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Performance and robustness of an ANAMMOX anaerobic baffled reactor subjected to transient shock loads

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ABSTRACT

The impacts of transient overloads on the performance of a laboratory-scale anaerobic ammonium oxidation (ANAMMOX) anaerobic baffled reactor was studied by increasing the substrate concentration or inflow rate to 1.5–3.0 times above normal values. These shocks, with the exception of the highest substrate shock, weakened the nitrogen removal efficiency (NRE) but improved the nitrogen removal rate by 0.01–0.18 g l^{-1} h^{-1}. The communities and the location of the sludge may be altered by distinct types of shocks. The substrate vibration data showed that the reactor was unresponsive to hydraulic shocks but sensitive to substrate shocks and the former compartments were more susceptible to the shocks. In the inhibition period, the pH and NRE of the reactor were related to the residual ammonium and free ammonia (FA) and FA was a factor in the reactor fluctuations. The Gaussian model proposed to describe the shocks response fits the experimental data well.

1. Introduction

Anaerobic ammonium oxidation (ANAMMOX) is a biological process in which ammonium (NH_4^+) is oxidized to dinitrogen gas (N_2) using nitrite (NO_2^-) as an electron acceptor, producing meager amounts of nitrate (NO_3^-) (Eq. (1)) (Strous et al., 1998). Compared with the conventional nitrification/denitrification process, the application of ANAMMOX for nitrogen removal could lead to significantly lower costs for aeration and exogenous electron donors. In laboratory-scale trials, an optimal nitrogen removal rate (NRR) has been shown to be 74.3–76.7 kg N m^{-3} d^{-1} (Tang et al., 2011), and there are several studies where an NRR above 20 kg N m^{-3} d^{-1} was obtained (Tsushima et al., 2007; Chen et al., 2010b; Tang et al., 2010; Ma et al., 2011). Given the appropriate operating conditions, ANAMMOX bioreactors have an amazing potential for high efficiency.

$$NH_4^+ + 1.31NO_2^- + 0.066HCO_3^- + 0.13H^+ \rightarrow N_2 + 0.26NO_3^- + 0.066CH_2O_{0.5}N_{0.15} + 2H_2O \quad (1)$$

For a successful and sturdy ANAMMOX process, in both laboratory-scale and full-scale reactors, the latent negative effects of the influential factors that emerge in daily operations should be studied. Variations in inflow loads, influent pH, reactor temperatures, and specific compounds, primarily exogenous toxic and inhibition compounds, lead to reactor performance deterioration (Leitão et al., 2006). Fluctuations in hydraulic and substrate loads are more common during routine work and are reported to be the responsible for losses in ANAMMOX activity. Reactors with diverse configurations make systems resilient to hydraulic and substrate shock loads. Nachaiyasit and Stuckey (1997a,b) evaluated perturbations during and after hydraulic and substance overloads in a methanogenic anaerobic baffled reactor (ABR). With a specific configuration design, the ABR has a "phase separation" characteristic that creates a sufficient buffer space for the overloads. The authors found that the reactor had a high tolerance to transient shocks and was minimally influenced by oscillations in inflow substrate concentrations and flow rates; even if such a disturbance occurred, the unit quickly recovered to the original processing level. Other researchers have shown that multi-stage wastewater treatment processes were capable of absorbing the shock loads, recovered quickly from the shocks, with recovery times proportional to the magnitude of the shock loads (Seetha et al., 2010). Jin et al. (2008) subjected three laboratory-scale ANAMMOX bioreactors to different substrate concentration and flow rate shocks. The reactors had dissimilar robustness, in accordance with the quantitative evaluation, due to the different reactor configurations. The instability indices indicated that the hydraulic shocks were less harmful than the substrate shocks.

The design of ABRs has been evolving since the early 1980s, and the ABRs currently possess several advantages over other well-established anaerobic reactors. ABRs have a better resistance to shock loads, longer biomass retention times and the ability to

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