Technology Evaluation of NH_4-based Aeration Control

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Outline

- ✓ Classification and principle
- ✓ Functions, benefits and performance
- ✓ Cost efficiency

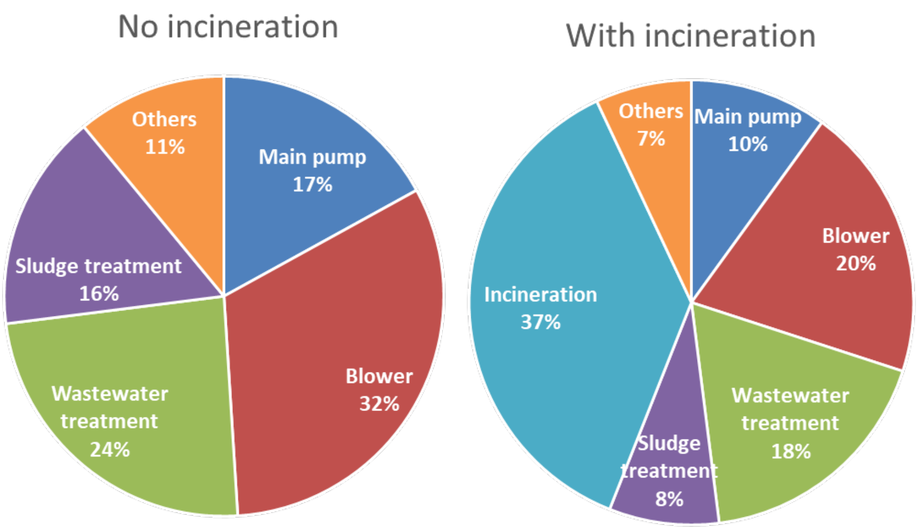
● Control and Reduction of Aeration

➢ Reducing aeration rate:

- ✓ Energy saving and cost reduction for WWTPs
- ✓ The contribution of consumed power and blowing power in wastewater treatment facilities.⇒ Importance of blowing power reduction

➢ Aeration control:

- ✓ Conventional/Current status:
  - ☐ Constant airflow (manual)
  - ☐ Inflow proportional
  - ☐ Constant DO
- ✓ New(?) technology:
  - ☐ ORP-based control
  - ☐ Dual DO control
  - ☐ NADH-based control
  - ☐ **NH_4-based control**
  - ☐ …



Proportion of energy consumption by facility in WWTP
(Survey results of 33 WWTPs by MLIT)
[Source] Sewerage Department, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism (2019): Introduction Manual of Energy Saving Technology for Energy Optimization of WWTPs(Draft)

● NH_4-based Aeration Control

- NH_4-based Aeration Control Technology:

  Technology to automatically control airflow rate based on online measurements including NH_4-N concentration for activated sludge processes

  - ✓ Using ammonia sensor (ISE).
  - ✓ Controlling aeration rate.
  - ✓ Online automatic control.

- ☐ JS has conducted a full-scale demonstration of ammonia control technology using NH_4 sensors since FY2013 (including B-DASH 2014-15).
- ☐ A number of case studies have been reported other than JS. Individual demonstration results are piling up at various facilities.

⇒ Need to organize multiple demonstration results in an integrated manner to clarify the performance and effects of the technology

⇒ JS conducted a "technology evaluation" in FY2019.

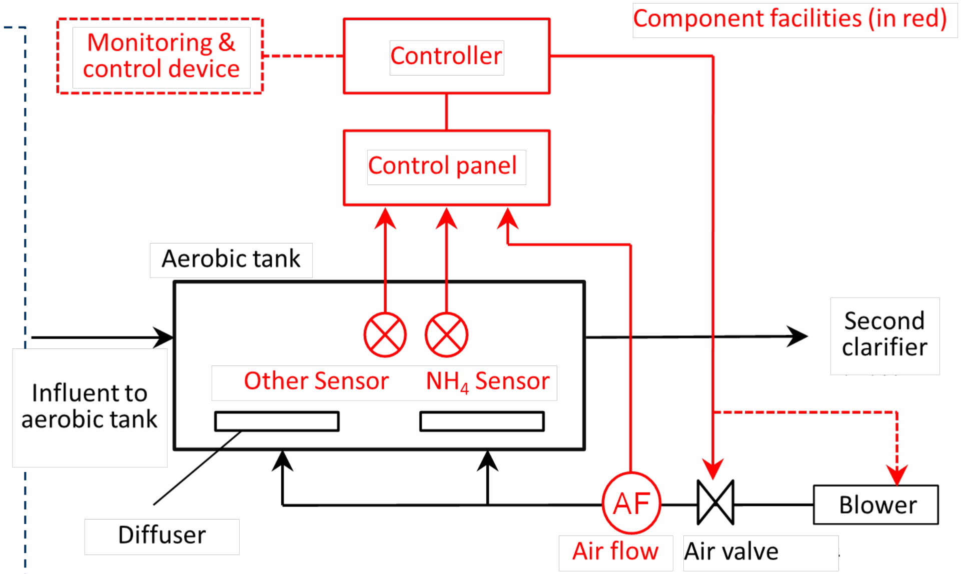


Image of NH_4 control technology

● Evaluation of NH_4 Control Technology

➢ Technology Evaluation Overview

- **Title: Technology Evaluation of Aeration Control Using NH_4 Sensor**
- **Period of evaluation:** Consultation in March 2019 to Report in April 2020
- **Evaluation by:** JS Technology Evaluation Committee, Chair: Prof. Furumai
  ⇒ Referred to "Technical Committee on Aeration Airflow Control Using NH4 Sensor" (Chair: Prof. Nagaoka)
- **Purpose of the evaluation:** Promoting the use of the technology ⇒ Encourage energy-saving and cost reduction for WWTPs

✓ Integrate and organize the latest technical knowledge, including the results of demonstrations
✓ Clarify the characteristics, functions, performance, and benefits of the technology

- **Evaluation details:** ① Technical features ② Approaches to adoption ③ Operation and management procedures of NH_4 control technology

The evaluation results were published as a "Report on the Evaluation of Aeration Control Using NH_4 Sensor“.

● Points of Evaluation

➢ Evaluation Data:

- ✓ Demonstration results of four different control technologies (JS joint research, one of which is B-DASH)
- ✓ Using numerical simulation with activated sludge model (ASM)

➢ Evaluation Parameters for Function/Performance:

- ✓ Reduction effect of airflow rate ⇒ Reduction rate against the conventional DO control
- ✓ Stability of effluent quality ⇒ NH_4-N concentration of effluent

➢ Policy of Evaluation:

- ✓ The evaluation is based on the demonstration results of four technologies. <u>It is an overall evaluation of "Aeration control technology" rather than an individual evaluation of each technology or comparison between them</u>.

Scope of Evaluation

The Target of the Technology:

- ✓ **Facility:** Aerobic tank of wastewater treatment facilities
- ✓ **Processes**: Activated sludge processes with full nitrification (CAS and other BNRs)
- ✓ **Treatment capacity:** More than 10,000 m^3/day (as amount of wastewater to be controlled)

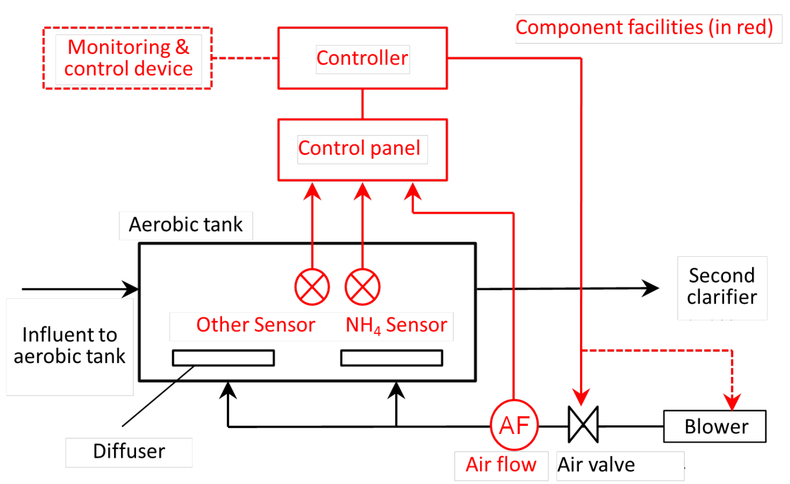
The Range of Evaluation:

- ✓ **Facilities:** Equipment that measures with sensors, calculates air flow rate, and outputs the target air flow rate to the air valve.

◆ **Component equipment:** Water quality analyzers (sensors, etc.), controllers, and other electrical equipment (instrumentation panels, monitoring controllers, etc.).

◆ **Equipment not to be evaluated:** Equipment that functions by receiving the output of the control (such as air volume control valves and blowers).

*When evaluating performance (air flow rate, effluent quality) and power consumption, the evaluation includes the aerobic tank, the second clarifier, and blowers.



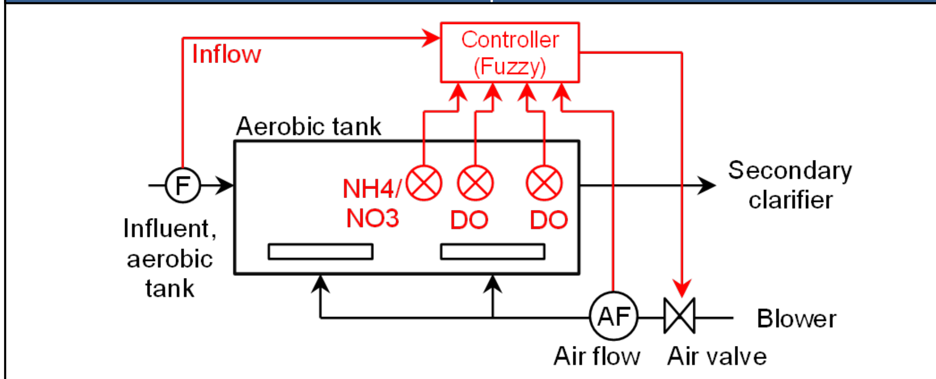
The scope of evaluation

Four Technologies Used for the Evaluation

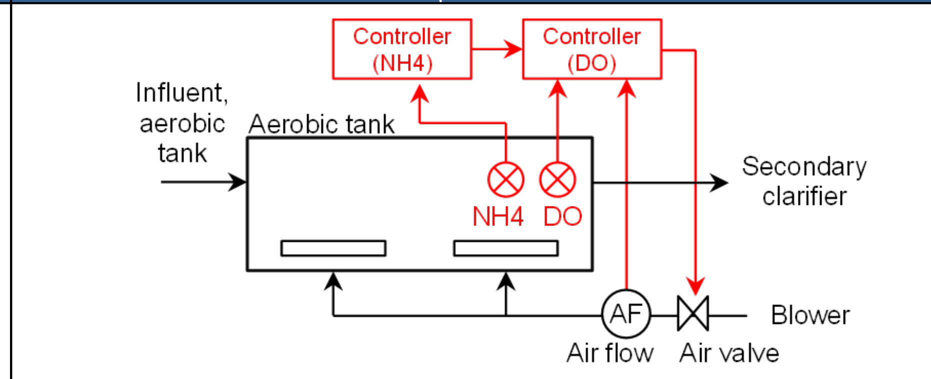
➢ Four technologies used for the evaluation：

Flow diagrams of the four systems

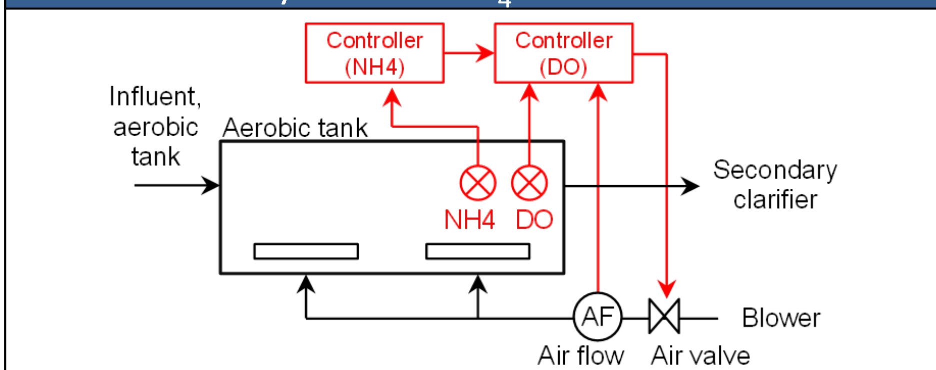
【System A】NH_4-fuzzy control



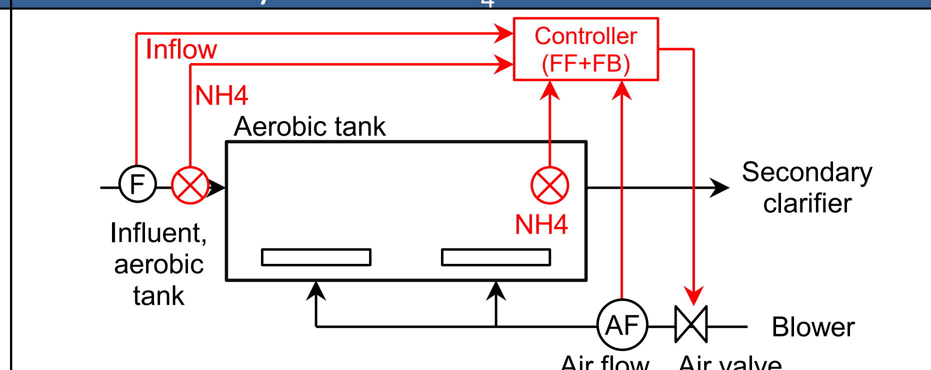
【System B】NH_4-DO cascade control



【System C】NH_4-DO control



【System D】NH_4-FF+FB control



【Joint researcher】

- System A：NISHIHARA Environment Co., Ltd.
- System B：Toshiba Infrastructure Systems & Solutions Corporation, Fukuoka Prefecture, Sewerage Management Center of Fukuoka Prefecture *B-DASH 2014-15 demonstration
- System C：Kobelco Eco-Solutions Co., Ltd. *Registered in the JS Innovation Program in February 2020
- System D：Nissin Electric Co., Ltd., NISSIN Systems Co., Ltd. *Registered in the JS Innovation Program in February 2020

● Categorize

➢ Classification of aeration control schemes

No control

【Example】
・Operation with constant airflow

Aeration airflow control

- **Feed forward (FF) control**

  【Example】
  ・Constant airflow control
  (Inflow proportional control)

- **Feedback (FB) control**

  【Example】
  ・Constant DO control
  ・**NH4-DO control**
  ・NADH control, ORP control

- **FF+FB control**

  【Example】
  ・**NH4-fuzzy control**
  ・**NH4-FF+FB control**
  ・Model prediction control

Systematization example of aeration airflow control technology

*__FF control__： Determine operation volume by measuring process disturbance (e.g., inflow quantity/quality)

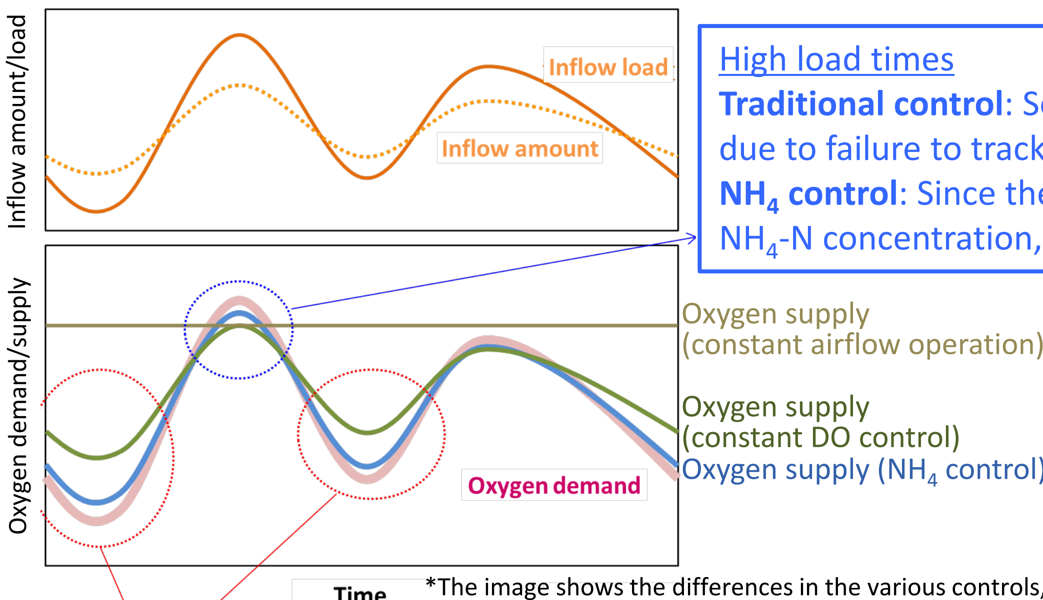
*__FB control__： Determine operation volume by measuring the state of treatment under disturbance, etc. (e.g., DO/NH4-N concentration in AT).

● Principle

➢ Key concept ①: Following changes in oxygen demand

Fundamental principles of the general aeration control: Make the oxygen supply track the time variation of oxygen demand in an aerobic tank

- ➢ **NH_4 control technology**: Improve tracking performance by using NH_4-N concentration as an indicator (specific method depends on individual technology)



*The image shows the differences in the various controls, and do not reflect the time delays caused by the mixing characteristics of the aerobic tank.

High load times

Traditional control: Some settings may cause insufficient oxygen supply due to failure to track

NH_4 control: Since the system increases the airflow depending on the NH_4-N concentration, oxygen supply is less likely to be insufficient.

【Key points】

- ◆Reducing airflow by NH_4 control mainly works to prevent excessive aeration during periods of low oxygen demand
- ◆NH_4 control does not always provide a lower targeted airflow than the conventional control

Low load times

Traditional control: High load setting leads to excessive airflow at low load

NH_4 control: High tracking performance of airflow even at low loads

Behavior images of ammonia control and conventional control against time variation of inflow load

● Principle (continued)

➤ Key concept ②: Trade-off between the reduction of airflow rate and nitrification performance

- ✓ Reducing the aeration airflow increases the NH_4-N concentration in effluent
- ✓ When trying to reduce the NH_4-N concentration of effluent, the aeration airflow increases

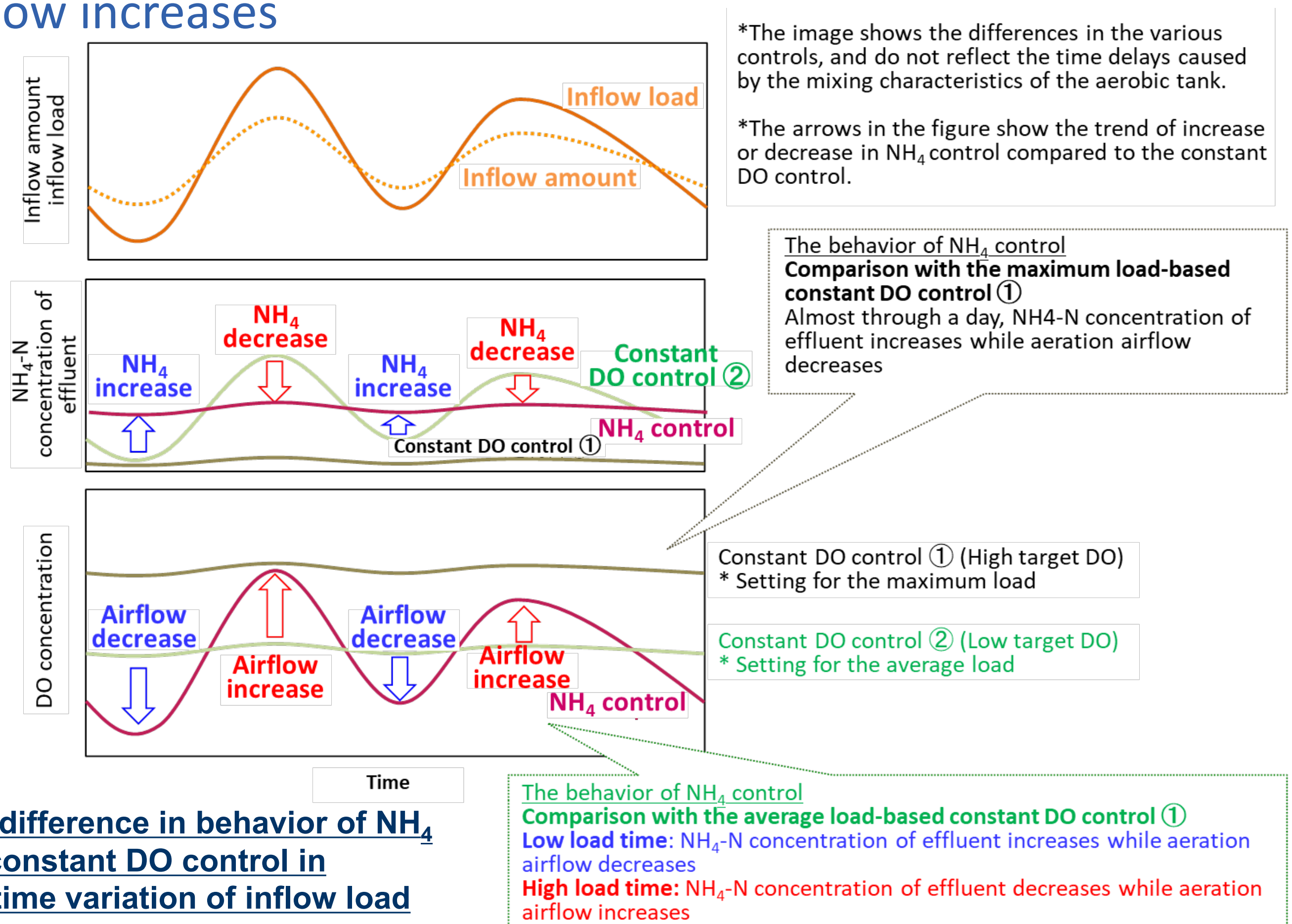
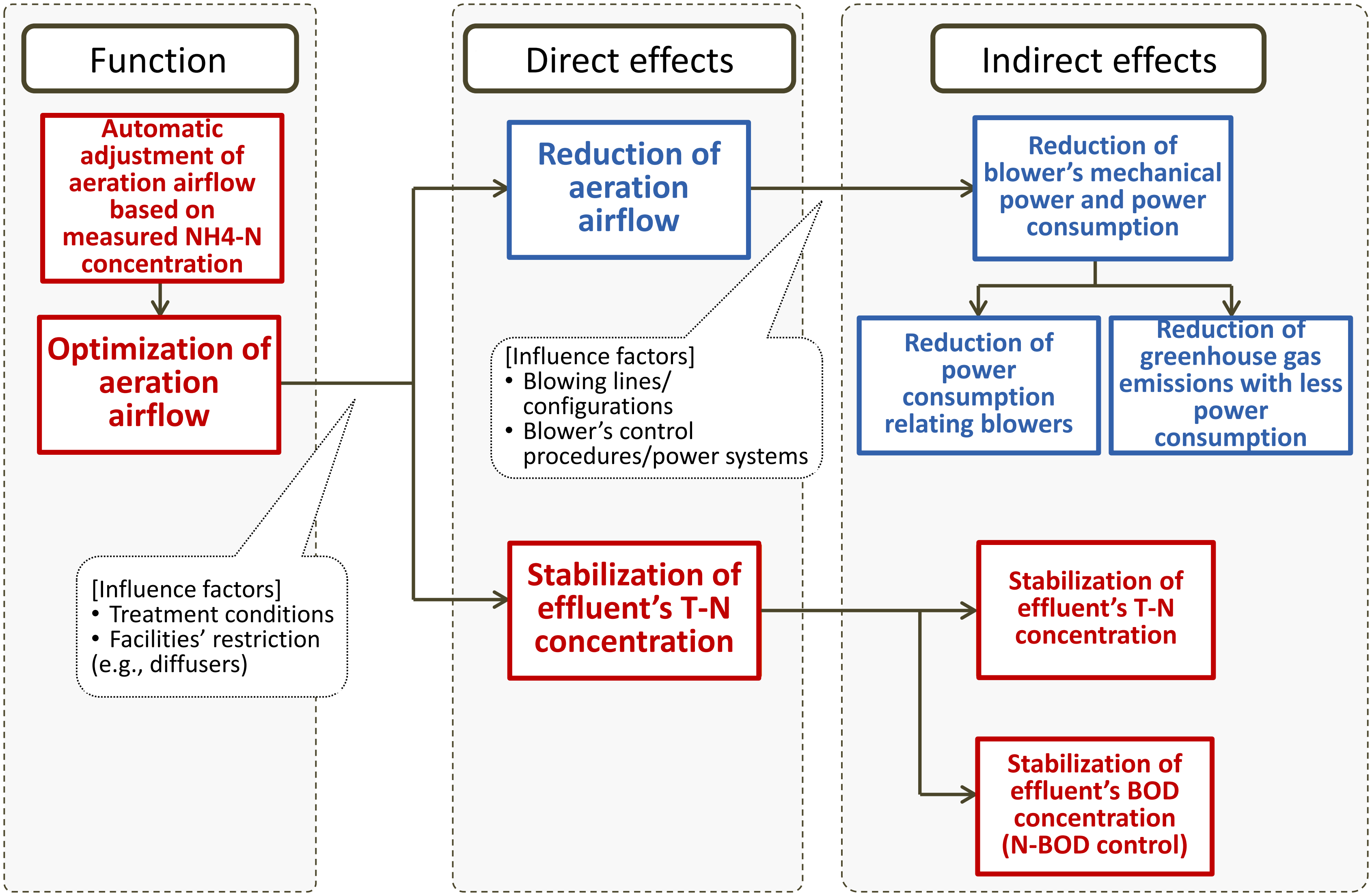


Image of the difference in behavior of NH_4 control and constant DO control in response to time variation of inflow load

● Benefits

➢ Benefits of introducing NH_4-based aeration control:

The relation between the function and adoption benefits of NH_4 control technology



● Function/Performance

➢ Results of Demonstration (System A-D):

Demonstrated over a long period using a single tank at each of the actual facilities
⇒Compare with the constant DO control as a scientific control

Results of aeration airflow reduction rate and effluent's NH4-N concentrations in the system A to D demonstrations

Control system	Control mode/desired value	Compared system	Reduction rate of aeration air flow		NH_4-N concentration of effluent*1 [mg/L]	
			Average reduction rate	Evaluation scheme	Demonstration	Control(constant DO control)
System A NH_4-fuzzy control	Test period Demonstration:1.8 yr. Control:1.0 yr.	Constant DO (1.5mg/L)	**20.4%**	• The reduction rate of airflow magnification against the period of constant DO control • The bottom row is the matching result of the demonstration and control periods.	0.9±0.7	0.9±0.8
	Test period Demonstration:1.0 yr. Control: 1.0 yr.	Constant DO (1.5mg/L)	**20.0%**		0.9±0.7	0.9±0.8
System B NH4-DO control	① Desired curve 1 (effluent quality)	Constant DO (2mg/L)	**6.4%**	• The reduction rate of air volume ratio (relative air volume) to control system • Excludes data on the lower limit of the airflow capability	0.4±0.2	0.0±0.1
	② Desired curve 3 (energy saving)	Constant DO (2mg/L)	**10.3%**		0.4±0.2	0.2±0.2
	③ Desired curve 3 (energy saving) + automatic correction	Constant DO (2mg/L)	**12.5%**	• The reduction rate of airflow magnification against the period of constant DO control	0.6±0.3	0.4±0.2
System C NH4-DO control	① Desired NH4-N: 3.8mg/L	Constant DO (2mg/L)	**11.0%**	• Reduction rate of the airflow magnification ratio relative to other series against the period of constant DO control	0.5±0.3	0.1±0.1
	② Desired NH4-N: 3.1-3.3mg/L	Constant DO (2mg/L)	**12.8%**		0.5±0.3	0.2±0.0
System D NH4-FF+FB control	① Desired NH4-N (FB): 2mg/L	Constant DO (2mg/L)	**10.5%**	• Reduction rate of aeration airflow per NH4-N load (vs. control tank with constant DO control) Since the comparison is based on the same period for two tanks sharing the same influent, this reduction rate is equivalent to the airflow's reduction rate. • Aeration airflow in the control tank corrected by ×0.88 (based on the actual results during the period of constant DO control in both tanks)	0.8±0.3	0.3±0.0
	② Desired NH4-N (FB): 1mg/L	Constant DO (2mg/L)	**14.5%**		0.3±0.0	0.3±0.0

*1.Period value and standard deviation. The original data are System A: 1-day average, System B: 1-day average (mode ①②), Spot value (mode ③), System C: 1-day average, System D: Spot value

● Function/Performance(continued)

- **Reduction of airflow rate:** Percent reduction of airflow rate compared to conventional constant DO control
  - ✓ Results of JS' demonstration: **10-20%**
  - ✓ Other domestic data: 10-30%
  - ✓ Overseas data: 10-20%

⇒ The demonstration results show that the new system is expected to reduce aeration airflow by **10%** or more than the conventional constant DO control

- **Stability of effluent quality:** NH_4-N concentration of effluent
  - ✓ Demonstration results of system A-D:
    - ◆ NH4 control: **0.3-0.9** mg/L(±**0.0-0.7** mg/L) * All data
      0.4-0.9 mg/L(±**0.2-0.7** mg/L) * Exclude values of grab sampling
    - ◆ Constant DO control: **0.1-0.9** mg/L(±**0.0-0.8** mg/L)

⇒ According to the demonstration results, the NH_4-N concentration (daily average water quality) of the effluent during the NH_4 control technology's operation period is **less than 1 mg/L in both average and standard deviation.**

● Function/Performance(continued)

➢ ASM simulation:

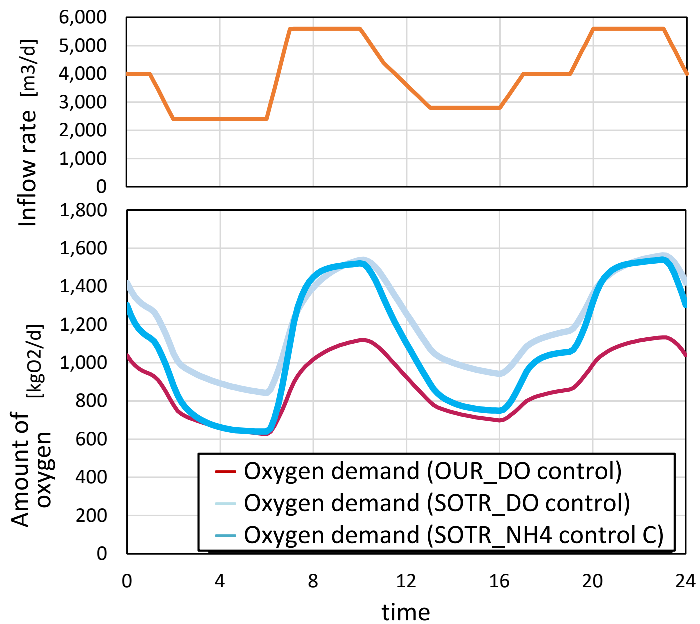
✓ **Computer simulation with the activated sludge model (ASM)** is beneficial for the following two purposes.

- ◆ Understanding principles and operation of the control
- ◆ Estimating the impact of various conditions

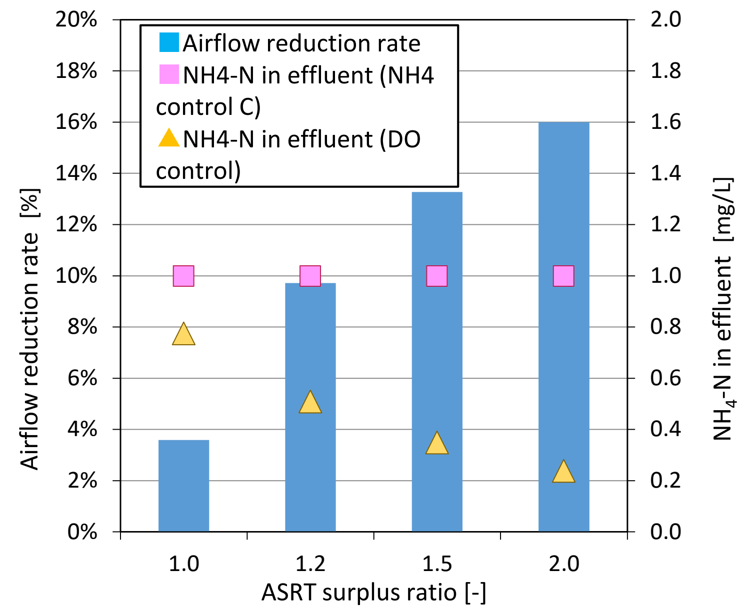
【Primary conditions】

- **Treatment process: CAS** (AOOO)
- **Aerobic tank HRT:** 10.0hr(daily average)
- **Water temperature:** 15.0℃ (Required ASRT for capacity calculation=7.9d)
- **Inflow load variation:** Peak water amount x 1.4, constant water quality
- **Biological reaction model :** ASM2d (Point Settler for final settling)

Example of visualizing tracking performance to oxygen demand



Example of presuming the impact of ASRT



● Cost Efficiency

➢ Estimating the cost recovery period at the prescribed aeration airflow reduction rate:

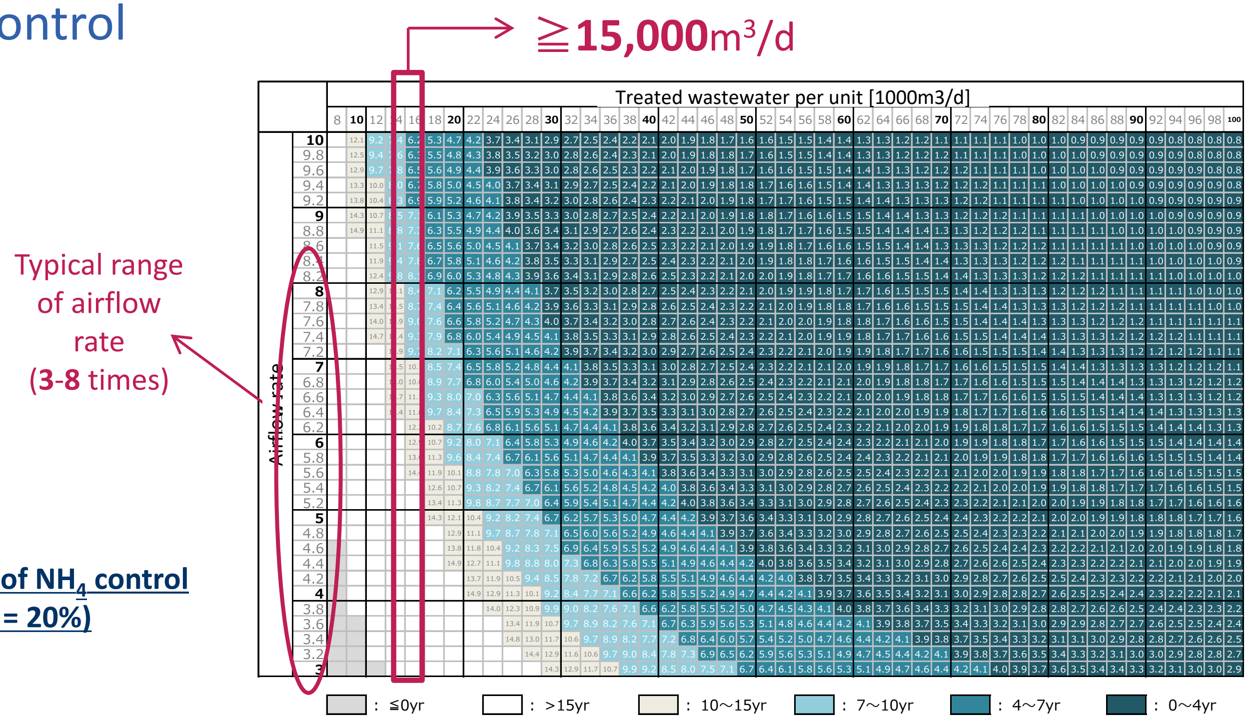
- ✓ **Costs of adoption:** construction cost(installation, remodel), operation costs(O&M costs of measuring instruments)
- ✓ **Cost of reduction:** electric power costs of blowers

> **⇒ The amount of water to be controlled per unit, which is economically beneficial against constant DO control, is about 15,000 to 30,000 m^3/d or more under the condition of a 10 to 20% reduction rate of aeration airflow.**

⇒The basic idea is to control multiple tanks at once

<u>* Typical amount (median) of treated wastewater per tank</u>

- 20-50MLD	:	**6,500**m^3/d
- 50-100MLD	:	**8,800**m^3/d
- 100MLD-	:	**11,500**m^3/d



<u>**Estimated cost recovery year for the adoption of NH_4 control technology (reduction rate of aeration airflow = 20%)**</u>

Conclusion

Evaluated the *Aeration Control Technology Using NH4 Sensor* based on the demonstration results of four different technologies

☺ Important evaluation results

【Function/performance】

- Reduction effects of aeration airflow : **10% or more** against constant DO control
- Stabilization effects of effluent quality (NH_4-N) : The mean and standard deviation are both **less than 1 mg/L**

【Profitability】

- The control technology will not be profitable unless one unit's wastewater volume is **more than 15,000 to 30,000 m^3/d**

【Future issues】

- Data accumulation of demonstration/actual operation
- Scheme/achievements for bulk control of multiple tanks
- New control scheme/technology
- Prediction procedure of adoption effects
- Development of various nitrification management (seasonal operation, etc.)
- Improvement and cost reduction of NH_4 Sensor

Thank you for your attention

【Acknowledgments】

- We sincerely appreciate the cooperation of the local governments and the parties involved in the joint research, etc., in the demonstration of each control technology.
- We also thank the JS Technology Evaluation Committee and the Technical Committee members for their deliberations in the evaluation.