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Discussion about Cause of Nitrous Oxide (N_2O) Emission in Wastewater Treatment Plant, Based on Long-Term Continuous Measurement

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Greenhouse Gas (GHG) from Wastewater Treatment

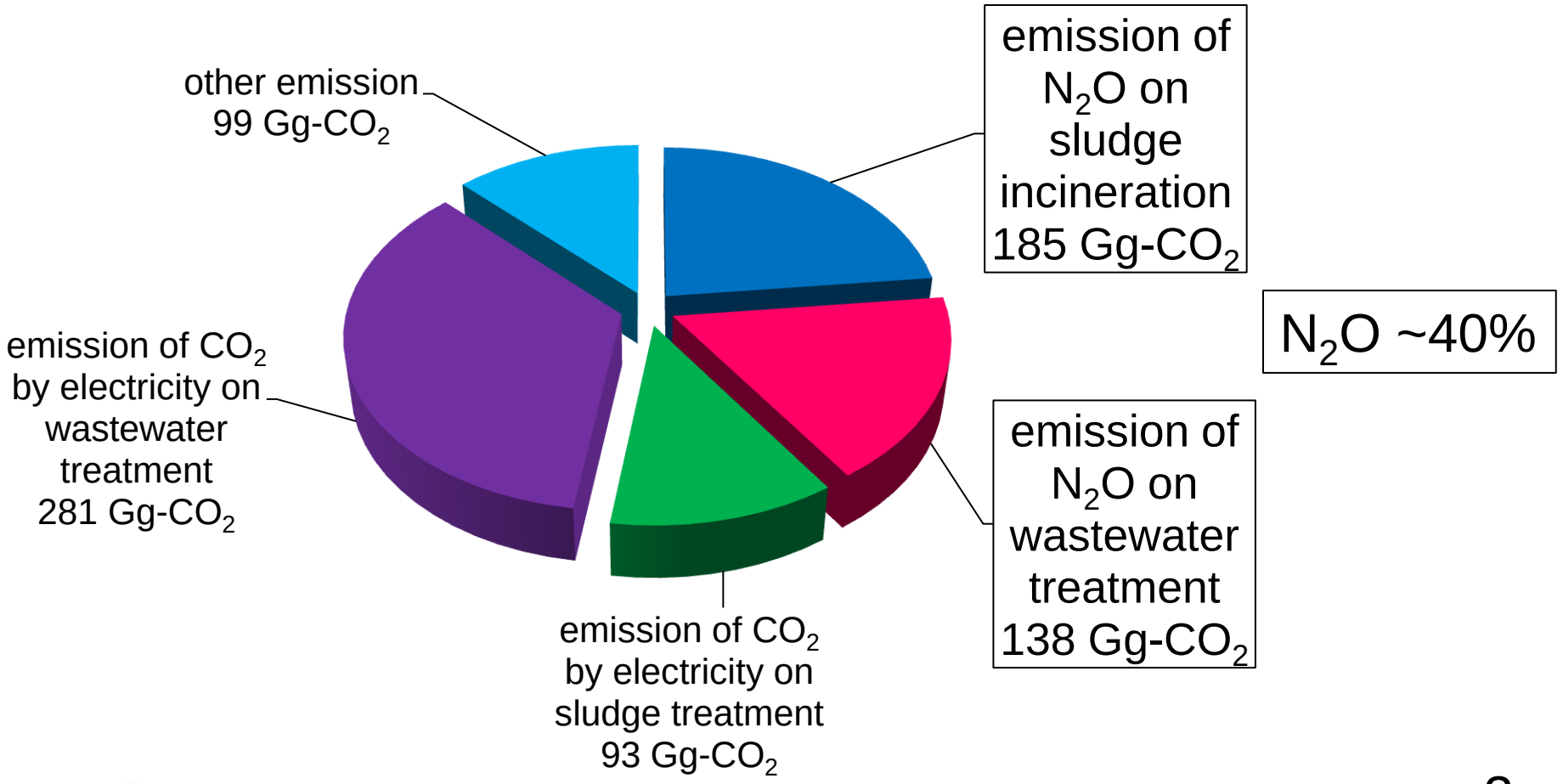
	CO_2 (carbon dioxide)	N_2O (nitrous oxide)	CH_4 (methane)
Wastewater Treatment	Electricity Consumption	Byproduct through Nitrogen Removal	Release of Dissolved CH_4 in Influent or Return Sludge
Sludge Treatment	Usage of Fuel	Byproduct of Sludge Incineration	Leakage from Anaerobic Digestion

Proportion of each GHG in Total Emission (2009)

	CO_2	N_2O	CH_4	others
USA	84	4	10	2
Japan	94	2	2	2

http://unfccc.int/resource/docs/2011/sbi/eng/09.pdf

Inventory of GHG
from the Bureau of Sewerage, Tokyo Metropolitan Government



Emission Factors in Japan

- Defined in “the Act on Promotion of Global Warming Countermeasures”
- Values Different from ICPP and other Countries
- Estimated from Measured Values in some Facilities for each Factors
- Allowed to Use Actual Data

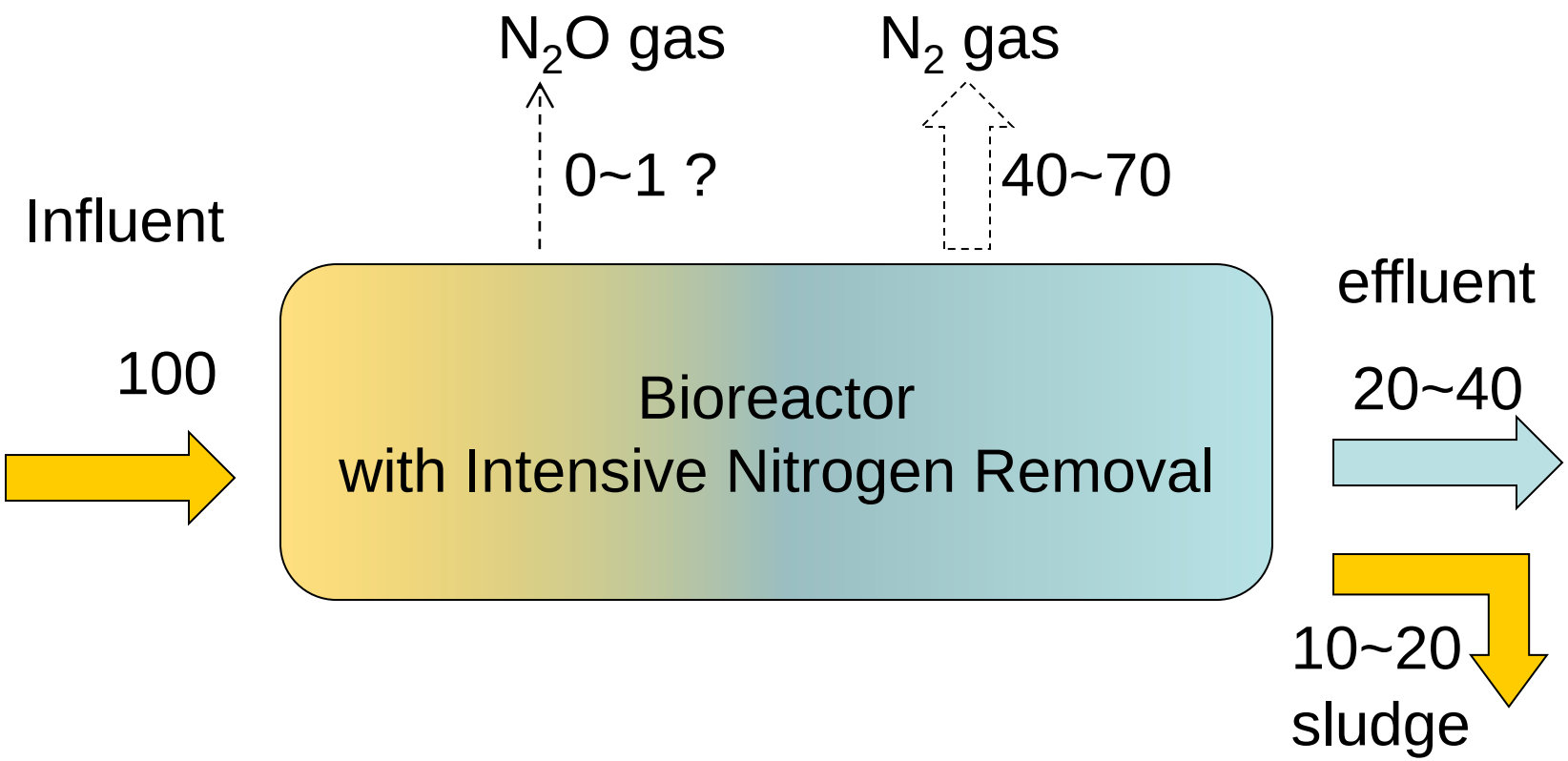
e.g. N_2O emission
= Emission Factor × Amount of Treated Wastewater

Comparison of Emission Factors of N_2O on Biological Treatment

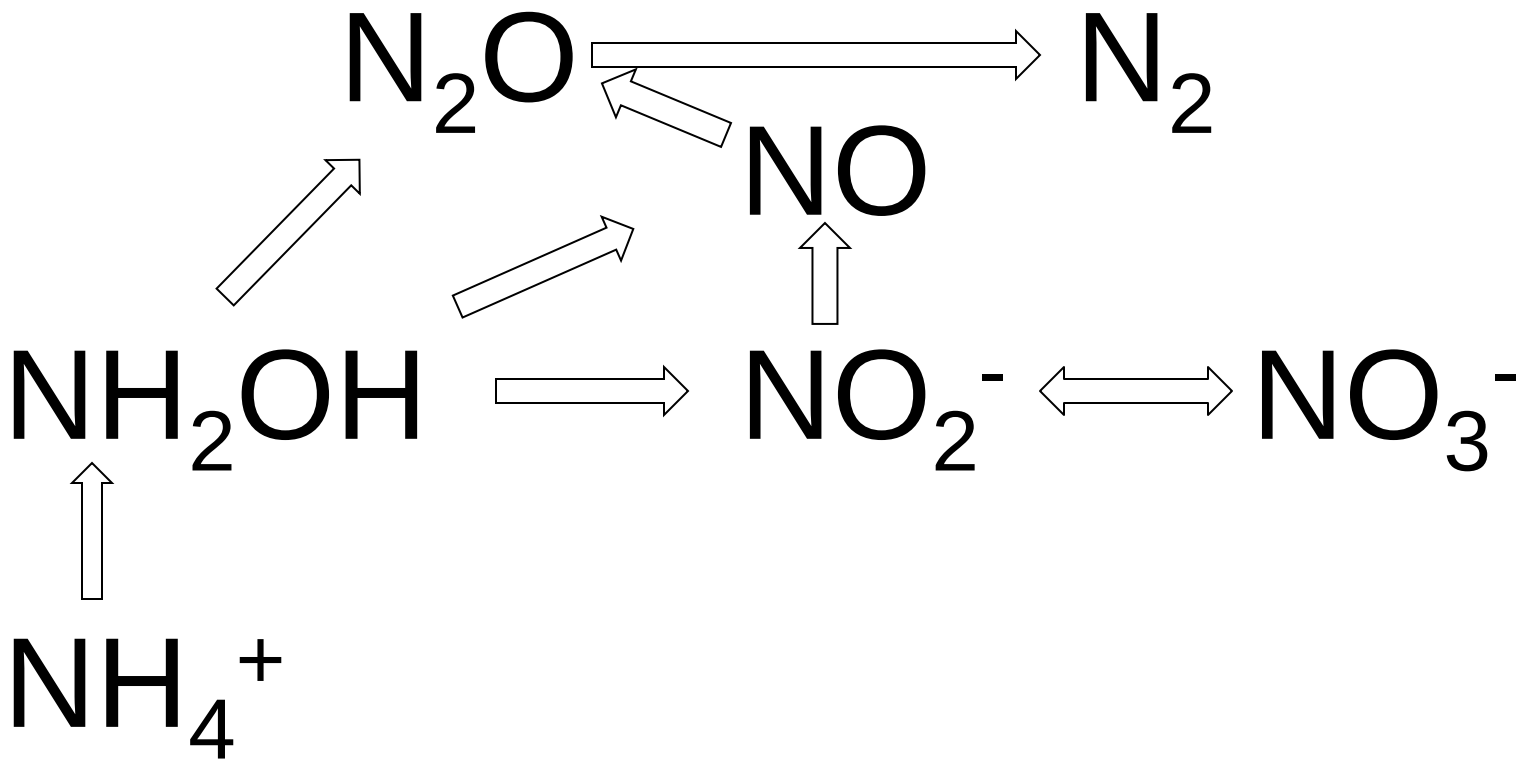
	N_2O emission factor [g-N_2O/person/year]
US EPA	7 *1
IPCC	3.2 (2 - 8) *2
Japan	30 *3,4
WERF Report	0.2 - 140

*1 with Intensive Nitrification and Denitrification
*2 Estimated from field testing data at a WWTP before 1995
*3 Estimated as Averaged Value of 8 data from 3 WWTPs before 1998
*4 Converted from 0.00016 [kg-N_2O/m^3] using Population of Tokyo District

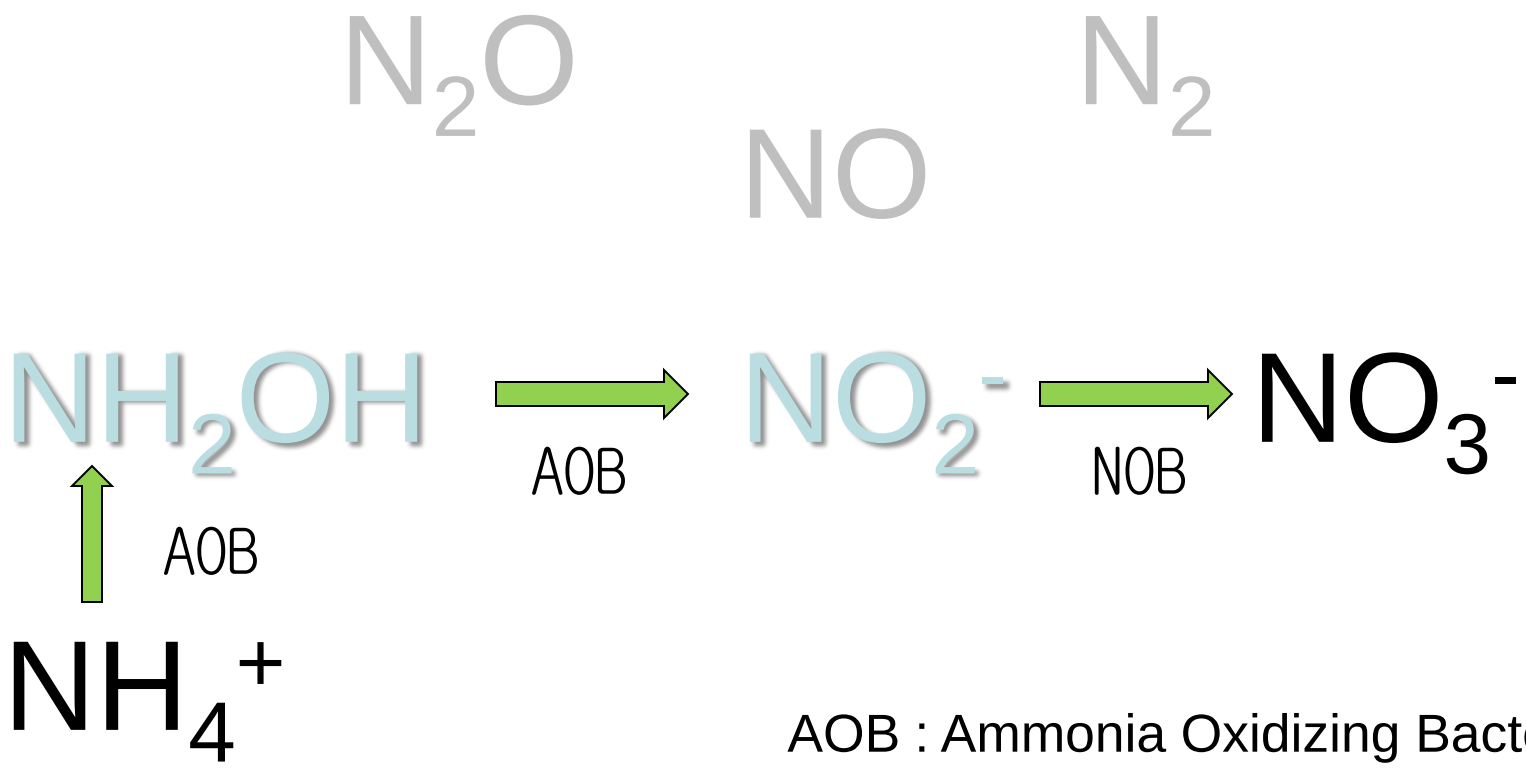
Balance of Nitrogen through Biological Nitrogen Removal



Pathways of Nitrogen Removal
- Possible Reactions -

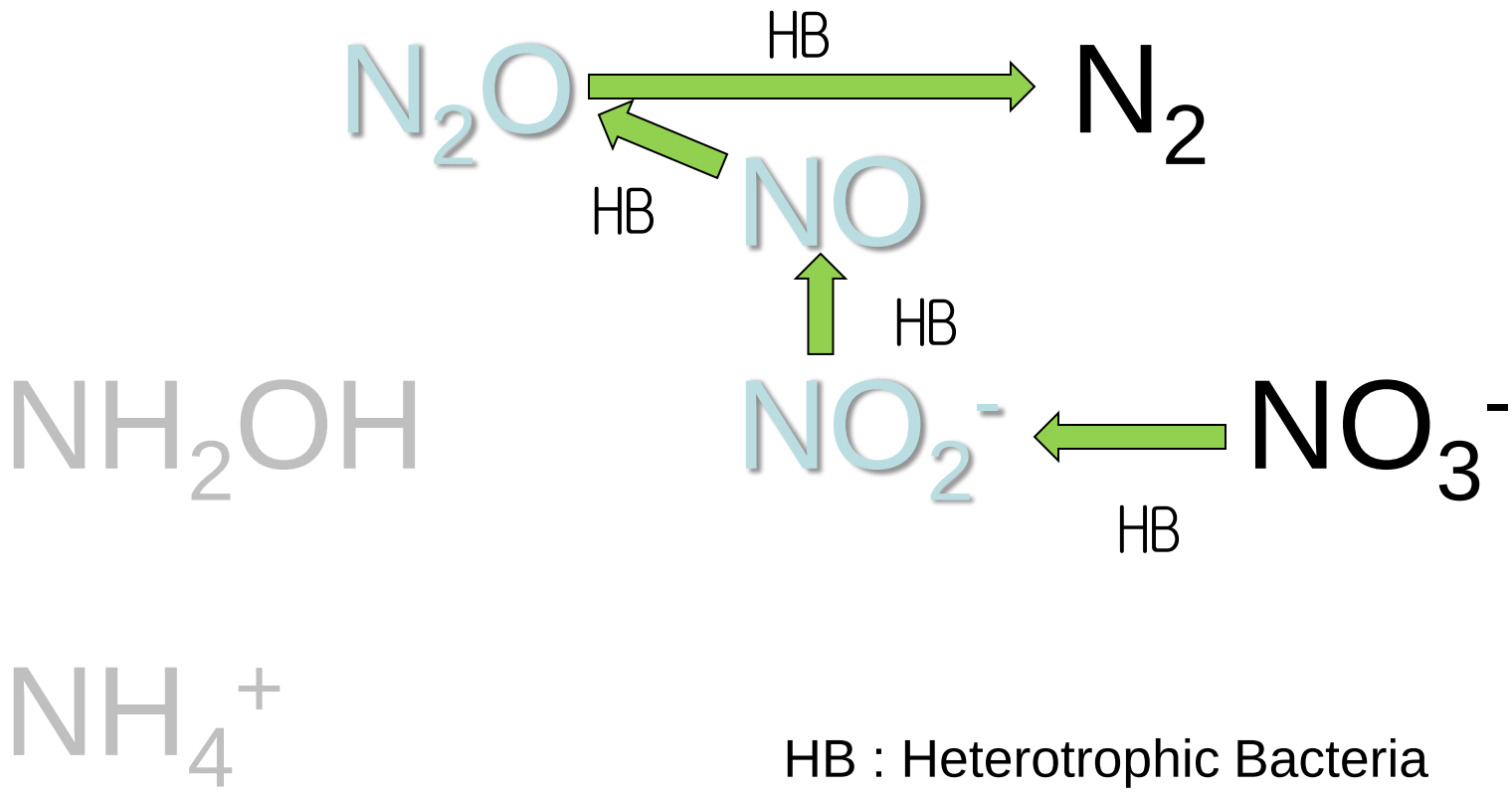


Pathways of Nitrogen Removal - Ideal Nitrification -



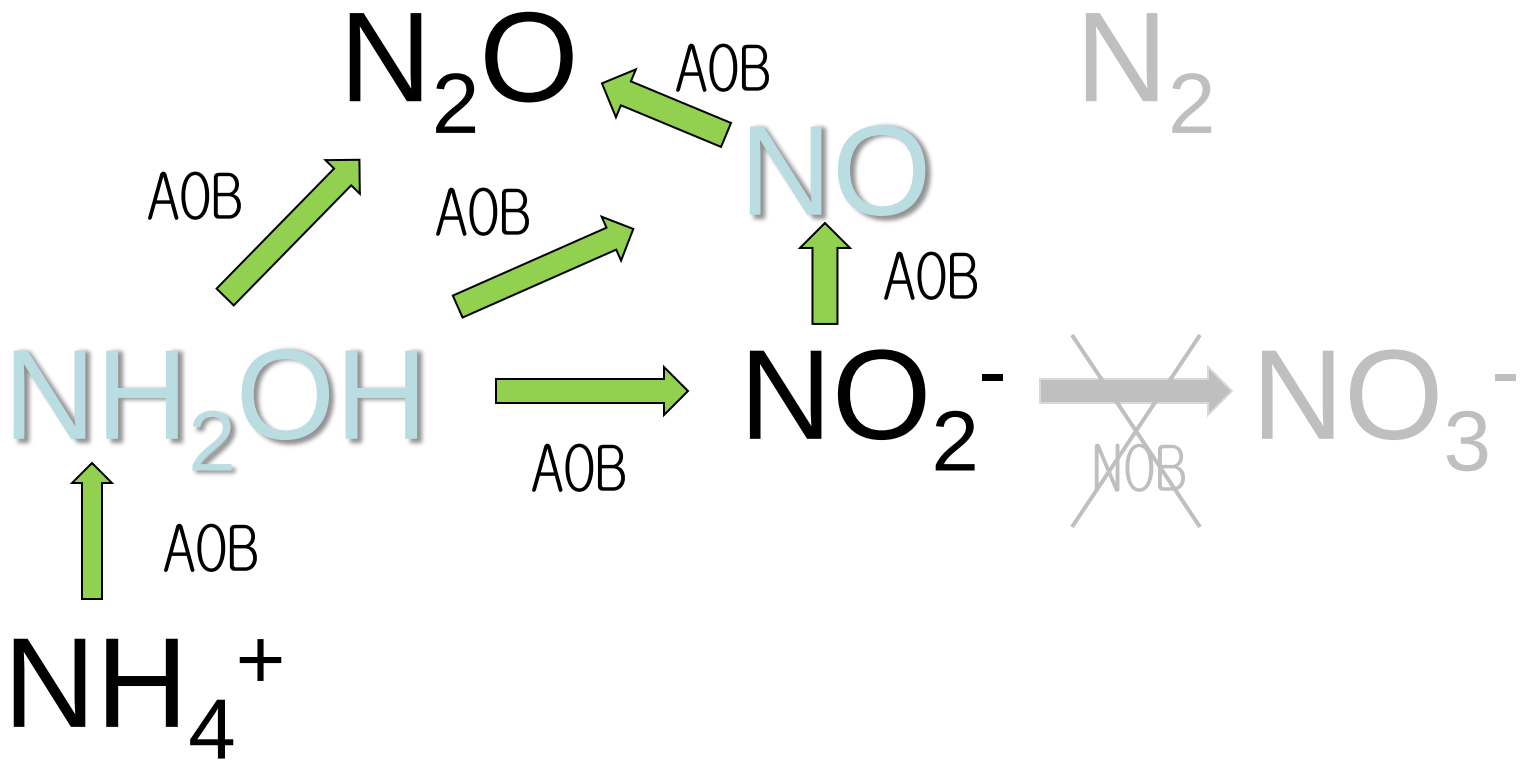
AOB : Ammonia Oxidizing Bacteria
NOB : Nitrite Oxidizing Bacteria

Pathways of Nitrogen Removal - Ideal Denitrification -



HB : Heterotrophic Bacteria

Pathways of Nitrogen Removal - Insufficient Nitrification -



Outline of Study

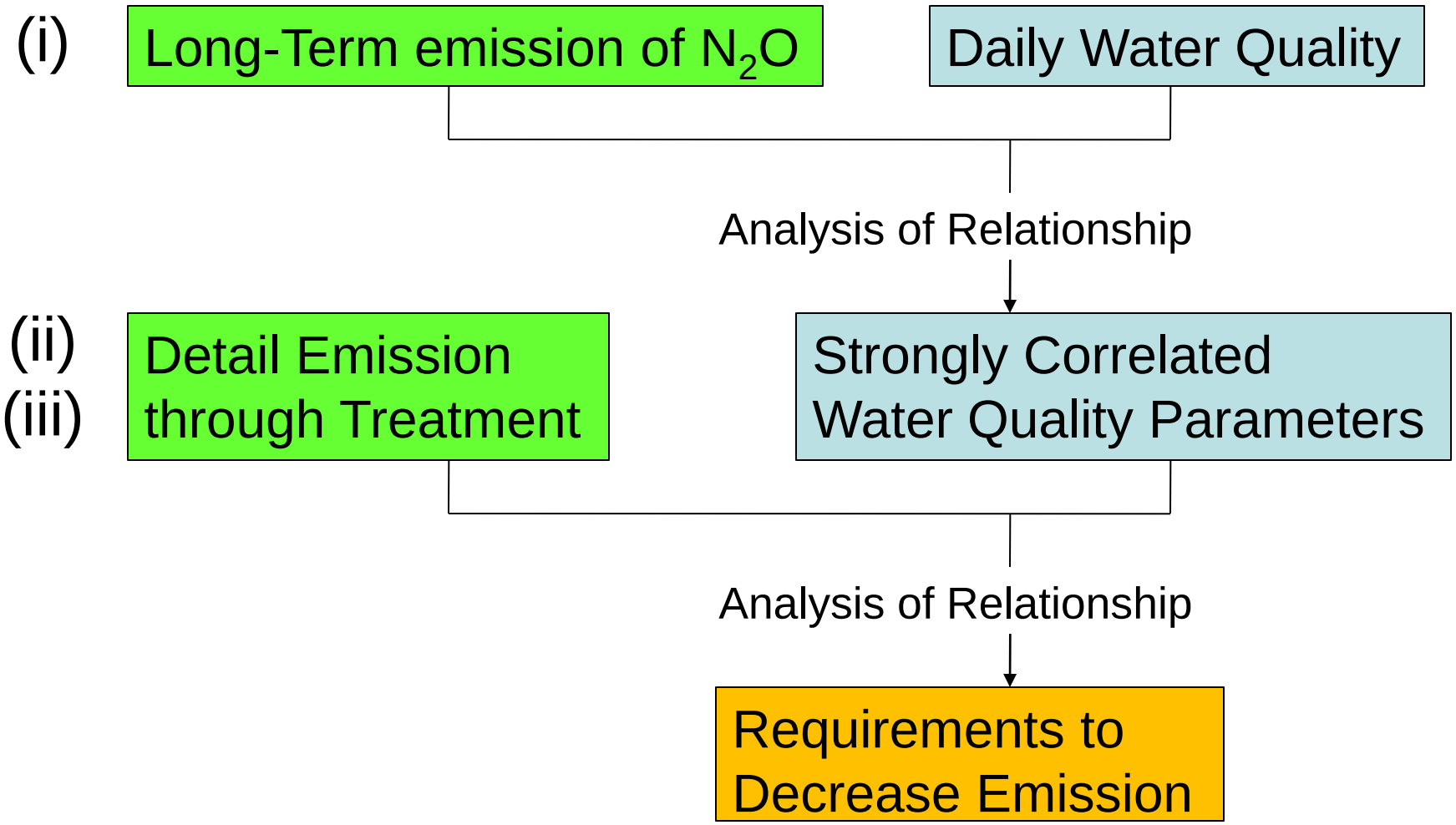
(i) Long Term Continuous N_2O Measurement

(ii) Relationship of Nitrification Progress and N_2O Emissions in Each Part of Reactor

(iii) Continuous Measurements of N_2O and NO_2^--N Concentration in Biological Reactor

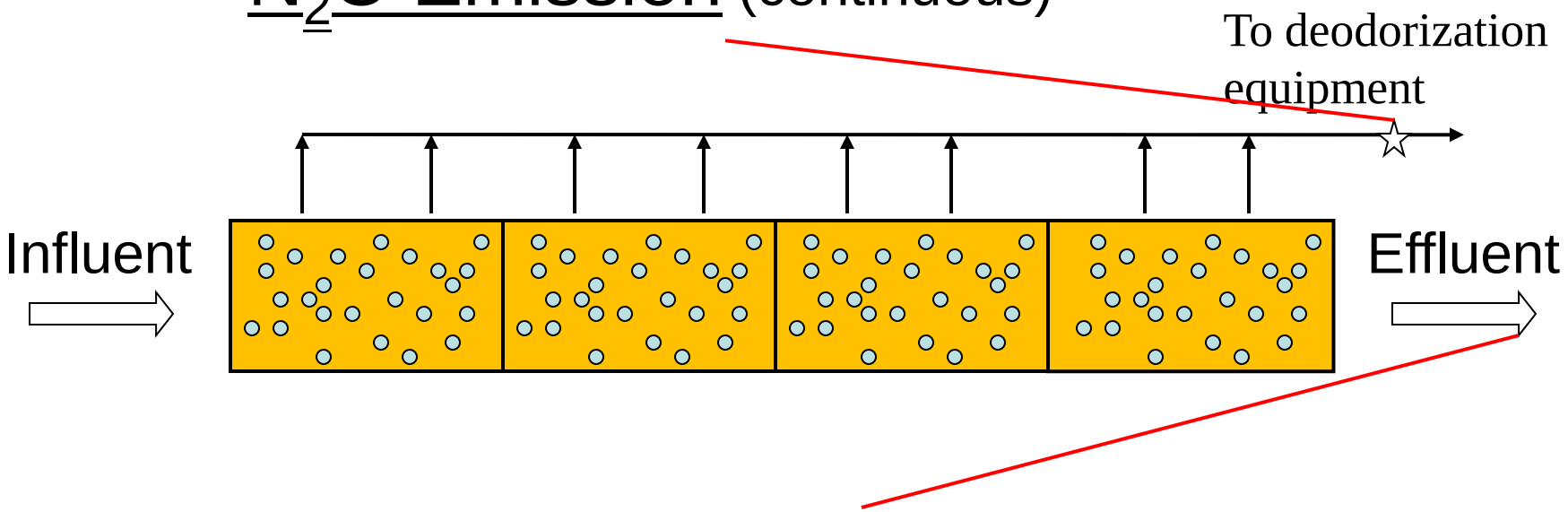
	N_2O Measurement		Water Quality Parameters			Measurement Period
	Site	Data Collection	Site	Data Collection	Items	
(i)	Whole Emission	Continuous	Effluent	Grab Sampling	Various	One Year
(ii)	Each Zone	Continuous	Each Zone	Grab Sampling	NO_2-N, NO_3-N	Two Days
(iii)	Last Zone	Continuous	Last Zone	Continuous	NO_2-N	Ten Days

Scheme of this Study



Sampling Site

N_2O Emission (continuous)



Daily Water Quality Parameters (grab sampling)

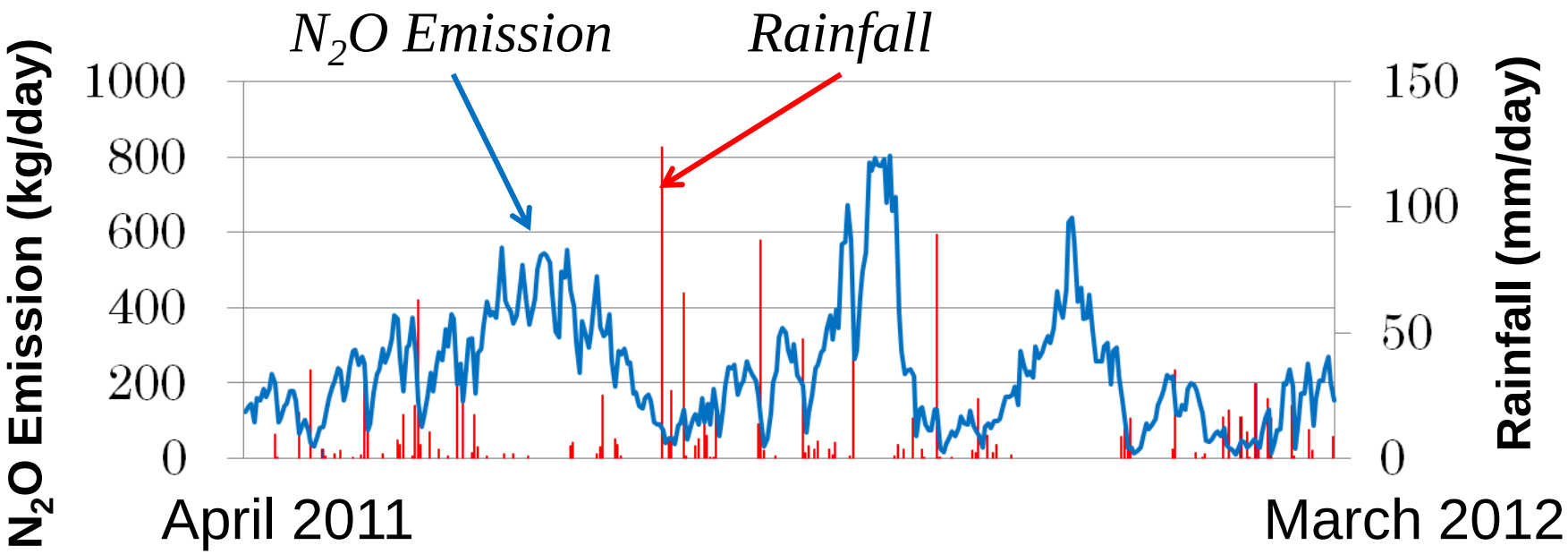
How to Measure N_2O Continuously

Covering

Exhaust Duct
for Deodorization

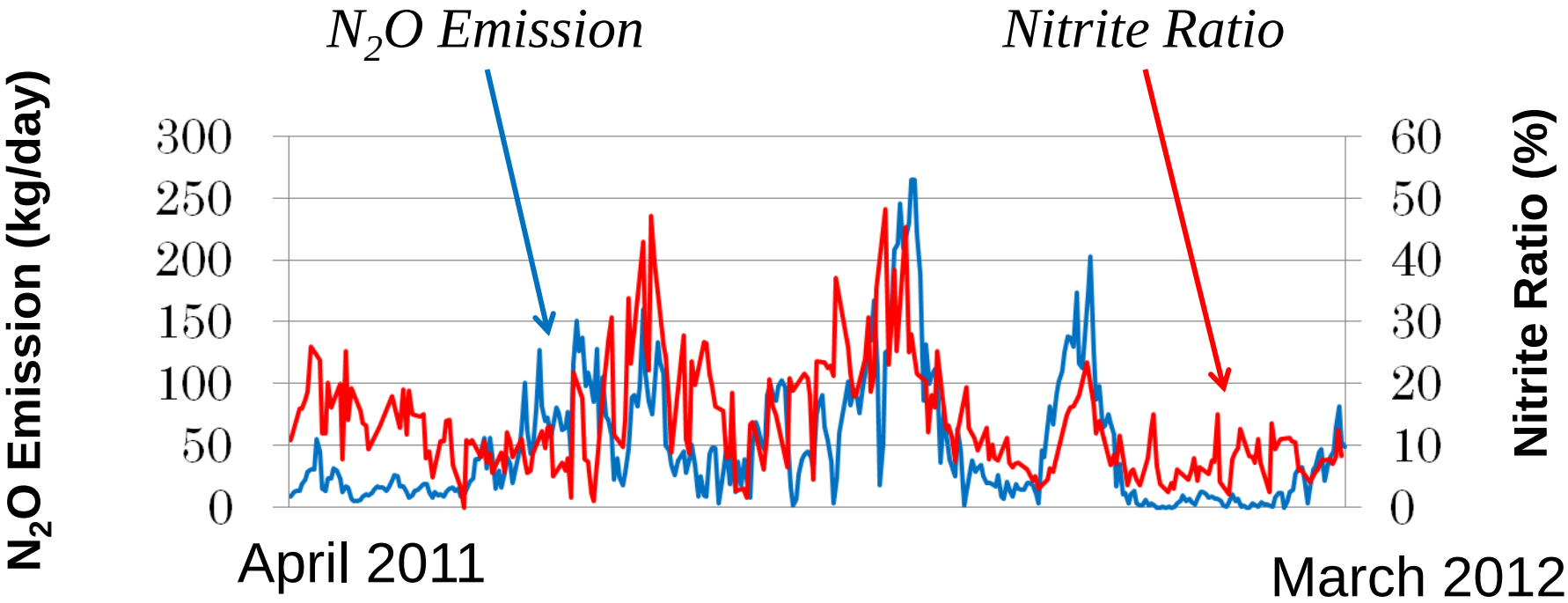
Continuous N_2O
Measurement Instrument

N_2O Emission all through the Year



- Wide Fluctuation
- Declining after Rainfall

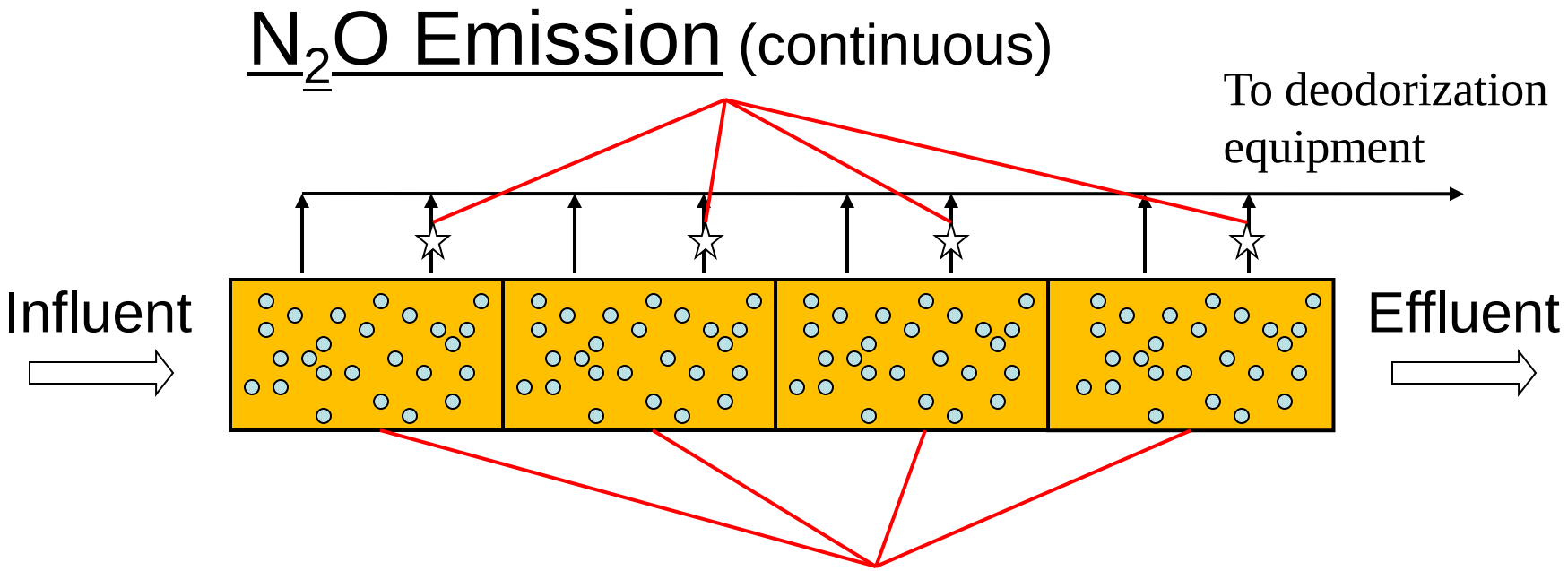
N_2O Emission vs. Nitrification



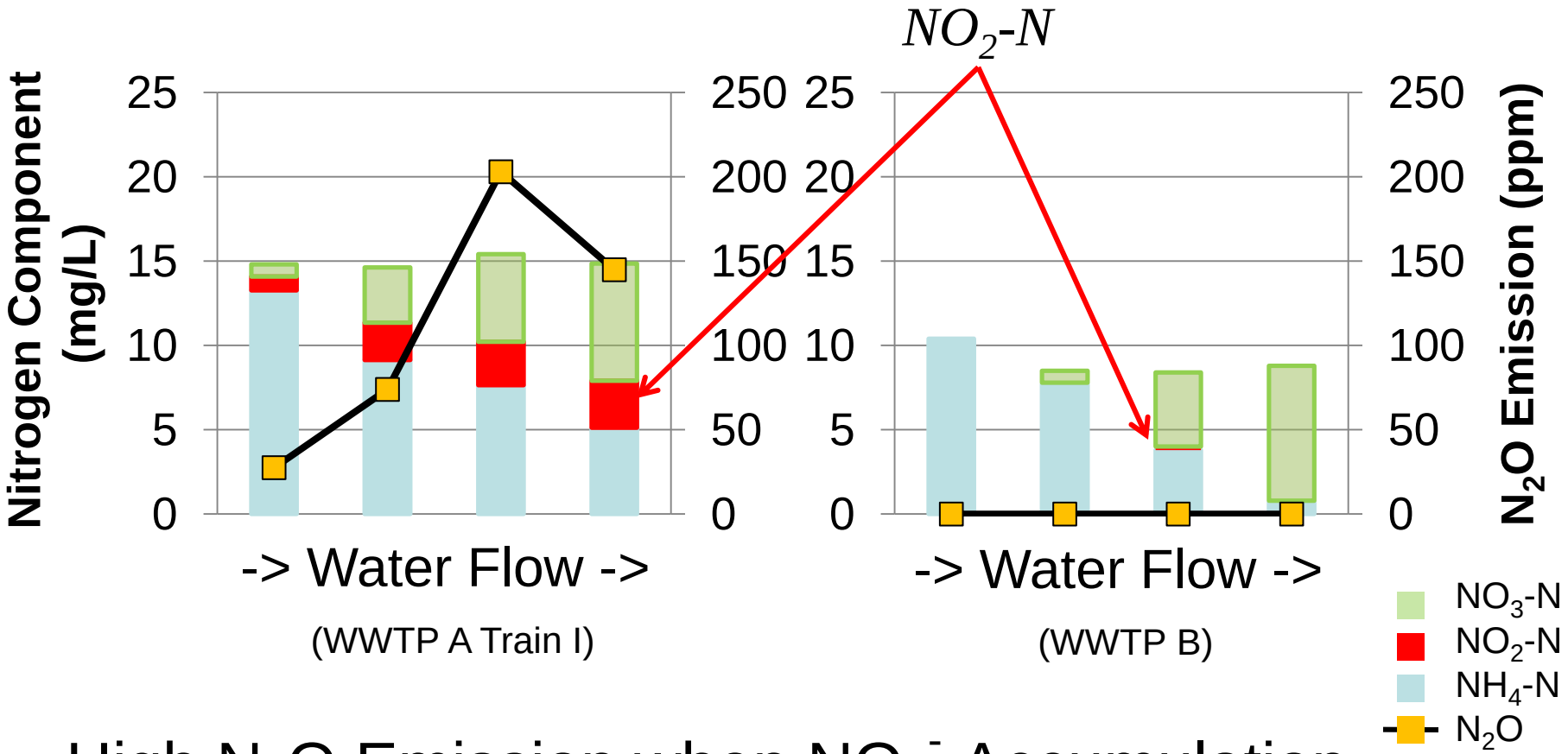
$$\text{Nitrite Ratio (\%)} = \frac{NO_2\text{-}N_{effluent}}{NH_4\text{-}N_{effluent} + NO_2\text{-}N_{effluent} + NO_3\text{-}N_{effluent}} \times 100$$

- Similar Trend of Residual NO_2^- with N_2O Emission

Sampling Site

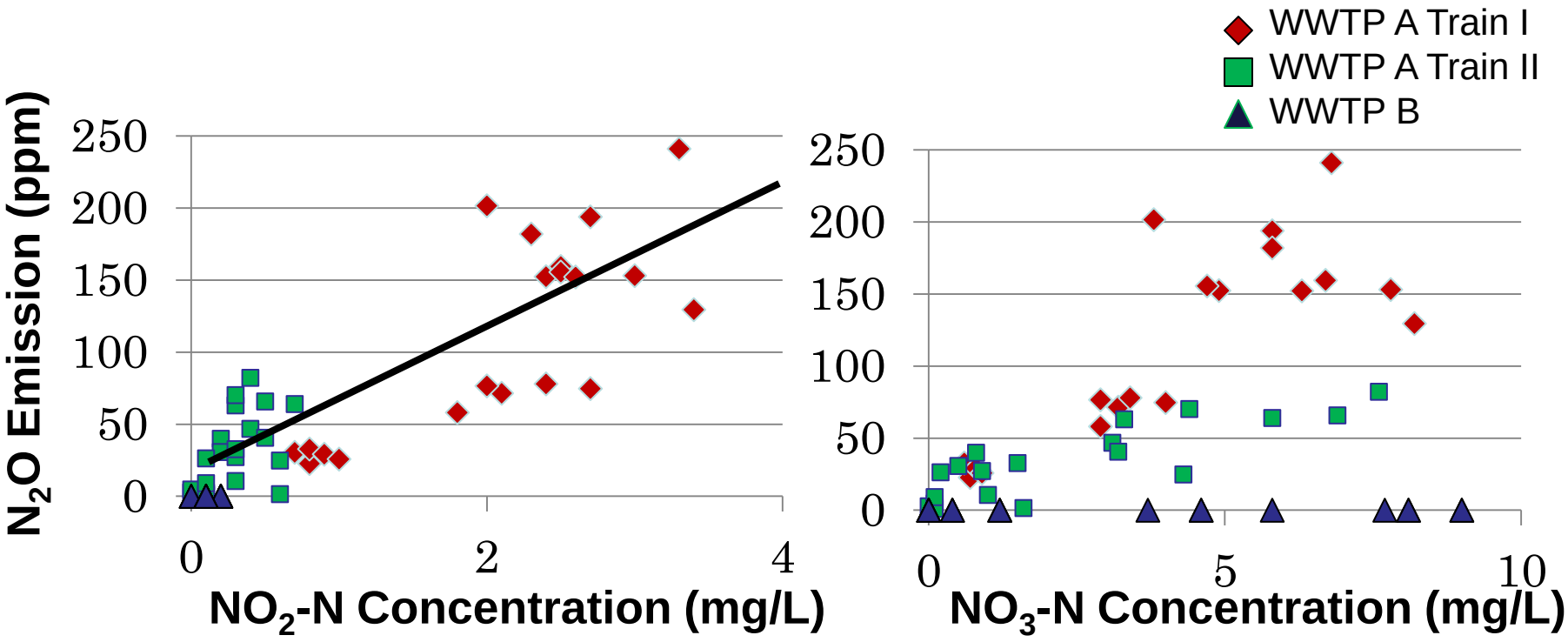


N_2O Emission from Bioreactor



- High N_2O Emission when NO_2^- Accumulation
- N_2O Generation even at Early Stage of Bioreactor

N_2O Emission vs. NO_2-N and NO_3-N

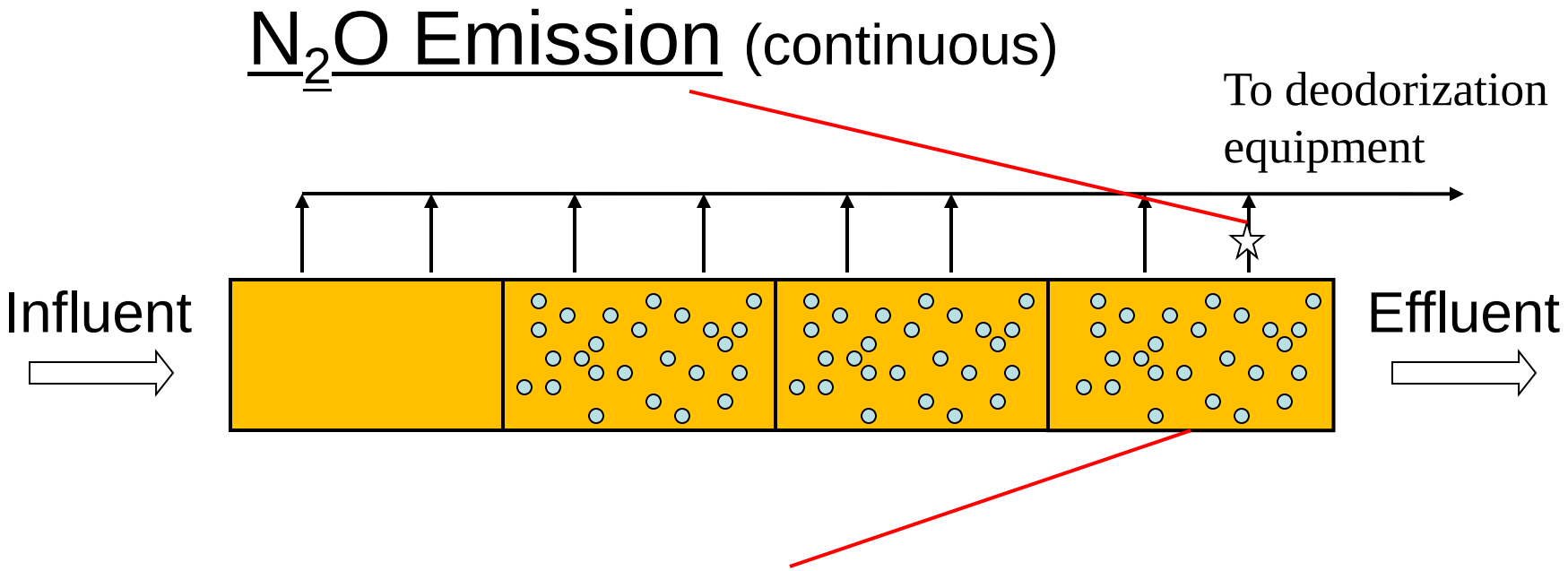


- Strong Correlation between N_2O and NO_2-N
- Week Correlation between N_2O and NO_3-N

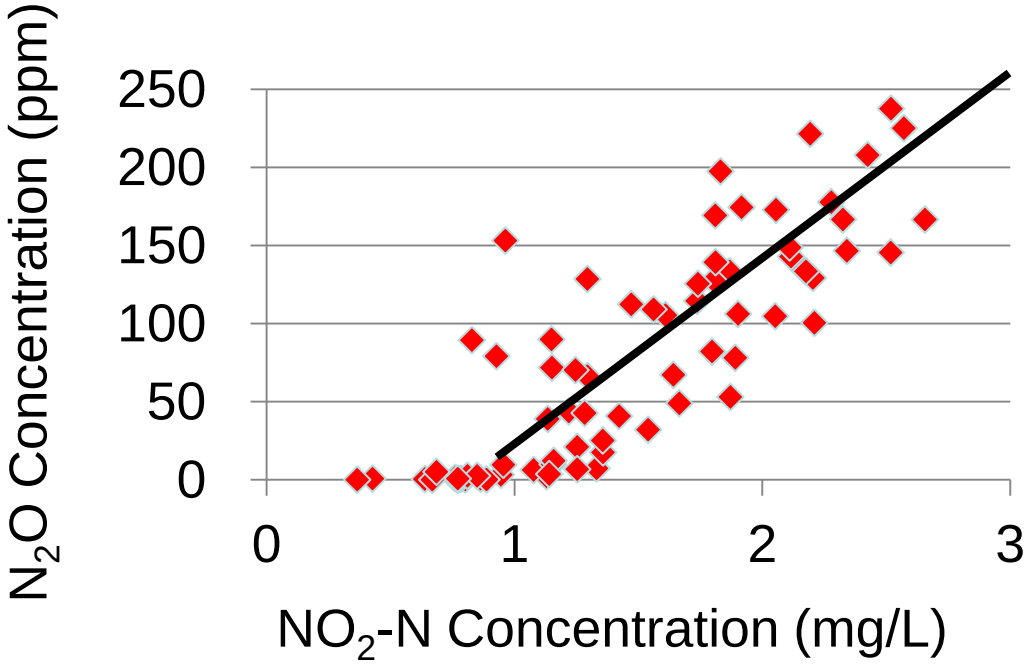
Results

- Sufficient Nitrification
  - -> No N_2O Emission
- Insufficient Nitrification
  - -> N_2O Emission all through Nitrification
- Strongly Correlated Water Quality Parameters
  - -> NO_2-N (not NO_3-N)

Sampling Site

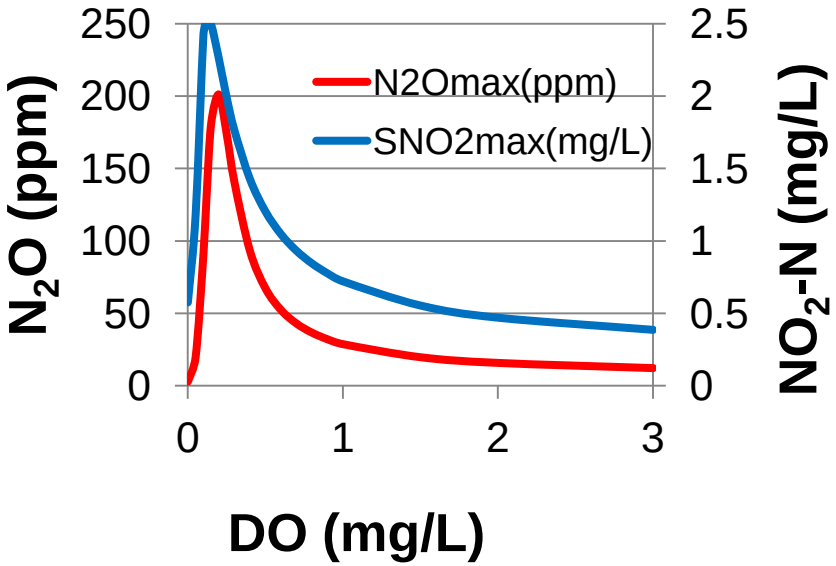


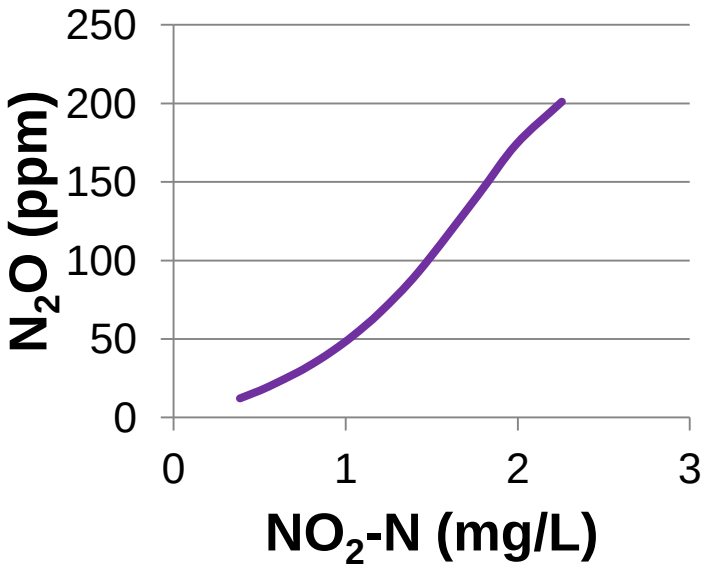
Results



- > 1.0mg/L of NO_2-N
  - -> Good Correlation between N_2O Emission and NO_2-N
- < 1.0mg/L of NO_2-N
  - -> Almost No N_2O Emission

N_2O Emission vs. NO_2-N by Mathematical Model





- Modified ASM by Ni *et al.* (2011)
- Initial Concentration of NH_4-N : 30mg/L
- Single Batch Reactor

Summary

- Long Term Continuous N_2O Measurement
  - Wide Fluctuation
  - Similar Trend of Residual Nitrite with N_2O Emission
- Relations of Nitrification Status and N_2O Emissions in Each Part of Reactor
  - High N_2O Emission when NO_2-N Accumulation
- Continuous Measurements of N_2O and NO_2^--N Concentration in Biological Reactor
  - Good Correlation between N_2O Emission and NO_2-N above 1.0mg/L of NO_2-N

Sufficient nitrification without nitrite accumulation is needed!

Tasks Ahead

- Continuous N_2O Measurement at several WWTPs
- Laboratory-scale and Pilot Plant Experiments to Find Operation Conditions for N_2O Reduction (without NO_2^- Accumulation)
- Confirmation of N_2O Reduction with Optimum Operation Conditions by Continuous N_2O Measurement
- Revision of Emission Factor of N_2O from Wastewater Treatment