Chemical Engineering Journal 200–202 (2012) 176–185

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Influence of effluent recirculation on the performance of Anammox process

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HIGHLIGHTS

- Two UASB reactors, with and without recirculation, were used for Anammox operation.
- Effluent recirculation promoted the efficiency and the stability of the process.
- The variation of substrate ratio did not significantly affect the stoichiometry.
- High pH and free ammonia hinder the further improvement of Anammox performance.

ARTICLE INFO

Article history:
Received 10 April 2012
Received in revised form 7 June 2012
Accepted 11 June 2012
Available online 19 June 2012

Keywords:
Anammox
Effluent recirculation
Recirculation ratio
Shear force
Granular sludge

ABSTRACT

A study employing two parallel, laboratory-scale upflow anaerobic sludge bed (UASB) reactors (R_1 without and R_2 with effluent recirculation) was performed to explore the impact of effluent recirculation with various recirculation ratios (r) on the performance of the anaerobic ammonium oxidation (Anammox) process. When the influent total nitrogen (TN) level was at 700 mg L^{-1}, the nitrogen removal rate of R_2 ($r = 0.5, 4, 5$) was stable at approximately 3.5 kg m^{-3} day^{-1}, which is higher than the value of 2.9 kg m^{-3} day^{-1} for R_1. This performance showed that the recirculation of effluent promoted the efficiency and stability of the Anammox process. The specific Anammox activity of the biomass in R_2 reached 13.3 mg-TN g^{-1}-VSS h^{-1}, which is 34.3% higher than that in R_1. The dilution effect and the hydraulic shear force enhanced the performance of the Anammox reactor. However, effluent recirculation was prone to causing variation in the influent qualities. The variation in the substrate ratio did not significantly affect the stoichiometry of the Anammox reaction or the substrate removal capacity, but the high pH resulting from effluent recirculation, with the corresponding high free ammonia concentration, appeared to hinder the further improvement of Anammox performance.

1. Introduction

The anaerobic ammonium oxidation (Anammox) process is a novel anaerobic, autotrophic, biological nitrogen-removal technology developed in the 1990s [1–3]. This process offers a sustainable alternative to conventional nitrification–denitrification systems with the advantages of a higher nitrogen removal rate, lower operational costs and reduced space requirements [4–7]. The first full-scale Anammox process, initiated in Rotterdam, was applied to treat sludge-dewatering effluents [5]. This system reached a stable nitrogen removal rate (NRR) of 9.5 kg-N m^{-3} day^{-1} [5]. Higher rates of performance have been achieved in laboratory-scale trials [8,9]. The highest NRR reported to date reached 77 kg-N m^{-3} day^{-1} [9]. As an novel biological nitrogen removal technology, Anammox has great prospects for applications in treating wastewater with low *C*/*N* and high levels of ammonium [4–6,10].

The granulation of Anammox sludge led to stable nitrogen removal [11]. An appropriate shear force facilitates the formation of Anammox granular sludge [12] and improves Anammox activity [13]. Generally, the hydraulic shear force is enhanced by shortening the hydraulic retention time (HRT) or manipulating effluent recirculation [12]. Gradually shortening the HRT facilitates the initiation of the process [14] and enhances the performance [8]. Because the Anammox process is vulnerable to substrate inhibition at high concentrations [15–17], reducing the HRT is not suitable for an Anammox reactor treating wastewater with high concentrations of substrates. The effluent recirculation is an alternative strategy.

Several studies have suggested that the performance of the Anammox process is enhanced by the use of appropriate effluent recirculation [5,9,13] with other positive operation conditions. Chen et al. [13] employed varied effluent recirculation ratios based on the substrate concentrations. Using this technique, the NRR was

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http://dx.doi.org/10.1016/j.cej.2012.06.046