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Sensitivity analysis of autotrophic N removal by a granule based bioreactor: Influence of mass transfer versus microbial kinetics

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HIGHLIGHTS

- Mass transfer and microbial kinetics mechanisms were studied systematically.
- Highest removal efficiency was obtained at an oxygen/TAN loading ratio of 1.9 gO_2/gN.
- Below this value N removal was impacted 75% by AOB kinetics and 10% by mass transfer.
- Above this value the activity of AnAOB is inhibited by oxygen and NOB are present.
- Mass transfer had similar impact on different granules sizes in the range of 0.5–2 mm.

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ABSTRACT

A comprehensive and global sensitivity analysis was conducted under a range of operating conditions. The relative importance of mass transfer resistance versus kinetic parameters was studied and found to depend on the operating regime as follows: Operating under the optimal loading ratio of 1.90 $(gO_2/m^3/d)/(gN/m^3/d)$, the system was influenced by mass transfer (10% impact on nitrogen removal) and performance was limited by AOB activity (75% impact on nitrogen removal), while operating above, AnAOB activity was limiting (68% impact on nitrogen removal). The negative effect of oxygen mass transfer had an impact of 15% on nitrogen removal. Summarizing such quantitative analyses led to formulation of an optimal operation window, which serves a valuable tool for diagnosis of performance problems and identification of optimal solutions in nitritation/anammox applications.

1. Introduction

Mathematical models of novel biological wastewater treatment processes are of great importance as a tool for developing an improved understanding and optimization of such new technologies. A substantial number of studies have investigated complete autotrophic nitrogen removal as an energy and cost efficient alternative treatment method in particular for wastewaters containing high concentrations of nitrogen and low concentrations of readily biodegradable organic matter. The limiting factors and bottlenecks of the process have yet to be thoroughly investigated and understood for development of optimal process solutions and implementations (Van Hulle et al., 2010).

Autotrophic nitrogen removal consists of two processes carried out by two different groups of bacteria. Nitritation (Eq. (1)) is the process in which ammonium (NH_4^+) is converted to nitrite (NO_2^-) by aerobic ammonium oxidizing bacteria (AOB). In the anammox process (Eq. (2)) the produced NO_2^- is used as electron acceptor to oxidize the remaining NH_4^+ to free nitrogen gas (N_2). This process is conducted by anaerobic ammonium oxidizing bacteria (AnAOB) (van de Graaf et al., 1995). Stoichiometric relations between the compounds involved in both reactions can be seen below in Eqs. (1) and (2) (Wiesmann, 1994; Strous et al., 1998):

$$NH_4^+ + 1.38O_2 + 0.09CO_2 \rightarrow 0.018C_5H_7NO_2 + 0.98NO_2^- + 0.95H_2O + 1.98H^+ \quad (1)$$

$$NH_4^+ + 1.32NO_2^- + 0.066HCO_3^- + 0.13H^+ \rightarrow 1.02N_2 + 0.26NO_3^- + 0.066CH_2O_{0.5}N_{0.15} + 2.03H_2O \quad (2)$$

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