Environmental Protection Agency report on nitrous oxide (N_2O) emissions from Danish wastewater treatment plants (WWTPs)

- a two year monitoring project

Nitrous oxide (N_2O) is a greenhouse gas produced during wastewater treatment primarily through biological processes. As N_2O is a greenhouse gas 298 times stronger than CO_2, the N_2O emissions are substantial in the total climate impact of wastewater treatment.

Based on limited data, the WWTPs have used a factor to estimate the N_2O emission. However, the available data shows that the N_2O emission varies in time and between plants. Therefore, more data is needed to achieve a reliable estimate of the N_2O emission from Danish WWTPs. To quantify the N_2O emission from Danish WWTPs, the Danish Environmental Protection Agency (EPA) launched a funding scheme aimed at Danish utilities to collect data on N_2O emissions. In the period 2018-2020, the N_2O emission from nine different plants was monitored. The nine WWTPs cover a range in terms of plant size, nitrogen load, aeration technology, sludge treatment and reject water handling.

Continuous, real-time N_2O measurements

Unisense Environment N_2O Wastewater Sensors were installed at all nine WWTPs to provide continuous, real-time measurements of N_2O concentration directly in the wastewater. The data collected using the N_2O sensors was subsequently used for calculating N_2O emissions using N_2O emission models. The emission data was used to calculate an overall average national emission factor which resulted in an emission factor of 0.84% N_2O-N/Total-N_{inlet}, corresponding to 0.0084 kg N_2O-N/kg Total-N_{inlet} with a variation of 0.24–1.24% N_2O-N/Total-N_{inlet}. This corresponds to about half of the 1.6% N_2O-N/T-N_{inlet} emission factor used in the IPCC report from 2019, but the previous reported national emission factor is about 2,5 times higher. The emission factor calculated from this study will be used as a basis for future inventories, as it is based on the most comprehensive dataset yet. The calculated emission factor represents an estimate and should be adjusted when further data becomes available.

Emission factors (% N_2O-N/T-N_{inlet})		
EPA report 2020	**Previous Danish 2019**	**IPCC 2019**
0.84%	0.32%	1.6%

Photo: HVIDPHOTOGRAPHY

Variations in individual measurements

The study showed a large variation in N_2O emission from plant to plant and in day-to-day emissions from individual plants. The data indicates that increased nitrogen load and a generally highly loaded biological process lead to higher N_2O emissions compared to lower loaded biological processes. Anammox sidestream processes have high nitrogen loading and nitrogen removal rates. This study found an emission factor of 5–6% N_2O-N/Total-N_{inlet} which is significantly higher than the average emission factor found for mainstream processes. Furthermore, this study indicated that there was a relationship between the residual available capacity in the biological treatment and the amount of nitrous oxide emitted, where a larger capacity emits less N_2O.

Large potential in the reduction of N_2O emissions

This study only offers indications of mechanisms leading to increased N_2O emissions, but the data clearly shows that ammonium loading, carbon loading and aeration are important factors for N_2O emissions. Online monitoring should be implemented to both understand N_2O emissions and implement online control strategies. In Denmark, it will be compulsory by 2025 to reduce greenhouse gas emissions. Limiting N_2O emissions from WWTPs will be part of reaching this goal. As most Danish wastewater treatment plants have not taken any steps to reduce emission, the potential for reducing the overall emission is very large. Collecting knowledge on nitrous oxide emission, triggers and mitigation strategies from national and international projects will also contribute to an increased understanding of the subject.

The recommended actions are:

- Install sensors and perform long-term measurement campaigns
- Utilize treatment capacity as much as possible in space and time, as high load leads to N_2O formation
- Use existing advanced online control systems to implement N_2O reduction strategies
- Study the correlation between load, amount of sludge, and N_2O emissions

You can find the full report (in Danish) here: https://www2.mst.dk/Udgiv/publikationer/2020/12/978-87-7038-254-0.pdf

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