# THE ROLE OF REAL-TIME NITRATE AND NITRITE MONITORING IN ACHIEVING NET ZERO WASTEWATER TREATMENT

*There is no one silver bullet for achieving net zero. However, improved process control and shortcut biological nitrogen removal, enabled through real-time nitrate and nitrite monitoring, can significantly reduce electricity demand for aeration, writes* ***John McGrath, Director, Aquamonitrix.***

Energy-efficient wastewater treatment is on the agenda for utilities everywhere as part of the drive to net zero, climate change abatement, the circular economy and pressures to play an increasingly positive role in the energy-water nexus.

Beyond purely environmental forces, resource efficiency may cut right to the economic heart of the wastewater treatment plant of the future. Energy use currently accounts for about a third of all operational costs in the average WWPT, and that figure could potentially increase if utilities are tasked with more stringent regulations for removing nutrients, pharmaceutical and personal care products and other contaminants of emerging concern.

## The energy paradox

The paradox is that the energy (chemical, thermal, etc.) locked up in wastewater is about six to nine times higher than the electric energy needed for its treatment, according to estimates by Andrea G. Capodaglio and Gustaf Olsson in their 2019 paper *Energy Issues in Sustainable Urban Wastewater Management.*

The theory, then, is that even if a fraction of this energy could be practically harnessed, the WWTP of the future could be a net energy producer.

In the here and now, a growing number of medium to large WWTP operators view anaerobic digestion of waste sludge as their best option for energy recovery. The resultant methane biogas has potential applications in space heating, vehicle fuel, or, as proposed by Capodaglio and Olsson, in high-efficiency combined heat and power plants.

Even with this scenario, however, existing AD technology would only meet about half of the average WWTP's energy requirements. So, carbon-neutral, renewable energy sources, such as wind and solar power, coupled with more energy-efficient treatment processes, are also required.

## Targeting aeration energy requirements

Secondary treatment, where biological nitrogen removal takes place, is the most obvious target for optimisation, since this requires aeration - the single most energy-intensive operation in conventional WWTPs, accounting for a whopping average of 50 per cent of total site energy consumption.

Of growing interest, shortcut biological nitrogen removal (SBNR) offers the potential to dramatically reduce these aeration requirements. The term can be confusing, however, as sometimes it is used to describe a shortcut known as nitrite shunt, while other times, it is used to describe the 'anammox' process.

Going back to basics, conventional biological nitrogen removal is a multi-stage process. In the nitrification phase, ammonium is oxidised to nitrite by ammonia-oxidising bacteria (AOB), and nitrite is, in turn, oxidised to nitrate by nitrite-oxidising bacteria (NOB).

This is followed by denitrification, when nitrate is reduced back again to nitrite, which is then converted to nitrogen gas.

Denitrification is performed by hetero-trophic bacteria that require a carbon source; whereas the AOB and NOB bacteria involved in nitrification are auto-trophic. However, to avoid dissolved oxygen becoming a rate limiting factor, this is the phase that requires high levels of aeration.

## Short-cut nitrogen removal

The nitrite shunt approach exploits the fact that nitrite is an intermediate in both the nitrification and denitrification steps of conventional BNR. Here the 'shortcut' is achieved by stopping the nitrification process at nitrite, which is then reduced directly to nitrogen gas.

A second form of SBNR also inhibits nitrate formation but then uses bacteria that were discovered in the 1990s for anaerobic ammonium oxidisation (anammox). In the first step, half the ammonium is oxidised to nitrite, and in the second step, the remaining ammonium is anaerobically oxidised to nitrogen gas, by the anammox bacteria using the nitrite as the substrate/ electron donor.

## A natural partner to anaerobic digestion

Both processes allow for significant aeration energy savings of 20 to 60 per cent. Not only that, but the need for a carbon source in the second step is either reduced or eliminated, which enables operators to increase carbon harvest in primary treatment.

The key to enabling either of the above routes lies in creating conditions favouring the growth of the nitrite-producing AOB (ammonia-oxidising bacteria) at the expense of the nitrate-producing NOB (nitrite-oxidising bacteria).

In this regard, shortcut nitrogen removal can be seen as a natural partner for anaerobic digestion as the promotion of AOB and inhibition of NOB is favoured by the warm, ammonia-rich effluent typical of AD waste solids, often referred to as side-stream or reject water.

Other factors favouring nitrite formation include reduced dissolved oxygen levels, shorter tank retention time, and transitioning between aerobic and anaerobic conditions by switching the aeration on and off.

Achieving shortcut nitrogen removal in 'mainstream' cold, dilute wastewater is also possible. For instance, in 2016, Watercare Services Limited demonstrated full-scale nitrite shunt at the Mangere and Rosedale Wastewater Treatment Plants in New Zealand. However, process control is a key challenge.

## Robust simultaneous real-time nitrate and nitrite monitoring

This is where we believe our Aquamonitrix® analyser can have a game-changing impact.

Capable of simultaneously monitoring nitrite and nitrate in real-time, Aquamonitrix® offers researchers, designers and operators the tools, for the first time ever, to truly get to grips with what is happening in biological nitrogen removal.

Unlike ISE sensors, which suffer from drift, Aquamonitrix® provides real-time accuracy and precision above 90 per cent with minimal requirements for servicing, maintenance or recalibration intervention.

Furthermore, as the analyser uses a sample loop approach, and requires just microlitres of sample per analysis, the simple, in-built sampling system is all that is required in most deployment cases.

Even in activated sludge, a low-cost centripetal filter sample system or settlement is sufficient, avoiding the need for the kind of high-cost sampling systems that UV analysers require in effluent matrices.

*Aquamonitrix® is currently being trialled by utilities in wastewater treatment plants in Ireland, the UK and Spain. Pictured: An Aquamonitrix unit being installed at a WWTP in northern Spain.*

The prospect of mainstream short-cut biological nitrogen removal has been described as a "paradigm shift for the industry, offering the opportunity for sustainable wastewater treatment, energy neutral or even energy positive facilities and dramatic reductions in treatment costs…[with] widespread environmental, economic and societal benefits" by Pusker Raj Regmi, Old Dominion University, Virginia, in his 2014 publication *Feasibility of Mainstream Nitrite Oxidizing Bacteria Out-Selection and Anammox Polishing for Enhanced Nitrogen Removal.*

Given that nitrate and nitrite are intermediates in the single most energy-intensive conversion in conventional wastewater treatment, a robust method to monitor them in real-time is likely to be a key enabler in process optimisation - even without SBNR.

The US Electric Power Research Institute, for instance, has estimated that energy savings of 10 to 20 per cent can be achieved in wastewater facilities simply through better control and optimisation of the process.

Likewise, a better understanding of the molecular processes and reaction kinetics that occur during biological wastewater treatment and better characterisation of the synergistic interactions that occur among diverse microbial communities has been identified as an important enabler of the energy-positive wastewater treatment plant of the future, by an interagency working group reporting to the US National Science Foundation, Department of Energy, and Environmental Protection Agency in 2015.

Aquamonitrix® is currently being trialled by utilities in wastewater treatment plants in Ireland, the UK and Spain. We believe it is an important piece in the net-zero jigsaw, and we are excitedly awaiting the benefits it will bring.

**For further information, visit https://aqaumonitrix.com**.