Bioresource Technology 102 (2011) 5486–5491

Contents lists available at ScienceDirect

Bioresource Technology

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

Effect of anoxic/aerobic phase fraction on N_2O emission in a sequencing batch reactor under low temperature

Zhen Hu [a], Jian Zhang [a,*], Huijun xie [b], Shanping Li [a], Jinhe Wang [c], Tingting Zhang [a]

[a] Shandong Provincial Key Laboratory of Water Pollution Control and Resource Reuse, School of Environmental Science and Engineering, Shandong University, 27 Shanda Nanlu, Jinan 250100, Shandong, PR China
[b] Environmental Research Institute, Shandong University, 27 Shanda Nanlu, Jinan 250100, PR China
[c] School of Municipal and Environmental Engineering, Shandong Jianzhu University, Jinan 250101, Shandong, PR China

ARTICLE INFO

Article history:
Received 24 May 2010
Received in revised form 7 October 2010
Accepted 8 October 2010
Available online 14 October 2010

Keywords:
Nitrous oxide
Wastewater treatment
Nitrification and denitrification
Anoxic/aerobic phase fraction
Temperature

ABSTRACT

Laboratory scale anoxic/aerobic sequencing batch reactor (A/O SBR) was operated around 15 °C to evaluate the effect of anoxic/aerobic phase fraction (PF) on N_2O emission. The ammonia removal exhibited a decrease trend with the increase of PF, while the highest total nitrogen removal was achieved at PF = 0.5. Almost all the N_2O was emitted during the aerobic phase, despite of the PF value. However, the net emission of N_2O was affected by PF. Under the premise of completely aerobic nitrification, the lowest N_2O emission was achieved at PF = 0.5, with a N_2O–N conversion rate of 9.8%. At lower PF (PF = 0.2), N_2O emission was stimulated by residual nitrite caused by uncompleted denitrification during the anoxic phase. On the other hand, the exhaustion of the easily degradable carbon was the major cause for the high N_2O emission at higher PF (PF = 0.5). The N_2O emission increased with the decreasing temperature. The time-weighted N_2O emission quantity at 15 °C was 2.9 times higher than that at 25 °C.

1. Introduction

The general degradation of water quality in rivers and lakes has led to more stringent effluent quality standards, in order to prevent eutrophication by reducing nutrient level in wastewater discharged into local waterways. Many modifications and novel processes have been developed and implemented for nitrogen removal from wastewater (Tchobanoglous et al., 2003).

In recent years, sequencing batch reactor (SBR) system has attracted a great deal of interest because SBR can carry out biological nitrogen removal in a single reactor by maintaining anoxic and aerobic stages sequentially (Andreottola et al., 2001; Wilderer et al., 2001). Anoxic/aerobic activated sludge process is one of the most widely used biological nitrogen processes. The simultaneous removal of organic and nitrogen can be accomplished through scheduling of the anoxic and aerobic phase and the allocation of reaction time can be changed by varying the phase lengths (Hong et al., 2008). The pre-denitrification phase can degrade the influent organic anaerobically, reduced the oxygen demanded in the following aerobic phase. More importantly, the alkalinity produced during the denitrification phase provide an optimum circumstance for the subsequential aerobic nitrification process, thus reduced the operation cost (Muller et al., 2003).

It is generally accepted that the biological treatment process of domestic wastewater occupies an extremely important position among the many sources of nitrous oxide (N_2O) (Peter et al., 1995; Kong et al., 2002). N_2O is an important greenhouse gas. It can cause the greenhouse effect and ozone depletion in the stratosphere. Its 100-year global warming potential is 298 times higher than that of carbon dioxide (CO_2) and it has a lifetime of 114 years (IPCC, 2007). The concentration of atmospheric N_2O is estimated to be approximately 314 ppbv, which is approximately 16% higher than that during the preindustrial era, and it continues to increase at a rate of 0.25%/year (Kishida et al., 2004). It is therefore of great importance to develop technologies that can suppress N_2O emission from wastewater treatment processes.

N_2O has been shown to be produced during both nitrification and denitrification in activated sludge and released to the atmosphere (Zheng et al., 1994; Tallec et al., 2008). Nitrification is the oxidation of NH_4^+ to NO_3^- via NO_2^-, which is achieved by two steps. Ammonia is firstly oxidized to nitrite by ammonia-oxidizing bacteria (AOB) and then converted to nitrate by nitrite-oxidizing bacteria (NOB) (Bock et al., 1986). N_2O is produced as one of the by-products during nitrification and there are two possible mechanisms of N_2O production (Prosser, 1989). Certain nitrifying bacteria generate N_2O from the reduction of NO_2^- under oxygen limiting conditions. Alternatively, N_2O can be produced by chemical decomposition of NO_2^- or various reactions of the intermediates formed during NH_4^+ oxidation (Ritchie and Nicholas, 1972).

* Corresponding author. Tel./fax: +86 0531 88363015.
E-mail address: zhangjian00@sdu.edu.cn (J. Zhang).

0960-8524/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2010.10.037

On the other hand, N_2O is one of the obligatory intermediates in denitrification. Through denitrification, NO_3^-–N is reduced to NO_2^-–N by nitrate reductase, which is then reduced to N_2O by nitrite reductase. N_2O is finally reduced to N_2 gas by N_2O reductase (Kimochi et al., 1998). Note that denitrifier can use NO_2^- or NO_3^- produced during nitrification. This coupling of nitrification and denitrification can occur when the conditions are favorable for both processes, especially in aggregates such as activated sludge (Zeng et al., 2003).

It has been reported that low DO concentration, low C/N ratio, low pH, short SRT or high nitrite concentration can result in N_2O accumulation during the biological nitrogen removal process (Zheng et al., 1994; Gejlsbjerg et al., 1998; Kampschreur et al., 2009). However, few studies have been reported on the effect of the anoxic/aerobic phase fraction (PF) on N_2O emission. In addition, most of the studies are preformed under the optimum temperature for nitrifier and denitrifier, around 25 °C, while many wastewater treatment plants are operated below this value for most of the year.

The aim of this paper is to evaluate the effect of anoxic/aerobic phase fraction on N_2O emission in biological nitrogen removal process under low temperature. For this purpose, a lab scale anoxic/aerobic sequencing batch reactor (A/O SBR) was operated under 15 ± 1 °C. Experiments were conducted at different phase fraction after proper acclimation. In addition, the effect of temperature on N_2O emission was investigated after the optimum phase fraction was selected.

2. Methods

2.1. Synthetic wastewater

The synthetic wastewater with COD concentration of 300 mg/L and NH_4^+–N concentration of 60 mg/L was comprised of (per liter): 195 mg $C_6H_{12}O_6$; 195 mg $CH_3COONa{\cdot}3H_2O$; 230 mg NH_4Cl; 200 mg $NaHCO_3$; 11 mg KH_2PO_4; 18 mg $K_2HPO_4{\cdot}3H_2O$; 10 mg $MgSO_4{\cdot}7H_2O$; 10 mg $FeSO_4{\cdot}7H_2O$; 10 mg $CaCl_2{\cdot}2H_2O$; and 1 mL nutrient solution. One liter of nutrient solution contained: 0.15 g H_3BO_3; 0.03 g $CuSO_4{\cdot}5H_2O$; 0.18 g KI; 0.12 g $MnCl_2{\cdot}4H_2O$; 0.06 g $Na_2MoO_4{\cdot}2H_2O$; 0.12 g $ZnSO_4{\cdot}7H_2O$; 0.15 g $CoCl_2{\cdot}6H_2O$; and 10 g ethylene diamine tetraacetic acid (EDTA) (Zeng et al., 2003).

2.2. Reactor setup and operation

All experiments were conducted in a gastight sequencing batch reactor, constructed using a transparent, rigid plexiglas cylinder, with an effective volume of 24 L. A peristaltic pump was used to feed the SBR with the synthetic wastewater from the water tank during the feeding phase. An electric agitator with a rectangular paddle, used to keep the suspension of the sludge during the anoxic phase, was installed over the reactor. The air needed during the aerobic phase was supplied by an air pump through a porous stone diffuser located at the bottoms of the reactor. A relatively low aeration rate, which was 7.5 $L_{air}/(L_{reactor}$ h), was used throughout the aerobic phase to mimic the actual wastewater treatment plant and achieve high nitrogen removal (Smith and Evans, 1982; Pochana and Keller, 1999). The off-gases were collected into gas sampling bags at intervals of 0.5 h. At the same time, liquid phase samples were taken to measure the water quality. Fig. 1 shows the schematic diagram of the experimental system.

The SBR was inoculated with microorganism from the Second Wastewater Treatment Plant of Everbright Water (Jinan) Ltd. (Jinan, China). During the whole experiments, the temperature was maintained at 15 ± 1 °C. Each cycle of SBR consisted of five steps: 10 min feeding, x h anoxic reaction, $(6 - x)$ h aerobic reaction, 40 min setting, and 10 min decanting. The value of x depends on the PF investigated. Five different PF were investigated in this study, as listed in Table 1. The mixed liquor suspended solid (MLSS) was maintained at approximately 4000 mg/L and certain amount of excess sludge was disposed at the end of aerobic phase to control the SRT at approximately 20 d.

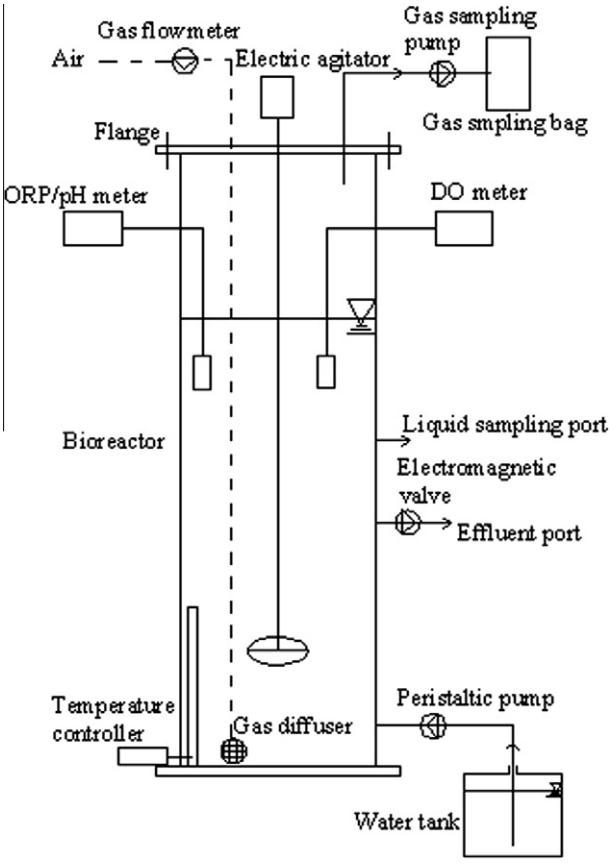

Fig. 1. Schematic description of the experiment system.

2.3. Analytical methods

COD, NH_4^+–N, NO_3^-–N, NO_3^-–N, TN, TP and MLSS were measured according to the standard methods (APHA, 1998). Dissolved oxygen was measured with a DO meter (HQ30d53LDO™, USA) and pH was measured with a pH meter (PHS-3C, China), every 10 min. The N_2O concentration was determined by a gas chromatography (SP-3410, China) with an electron capture detector (ECD) and a Poropak Q column, using 30 mL/min high-purity nitrogen as the carrier gas. The temperature of the detector and oven were set at 360 °C and 50 °C, respectively (Wu et al., 2009).

2.4. Calculation of N_2O emission rate and emission quantity

During the anoxic phase, the whole reactor was gas tight, and the N_2O emission rate was calculated through the increase of

Table 1
The operation conditions of SBR.

Scheduling	I	II	III	IV	V
PF	0.5	0.2	1	2	5
x (h)	2	1	3	4	5