Total and stable washout of nitrite oxidizing bacteria from a nitrifying continuous activated sludge system using automatic control based on Oxygen Uptake Rate measurements

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Abstract

Partial nitrification (ammonium oxidation to nitrite) has gained a lot of interest among researchers in the last years because of its advantages with respect to complete nitrification (ammonium oxidation to nitrate): decrease of oxygen requirements for nitrification, reduction of COD demand and CO₂ emissions during denitrification and higher denitrification rate and lower biomass production during anoxic growth.

In this study, an extremely high-strength ammonium wastewater (3000–4000 mg N L⁻¹) was treated in a continuous pilot plant with a configuration of three reactors in series plus a settler. The system was operated under the maximum possible volumetric nitrogen loading rate, at mild temperature (around 25 °C), with high sludge retention time (around 30 d) and significant nitrifying biomass concentration (average of 1800–600 mg VSS L⁻¹).

The implemented control loops transformed the system, which was operating with complete nitrification, into a continuous partial nitrification system. Nitrite oxidizing bacteria (NOB) washout was accomplished with local control loops for pH and dissolved oxygen (DO) with proper setpoints for NOB inhibition (pH = 8.3 and DO = 1.2–1.9 mg O₂ L⁻¹) and with an inflow control loop based on Oxygen Uptake Rate (OUR) measurements, which allowed working at the maximum ammonium oxidation capacity of the pilot plant in each moment. This operational strategy maximized the difference between ammonia oxidizing bacteria (AOB) and NOB growth rates, which is the key point to achieve a fast and stable NOB washout. The results showed a stable operation of the partial nitrification system during more than 100 days and NOB washout was corroborated with fluorescence in-situ hybridization (FISH) analysis.

1. Introduction

Partial nitrification (ammonium oxidation to nitrite) has gained a lot of interest among researchers in the last years, especially in the field of high-strength ammonium wastewater treatment. Turk and Mavinic (1987) demonstrated that this shortcut in the biological ammonium removal process has several advantages with respect to the complete nitrification (ammonium oxidation to nitrate): (1) a 40% reduction of COD demand during denitrification; (2) 63%
The temperature is another important factor in the difference between the growth rates of AOB and NOB populations. In our study, taking into account only the effect of temperature over kinetic parameters, the net growth rates \( \left( \mu_{\text{max}} - b_{\text{max}} \right) \) for AOB and NOB at the temperature of operation (25 °C) were 0.86 and 0.77 \( \text{d}^{-1} \), respectively. It means that the temperature effect only separated a 10% the net growth rate of both populations and it was not a key factor for nitrite accumulation. However, if the system would be operated at 30 or 35 °C, the difference between both net growth rates would be increased to 28% and 38%, respectively. This fact demonstrates that is more difficult to achieve a total stable NOB washout at mild temperatures. Most of the references of partial nitrification systems that obtained almost 100% of nitrite accumulation are processes operating at temperatures of 30–35 °C (Peng et al., 2004; Fux et al., 2006; Mace et al., 2006; Chuang et al., 2007). Only few studies also achieved a 100% of nitrite accumulation operating at mild temperatures (Li et al., 2004; Lemaire et al., 2008).

As result of this kinetic study, it was demonstrated that the complete and stable NOB washout in our system was achieved with a combination of several factors: FA and FNA inhibitions and DO limitation, being the most significant one, the inhibition of NOB by FA. This inhibitory effect was produced by the TAN accumulation in the pilot plant (mainly in R1 and R2) and the pH setpoint (8.3) used in the second strategy. This TAN accumulation (Fig. 5c) was produced and maintained by the applied real-time-control. Therefore, the automatic control of the NLRv allowed, simultaneously, achieving 100% of partial nitrification and operating at the current maximum nitrification capacity.

4. Conclusions

- An extremely high-strength ammonium wastewater was treated in a nitrifying activated sludge pilot plant with 100% partial nitrification to nitrite at mild temperature (25 °C) and high SRT (30 d). The system was based on continuous operation with a configuration of three reactors in series and a settler. A real-time-control loop based on OUR measurements was used to adapt the ammonium loading rate to the current maximum ammonium oxidation capacity of AOB. pH and DO setpoints were modified to increase NOB inhibition, but the OUR control loop allowed to maintain the maximum AOB activity.

- The applied control strategy maximized the difference between AOB and NOB growth rates, which is the key point to achieve a fast and stable NOB washout.

- A kinetic study demonstrated that the complete and stable NOB washout in the system was achieved with a combination of several factors: FA and FNA inhibitions and DO limitation, being the most significant the inhibitory effect of FA over NOB biomass.

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