

Sustainable nitrification in fluidised bed reactor with immobilised sludge pellets

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ABSTRACT

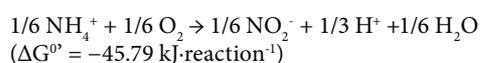
Sustainable immobilised microbial pellets were developed with water-borne polyurethane (WPU) material together with powdered activated carbon (PAC) and activated sludge as microbial inoculums for nitrification or partial nitrification. The nitrification performance and the influencing factors were studied with lab-scale aerobic fluidised bed reactors (FBR) under various temperature conditions. During the start-up period, quickly increasing the influent ammonium concentration from 40 to 320 mg N·ℓ⁻¹ led to a stable nitrification performance with high nitrite accumulation (>80%). Characterisation of the FBR performance indicated that the desired partial nitrification could be achieved at pH 7.8–8.5, dissolved oxygen (DO) 3–5 mg·ℓ⁻¹ and temperature between 24 and 29°C. Addition of organic carbon (glucose) improved the ammonium removal but decreased the nitrite accumulation ratio significantly. TOC concentration above 800 mg·ℓ⁻¹ was not able to cause the inhibition of the heterotrophs over the nitrifiers. PCR-DGGE results indicated the presence of *Nitrosomonas* (ammonia-oxidising bacteria) and *Nitrobacter* (nitrite-oxidising bacteria) in the immobilised pellets.

Keywords: bioimmobilisation, ammonium, partial nitrification, wastewater treatment

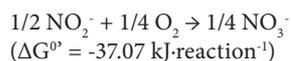
INTRODUCTION

The problems caused by ammonium and total nitrogen in municipal, agricultural and industrial wastewater have become a significant concern throughout the world. Discharge of high nitrogen-containing effluent to aqueous environments could cause ammonia toxicity problems and eutrophication of surface receivers. Regulatory agencies in many countries, including China, have required increasingly stringent water quality criteria for ammonium and total nitrogen (TN) removal.

Partial nitrification, i.e., the conversion of NH₄⁺-N to NO₂⁻-N is considered as the most cost-effective biological process for further TN removal. Nitrification is a 2-stage reaction i.e. oxidation of NH₄⁺-N to NO₂⁻-N by ammonia-oxidising bacteria (AOB) as:



This followed by oxidation of NO₂⁻-N to NO₃⁻-N by nitrite-oxidising bacteria (NOB) (Rittmann and McCarty, 2001) as:



Partial nitrification involves only the first reaction and the product nitrite could be denitrified by denitrifiers in the presence of an organic electron donor source, so-called short-cut denitrification (Gao et al. 2010). Partial nitrification could be incorporated with anaerobic ammonium oxidation (ANAMMOX) processes (Kartal et al., 2010). Both would

significantly reduce energy consumption for nitrate production and for providing an organic electron donor source for denitrification. Most approaches toward the achievement of partial nitrification have been reported within recent decades (Guo et al., 2010; Kim et al., 2005; Sliemers et al., 2005). Due to the higher growth rate of AOB than NOB (Munz, 2011), maintaining the predominance of AOB over NOB is one of the key factors for achieving successful partial nitrification. In order to prevent nitrite oxidation and to achieve stable partial nitrification, various approaches have been used, including addition of specific inhibitors for the NOB (Oguz, 2005), and control of the dissolved oxygen (DO) (Garrido et al., 1997) and pH (Ciudad et al., 2007). However, some options are not easily practicable. The inhibition of NOB may not be effective because of microbial adaptation ability. A relatively low DO is a crucial factor to achieve stable partial nitrification (Garrido et al., 1997) but a low-DO condition may cause the growth of filamentous bulking sludge (Colliver and Stephenson, 2000) or emission of the greenhouse gas nitrous oxide (N₂O) via denitrification (Kampschreur et al., 2008, 2009). Other research results showed that pH is not a parameter which can be optimised for accumulating nitrite, as complete nitrification to nitrate occurs within a wide pH range, between 6.45 and 8.95, while a pH lower or higher than this range may cause complete inhibition of nitrification (Ruiz et al., 2003). The growth of NOB was observed to be inhibited in the presence of high ammonia levels (Kim et al., 2005). The control of ammonia level, if possible, could provide a selection pressure for NOB.

Immobilisation of microbial cells is one of the approaches used to keep the target cells in a bioreactor, without undesired washout, and has been intensively investigated, especially for industrial fermentation products, since the late 1960's. Immobilisation by encapsulation or entrapment of cells in polymer gel-matrix is distinct from microbial granulation which occurs as a result of the action of microbial materials (Hickey et al., 1998; Liu and Tay, 2004). The most active investigation of microbial cell immobilisation (Cassidy et al., 1996) has focused

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