UNISENSE ENVIRONMENT

Watercare

N_2O sensor matches 91% of measured off-gas emissions

Case Study: Full-scale comparison of N_2O emissions determined by liquid sensors and off-gas measurement

Rosedale Wastewater Treatment Plant, Auckland, New Zealand

The Rosedale WWTP is operated by Watercare, New Zealand's largest water and wastewater utility. The plant serves almost 220,000 people and local biogas production provides 60% of the plant's energy demand.

What to kN_2Ow about N_2O emissions?

N_2O (nitrous oxide) emitted from wastewater treatment plants (WWTPs) is a concern due to its environmental impact. N_2O is a potent greenhouse gas (GHG), with a global warming potential that is 273 times higher than that of CO_2 (carbon dioxide). WWTPs are a significant source of N_2O emissions, as the biological wastewater treatment processes produce N_2O.

Studies from around the world have shown that it can comprise up to 50-90% of a single treatment plants' GHG emissions. For this reason, reducing the N_2O emissions at WWTPs is a sustainability target of highest importance for most modern water utilities.

measure to kN_2Ow

After solids are removed through settlement, Rosedale WWTP achieves biological nitrogen removal through nitrification and denitrification in a Modified Ludzack-Ettinger (MLE) process divided into 4 trains. A simplified representation of the 4th process train is presented in Figure 1.

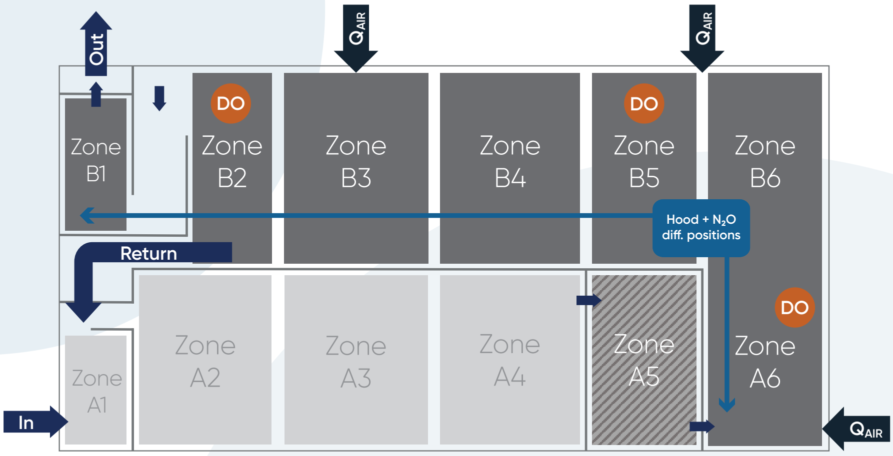

Figure 1: Schematic drawing of the MLE4 activated sludge process with direction of water flow and measuring locations. Light grey zones A1-A4 are unaerated while dark grey zones A6 and B1-B6 are aerated. Zone A5 can be aerated on demand. Hood: Location for off-gas sampling – measured in all aerated zones; N_2O: location of N_2O Sensor; DO: Location of oxygen sensor; Q_{AIR}: location of airflow measurement.

The tank has an airflow measurement for each of the three aeration zones A5/A6, B5/B6 and B2/B3/B4. This allows monitoring of the airflow split between the different aerobic zones. The airflow rate per cell was calculated based on the measured air flow rate to an aeration zone and assuming the air is distributed in proportion to the number of diffusers in each cell.

Monitoring N_2O with Off-Gas and Liquid Phase Sensors

N_2O monitoring was implemented in the aerated parts of the sludge tanks. Measuring equipment consisted of gas hoods connected to a Picarro gas analyzer and two N_2O Wastewater Sensors for the liquid phase.

One N_2O Wastewater Sensor and gas hood were moved progressively through the different aerobic cells, from cell A6 to cell B1. This was used to measure the gas-phase and liquid-phase N_2O concentrations, to allow an understanding of both the N_2O generation (liquid phase) and emission (stripping into the gas phase).

Comparing N_2O Concentrations from Off-Gas and Sensors

The complete set of equations including temperature correction in the Unisense Environment manual[1] were used for calculating the off-gas N_2O concentration in aerated zones based on the dissolved N_2O concentration and the superficial gas velocity (air flow rate divided by reactor aerated surface area).

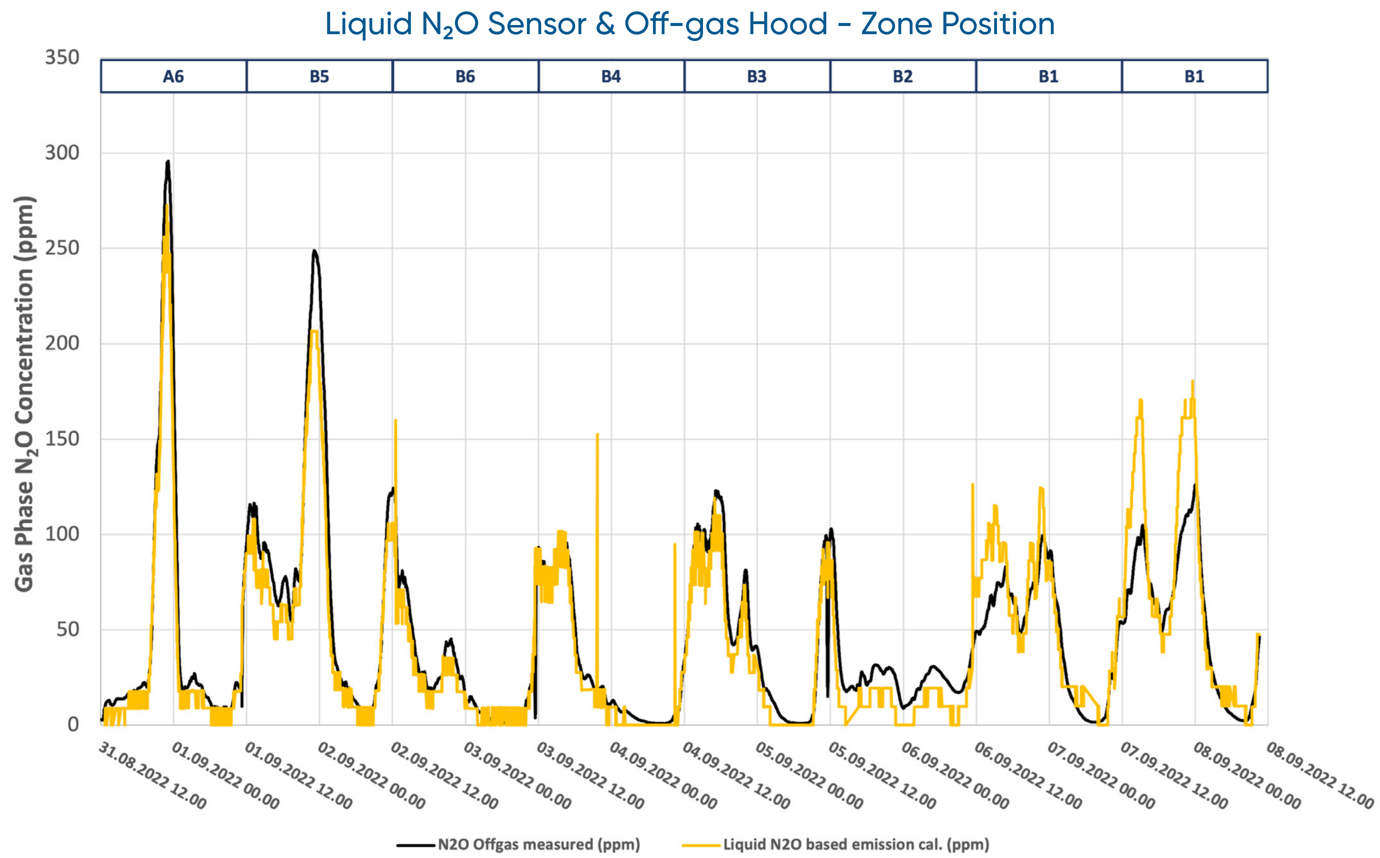

Figure 2: Gas phase N_2O concentration calculated based on the liquid N_2O sensor versus measured off-gas.
9 days of data shown with 1.3 days per zone monitored. Refer to Fig. 1 for measuring locations.

The N_2O concentration in the off-gas was measured and then compared with the emission predicted by the liquid N_2O sensor and airflow. Figure 2 shows the comparison between the measured and predicted concentrations.

The results showed very good agreement between the gas phase N_2O concentration calculated based on the liquid N_2O sensor and those measured in the gas phase. At Rosedale WWTP, 91% of the measured off-gas emission reference was described using the liquid N_2O sensor and calculations, exemplifying that the dissolved N_2O concentration can be used to provide a good estimate of N_2O emission rates[2].

The average N_2O emission rate

The average N_2O emission rate for a two-week monitoring period was calculated by summing up the N_2O emissions from the individual cells. The emission from each cell was found by multiplying the off-gas N_2O concentration from the cell by the measured airflow to that cell. For practical reasons it is not possible to measure the off-gas concentration in every cell simultaneously. For this study the N_2O emissions from the anoxic zones are assumed to be small and have been ignored (see ref. 1 for more information).

The average N_2O emission rate for MLE4 for the two-week period was calculated to 4.15 kg N_2O-N/d. Based on the average influent total nitrogen load to the plant during this period with 25% going to MLE4, an emission factor (EF_{N_2O}) of 0.005 kg N_2O-N/kg$N_{influent}$ (0.5% N_2O-N/$TN_{influent}$) can be deducted.

Long-Term Monitoring Recommended

The survey was conducted over a short period and the recommendation is that longer-term monitoring will provide further confidence in the EF_{N_2O} figure. Monitoring for a period of at least a year would be required to understand the seasonal variations.

Reference

[1] Unisense Environment (2024, February). "*N2O Mass Transfer Coefficient Calculation from Aeration Field Size and Air Flow*". https://unisense-environment.com/manuals/

[2] Prediction of Wastewater Treatment Greenhouse Gas Emissions Using a Real-Time Model, David Hume (Mott MacDonald), Kenny Williamson (Watercare Services Ltd.), Kevan Brian (Watercare Services Ltd.), Nick Dempsey (Mott MacDonald) Water New Zealand Conference and Expo 2022.

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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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