National N_2O mapping and reduction of N_2O-emission from Fornæs WWTP through advanced online-control

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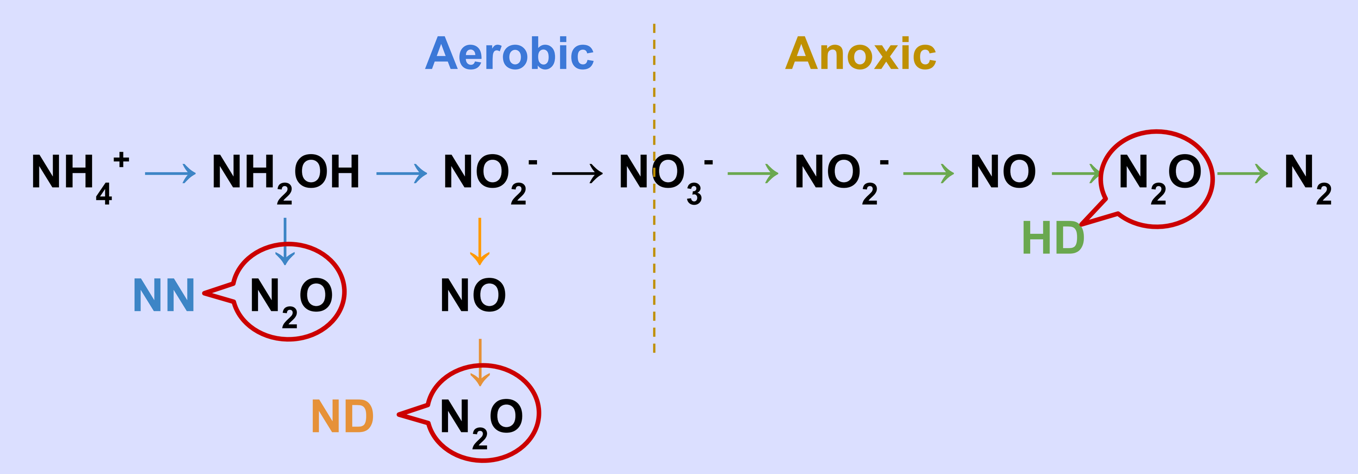
INTRODUCTION

Nitrous oxide (N_2O) has been identified as a significant contributor to the water sector's carbon footprint. N_2O is produced as a byproduct of nitrogen removal in biological wastewater treatment plants (WWTP), and it is therefore obligatory for the water sector to look into this if they want to reduce their carbon footprint.

The scope of this project is to identify different N_2O pathways by looking into examples from Danish WWTP plants. The design, composition of load and control strategy have a big impact on the N_2O production of the specific plant, and will impact which N_2O pathway which is dominant. Only by data observation and analysis can the correct control method be applied, and N_2O reduced. Due to lack of data from Fornæs WWTP, this poster will use an example from Næstved WWTP.

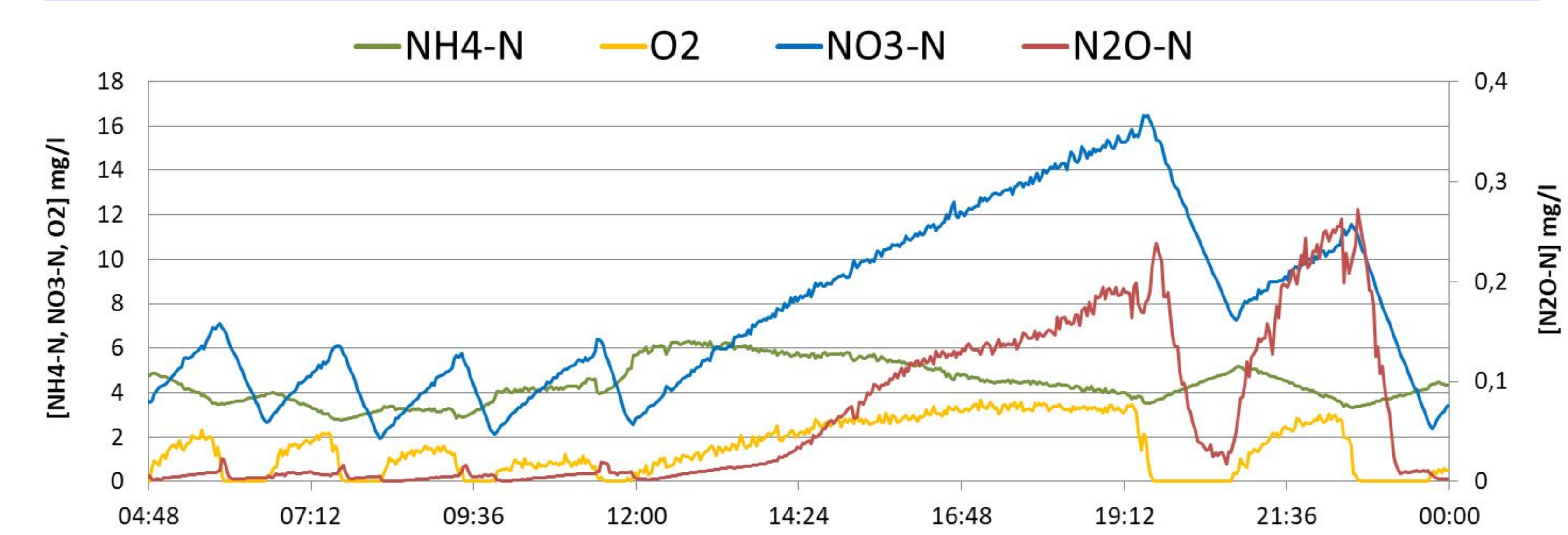
N_2O production pathways



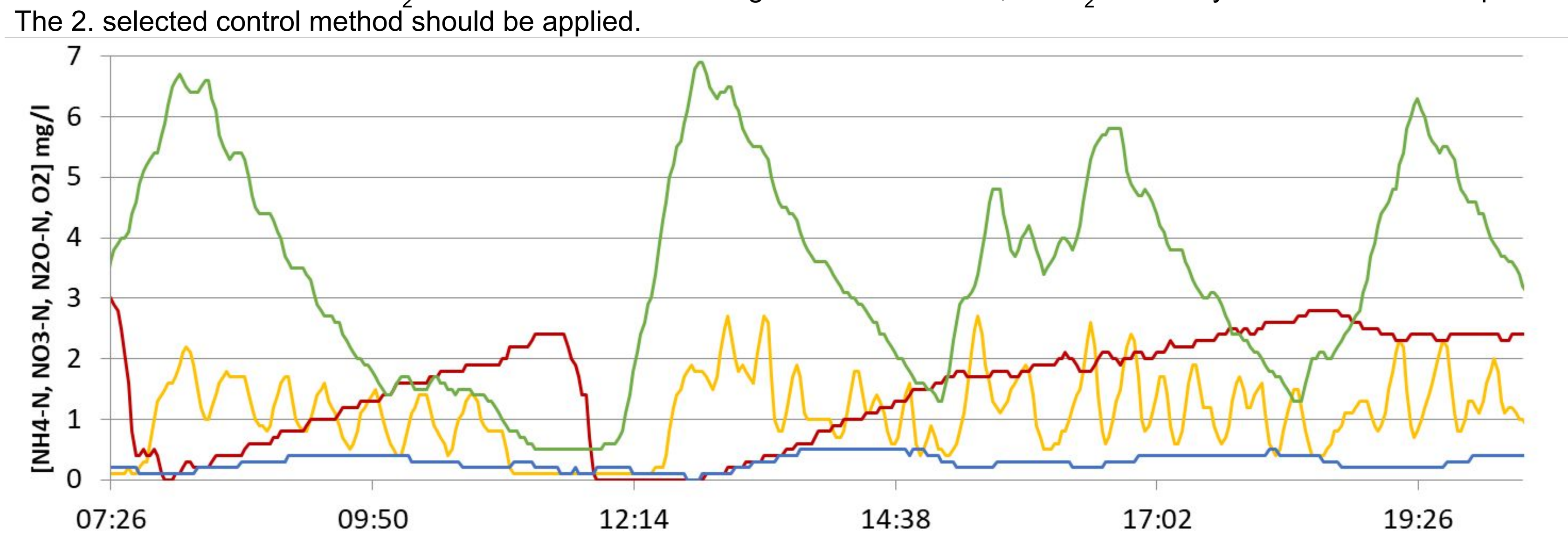
NN - Nitrifier nitrification pathway: Carried out be AOB (ammonia oxidizing bacteria). Related to increased ammonium oxidation rate (AOR). Also affected by increasing temperature and increasing pH

ND - Nitrifier denitrification pathway: Carried out by AOB. Relates to a limited oxygen availability and excess of NO_2^-.

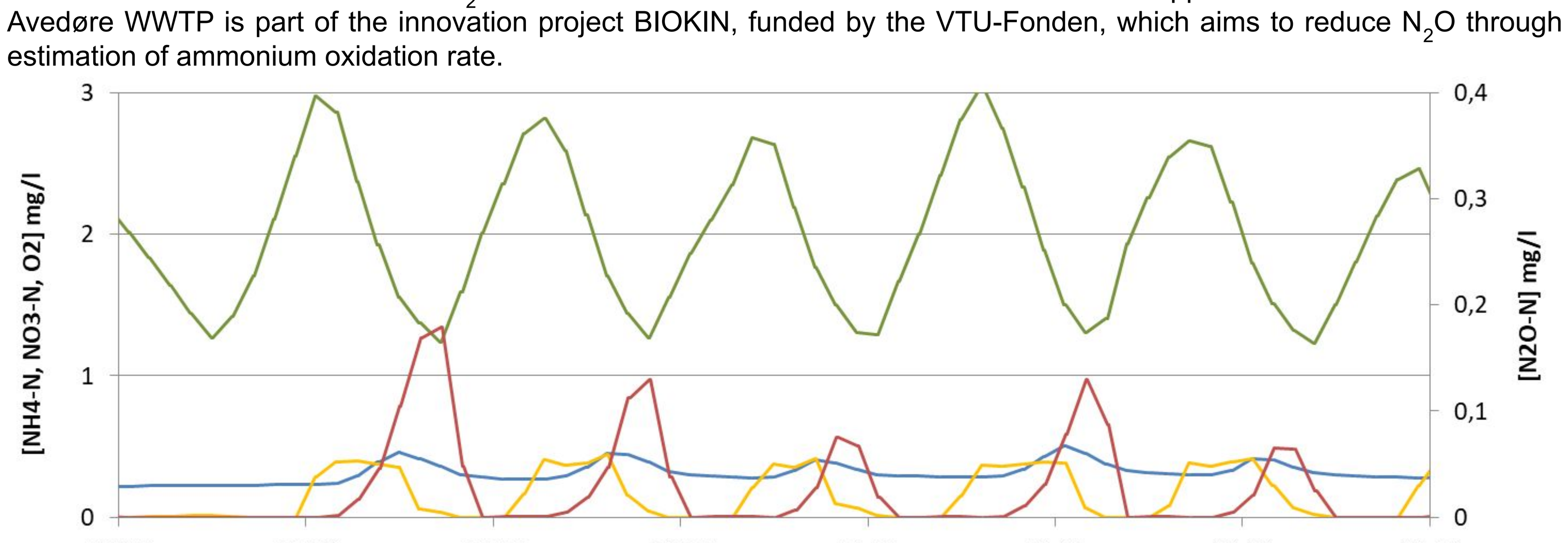
HD - Heterotrophic denitrification pathway: Carried out by heterothrophic bacteria. Relates to carbon limited conditions. Are also affected by decreasing temperature and decreasing pH.



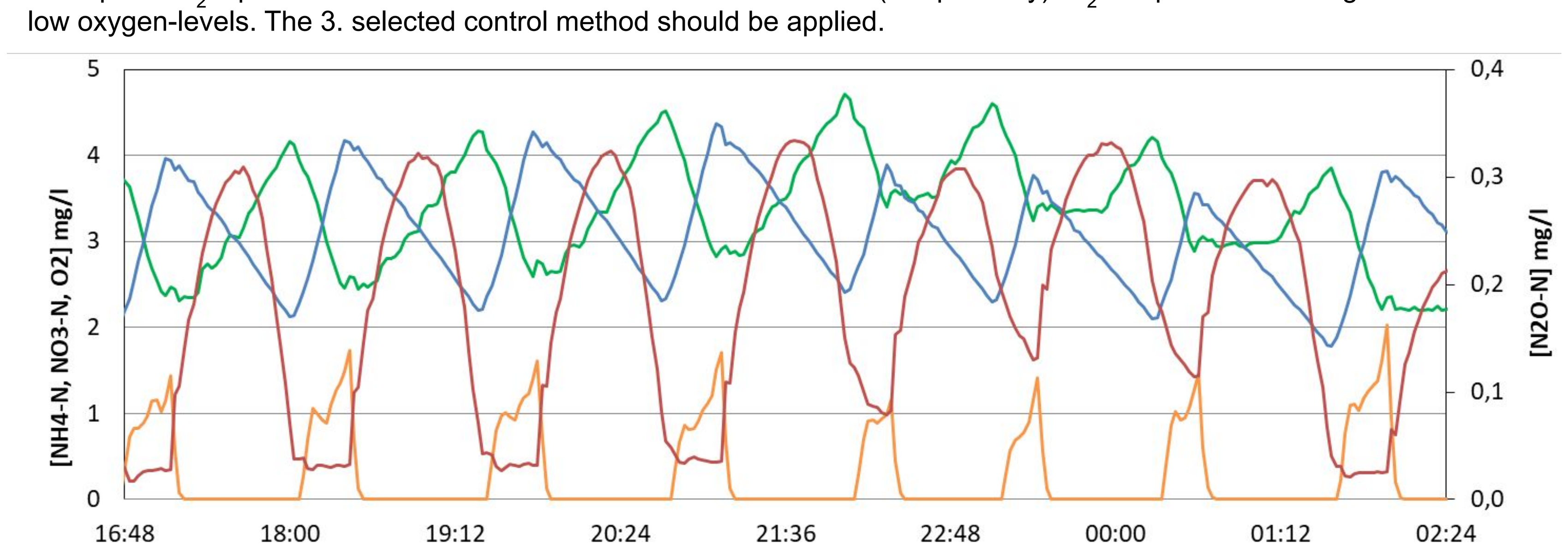
Example of N_2O-production at Mariagerfjord WWTP 3/1-2020 (NN-pathway). N_2O is produced during aeration, and removed in the breaks when O_2 is removed. Because of high amounts of COD, the N_2O is easily removed in the DN-phase. The 2. selected control method should be applied.



Example of N_2O-production at Avedøre WWTP from the 10/5- 2022 (NN-pathway). N_2O is produced during aeration, and removed in the short breaks when O_2 reaches 0. The 2. selected control method should be applied.
Avedøre WWTP is part of the innovation project BIOKIN, funded by the VTU-Fonden, which aims to reduce N_2O through estimation of ammonium oxidation rate.



Example of N_2O-production at Næstved WWTP from the 12/6- 2020 (ND-pathway). N_2O is produced during aeration at low oxygen-levels. The 3. selected control method should be applied.



Example of N_2O-production at Aalborg East WWTP from 2019 the 26/5-2019 (HD-pathway). N_2O is produced in the beginning of the DN phase and removed in the end of the DN phase. The 1. selected control method should be applied.

N2O mechanisms → Selected control method

N2O mechanisms	Selected control method
1. Production of N_2O in the denitrification-phase (Heterotrophic denitrification)	• Controlled dosing of COD during denitrification • Extended denitrification-phase until N_2O is belove a setpoint.
2. Production of N_2O during aeration and high NH4 loads. (Nitrifier nitrification)	• Force aeration to stop when N_2O reaches a setpoint* • Equalize loads if possible
3. Production of N_2O during aeration and low O_2 levels. (Nitrifier denitrification)	• Force aeration to stop when N_2O reaches a setpoint* • Increase the O_2 level

METHODS

In order to observe how N_2O is produced in relation to NH_4, NO_3 and O_2-levels, it is crucial to have online sensors in the waterphase. Most Danish WWTPs do already have online NH_4, NO_3 and O_2 sensors in order to observe and control the nitrogen removal processes. Next step has been to install N_2O-online sensor in the waterphase.
By being part of many N_2O measuring-project, we have had the opportunity to gather knowledge from a broad range of Danish WWTP. Here examples from 4 WWTP is shown.

N_2O is produced through three different pathway during nitrification (N) and denitrification (DN). It varies a lot from plant to plant which pathway is dominant, and what N_2O-pattern we see in the online data. It is not always clear which pathway that is dominant or the reason for a high N_2O.

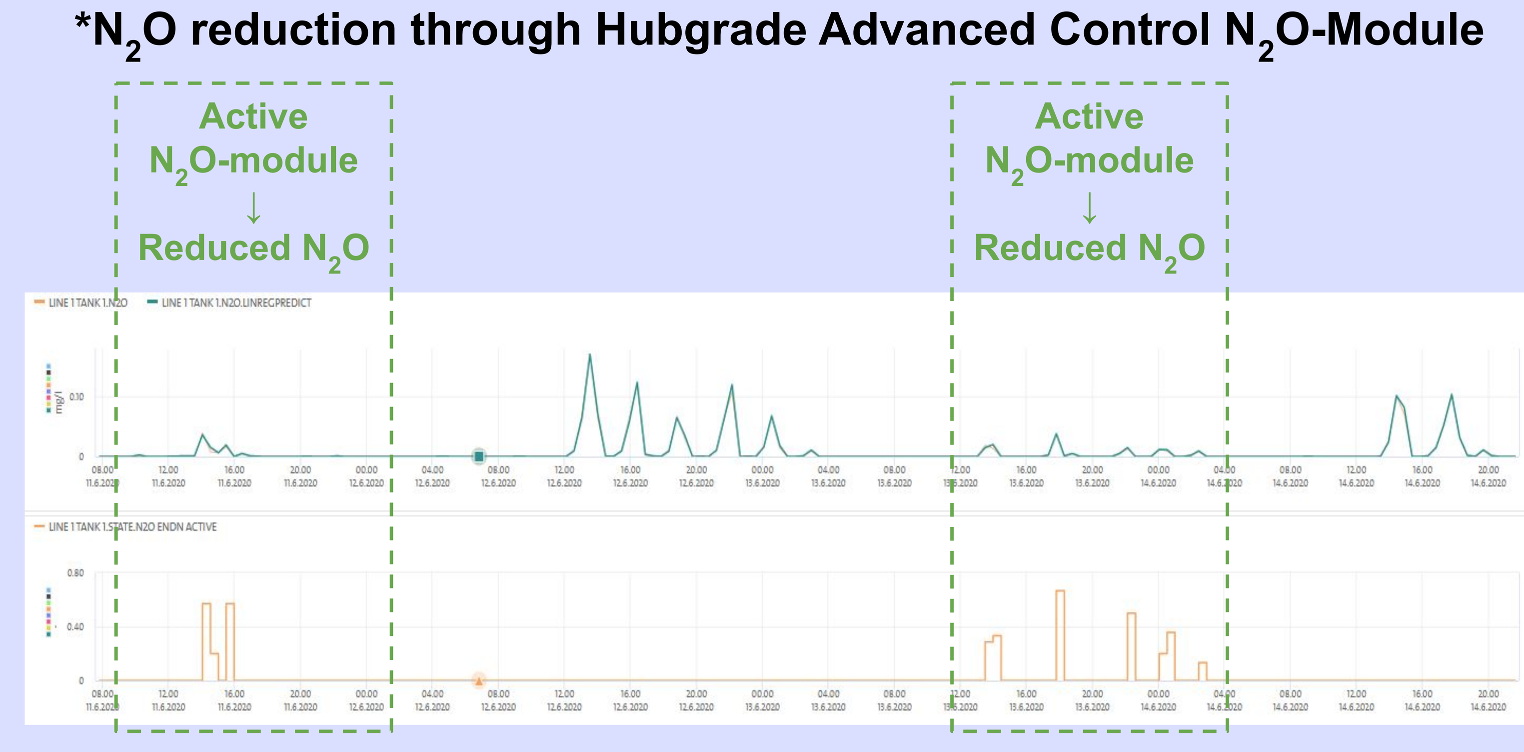
To try to understand the N_2O-production at each plant, we have looked into the data, and observed how NH_4, NO_3, O_2 and N_2O relates. That requires qualitative analysis of the figures of measured data. When the dominant pathway have been identified it is possible to suggest a control method.
Based on literature and in-situ experience, three N_2O control methods has been selected (see above).

RESULTS & DISCUSSION

In order to take action about N_2O reduction, the following method has been identified:

- Go through you treatment plant in order to find the relevant processtanks, where nitrogen removal takes place.
- Install N_2O sensor in the processtank
- Observe the pattern of N_2O production
- Select the control strategy based on the observed N_2O mechanism
- Implement the control strategy through advanced online control.
- Evaluate the N_2O reduction and reconsider

*N_2O reduction through Hubgrade Advanced Control N_2O-Module



Example of N_2O-reduction at Næstved WWTP. N_2O is produced during the aerated phase due to the ND passway. To reduce N_2O emission, the aerated phase is interrupt when N_2O reach a certain setpoint. The N_2O is quickly reduced when the O_2 is removed, showing sufficient COD for destruction of N_2O.
The activation of the N_2O-module do not affect the NH_4 in the outlet.

CONCLUSIONS

N_2O play a major part of wastewater treatment plants climate impact and it is crucial to look into this challenge for all plants in order to tackle it.
In order to reduce N_2O, the first step is to get knowledge of the amounts and the pattern of production, in order to interpret the biological pathways.
First when you have this knowledge, you can choose the best control method and start reducing the emission.

References:
- Fink, J. 2022. Analysis, mitigation and modeling of nitrous oxide emission from Fornæs wastewater treatment plant. Master thesis, Department of Biological and Chemical Engineering, Aarhus University.
- Ekström, S.E.M., Vangsgaard, A.K., Lemaire, R., Valverde Pérez, B., Benedetti, L., Jensen, M.M., Smeths, B.F. (2017). Simple control strategy for mitigating N2O emissions in phase isolated full-scale WWTPs. In Proceedings of 12th IWA Specialized Conferende on Instrumentation, Control and Automation Quebec, Canada; IWA Publishing.

*Krugers patented N2O-module in Hubgrade