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Performance of autotrophic nitrogen removal in the granular sludge bed reactor

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HIGHLIGHTS

- A new and high-rate autotrophic process for nitrogen removal was developed.
- The volumetric capacity reached the top level reported so far.
- The predominant functional microorganisms were analyzed.
- The main operation parameters were optimized.
- The working mechanisms were investigated.

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ABSTRACT

The autotrophic nitrogen removal process in the granular sludge bed reactor (GSB-ANR process) is a new and promising biotechnology for nitrogen removal from wastewater, which requires single reactor, simple operation and inorganic carbon. The results showed that the GSB-ANR process could be successfully started up with nitrifying granular sludge as inoculum. The volumetric nitrogen loading rate and the volumetric nitrogen removal rate reached 5.44 and 2.57 kg N m^{-3} day^{-1}, respectively, which were significantly higher than the level reported for the autotrophic nitrogen removal processes in single reactor. The predominant functional microorganisms were from Planctomycetes and *Nitrosomonas*. The excellent performance of GSB-ANR process was ascribed to: (a) The high activities of aerobic ammonia-oxidizing bacteria (AOB) and anaerobic ammonium oxidation (ANAMMOX) bacteria; (b) the good settlability of the granular sludge; (c) the suitable DO concentration that satisfied the oxygen requirement of AOB and prevented ANAMMOX bacteria from oxygen inhibition.

1. Introduction

After the secondary treatment, the organic pollution from industrial, agricultural and municipal wastewaters has been effectively controlled. However, the secondary effluents still contain nitrogenous pollutants, which have become an increasingly important environmental issue (Chen et al., 2009; Pynaert et al., 2003). At present, the traditional nitrification–denitrification process is the most widespread technology for nitrogen removal in wastewater treatment plants (Pynaert et al., 2004). But, due to the denitrification step requires a biodegradable organic carbon as an electron donor, it has shown some weaknesses when it is applied to the treatment of secondary effluent with low C/N ratio (Sun et al., 2010). Fortunately, some new nitrogen removal technologies such as ANAMMOX (anaerobic ammonium oxidation) process have been developed, which are helpful to solve the problem from low C/N ratio (Sun et al., 2010; Van de Graff et al., 1996). Recently, ANAMMOX process has been successfully applied to the nitrogen removal from centrifuged sludge digestate, with a volumetric conversion rate of 9.5 kg N m^{-3} day^{-1} (van der Star et al., 2007), which is far higher than that of the traditional nitrogen removal processes (<0.5 kg N m^{-3} day^{-1}) (Gerardi, 2002).

Because ANAMMOX process requires the substrate with suitable ammonium to nitrite ratio, it was generally combined with the partial nitrification (PN) process, where 50% of ammonium is oxidized to nitrite (Cho et al., 2011; Gong et al., 2007; Vazquez-Padin et al., 2009). However, compared with the ANAMMOX process PN process showed a low conversion rate ($\leqslant$3.3 kg N m^{-3} day^{-1}) (Ruiz et al., 2003) because of the product (nitrite) inhibition on nitrifying bacteria (Vazquez-Padin et al., 2009). Moreover, it is difficult to regulate the influent NH_4^+N/NO_2^-–N ratio in ANAMMOX process (Vlaeminck et al., 2009; Zhang et al., 2011). In order to

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