figure 2** Schematic diagram of the developed system.

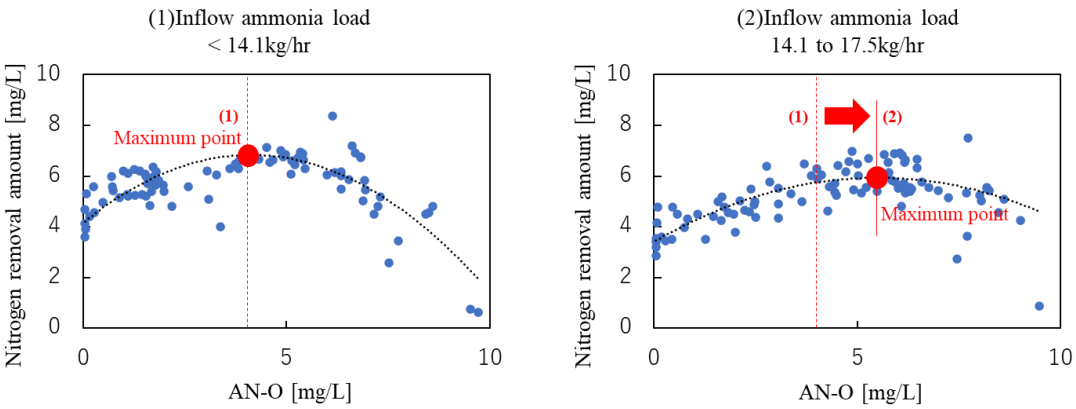


**Figure 3** The relationship between nitrogen removal amount and AN-O.

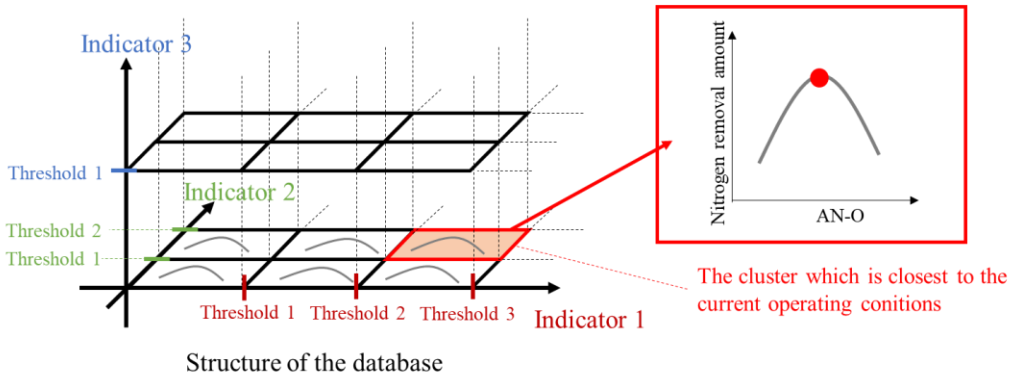


**Figure 4** The schematic diagram of the ACTSF.

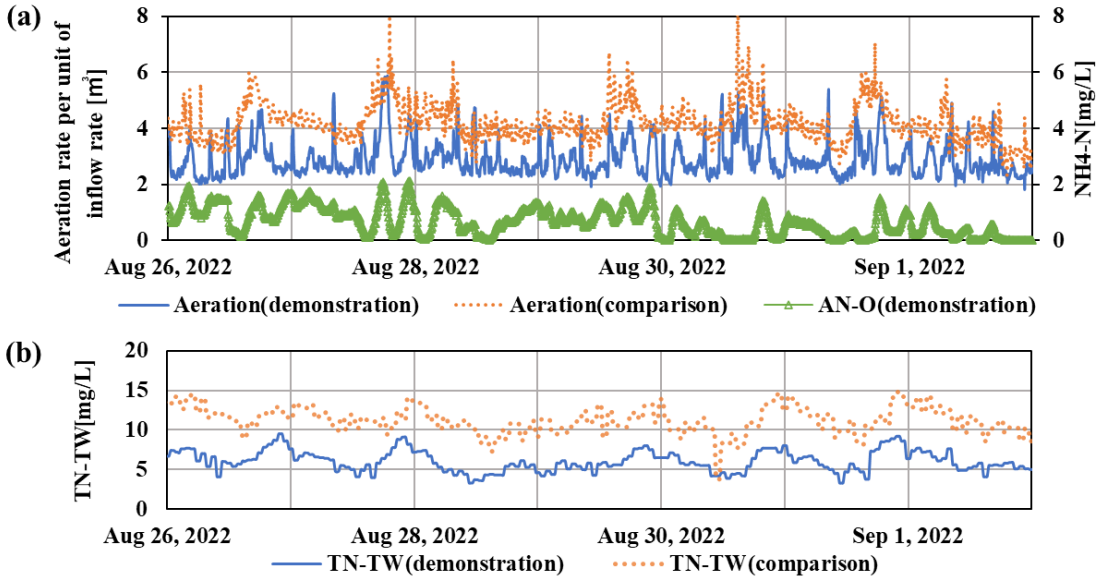


**Figure 5** The weekly trends of aeration rate and TN-TW in the demonstration test

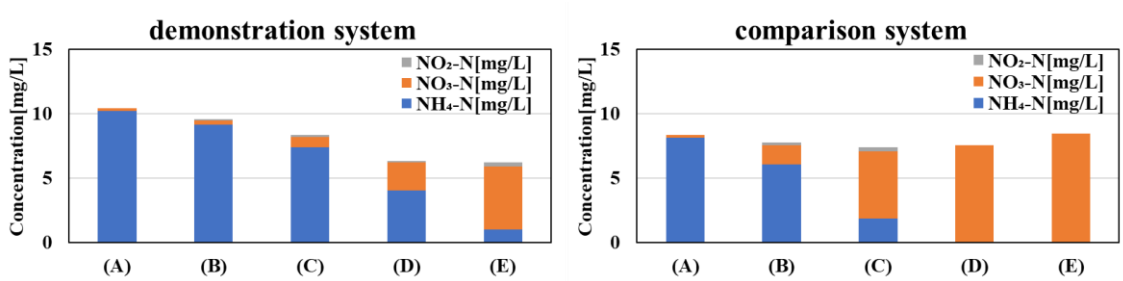


**Figure 6** $NH_4$-N, $NO_3$-N, and $NO_2$-N concentrations at sampling points.