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Aquafin

N_2O Sensor Controls Emissions from Deammonification Processes

High N_2O Emissions from Side Stream Processes

Wastewater treatment plays an important part in the global ambition to reduce the climate impact of human activities. The potent greenhouse gas nitrous oxide (N_2O) is often the most important fraction of emissions in a wastewater treatment plant (WWTP)[1].

Conventional wastewater treatment typically has emissions in the range of 0.05 - 1.5% kg N_2O/kg N_{inlet}.
Side stream treatment processes have been reported in the range of 2-6% or more.

Signal can be used to control deammonification

N_2O can be used as a proxy value for NO_2^- and is often easier to measure in real time. This enables control strategies, in which an N_2O setpoint is used for aeration and loading, balancing the substrate availability and reducing the emissions from deammonification.

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Research has shown that highly loaded processes based on Anammox are a risk for large emissions of N_2O[2].

Sludge reject water from the dewatering processes returns high nitrogen (N) loads to the WWTP which increases the need for aeration. To reduce aeration energy, WWTPs often install intensified sidestream processes, such as deammonification using anammox bacteria.

Anammox as alternative process

Anammox is a nitrogen removal process where N_2 is formed from NH_4^+ and NO_2^- (Fig. 1). Controlling the substrate availability and balance is important for the successful implementation and operation of the process.

Two substrate control strategies that have been suggested are PNA (Partial nitrification/anammox) and PdNA (Partial denitrification/anammox). The PNA process aims at partial nitrification by inhibiting NOB (nitrite-oxidizing bacteria) to supply NO_2^- for anammox. On the other hand, PdNA aims at partial denitrification to supply NO_2^- (Fig. 1).

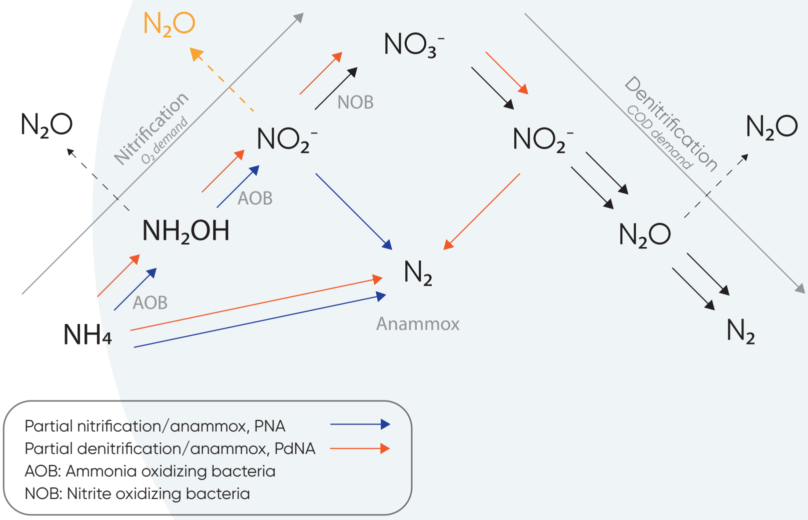

Figure 1: Processes of Nitrogen conversion in wastewater treatment and routes of N_2O emissions

While it might appear as a detour, PdNA for anammox is often operationally easier to achieve. In PdNA, the relationship between COD/N and N_2O can be used for controlling the partial denitrification process to accumulate nitrite for anammox by keeping the COD/N ratio below 1.

The N_2O sensor can monitor the N_2O formation and decrease the carbon loading to achieve partial denitrification to NO_2^-, which can be used for anammox. The carbon can then be harvested and used for biogas production.

NO_2^- is the key substrate, besides NH_4^+, for anammox, but it is difficult to measure NO_2^- with present sensors. The measurement will be indirect as NO_2^- is formed and consumed inside biofilm or granules and autosampler-based technologies do not deliver real-time data. Unlike NO_2^-, N_2O is not consumed by the anammox bacteria and therefore online N_2O monitoring will provide a more precise measure of the substrate balance in real time. As N_2O is tightly linked to NO_2^- concentration through both nitrification and denitrification, the N_2O sensor can be used as a proxy for NO_2^-.

N_2O Mitigation - from Pilot to Full-Scale

The main Belgian utility for sewer transport and wastewater treatment, Aquafin, has set ambitious targets for climate neutrality. To better understand their key emission sources, Aquafin monitors N_2O in a pilot-scale deammonification plant, a twin of the full-scale process at the WWTP in Dendermonde, Belgium[3]. The reactor is equipped with off-gas nitrous oxide measurement as well as a Unisense Environment N_2O wastewater sensor for dissolved N_2O. With the combination of the two measurements, Aquafin can fine-tune the effect of different aeration regimes.

Figure 2 shows the results of short-pulsed aeration (left) vs. longer aeration periods (right). In order to reduce emissions, it was advantageous to aerate in shorter pulses, avoiding the build-up of nitrite, minimizing dissolved N_2O formation, and promoting subsequent biomass selection. Short pulses of aeration resulted in a drop in the emission factor from 3.3% to 1.3% kg N_2O/kg $N_{removed}$. With these results in hand, Aquafin was able to implement short aeration periods at the WWTP in Dendermonde to start minimizing N_2O in full-scale. A simulated full control implementation produced a further drop in the N_2O emission factor to 0.9% kg N_2O/kg $N_{removed}$, while the load capacity dropped as well.

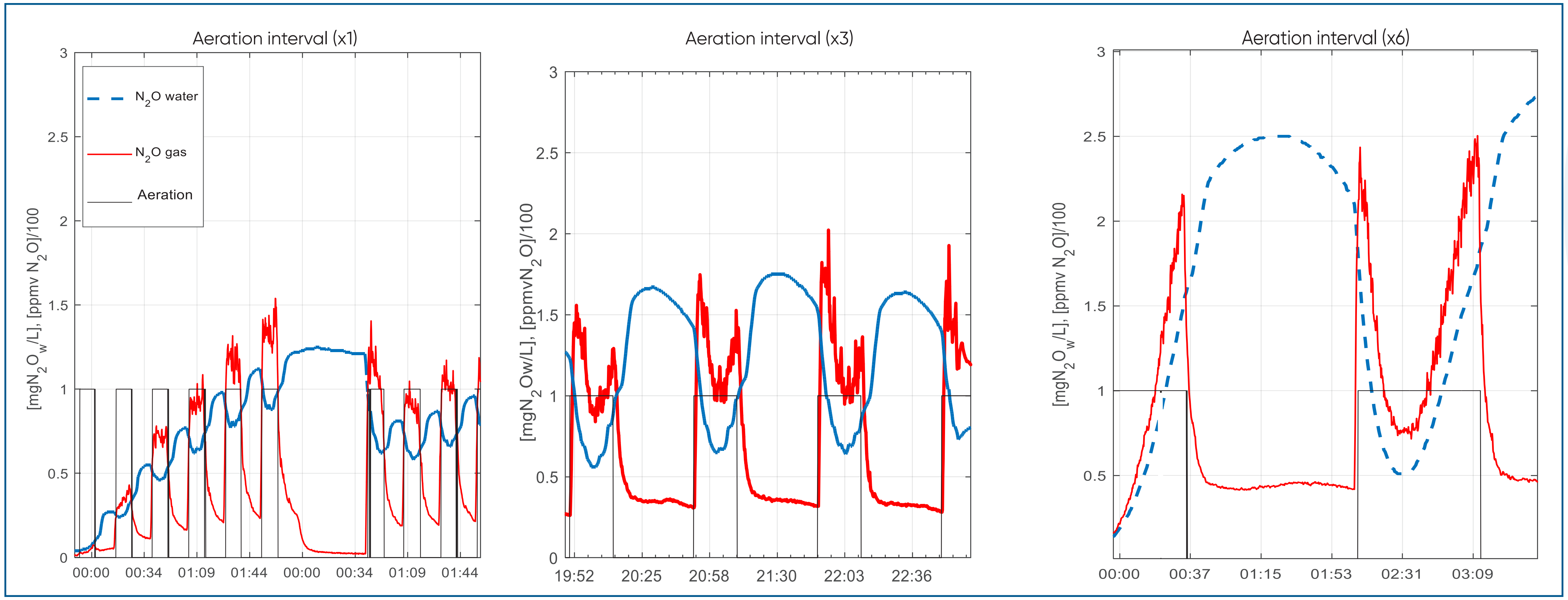

Fig. 2: Typical liquid and gas phase N_2O concentrations related to aeration frequency in a pilot scale deammonification reactor of the utility Aquafin, Belgium..

According to Alessio Fenu, senior R&D Engineer at Aquafin, "the dissolved measurement of N_2O is a very useful tool for investigating any process in view of N_2O mitigation, and crucial in setting up a real-time process control."

In another example, researchers from a leading utility in Denmark have developed a control strategy where aeration and loading are based on the online N_2O value instead of controlling it based on pH. In essence, an N_2O setpoint is used to reduce aeration, tuning down nitrification when there is too much NO_2^- present. This effectively uses N_2O as a proxy for NO_2^- and reduces the likelihood of a substrate imbalance of NH_4^+/ NO_2^- and subsequent N_2O formation.

Avoid N_2O emission and document your CO_2 footprint

In conclusion, the N_2O Wastewater Sensor can be used as a tool for process control in anammox by tightly controlling the substrate ratio between Nitrite and Ammonium. Specific control strategies depend on the reactor design and its limitations. Future-oriented utilities and technology providers have the ability to document CO_2-footprints from sidestream processes, allowing direct comparison with conventional activated sludge processes. This allows making informed decisions about process control and future investments with overall climate neutrality as a target.

References

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Nitrous Oxide process sensor for online wastewater treatment optimization, low-cost greenhouse gas reduction, and reliable sustainability accounting

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