Chemical Engineering Journal 235 (2014) 19–26

Contents lists available at ScienceDirect

Chemical Engineering Journal

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

Effect of influent ammonium concentration on the shift of full nitritation to partial nitrification in a sequencing batch reactor at ambient temperature

Dong Wei, Xiaodong Xue, Liangguo Yan, Meng Sun, Ge Zhang, Li Shi, Bin Du *

School of Resources and Environmental Sciences, University of Jinan, Jinan 250022, PR China

HIGHLIGHTS

- Full nitritation and partial nitrification processes were successfully achieved.
- Settling property of the sludge was improved by the strategy of reducing settling time.
- AOB was the dominant nitrifying bacteria according to FISH analysis.
- FA and FNA were the potential compounds for inhibiting the activity of NOB.

ARTICLE INFO

Article history:
Received 10 May 2013
Received in revised form 25 August 2013
Accepted 1 September 2013
Available online 8 September 2013

Keywords:
Shortcut nitrification–denitrification
Partial nitrification
Sequencing batch reactor (SBR)
High strength ammonia wastewater
Fluorescence in situ hybridization (FISH)

ABSTRACT

The objective of this study was to evaluate the conversion of full nitritation to partial nitrification processes by altering the influent ammonium concentration in a sequencing batch reactor at ambient temperature. After 150 days' operation, full nitritation and partial nitrification processes were successfully achieved when the influent NH_4^+—N concentrations up to 400 and 720 mg/L, respectively. Meanwhile, sludge volumetric index (SVI) gradually decreased from 127.4 to 63.4 mL/g, while the average size of sludge improved from 29.5 to 195.6 μm by the strategy of reducing settling time. Ammonium-oxidizing bacteria (AOB) were the dominant nitrifying bacteria according to the fluorescence in situ hybridization (FISH) analysis. Free ammonia (FA) and free nitrous acid (FNA) were the potential compounds for inhibiting the activity of nitrite-oxidizing bacteria (NOB). The obtained results may help to promote the development of new biological nitrogen removal processes in engineering, especially in relation to nitrogen-rich wastewaters.

1. Introduction

Biological nitrogen removal (BNR) is commonly used in wastewater treatment plants involving two processes: NH_4^+—N is oxidized to NO_3^-—N during aerobic nitrification process and NO_3^-—N to molecular nitrogen during anoxic denitrification [1]. In recent years, new biological nitrogen removal processes are wildly investigated due to their superiority to traditional BNR. Compared to conventional nitrification–denitrification processes, shortcut nitrification–denitrification process via NO_2^-—N (full nitritation, 100% ammonium conversion to nitrite) theoretically saves approximately 25% of electron acceptor (oxygen) for nitrification, 40% of electron donor (organic carbon) for denitrification and achieves a lower sludge production [2,3]. The combination of a partial nitrification process (SHARON) and anoxic ammonium oxidation process (Anammox) is a novel, environmental friendly and cost-effective biotechnology [4]. Partial nitrification process is used to provide the feed for Anammox process only 50% of the ammonium needs to be converted to nitrite, and the following denitrification of nitrite to dinitrogen gas using ammonia as electron donor [5]. Anammox process offers several advantages over conventional nitrification–denitrification systems including higher nitrogen removal rate, lower sludge production and less space requirement [6].

Since either full nitritation or partial nitrification needs successful and stable nitrite accumulation, therefore, the same characteristic of the two processes is the enrichment of ammonium-oxidizing bacteria (AOB) and limitation–inhibition–washout of nitrite-oxidizing bacteria (NOB) [7]. To inhibit the activity of NOB, various control strategies have been investigated using synthetic wastewater, including pH values, dissolved oxygen (DO), temperature, free ammonia (FA) and free nitrous acid (FNA). Guo et al. reported the short- and long-term effects of temperature on partial nitrification in a sequencing batch reactor (SBR) treating domestic wastewater [8]. Chuang et al. achieved partial

* Corresponding author. Tel./fax: +86 531 8276 7370.
E-mail address: dubin61@gmail.com (B. Du).

1385-8947/$ - see front matter
http://dx.doi.org/10.1016/j.cej.2013.09.005

nitrification to nitrite using a down-flow hanging sponge reactor under limited oxygen condition [9].

Among all those factors, FA was commonly selected as a key parameter to achieve nitrite accumulation due to its different inhibition values on AOB and NOB [10]. Its value is determined by the ammonia, pH values and temperature levels. Anthonisen et al. first reported that FA concentration could inhibit *nitrosomonads* and *nitrobcaters* in the ranges of 10–150 and 0.1–1.0 mg/L [11]. Bae et al. reported that the influent FA concentrations were always in the inhibitory values (0.1–4.0 mg/L) for NOB [12]. In addition, compared to pH value and temperature, influent ammonium concentration has been proved feasible to lead to desirable FA to achieve nitrite accumulation because of its easy implementation when treating high-ammonia wastewater [13]. Therefore, it was postulated that, at certain influent ammonium concentration, the activity of NOB will be selectively inhibited, while the activity of AOB will not be affected (full nitritation). If the ammonium concentration continues to increase, AOB will be partly inhibited following NOB due to the increased FA value (partial nitrification). Thus, a full nitritation process could be transformed to a partial nitrification process by the strategy of nitrogen loading rate increase. When the above process achieved, it is expected that the following denitrification process using Anammox technology (partial nitrification-Anammox) instead of adding external carbon sources (full nitritation) to achieve nitrogen removal.

Therefore, the objective of this study was to evaluate the feasibility of conversion of full nitritation to partial nitrification in a SBR. To achieve this purpose, increasing influent ammonium concentration was selected as an operational strategy for the inhibition of NOB [14]. Fluorescence in situ hybridization (FISH) assay was conducted to assess the relative abundance of AOB and NOB. Meanwhile, settling time was selected to improve the settling property of the sludge. The obtained results could provide further information in the development of high strength ammonia wastewater treatments for full-scale application.

2. Materials and methods

2.1. Reactor and reagents

The experiment was carried out in a lab-scale SBR with a working volume of 6.28 L (Fig. 1). The internal diameter and working height of the reactor were 10 cm and 80 cm, respectively. The influent wastewater was prepared in a storage tank (20 L) and introduced to the reactor by a water pump. Oxygen was supplied by an air pump through an air diffuser at the bottom of reactor. The reactor was operated at a volumetric exchange ratio of 50% with a cycle of 8 h. Sludge retention time (SRT) was controlled at about 30 days by withdrawing the sludge at the end of aerobic period. The temperature was maintained at room temperature (24–28 °C).

All the chemicals were purchased from Tianjin Damao chemical reagent factory (China) and used of analytical reagents grade. Double distilled water was used to monitor throughout the experiments.

2.2. Nutrient-rich wastewater

The synthetic wastewater fed to the reactor were as follows: COD (as sodium acetate) 600 mg/L; NH_4^+—N (as ammonium chloride), 200–720 mg/L; K_2HPO_4, 112 mg/L; $CaCl_2$, 40 mg/L; $MgSO_4{\cdot}2H_2O$, 20 mg/L; $FeSO_4{\cdot}2H_2O$, 20 mg/L and microelement solution 1.0 mL/L. The influent pH values were adjusted to 7.5–8.5 by adding $NaHCO_3$. The composition of the trace mineral solution was derived from the literature reported by Tay et al. [15].

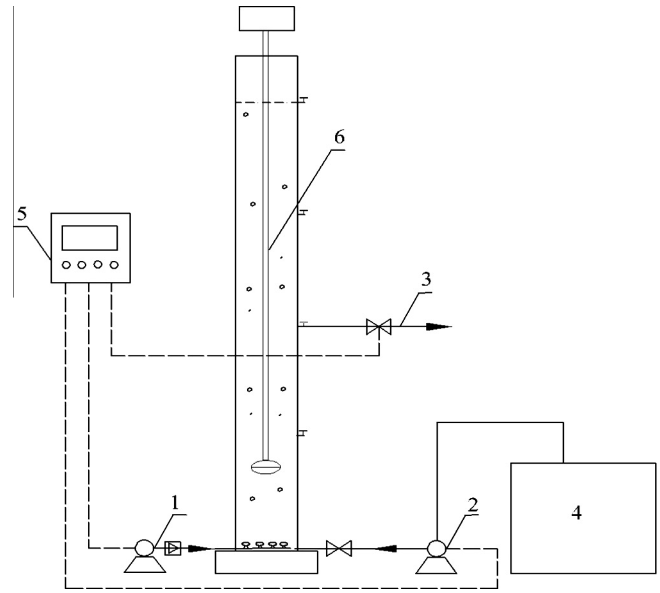

Fig. 1. Schematic representation of the SBR in this study: (1) air pump, (2) influent pump, (3) effluent outlet, (4) water storage tank, (5) time controller, and (6) electric agitator.

2.3. Operation strategy

In order to achieve better effluent quality not only in organic matter but also nitrogen removal, the reactor was operated by alternating anoxic and aerobic phases. Each cycle (8 h) consisted of the following: 5 min for influent filling, 85 min for anoxic phase and 300 min of aeration. A settling time of 20 min was applied in start-up stage to retain most of sludge and gradually reduced to 10 min to improve the settling property of sludge. The rest of time was for effluent removal and idle. Table 1 shows the detailed experimental conditions during different operational stages for the reactor. The influent COD concentration was fixed at 600 mg/L, while the influent NH_4^+—N concentrations were increased from 200 to 720 mg/L.

2.4. Seeding sludge

The activated sludge used in the present study was received from an aeration unit of a WWTP located at Shandong province in China, which used 2-stage A/O process in activated sludge treatment (2500 m^3/day). The initial mixed liquor suspended solids (MLSS) concentration and sludge volume index (SVI) of the seeding sludge in the reactor were about 3 g/L and 127.4 mL/g, respectively.

2.5. Fluorescence in situ hybridization (FISH)

FISH analysis was used to determine the quantity of NOB and AOB in the sludge during different operational period. The detail of 16S rRNA-targeted oligonucleotide probes used in this study was as following: FITC-labeled EUB338, EUB338-II and EUB338-III for targeting all bacteria; Cy3-labeled NSO1225 for ammonia-oxidizing bacteria; Cy5-labeled Nit3 and Ntspa662 for nitrite oxidizing bacteria [16]. CNit3 and Cntspa662 were used as competitive probes to avoid any mismatch during the hybridization as reported by Xue et al. [17]. Randomly selected at least 10 different fields of each sludge sample were used to quantify using Image-pro plus 6.0 Software® as reported by Guo et al. [18].