Using Real-time Nitrite Monitoring to Understand and Reduce Nitrous Oxide Emissions

Achieving net-zero greenhouse gas emissions is one of the most challenging targets facing the wastewater sector. In terms of energy inputs, the industry has been aided by progressive decarbonisation of grid electricity and the addition of onsite renewables. Many players have also begun to electrify their vehicle fleets, with further longer-term scope for biogas, biofuel and, potentially, hydrogen-powered HGVs.

That leaves emissions from the actual treatment process itself as the outlier, with no convenient solution in sight. The three process-generated greenhouse gases of concern are carbon dioxide, methane and nitrous oxide (N_2O). Of these, the dynamics surrounding nitrous oxide formation are the least well understood.

The knowns and unknowns

What we do know is that the global warming potential of nitrous oxide is about 300 times higher than that of CO_2 and that, unlike carbon dioxide, there are no obvious sinks for N_2O. Furthermore, nitrous oxide has a long residence time in the atmosphere (over 100 years), after which, it enters the stratosphere, with the potential to cause ozone depletion and ozone holes.

In wastewater treatment, we also know that N_2O is produced in both the nitrification and the denitrification stages of biological nitrogen removal (BNR).

However, it seems that no one generic emission factor can predict N_2O emissions at the individual plant level. For instance, there are significant variations in emission characteristics from different BNR processes, such as Conventional Activated Sludge, Sequencing Batch Activated Sludge, Oxidation Ditch, SBBR and CANON.

That's not surprising, perhaps. However, within a process, nitrous oxide emissions can vary by time of day and by season - possibly due to changes in microbial communities. Likewise, at a fixed point in time, there can be variations in emissions from different lanes within the same tanks.

Even at an overarching sectoral level, the contribution of wastewater treatment to total anthropogenic nitrous oxide emissions is unclear. Historic estimates based on 'top down' Intergovernmental Panel on Climate Change (IPCC) 2006 figures are believed to be too low. In 2019, the IPPC refined its approach. However, some within the industry question whether this revised emission factor is too high.

Building consensus

Although there is no silver bullet, experiences from WWTP monitoring programmes in Denmark, the Netherlands and elsewhere are showing strong convergence on the major variables that influence nitrous oxide formation.

For instance, with dissolved oxygen, there appears to be a Goldilocks factor at play – in that both low and high DO levels can be risk factors for increased N_2O emissions. The concentration range should be 'just right'. Other risk factors include a low COD/N ratio, spikes in ammonia load and nitrite accumulation.

Modelling N_2O emission risks

Several models have also emerged for use at the plant level. At an Aquaenviro conference on Net Zero earlier this year, Paul Lavender, Director of Water Utilities (UK) at Royal HaskoningDHV, highlighted some of the early work coming from the Netherlands over a decade ago. This included outputs from his own company and others, such as STOWA (the Dutch Foundation for Applied Water Research), working with the Global Water Research Coalition.

The thrust of the STOWA model is that nitrite and ammonia concentrations in the final effluent provide a good indicator of nitrous oxide risks. In a nutshell, high-quality effluents (low ammonia and low nitrite concentrations) indicate a low risk of N_2O emissions.

More recently, several Dutch WTTP operators, including Waterboard de Dommel, have been using an AI-based N_2O risk model developed by Jose Porro, the founder of New York-headquartered Cobalt Water. In September 2020, Jose presented some of the results at a webinar chaired by Amanda Lake, European Process Lead for Water at Jacobs. One of the treatment plants in Eindhoven reduced emissions by 30%, while a plant in Land van Cuijk reduced N_2O emissions by 70%.

The Jacob's webinar also looked at experiences in Denmark, where the N_2O microsensor producer Unisense, and WWTP operators like Biofos, have been at the coalface. Unisense's CTO Mikkel Andersen reinforced the point that a control strategy based on DO is not adequate for operators serious about N_2O reduction. He advocated the use of N_2O measurements as a proxy for nitrite – in tandem with dissolved oxygen.

Advances in instrumentation to better control BNR processes

There has also been progress on the instrumentation side. Operators are already measuring DO, and Unisense's gas microsensor for nitrous oxide has been around for some time. Now, new real-time analysers to help with other parameters are coming to the market. This includes our own Aquamonitrix® real-time nitrate and nitrite analyser. Aquamonitrix® is robust in wastewater, with good biofouling resistance, and it directly measures nitrite and nitrate with high accuracy and specificity. So, although the challenge of tackling N_2O is not easy, the toolkit is there. The time has come to know more and to do more.

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Aquamonitrix® for nitrite (and nitrate) monitoring to tackle nitrous oxide emissions

The Aquamonitrix® analyser provides an easy way for WWTP operators to accurately monitor nitrite (and nitrate) in real-time, offering the following advantages over conventional sensors:

- **Specific, directly measured values of nitrate and nitrite (not calculated/compensated or combined values for the two anions)**

Unlike conventional optical analysers that rely solely on UV or LED detection, Aquamonitrix® incorporates a rapid ion chromatography column that separates the nitrogen anions before they reach the UV LED detector. This allows the unit to measure nitrite and nitrate separately – with unrivalled specificity.

- **Lab-quality accuracy in both fresh and wastewater**

The integration of the ion chromatography column also overcomes interference issues encountered in wastewater when using standard UV- and LED-based analysers. As a result, Aquamonitrix® provides laboratory-quality accuracy in both fresh water and wastewater.

- **Low blockage and biofouling potential in wastewater**

The Aquamonitrix® sample intake system is robust against biofouling and blockages. Moreover, the ability to analyse a microfluidic volume greatly simplifies sample handling demands. This can eliminate the need for sampling infrastructure, pre-treatment or costly, add-on sampling equipment.

- **Near-continuous monitoring with real-time data communication**

Capable of sampling every 15 minutes, Aquamonitrix® allows for near-continuous monitoring. Data is instantaneously transmitted to the user's choice of SCADA/central control system and/or telemetry/data management system. We also provide the proprietary Datamonitrix data management platform, for configurable alarms and alerts, and analyser self-diagnostics, all direct to your PC.

- **Stable accuracy and calibration combined with portability**

Even when Aquamonitrix® is moved to a different location or a different sampling matrix, its calibration remains stable. The analyser unit is lightweight and portable, allowing for easy monitoring at multiple points around a plant.

- **Plug and play setup**

Order Aquamonitrix® today, and once it's on-site, unbox it, and you can have your analyser up and monitoring in about two hours. You don't need any additional site or sampling infrastructure.

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