Aeration control in a full-scale activated sludge wastewater treatment plant: impact on performances, energy consumption and N2O emission

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Abstract: This work investigated the impact of aeration control strategy on energy consumption and nitrous oxide (N_2O) 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 N_2O emission factor was comparable in both systems (in the order of magnitude of 0.004% of the influent TKN load), N_2O 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 N_2O transfer from the gas phase to the liquid phase.

Keywords: Aeration control strategy; nitrous oxide emission; activated sludge

INTRODUCTION

In activated sludge systems, aeration provides oxygen required by aerobic treatment processes, ensures mixing and homogenization of the mixed liquor and strips gases produced by the degradation processes. However, aeration is also known to be one of the largest energy consumers in wastewater treatment plants (WWTPs). In order to optimize oxygen supply, new control systems have recently been proposed, including those based on the continuous monitoring of nitrogen forms (NH_4^+, NO_3^-). 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 (N_2O) emissions remains unclear.

Nitrous oxide is an important greenhouse gas, about 300 times more effective than carbon dioxide (CO_2), and a major sink for stratospheric ozone [1]. In biological wastewater treatment, microbial processes such as hydroxylamine oxidation, nitrifier denitrification and heterotrophic denitrification have been identified as a major source of N_2O production [2]. *In situ*, several parameters favoring N_2O production were identified and dissolved oxygen concentration is considered as one of the most important parameter controlling N_2O production during both nitrification and denitrification processes. It has been observed that a low concentration in the aerated zones may enhance N_2O 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 N_2O emissions [3]. Moreover, oxygenation conditions (i.e. periodical switch between anoxic and oxic conditions) may also trigger the accumulation of nitrous oxide [4].

This work aims therefore at comparing N_2O emission patterns and energy consumption for aeration of two activated sludge tanks treating the same effluent and operated with different aeration control strategies. To our knowledge, this is the first *in situ* study dedicated to the evaluation of the impact of aeration control on nitrous oxide emission in activated sludge wastewater treatment plants.

MATERIAL AND METHODS

N_2O 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 BOD_5/kg MLVSS/d) and with different aeration control strategies. Each tank is of annular type with a central anaerobic zone and an alternate aeration mode in the outer ring. Aeration tank 1 is equipped with a new aeration control system (Ammonair®, based on the continuous monitoring of the concentration of NH_4^+ and O_2) that maintains low dissolved oxygen concentrations in the bulk creating favorable conditions for the simultaneous nitrification and denitrification. Air is supplied by two variable-speed blower working either simultaneously or alternately. Aeration tank 2 is equipped with a conventional aeration control system (O_2/ORP) with distinct nitrification and denitrification phases. Air is supplied by a constant-speed blower and a variable-speed blower working simultaneously.

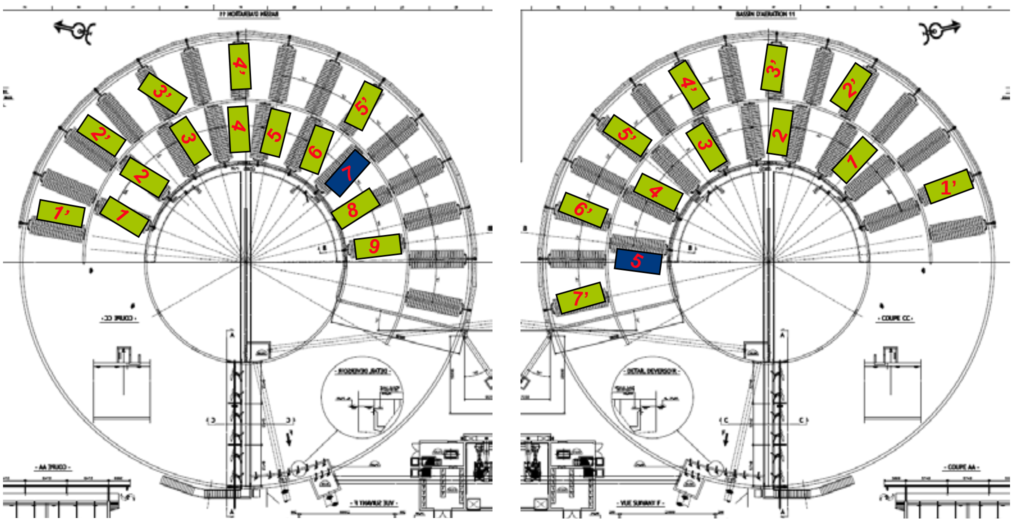

Figure 1. Sampling points for oxygen mass transfer measurement (▭) and collectors position for the monitoring of N_2O emissions (▬) in tank 1 (right) and tank 2 (left)

Oxygen transfer was measured using the off-gas method [5] on different locations of the aerated zone of each tank (Fig.1). Gas emissions were collected with a floating chamber technique [6] in both aerated and non-aerated zones. The N_2O concentration was continuously monitored and analyzed, over a 24 h period, in a zone representative of the measured gas/liquid mass transfer parameters (positions 5 and 7 in aeration tank 1 and tank 2, respectively). Influent and effluent composition was accessed using 24-h composite samples and analysed by standard methods.

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 N_2O concentrations in both systems show different patterns depending on the adopted aeration control strategy (Fig .2).

In aeration tank 1, during both aerated and non-aerated phases, N_2O concentration was almost always higher or equal to the atmospheric concentration (350 ± 30 ppb). A decrease of the off-gas N_2O concentration below the atmospheric concentration (up to 127 ppb) was observed once (from 6:50 AM to 7:05 AM) that is consistent with a sharp increase of the air flow rate to unclog diffusion membranes (from 3000 Nm^3/h to 14000 Nm^3/h). In aeration tank 2, 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.

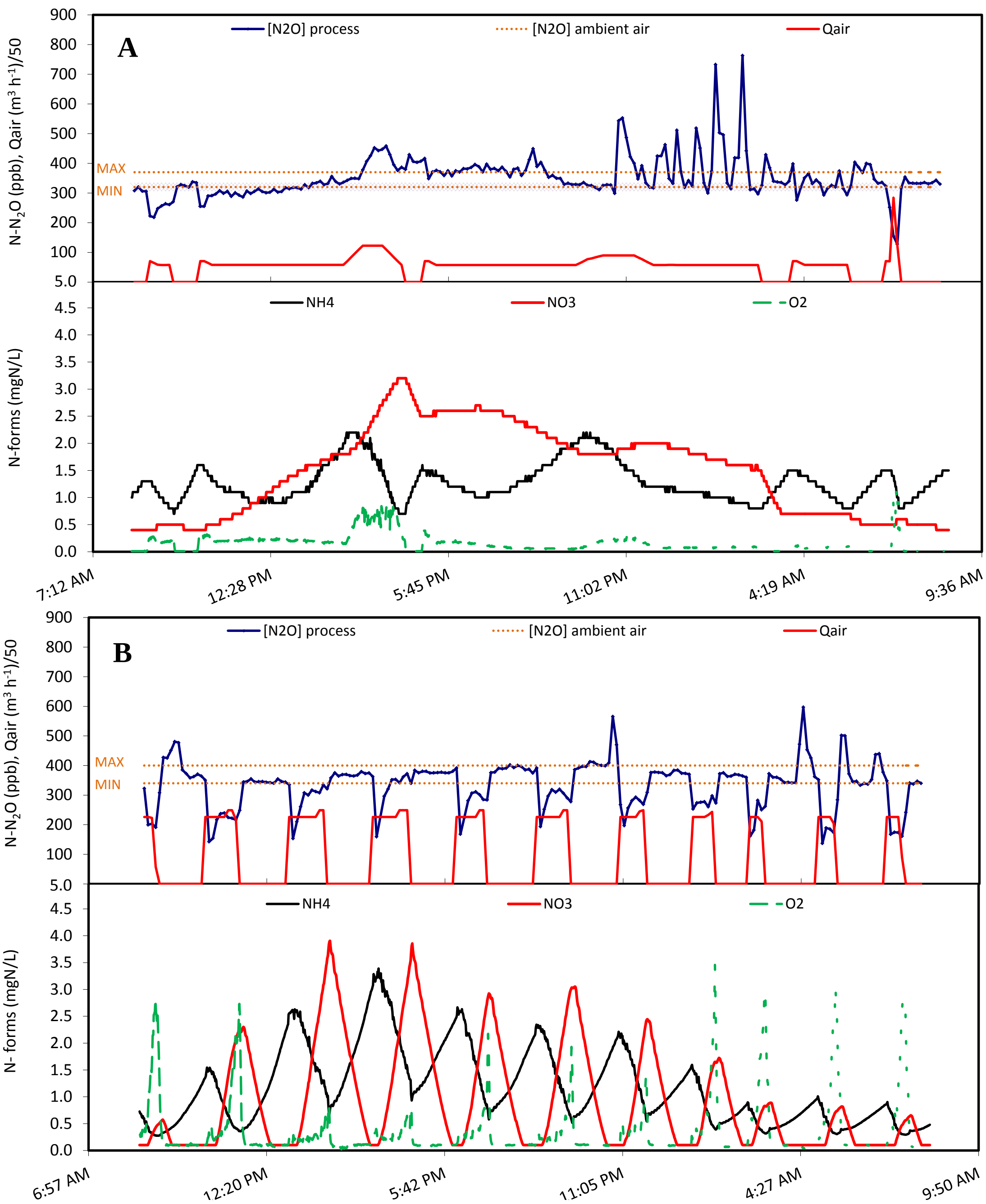

Figure 2. Off-gas N_2O concentration, air flow and nitrogen forms concentration in tank 1 (A) and tank 2 (B) - aerated zones.

The N_2O emission rate was in the order of magnitude of 33 g $N\text{-}N_2O/d$ and 28 g $N\text{-}N_2O/d$ 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) [7, 8]. Considering the fact that the off gas N_2O concentrations were close to the atmospheric concentration, the uncertainty of the estimated N_2O emission factor can be significant. However, the low N_2O emission factor reported is in accordance with some literature findings. Low N_2O emissions were reported in BNR processes whom operation: (i) maintain low nitrogen forms concentrations in the bulk (such as low-loaded plants) and (ii) ovoid their transient accumulation [7, 9].

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, from the active power of blowers, to be on average 30% greater in aeration tank 2 than in tank1.

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 including process modelling 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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