N_2O Wastewater Sensor - A tool for Carbon Dosage Control

The N_2O Wastewater Sensor makes it possible for you to measure nitrous oxide (N_2O) emissions directly from individual wastewater treatment plants (WWTPs). With hundreds of installations worldwide, the sensor is established as a very durable process sensor requiring minimal maintenance. The data collected from sensor installations have been key to shaping mitigation strategies.

N_2O as a control parameter for carbon dosage

When the sensor is installed to monitor the N_2O concentration in the liquid, you can use N_2O as a control parameter for carbon dosage in the denitrification process. Nitrogen removal in wastewater is achieved through a combination of nitrification and denitrification as well as anammox (anaerobic ammonium oxidation). N_2O is an obligate intermediate formed during denitrification. However, N_2O is also formed during nitrification which is the main source of N_2O emissions from WWTPs (Fig. 1).

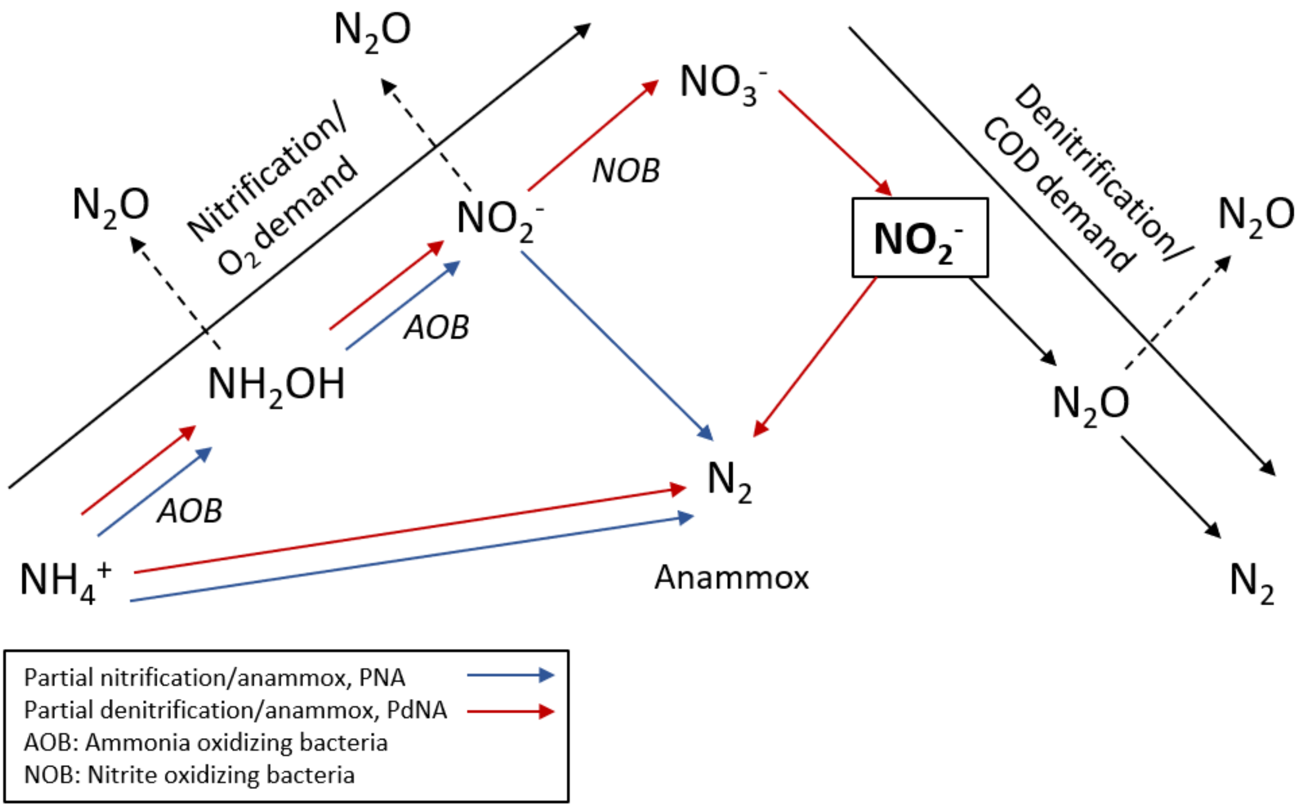

Fig. 1: N_2O production pathways in WWTPs

Measuring N_2O yields important insights about all key substances

N_2O formation is linked to the ammonium (NH_4^+) loading, and N_2O formation increases as the NH_4^+ turnover increases. If high NH_4^+ oxidation rates lead to NO_2^- accumulation, N_2O will build up in the liquid as a warning.

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. 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. Thus, N_2O is tightly linked to NO_2^- concentration through both nitrification and denitrification. This means that you can use the N_2O sensor as a proxy for NO_2^-.

Carbon dosage can prevent excessive N_2O emissions

Applied research has shown that a low COD/N ratio can lead to increased N_2O production and that a COD/N ratio below 3.5 can lead to significant N_2O emissions. Fig. 2 demonstrates the relationship between COD/N and N_2O. The bell-shaped relationship between N_2O and COD/N makes it possible to avoid excessive N_2O emission by aiming for either a high (>3.5) or a low (<1) COD/N ratio (Fig. 2).

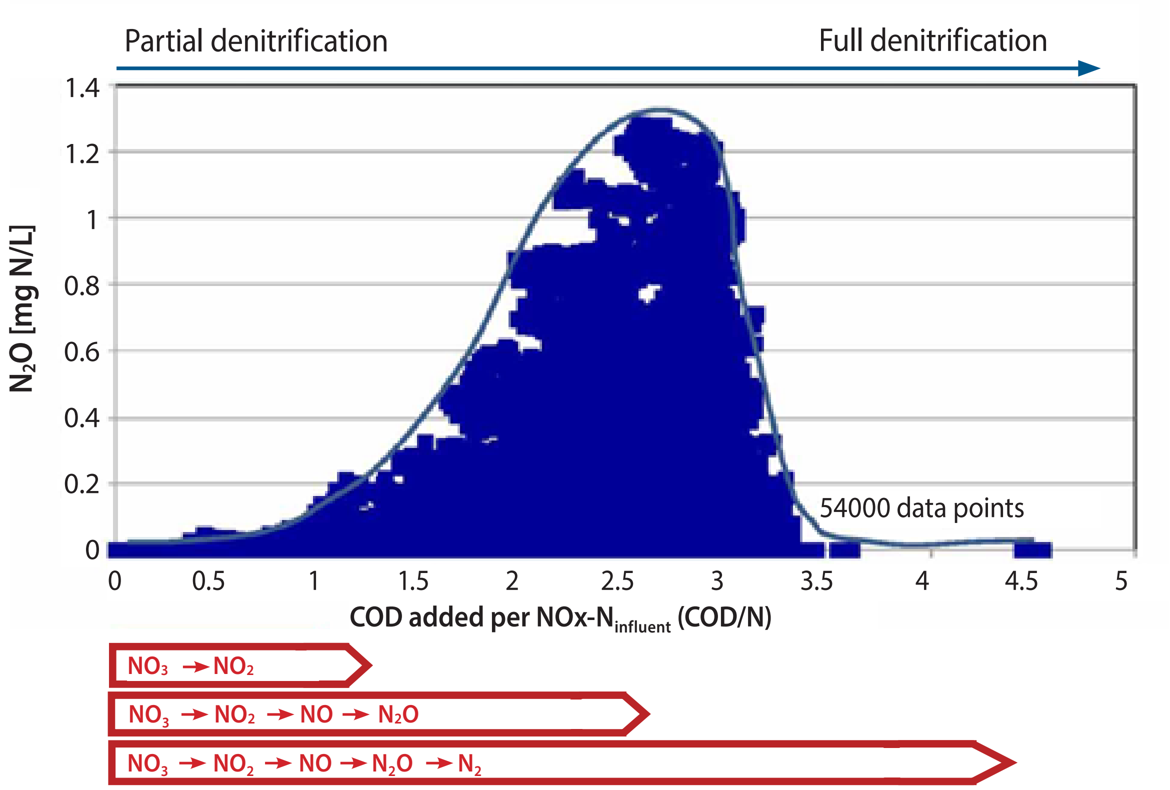

Fig. 2: Correlation between COD/$N_{influent}$ ratio and N_2O concentration. Redrawn from Andalib et al. 2017.

From a process control standpoint, the slope of the N_2O curve in response to the different COD/N-ratios can be used as an indicator for the dominating sludge process. If you aim for complete denitrification to N_2 to avoid N_2O, you can apply the N_2O sensor to monitor N_2O concentration and increase the carbon load when the N_2O concentration increases to ensure a COD/N ratio above 3.5.

Anammox as an alternative

Anammox is an alternative nitrogen removal process where N_2 is formed from NH_4^+ and NO_2^- (Fig. 1). Controlling the substrate availability is important for the successful implementation of anammox. 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 increase the NO_2^- available for anammox. However, the out-selection of NOB has proven operationally difficult. On the other hand, PdNA aims at partial denitrification to increase NO_2^- availability (Fig. 1).

While it might appear as a detour, anammox is operationally easier to achieve. The process has been demonstrated at temperatures down to 20°C, which makes it relevant in many parts of the world during summer. In the PdNA case, the relationship between COD/N and N_2O can be used for controlling the partial denitrification process to accumulate nitrite for anammox and keep 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.

Avoid N_2O emission and document your CO_2 footprint

In conclusion, you can use the N_2O Wastewater Sensor as a tool for carbon dosage whether the aim is complete denitrification to avoid N_2O emission or PdNA where the sensor is used as a proxy for NO_2^-. Simultaneously, the new PdNA and PNA processes will make it possible for you to document their CO_2-equivalent footprints in comparison to conventional activated sludge processes.

References

Andalib et al. 2017. Correlation between nitrous oxide (N_2O) emission and carbon to nitrogen (COD/N) ratio in denitrification process: A mitigation strategy to decrease greenhouse gas emission and cost of operation. Water Science & Technology 76. 10.