Technical Evaluation Report on Aeration Airflow Control Technology Using Ammonia Meter (Draft)

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Technical Evaluation Committee
Japan Sewage Works Agency

Technical Evaluation Committee

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Special Committee on the Aeration Airflow Control Technology Using Ammonia Meter

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Table of contents

Background of the Technical Evaluation

Energy savings at wastewater treatment plants (WWTPs) are essential for reducing operation costs and GHG emissions. In WWTPs that adopt activated sludge processes, approximately 50% of energy consumption is attributed to wastewater treatment facilities, particularly blowers. Therefore, reducing the energy consumption of blowers is effective for WWTPs in terms of energy savings.

Traditional aeration volume adjustments have been automatic control technology (aeration volume control technology), such as inflow ratio control (constant air supply ratio control) or DO control. However, exceeding the aeration air volume reduction worsens wastewater treatment performance, and these methods have issues with the effects of aeration reduction and adaptability to inflow rate or load fluctuations.

The Japan Sewage Works Agency (JS) has continuously researched and developed a new aeration air volume control technology since 2003. After 2013, JS developed and demonstrated multiple aeration control technologies using ammonia meters in joint research with private companies or the Breakthrough by Dynamic Approach in Sewage High Technology (B-DASH) project. An ammonia meter is a concentration meter of the ion electrode-type ammonia nitrogen (NH_4-N). Aeration control using ammonia meters automatically regulates aeration airflow based on the NH4-N concentration measured by the ammonia meter. The promising technology enables control by reflecting the progress states of

nitrification, an essential biological reaction within aeration tanks. Further, it reduces aeration flow while maintaining stable treated water quality, including NH4-N concentration.

Besides JS, some local governments or private companies have been reported to study such aeration control technologies. Still, they are in the stage of demonstrating individual techniques. Popularizing a new aeration control technology requires organizing multiple demonstration results comprehensively and clarifying their function, performance, and adoption benefits.

Given the above background, in March 2019, the JS president consulted the technical evaluation committee to evaluate aeration air volume control using an ammonia meter. While the technology was initially referred to as "Aeration air volume control technology using ammonia meter " and later changed to "aeration airflow rate control technology using ammonia meter," this report uses the revised name as the technology's name.

Objectives of the Technical Evaluation

This technical evaluation aims to comprehensively organize the latest technical knowledge of multiple "Aeration airflow control using an ammonia meter" based mainly on JS's research results and clarify its technical features, functions, performances, adoption benefits, introduction study procedures, and design and operation management methods. It also aims to promote the popularization and save energy and

costs of WWTPs.

Target Technology

This technical evaluation deals with "Aeration airflow control technology using an ammonia meter (Ammonia control technology)." The technical performance and economic efficiency will be evaluated primarily based on the results of four technologies developed or demonstrated through joint research with private companies.

Scope of Evaluation

Ammonia control is adaptable to activated sludge process reaction tanks performing nitrification. This technical evaluation primarily focuses on reaction tanks of WWTPs, which employ the conventional activated sludge process for nitrification acceleration or the biological nitrogen/phosphorus removal process.

From an economic perspective, the evaluation targets are facilities or lines with a daily treatment volume of 10,000 m^3 or more.

The evaluation shall scope devices that perform sensor measurements, calculate targeted aeration airflows, and output to aeration airflow-adjusting valves, among other functions.

Features of the Technology

1. Definition and Classification of the Technology

1) Definition of the technology

This technical evaluation defines "Aeration air flow control technology using ammonia sensor" as "Technology automatically controls the aeration airflow of reaction tanks based on the measurement values of sensors of ammonia nitrogen concentration within reaction tanks of the activated sludge process."

2) Classification of the Technology

Aeration airflow control technology is commonly classified as a) Feedforward (FF) control, b) feedback (FB) control, and c) the combination of a and b (FF+FB) control. Various FB or FF+FB controls have been developed and demonstrated for ammonia control technology. The four control systems this technical evaluation dealt with are classified as any of a) NH_4: fuzzy control, b) NH_4-DO control, and c) NH_4: FF+FB control.

2. Principle of the Technology

① The most fundamental principle of aeration airflow control technology is making the oxygen supply velocity follow the time fluctuation of the oxygen demand rate in the biological treatment process in the reaction tanks.

② Ammonia aeration airflow control technology changes the oxygen supply velocity by increasing or decreasing the aeration airflow based on the NH4-N concentration inside a reaction tank, which is used as an indicator. While the changing methods vary depending on the control

technology, the fundamental goal is to improve the followability against time fluctuations in oxygen demand compared to conventional control methods, including water volume ratio control and constant DO control.

③ The reduction effects of the aeration airflow are mainly obtained by inhibiting excessive aeration during low-load inflow to reaction tanks and low oxygen demand. On the other hand, during high-load inflow and high oxygen demand, the aeration airflow of ammonia control technology is sometimes higher than that of conventional control technology.

④ The typical operation cycle of the ammonia control technology is below an hour, and it does not aggressively control the volume of nitrification bacteria in the activated sludge. This means that ammonia control is not principally assumed to change the nitrification inhibition to nitrification acceleration by itself.

3. Effects and purposes of the technology

1) Effects of the ammonia control technology

① The unique function of the ammonia control technology is to automatically control the aeration airflow of reaction tanks based on the measurement values of NH_4-N concentration, etc., to optimize the aeration airflow. This function enables (a) reducing the aeration airflow and (b) stabilizing NH4-N concentration in treated wastewater, two

direct and essential benefits.

② The indirect benefits of the aeration airflow reduction are the reduction of power consumption and GHG emissions by decreasing the blower's power.

③ The indirect benefits of treated wastewater’s stable NH4-N concentration are stable T-N concentration and risk reduction of the increased BOD concentration by N-BOD expression.

④ The secondary benefit of ammonia control technology is that NH4-N concentration data can be utilized during the usual operation management.

2) Purpose of ammonia control technology

The technology primarily aims to optimize the aeration airflow while maintaining the target wastewater quality, mainly in terms of NH_4-N concentration.

4. Application targets of the technology

① This technical evaluation mainly deals with the following items.

- Facilities: Reaction tanks of WWTPs
- Wastewater treatment method: Conventional activated sludge (CAS) process of accelerated nitrification and biological

nitrogen/phosphorus removal processes of only accelerated nitrification operation

- Target scale of facility: A treatment capacity of approximately 10,000 m^3 per day or more

② The following requirements are especially suitable for applying ammonia control technology.

- Improvement of nitrification performance: significant fluctuation of the inflow load of NH4-N, treated wastewater having unstable NH4-N concentrations, etc.
- Significant reduction effects of aeration airflow include a large reaction tank or treated water volume, a high air delivery ratio, and other factors.

5. Configuration of the technology

① An ammonia control technology consists of a water quality measurement device, including an ammonia meter, and a controller. However, in some cases, devices such as monitoring control devices require modifications to be applied to individual technologies or the existing electric facilities' configurations.

② Ammonia control technology is primarily applied to valves that adjust the aeration airflow in target facilities. Still, depending on their

configurations or blowing systems, it may also be used directly on blowers.

③ This technology evaluation assumes an ion electrode type, which enables real-time continuous measurement as an ammonia meter.

6. Function and performance of the technology

1) Reduction of the aeration airflow

① The function of the ammonia control technology is to ensure that oxygen supply volumes follow the time fluctuation of oxygen demand in a reaction tank. Its followability is usually higher than that of the conventional DO constant control, and especially in time zones of low inflow load, it works to inhibit excessive aeration.

② The reduction effects of aeration airflow by ammonia control technology are affected by inflow load fluctuation, treatment requirements of a reaction tank, such as ASRT, and aeration airflow adjustment/control methods of comparison targets. Still, a 10% or more reduction effect can be expected compared to the conventional constant DO control based on demonstration results.

③ In the activated sludge process, aeration airflow reduction and nitrification performance, such as NH_4-N concentration, are trade-offs. Allowing low-concentration NH4-N to exist may improve the reduction

effects of the aeration airflow.

④ From the abovementioned point of view, reducing the NH_4-N concentration in treated water by ammonia control against unstable nitrification performance may increase the aeration airflow.

2) Stabilization of treated water quality

① The function of ammonia control technology is to keep NH_4-N in treated water at a low concentration during nitrification.

② Some ammonia control technologies have the target concentration of NH_4-N in the lower part of reaction tanks as a control parameter; others do not. Thus, the possibility of setting a direct target NH_4-N concentration of treated water varies depending on each control technology.

③ Demonstration results have shown that ammonia control technology achieves 1mg/l or less NH4-N concentration in treated water with daily average quality for both average and standard deviation.

④ Maintaining a low NH4-N concentration in treated water indirectly benefits the stabilization of T-N concentration or BOD concentration.

⑤ The ammonia control technology is not expected to function to transfer the situation of no nitrification progress to nitrification acceleration. It is also not assumed to maintain inhibiting nitrification.

7. Economic efficiency

1) Introduction costs

① The ammonia control technology costs to set up measurement devices like an ammonia meter, a controller, and remodel monitoring control devices.

② This measurement device, including ammonia meters, also requires operation and management costs.

2) Costs for reduction

① Aeration airflow reduction by introducing ammonia control technology can be expected to reduce the power consumption of blowers.

② However, the reduction range of blower power against aeration airflow reduction enormously varies depending on the power features of blowers, control methods, and requirements of blowers and their systems.

3) Economic efficiency

① While the introduction costs of ammonia control technology are approximately proportional to the number of control units, the minimum unit of a control configuration device set, the introduction costs per unit do not depend on the control targeted flow rate. On the other hand, the power cost reduction for blowers achieved by the

technology is proportional to the control-targeted flow rate. It does not depend on the number of control units. This means that the economic efficiency of the ammonia control technology significantly depends on the flow rate per unit; it is more beneficial at a higher flow rate.

According to the estimation using the minimum costs of the four technologies that this evaluation deals with, the economically efficient target control flow rate per unit against constant DO control is approximately 15,000 to 30,000 m^3 per day or more, under the condition of aeration reduction rates of 10 to 20%.

Planning and Design Approach

1. Considering technology introduction

① Verifying cost-effectiveness and estimating introduction effects and costs are required when considering introducing ammonia control technology at the planning and design stages.

② Specifically, the introduction should be based on verifying the application requirements, effects, costs, and economic efficiency.

2. Design considerations of the technology

(1) Consideration of the system configurations

Ammonia control technology shall be considered for the following items in its system configurations.

- The scope of the introduction targets facilities and the number of control units
- Control flow and configured facilities

(2) Design considerations of the individual facility

Each device configuring the ammonia control system shall be designed separately. Specific consideration items conform to each control system's design approach, and the following notes apply to both the ammonia meter and the controlling controller.

① The types, specifications, and setting places of the ammonia meter to be used shall be considered based on the performance requirements of each system.

② Designing install locations and functions of the controlling controllers shall accompany the existing monitoring control devices. Additionally, a switch function to a backup control should be considered in the event of ammonia meter failure.

③ Considering the blower control method, which uses ammonia control technology to reduce the aeration airflow and the blower's machinery power, is favorable.

Operation and Management Approach

1. Operation management of the wastewater treatment facilities

① Wastewater treatment facilities introducing ammonia control technology shall be given operation management for appropriate functions.

② Specifically, the operation management shall assume nitrification acceleration. To achieve this, A-SRT management shall be designed to maintain nitrifying bacteria within.

③ The batch control of multiple tanks shall be noted to keep treatment situations equivalent among tanks.

2. O&M of ammonia control technology

① Meters for control shall be operated and maintained correctly. The ammonia meter requires (a) regular calibration and cleaning of sensors and (b)exchange of electrodes depending on their degradation.

② Control parameters and target values shall be reviewed and refreshed during operation as required.

③ Other devices configuring control shall also be appropriately maintained.

Future Issues

The ammonia control technology requires addressing the following future issues and accumulating relevant knowledge.

- Ammonia control technology requires addressing the following problems and accumulating knowledge in the future.
- Data accumulation relating to demonstration and practical application.
- Approach and achievement of the batch control for multiple tanks
- New control approach or technology
- The prediction approach of the Introduction effects, including aeration airflow reduction, and treated wastewater qualities
- Expansion to various nitrification controls, including seasonal operation management
- Improvement and cost reduction of the ammonia meter