

IMPACT OF AERATION CONTROL ON N₂O EMISSION IN A FULL-SCALE ACTIVATED SLUDGE WASTEWATER TREATMENT PLANT

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ABSTRACT

This work investigated the impact of aeration control strategy on energy consumption and nitrous oxide (N₂O) emission in a full-scale wastewater treatment plant. Two identical activated sludge processes treating the same effluent but operated with different aeration control strategies were compared. Aeration tank 1 was operated with a new control strategy favouring the simultaneous nitrification denitrification (SND) whereas aeration tank 2 was operated with a conventional control strategy with distinct nitrification and denitrification phases. Results indicated that whereas the N₂O emission factor was comparable in both systems (in the order of magnitude of 0.004% of the influent TKN load), N₂O emission pattern was dependent on the adopted aeration control strategy. It has been observed that high aeration flow rates (aeration tank 2) were likely to promote N₂O transfer from the gas phase to the liquid phase.

INTRODUCTION

In conventional wastewater treatment plants (WWTPs) the aeration of the bioreactors is one of the largest energy consumers (Fayolle et al., 2010). In order to optimize oxygen supply, new control systems have recently been proposed, including those based on the continuous monitoring of nitrogen forms (NH₄⁺, NO₃⁻). Such systems regulate the air supply according to nitrogen load to be treated and maintain relatively low dissolved oxygen concentrations in the basins. However, if these new control strategies help to reduce the energy consumption, their impact on nitrous oxide (N₂O) emissions remains unclear.

In WWTPs the release of N₂O from biological nitrogen removal processes is well recognized (Wunderlin et al., 2012). It has been identified to be particularly influenced by the DO concentration and rapidly changing oxygenation conditions - i.e. periodical switch between anoxic and oxic conditions (Chandran et al., 2011). It has been observed that a low concentration in the aerated zones may enhance N₂O production throughout the nitrifier denitrification pathway. At the same time, too high aeration rates in the nitrification tank may lead to an increased oxygen introduction to the denitrification tank and lead to incomplete heterotrophic denitrification with enhanced N₂O emissions (Ahn et al., 2010, Kampschreur et al., 2009). Within this context, this work aims at comparing N₂O emission patterns from two activated sludge tanks treating the same effluent and operated with different aeration control strategies. Energy consumption for aeration and performances of each tank were characterized. The influence of process conditions (DO concentration, organic and nitrogen loading rates, liquid/gas mass transfer,...) on N₂O emission has also been investigated.

MATERIAL AND METHODS

N₂O emissions and nitrogen removal efficiencies were investigated in a full-scale domestic wastewater treatment plant (230 000 PE) located in France. The facility consists of two parallel activated sludge lines operated under extended aeration ($F/M < 0.1$ kg BOD₅/kg MLVSS/d) and with different aeration control strategies.

Aeration tank 1 is equipped with a new aeration control system (Ammonair®, based on the continuous monitoring of the concentration of NH₄⁺ and O₂) that maintains low dissolved oxygen concentration in the bulk creating favorable conditions for the simultaneous nitrification and denitrification. Aeration tank 2 is equipped with a conventional control system (O₂/ORP) with distinct nitrification and denitrification phases.

Oxygen transfer was measured using the off-gas method (ASCE, 1996) on different locations of the aerated zone of each tank (Fig. 1). Gas emissions were collected with a floating chamber technique (Peu et al., 1999) in both aerated and non-aerated zones. The N₂O concentration was continuously monitored and analyzed, over a 24 h period, in a zone representative of the measured gas/liquid mass transfer parameters (Fig. 1). N₂O fluxes were correlated with sampling location-specific pH, activated sludge mixed-liquor temperature, DO, COD and N-form concentrations. Removal performances of each tank were evaluated. Influent and effluent composition was accessed using 24-h composite samples and analyzed by standard methods.

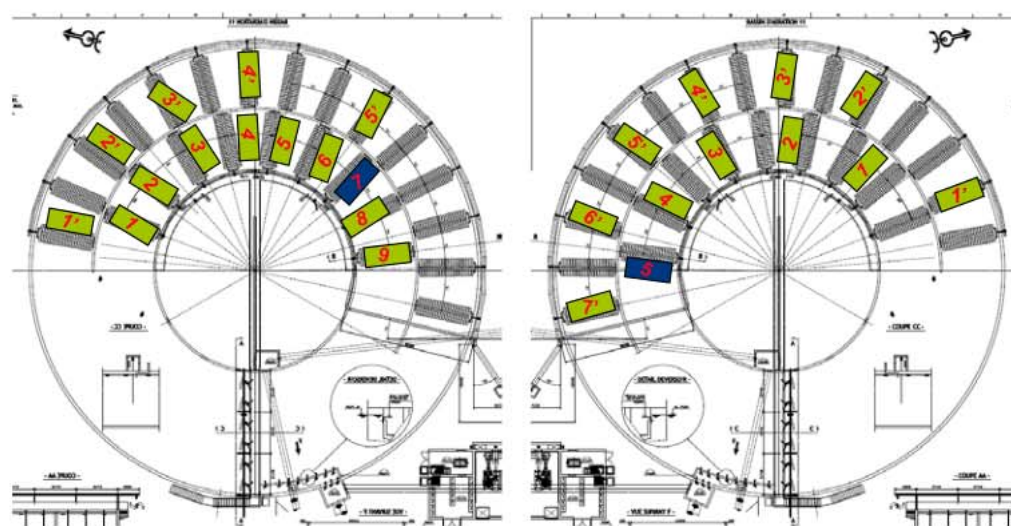


Figure 1. Sampling points for oxygen mass transfer measurement (■) and collectors position for the monitoring of N₂O emissions (■) in tank 1 (right) and tank 2 (left)

RESULTS AND DISCUSSION

Both reactors were operated with the same MLSS concentration (4.5 g/L) and showed similar removal performances (not shown). Off-gas N₂O concentrations in both systems show different patterns depending on the adopted aeration control strategy (Fig. 2). In aeration tank 1 (A), during both aerated and non-aerated phases, N₂O concentration was almost always higher or equal to the atmospheric concentration (370 ± 30 ppb). A decrease of the off-gas N₂O concentration below the atmospheric concentration (up to 127 ppb) was observed once (from 6:50 AM to 7:05AM) that is consistent with a sharp increase of the air flow rate to unclog diffusion membranes (from 3000 Nm³/h to 14000 Nm³/h).

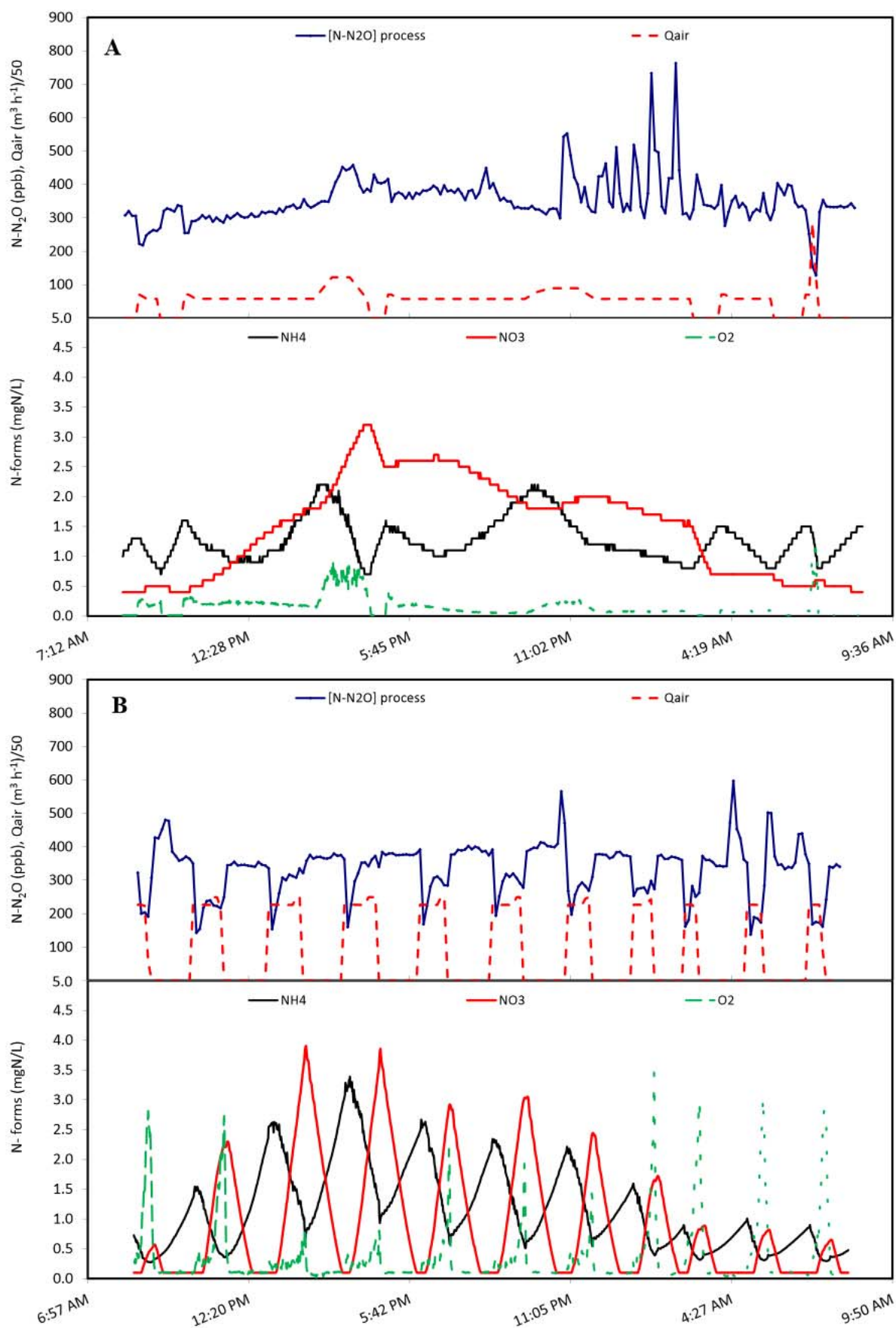


Figure 2. Off-gas N₂O concentration, air flow and nitrogen forms concentration in tank 1 (A) and tank 2 (B) - aerated zones

In aeration tank 2 (B), a rapid decrease of the N_2O concentration below the atmospheric concentration (up to 140 ppb) is observed at the beginning of each aerated period. The decrease of the N_2O concentration is certainly due to mass transfer from the gas phase to the liquid phase enhanced by the high air flow rate in aeration tank 2 (on average 11200 Nm^3/h). After this decrease, the N_2O concentration in tank 2 progressively increased up to the atmospheric concentration during both aerated and non-aerated phases.

The N_2O emission rate was in the order of magnitude of 33 g N- N_2O /d and 28 g N- N_2O /d for aeration tank 1 and 2, respectively. The N_2O emission factor is similar in both aeration tanks: 0.004% of the influent TKN load. This value is in the low range of reported literature values - 0.001 - 4.0% of the influent TKN load - (Foley et al., 2010, Stümer et al., 1995). Considering the amount of N_2O in the air blown into the aeration tank, a net N_2O **production** is observed in aeration tank 1 whereas a **consumption** of N_2O is observed in aeration tank 2. The phenomenon of N_2O consumption has already been observed in some low-loaded wastewater treatment plants (Foley et al., 2010). However the biological mechanisms of this consumption remains unclear.

Oxygen mass balance performed indicated that the air consumption for biological treatment was significantly different in both basins. Oxygen mass transferred to aeration tank 1 and tank 2 was 17700 kgO_2/d and 30700 kgO_2/d , respectively. Energy consumption for the aeration was estimated to be on average 30% greater in aeration tank 2 than in tank 1.

CONCLUSION

This study investigated performances, energy consumption and N_2O emissions from two activated sludge tanks treating the same effluent and operated with different aeration control strategies. Preliminary results indicated that although aeration control system was different, N_2O emission factor was comparable in both systems. Besides, it has been observed that high aeration flow rates (aeration tank 2) were likely to enhance N_2O transfer from the gas phase to the liquid phase at the beginning of the aeration phases. The comparison of aerated tanks on their energy consumption indicates that with Ammonair® control, energy consumption for aeration was reduced by about 30%. Further work has to be carried out to better understand the relationship between the observed N_2O emissions, gas transfer and the biological mechanisms of the production and/or consumption of N_2O .

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