Innovative Circular Technologies for Harmful Nitrogen Compounds/ To Solve Planetary Boundary Issues

Theme 2. Recycling nitrogen compounds in wastewater to ammonia resource
Theme 2-1. R&D on microbial conversion of nitrogen compounds to ammonia

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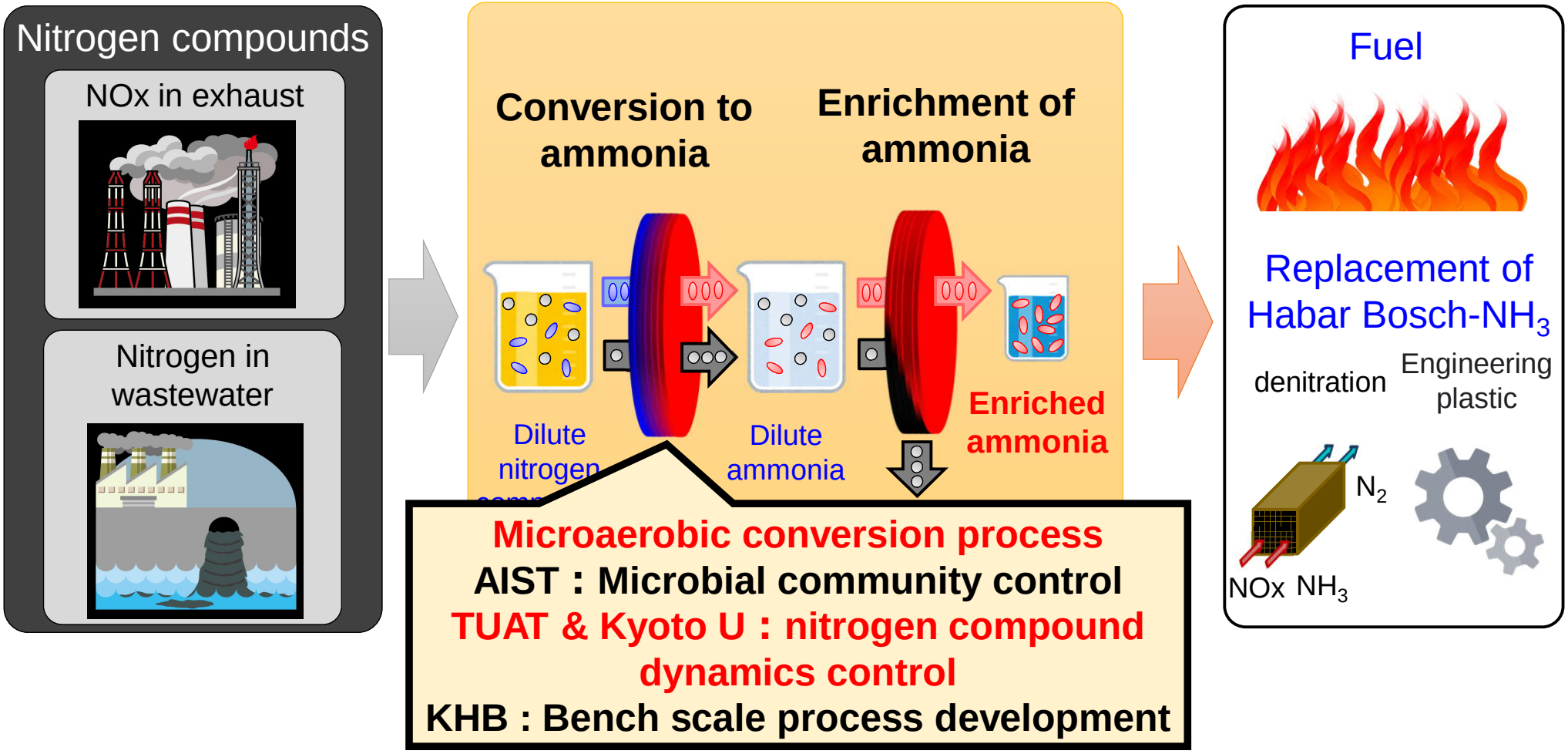
Implementing organizations : National Institute of Advanced Industrial Science and Technology (AIST),
The University of Tokyo, Waseda University,
Tokyo University of Agriculture and Technology, Kobe University,
Osaka University, Yamaguchi University, Kyowa Hakko Bio Co., Ltd.,
ASTOM Corporation, Toyobo Co., Ltd., FUSO Corporation, Ube Industries, Ltd,

Position in the Project



Target of Theme 2 for FY2029：Pilot-scale demonstration (5～15 m^3/d) of recovery and condensation of ammonium from wastewater

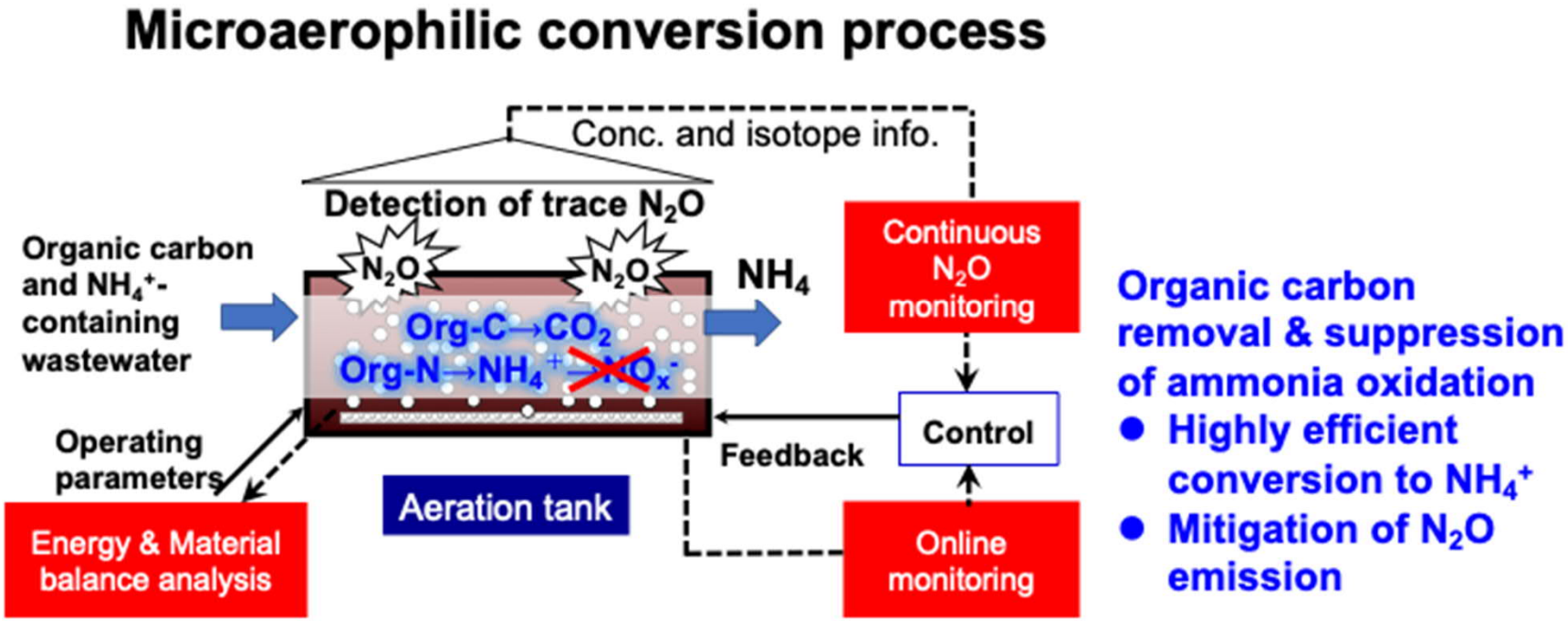
Position of TUAT and Kyoto Univ.: Establishing operation conditions for highly efficient NH_4^+ conversion and N_2O emission mitigation

Target of TUAT and Kyoto Univ. for FY 2029: Support for the pilot-scale demonstration by controlling nitrogen compound dynamics

Details and Items of R&D

R&D objectives

Evaluating dynamics of nitrogen compounds to develop a microaerophilic process to achieve highly efficient NH_4^+ conversion and minimize N_2O emission



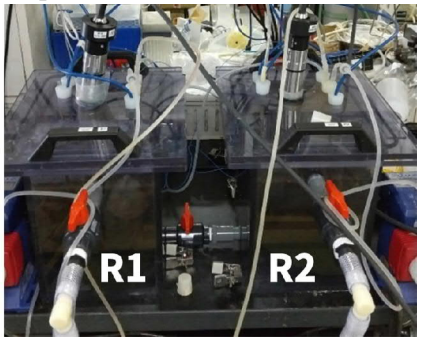
R&D items

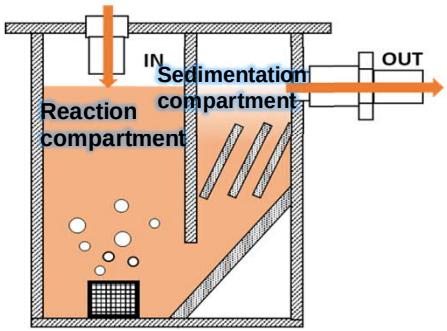
- Development of operation management based on nitrogen compound dynamics control (TUAT)
- Energy and material balance evaluation and N_2O emission mitigation strategy development (Kyoto Univ.)

Achievement (1) Performances of a simplified reactor (TUAT)

- Stable suppression of ammonia oxidation and N_2O emission by a simplified laboratory-scale reactor fed with synthetic wastewater (extended by the results attained under the NEDO New Energy and Environment Program)

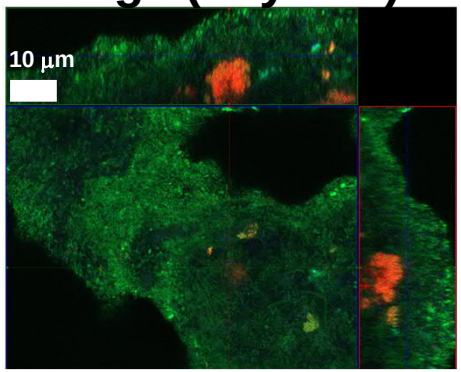
◆Reactor configuration and operation conditions





Period [day]	HRT [hr]	SRT [day]	Aeration rate [L/min]
0~250	10	30	2.0

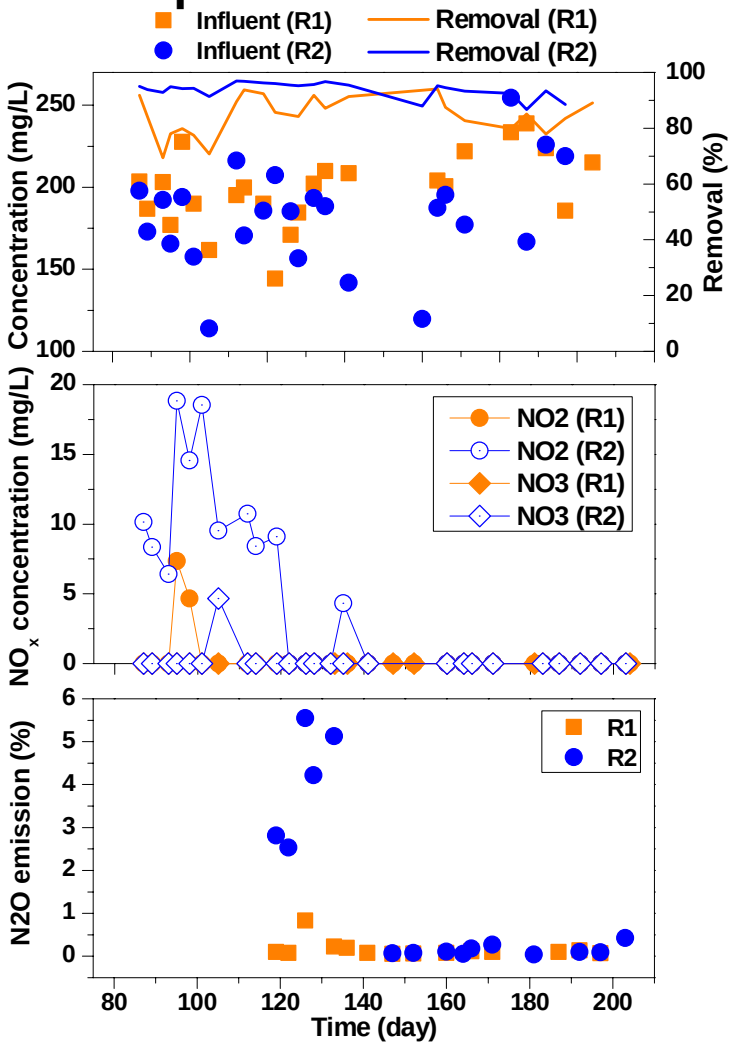
◆Spatial bacterial distribution in activated sludge (day 156)



Blue: *Nitrospira*
Red: AOB
Green: All bacteria

Limited oxygen supply
- **Suppression of growth of ammonia-oxidizing bacteria (AOB)**
- **Limited localization of AOB in activated sludge**

◆Reactor performances

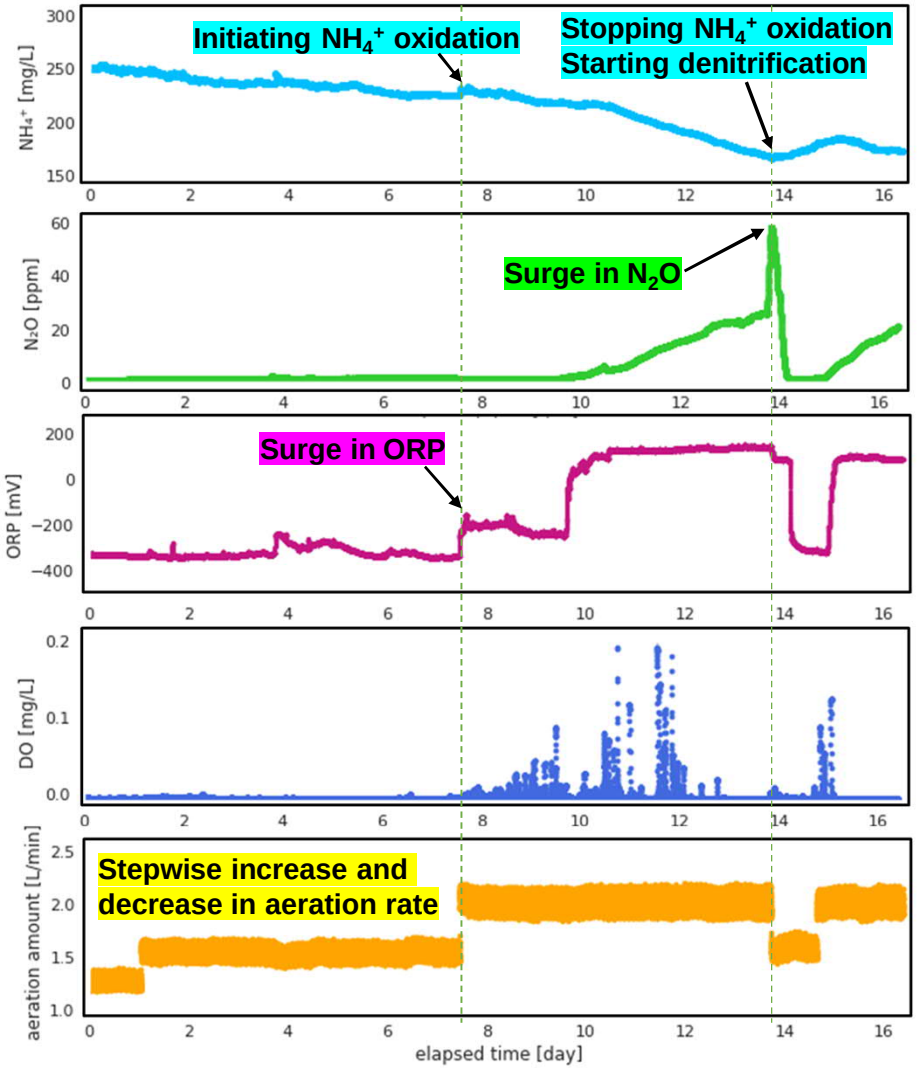


- **Stable organic carbon removal**
- **Suppression of ammonia oxidation**
- **N_2O emission mitigation (Emission factor <0.1%)**

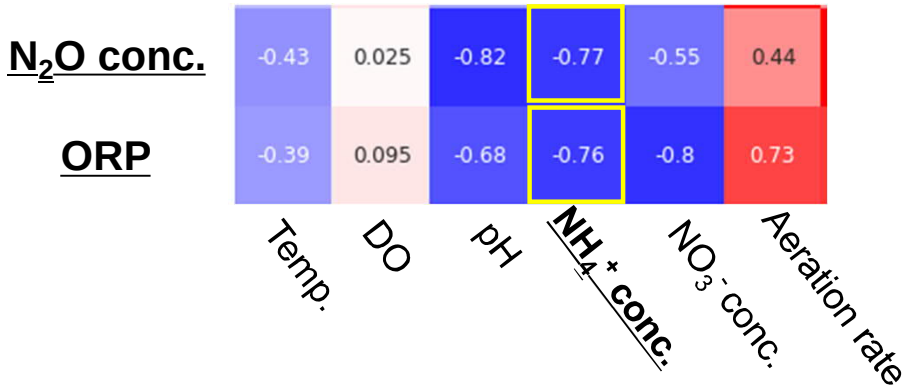
Achievement (2) Dynamics of performance with actual industrial wastewater (TUAT)

- Identification of operating parameters rapidly responsive to NH_4^+ fluctuations in the microaerophilic conversion process

◆ Dynamics of online monitoring parameters



◆ Correlations of ORP & N_2O with monitoring parameters



- Extraction of significant parameters by the Pearson correlation coefficient
- N_2O & ORP have high correlations with NH_4^+ conc. and aeration rates

◆ Reactor performance with industrial wastewater

Component	Concentration [mg/L]
TOC	755
TN	268
NH_4^+-N	259
NO_2^--N	1.56
NO_3^--N	0

Operation Condition	
Inflow load	0.50 kg-C/m³/day
HRT	40 h

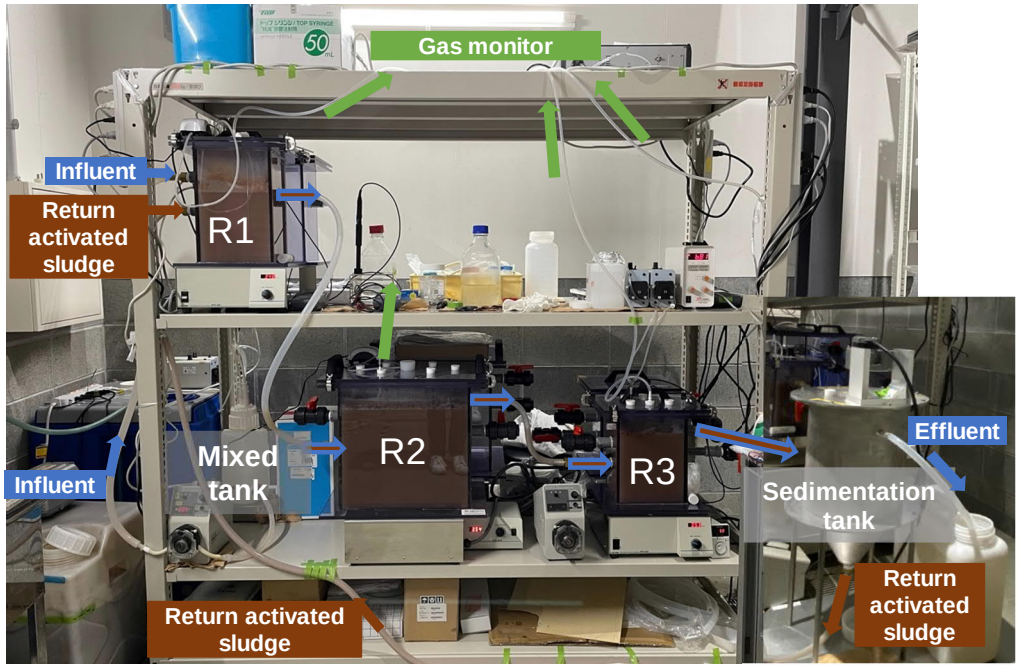
Contents	Conversion [%]
TOC	ca. 78%
T-N	ca. 93%
NH_4-N	ca. 86%

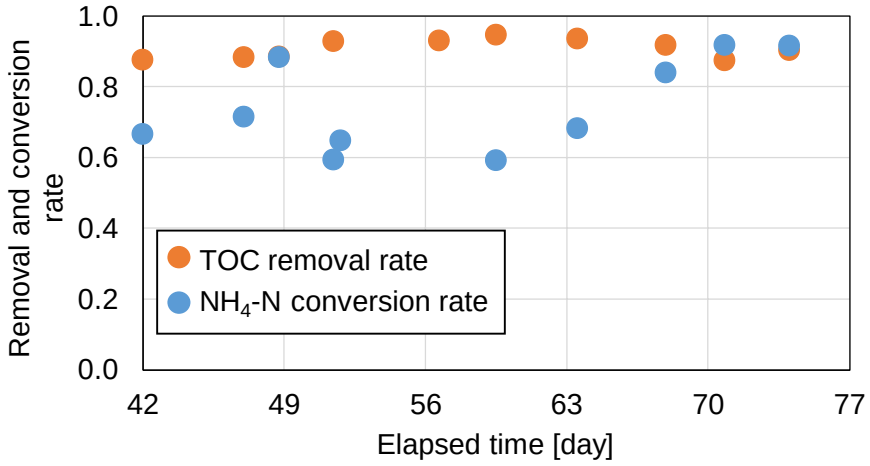
- Stable conversion of N compounds to NH_4^+

- Unwanted NH_4^+ oxidation→tracked by ORP
- Stopping NH_4^+ oxidation →tracked by N_2O conc.
- Significance in ORP and N_2O monitoring

Achievement (3) Construction of a microaerophilic system and performances (Kyoto Univ.)

- Construction of a laboratory-scale microaerophilic system for conversion from organic nitrogen to ammonia in wastewater
- The system has started up and the identification of key parameters for ammonia conversion is underway





Operation conditions

Startup experiment was implemented (74 day)

Stable operation was achieved from day 42

The tank R2 was incorporated on day 22 and sludge withdrawal was initiated on day 42

Influent wastewater (Synthetic wastewater)

- Total N (TN) = ca. 480 mg/L, NH_4-N = ca. 370 mg/L
- Total organic carbon (TOC) = ca. 320 mg/L

MLSS = ca. 2500 mg/L

HRT = 30 hrs, SRT = 30 days

	Volume (L)	Ave. aeration rate (L/min)	DO (mg/L)
R1	8.0	0.96	0.01
R2	26.2	0.65	0.01
R3	5.2	0.60	0.5

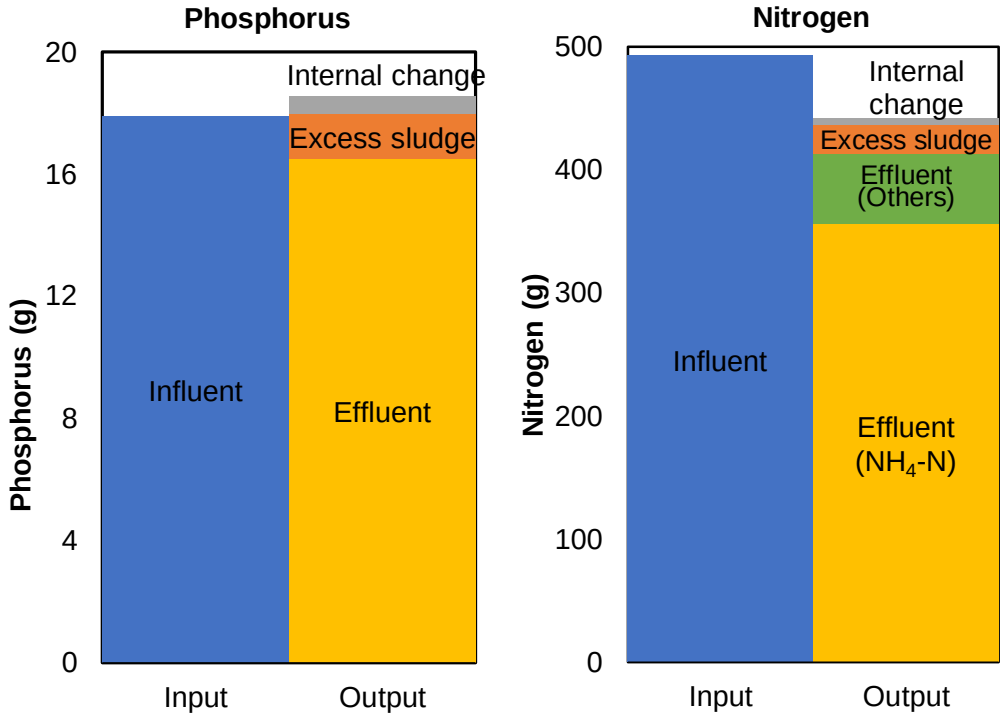
- TOC removal efficiency = ca. 91%
- NH_4-N conversion efficiency* = ca. 75%

(*Percentage of eff. NH_4-N over inf. TN conc.)

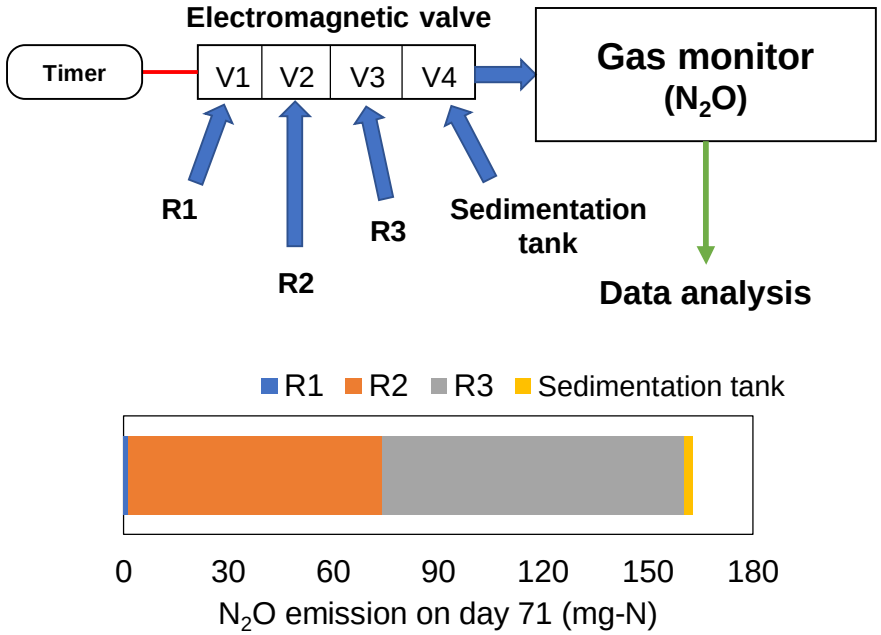
Achievement (4) Nitrogen and phosphorus balances in a microaerophilic system (Kyoto Univ)

- Evaluation of nitrogen and phosphorus balances at the startup experiment
- Estimation of an N_2O emission factor via the continuous monitoring of gaseous N_2O

Mass balance (42-74 day)



The amount of G-N_2O emission from each reactor



- The amount of effluent P was ca. 103% of influent P.
  → Phosphorus balance was ensured
- The amount of effluent N was ca. 90% of effluent N (including the internal change)
  → Nitrogen loss (ca. 10%) could be due to the emissions of N_2 or N_2O

- The N_2O emission factor on day 71: ca. 1%
  (Only gaseous N_2O was considered)
- The amount of D-N_2O will be taken into analysis

Summary

Position in the project

R&D of microaerobic conversion process from nitrogen compounds to NH_4^+

Target for FY 2029

Construction and demonstration of a pilot-scale microaerobic conversion process for ammonium recovery using actual wastewater

R&D items

- Development of operation management based on nitrogen compound dynamics control (TUAT)
- Energy and material balance evaluation and N_2O emission mitigation strategy development (Kyoto Univ.)

Achievement

(TUAT)

- Stable conversion to ammonia using a simplified reactor fed with actual industrial wastewater
- Identification of online monitoring parameters to indicate start/stop points of ammonia oxidation

(Kyoto Univ.)

- Evaluation of nitrogen and phosphorus balances at the startup experiment
- Estimation of an N_2O emission factor via continuous online gaseous N_2O monitoring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