Simulation of Start Up and Operation of Autotrophic Nitrogen Removal Processes

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INTRODUCTION

Recently innovative processes for nitrogen removal from concentrated streams were developed based on the ANoxic AMMonium OXidation (ANAMMOX) (Jetten *et al.*, 1999). In this process nitrite is used as electron acceptor for the oxidation of ammonium. Nitrite and ammonium are consumed in an almost equimolar ratio. The main reaction product is nitrogen gas, although about 10 % nitrate is produced. Waste water streams with an almost equimolar ammonium:nitrite ratio are not known, but examples of streams with high ammonium concentration are numerous (digestor effluents, landfill leacheates,…). Hence, this Anammox suited influent has to be produced in a preceding partial nitritation step. Care should be taken in this step that only few nitrite peaks are entering the Anammox reactor since Anammox organisms are inhibited by nitrite. Such combined partial nitritation-Anammox processes is called autotrophic nitrogen removal.

In literature few studies towards modelling and simulation of this autotrophic nitrogen removal are presented. Hao *et al.* (2002a&b) performed a thorough simulation study on the behaviour of a partial nitrification-Anammox system under different process conditions. However no verification with real data was performed and no start-up dynamics were included in the study. Koch *et al.* (2000) performed simulations with a similar system, but also did not include any start-up simulation or study of long-term dynamic effects.

The aim of this study was therefore to compare a model for the autotrophic nitrogen removal process with start-up and dynamic data from lab-scale reactors. With the help of the model the behaviour of the reactors could be explained and predictions about future operations could be made.

EXTENSION OF ASM1

The model for the autotrophic nitrogen removal process is an extension of ASM1 (Dapena et al., 2004; Wyffels et al., 2004). In the model ammonia (S_{NH3}) rather than ammonium, and nitrous acid (S_{HNO2}) rather than nitrite are used as actual substrates for ammonium oxidizer and nitrite oxidizer growth, respectively (Anthonisen et al., 1976). The stoichiometry of the reactions is however expressed in terms of the corresponding concentrations of total ammonia nitrogen (S_{NH}) and total nitrite nitrogen (S_{NO}), as typically done. Oxygen (S_O) is used as electron acceptor for autotrophic growth. To describe the growth kinetics of Anammox Total ammonia nitrogen (S_{NH}) and total nitrite nitrogen (S_{NO}) instead of ammonia and nitrous acid are used. This is because it is not yet determined whether it is only the uncharged form that is the real substrate. Temperature dependency of process kinetics is taken into account by Arrhenius-type equations.

EXPERIMENTAL SET-UP

The partial nitritation reactor used in this study was a 1.5 l membrane bioreactor (MBR) operated under oxygen limited conditions and a temperature of 30°C (Wyffels et al., 2004). The hydraulic retention time (HRT) and aeration rate (Kla) were gradually decreased to produce an Anammox suited effluent. The Anammox reactor was a 1 l sequencing batch reactor (SBR) operated at 35°C. Start-up of the reactor lasted 2 months and was accomplished by gradually increasing the influent ammonium and nitrite concentrations (Dapena et al., 2004).

SIMULATION RESULTS

Simulated effluent concentrations of both systems were compared with measurements and agree well. As an example, the ammonium concentration in both reactors is depicted in Figure 1. Note that some disturbances occurred in the Anammox reactor after day 120. With the model several questions concerning the system can be answered. For example, simulations at different temperatures with the MBR reactor reveal that aeration control is necessary to account for varying ambient temperatures during the year. Further a colour change from brownish to red (the typical Anammox colour) was observed at day 100 of the experiment. Simulations showed that at that time the Anammox organisms became dominant.

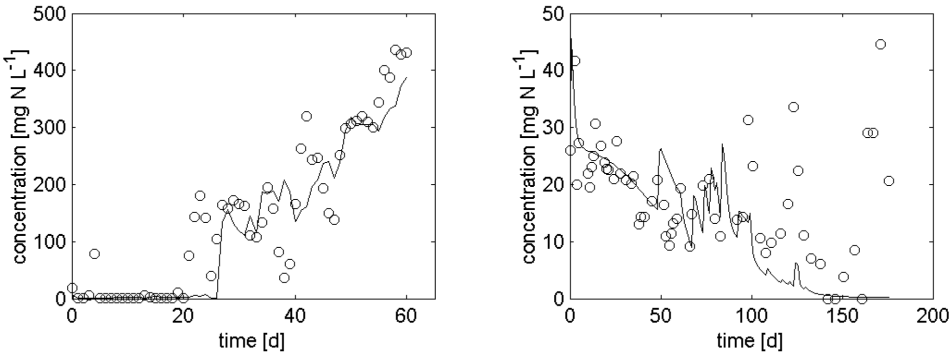

Figure 1. Simulated (—) and measured (o) ammonium concentration of start-up and operation of an autotrophic nitrogen removal system: partial nitritation (left) and Anammox (right).

CONCLUSION

A model to describe autotrophic nitrogen removal was compared to measurement data of start-up and operation of lab-scale reactors. Good agreement was found and several questions concerning the system can now be answered through simulation.

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