Case Study: Direct Effect of Activated Sludge Concentration on N_2O Emission and CO_2-equivalents at Full-scale

BIOFOS Avedøre WRRF, Copenhagen, Denmark

Avedøre is a 345,000 PE Water Resource Recovery Facility (WRRF) employing the activated sludge process in four parallel tanks (LT1-LT4), each consisting of two alternatingly fed and intermittently aerated compartments regulated by STAR Control®.

What to kN_2Ow about N_2O emissions?

Wastewater treatment contributes significantly to the global greenhouse gas (GHG) stock through the production and emission of nitrous oxide (N_2O).
The increase of the wastewater N_2O emission factor (EF_{N_2O}) to 1,6% N_2O-N/TN by $IPCC_{2019}$ underlines this.
In Denmark, a new national EF_{N_2O} of 0.84% N_2O-N/TN has been adopted by the Danish EPA based on a 2-year monitoring campaign on 10 different WRRFs in 2021.

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Over more than 4 years, nitrous oxide emissions from Avedøre's biological process tanks have been measured to derive the underlying process mechanisms responsible for climate gas emissions. Figure 1 shows the four years of online monitoring of N_2O in 4 of the 8 process compartments at Avedøre WRRF (i.e. monitoring 50% of the bioprocess). The data was collected in the SCADA system and the N_2O emission is presented as daily averages of KgN N_2O /day. The graph highlights the dynamic seasonal and yearly patterns. Although the yearly pattern is repeating, the emission magnitude varies significantly between years.

Insights from Continuous Monitoring of Nitrous Oxide

During the 4 years of online N_2O emission monitoring, the data showed a high and variable EF_{N_2O} above the $IPCC_{2019}$ factor based on daily TN_{Load} or daily $TN_{Treated}$. Furthermore, simple process changes have made a significant impact on the cumulative N_2O emissions. Based on the IPCC CO_2-equivalent factor (CO_{2-eqv}) of 298 kg CO_2 per kg N_2O, the total CO_2 footprint ranged from 18,396 in 2019 and 9,885 Ton CO_{2-eqv} in 2021. On average, in the periods of winter and summer emissions are 6.22 and 49.79 Ton CO_{2-eqv}/day.
The EF_{N_2O} of Avedøre WRRF is 2 – 4 times higher than national Danish emission factor and the $IPCC_{2019}$ factors. This highlights the importance of performing on-site monitoring of N_2O rather than relying on average assumptions. N_2O emission and inferred CO_2 footprint were highly variable and yet seasonally dependent, emphasizing the need for long-term continuous monitoring.

MLSS Control: A Key Factor in Lowering N_2O Emissions

Law et al. (2012) found that increased N_2O production is due to an increased specific NH_3 oxidation rate by AOBs. To decrease this rate, we tested increasing the MLSS (mixed liquor suspended solids) concentration in LT31 and LT32 while keeping LT11 and LT12 as reference tanks. Figure 2 shows a significant reduction in N_2O emissions during the spring months of 2020 and 2021, matching with the increased MLSS concentration.

The MLSS controlled tanks exhibited a lower EF_{N_2O} of 0.58% and 0.83% of the daily TN_{Load} for the years 2020 and 2021. The large seasonal and yearly variations demonstrate the need for long-term monitoring campaigns and the present work exemplifies the difficulty in extrapolating even yearly emission results or use of a reference year for a general N_2O emission factor.

Figure 1: Data from 4 years (1,565 days) of N_2O monitoring, using four N_2O sensors, is shown as daily mean N_2O emissions in KgN/day. The yearly and especially seasonal variations, between winter (Oct-Mar) and summer (Apr-Sep), are observed. N_2O emissions for aerated and non-aerated zones were calculated online following Baresel et al. 2016.

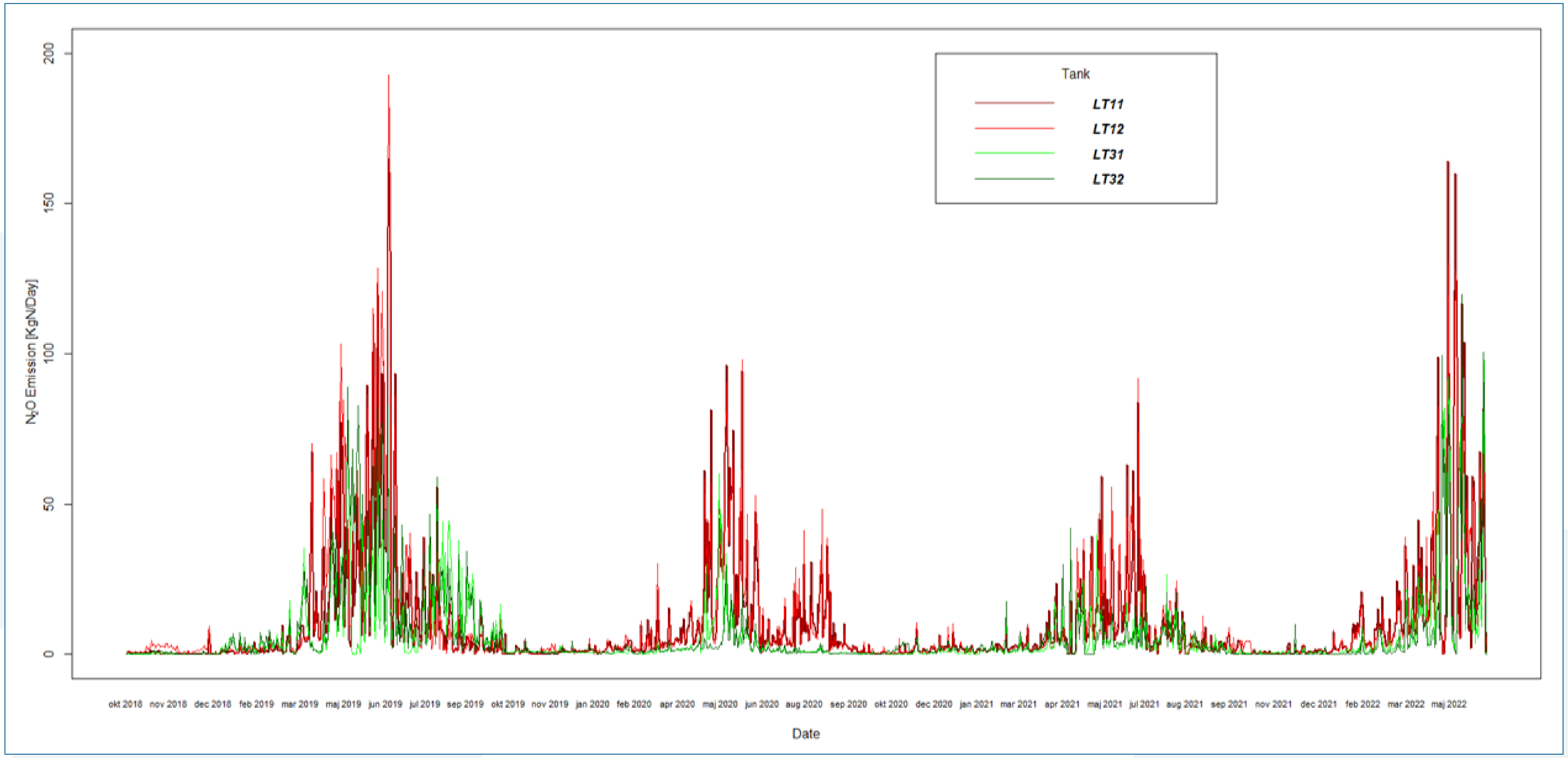
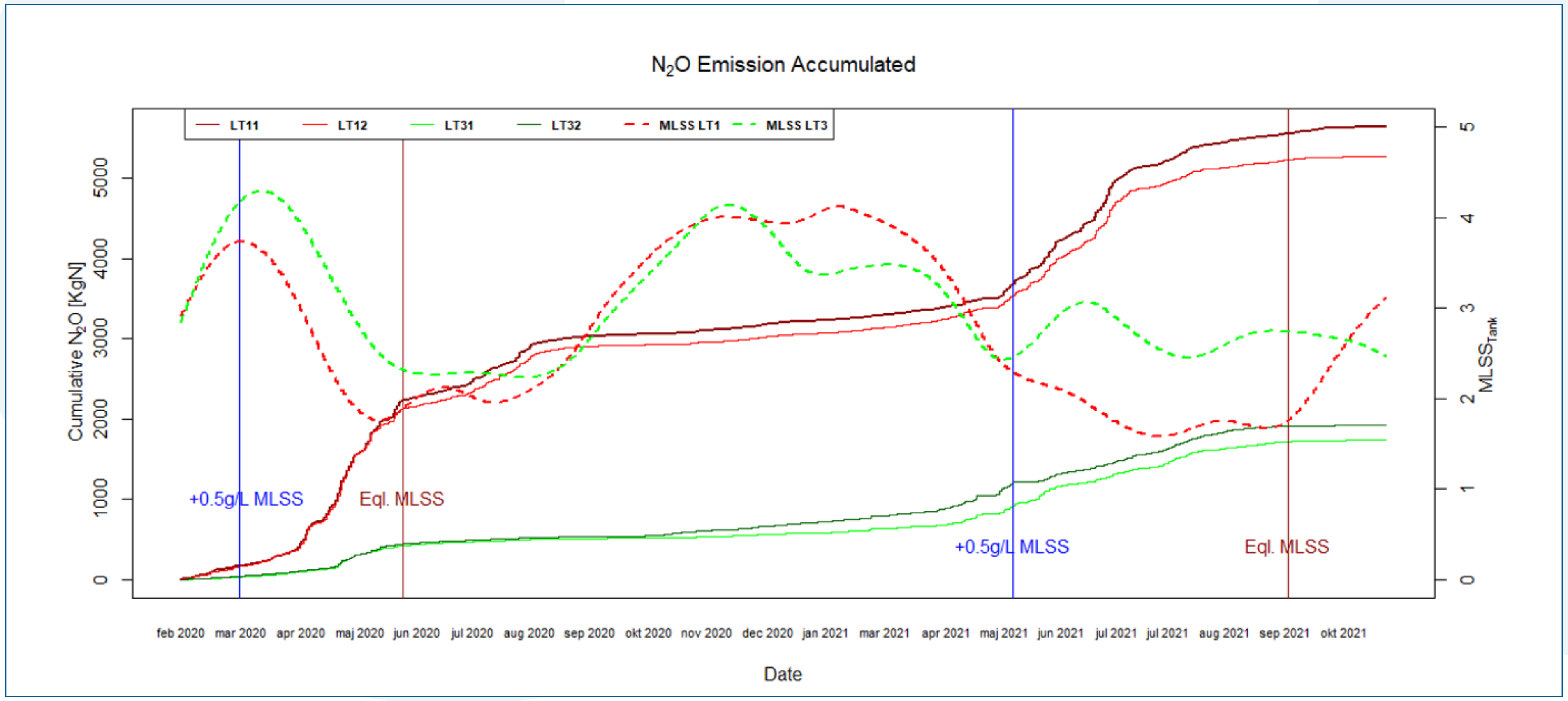


Figure 2: Cumulative plot of the N_2O emission from February 2020 to November 2021 from a total of 655 days. Comparison of the $CO_{2\text{-eqv}}$ emission per day (Ton $CO_{2\text{-eqv}}$ /Day) between the reference tanks LT11 and LT12 (red) and the higher MLSS tanks LT31 and LT32 (green).



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