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Technical Note

Bio-augmentation to rapid realize partial nitrification of real sewage

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HIGHLIGHTS

- ▶ Partial nitrification of sewage was promoted by the bio-augmentation process.
- ▶ Nitrite pathway was maintained by controlling DO and NLR after bio-augmentation.
- ▶ The effluent of sewage treatment was suitable to feed anammox process.
- ▶ Integration of bio-augmentation and anammox was favorable to treat real sewage.

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ABSTRACT

The feasibility of bio-augmentation processes in promoting start-up of partial nitrification of sewage was investigated in this study. Initially, partial nitrification was well-established in an anoxic/oxic reactor treating high-strength ammonia wastewater. Then the influent was replaced by real sewage instantly or gradually. In both cases, nitrite pathway could be maintained for 5–7 d. However, it was eventually destroyed due to the inevitable over-aeration. In another strategy, sewage was treated in the adsorption/biodegradation reactor. The nitrite pathway was obviously promoted by addition of the previous activated sludge from high ammonia wastewater treatment. Nitrite accumulation efficiency of sewage was quickly increased from 26% to 86% and maintained at a high level for 2 months. Moreover, the effluent has a favorable ratio of NH_4^+/NO_2^- for feeding anammox process. The experimental results indicated that appropriate bio-augmentation strategies could significantly improve the build-up partial nitrification of sewage in the pretreatment of anammox.

1. Introduction

Anaerobic ammonium oxidation (ANAMMOX) consists of a preceding partial nitrification oxidizing 50% of the ammonium to nitrite and the process converting the following ammonia and nitrite to nitrogen gas directly. This novel biotechnology has been successfully applied in the high-strength ammonium wastewater treatment (Van Hulle et al., 2010). Meanwhile, its potential on low ammonium sewage treatment also causes extensive concerns (Kartal et al., 2010). However, it is still rarely realized in sewage treatment yet, primarily owing to the difficulties in establishing partial nitrification. Nitrite pathway of sewage is also very vulnerable to the fluctuations and difficult to re-started once being deteriorated (Ma et al., 2009). Therefore, effective technologies are still required for accelerating the start-up and enhancing the stability of sewage partial nitrification.

Bio-augmentation is one of the possible methods to promote the partial nitrification of sewage. In wastewater treatment plants, high ammonia reject water originated from the dewatering of the digested sludge could be used to enhance nitrification activity of the main stream. Several strategies have been proposed such as directly mixing reject water with the return sludge or adding excess sludge from the reject water treatment, which is known as the bio-augmentation process (Bartrolí et al., 2011). Besides the high activity of nitrification, stable nitrite pathway is always obtained in the reject water treatment (Tora et al., 2010). Thus, the bio-augmentation process has the potential on improving the partial nitrification of sewage. However, most literatures only focused on enhancing the nitrification activity and reducing the minimum sludge retention time (SRT) of the main stream. The establishment of partial nitrification is rarely reported. Therefore, the feasibility of bio-augmentation technology in establishing nitrite pathway of sewage and the relevant optimization still need research.

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In this work, bio-augmentation process was used to quickly realize the partial nitrification of sewage. The feasibility of different bio-augmentation strategies was investigated. The mechanisms of the establishment of partial nitrification were also discussed.

2. Material and methods

2.1. Experimental reactors

Two different continuous bioreactors were used in the study. One was the anoxic/oxic (A/O) reactor, which was illustrated in Fig. 1a. It has an operational volume of 36 L. The first section was set as the anoxic zone and the others were aerated by an air pump. The settler was cylindrical with a working volume of 18 L. Both flow rates of influent and sludge circulation were controlled by peristaltic pumps. Sludge recycle ratio was 0.5 and mixed liquor suspended solids (MLSS) was 4000 ± 500 mg L^{-1}. Hydraulic retention time (HRT) and SRT were 0.8 and 20 d, respectively. Temperature was 25.2 ± 2.0 °C.

The modified adsorption/biodegradation (A/B) reactor was shown in Fig. 1b. Adsorption reactor (24 L) was operated for quick removal of organics and phosphorous. DO was controlled at 2.0 mg L^{-1} and MLSS = 4000 mg L^{-1}, HRT = 3 h. Biodegradation reactor (24 L) was responsible for the establishment of partial nitrification. It was divided into five aerated zones following with a 12 L settler. DO was controlled at 0.3 mg L^{-1} and MLSS = 3000 mg L^{-1}. HRT = 6 h. Temperature for the operation of A/B reactor was 28.2 ± 1.0 °C.

2.2. Seed sludge and raw water

Reject water, sewage and seed sludge used in the experiment were all collected from GaoBeiDian wastewater treatment plant (10^6 m^3 d^{-1}) in Beijing, China. Reject water was collected from the dewatering devices treating sludge from the mesophilic anaerobic digesters. Sewage wastewater was withdrawn from the effluent of the primary sludge tank. Seed sludge was collected from the pipes of returned sludge. The main characteristics of the reject water and sewage are presented in Table 1.

2.3. Analysis methods

Sludge sample was collected to measure NH_4^+, NO_3^-, NO_2^-, MLSS according to the standard methods (APHA, 1995). The alkalinity was measured by titrating 50 mL sludge sample with hydrochloric acid (0.02 M) to pH = 4.3. Temperature, DO and pH value was monitored by using WTW pH/oxi340i and corresponding probes (WTW, Germany).

2.4. Fish analysis

Sludge samples from both bioreactors were analyzed for ammonium-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB) by fluorescence in situ hybridization (FISH). Sample fixation and hybridization steps were carried out according to the method previously described by Amann (1995). The images of samples were collected using the OLYMPUS-BX52 fluorescence microscope (Japan). Image-pro plus 6.0 Software was used for FISH quantification as detailed by Crocetti et al. (2002). AOB or NOB population was determined as the average percentage of all bacteria.

3. Operational strategies

In order to examine the feasibility of bio-augmentation in improving the partial nitrification of sewage, different strategies were investigated in this study.

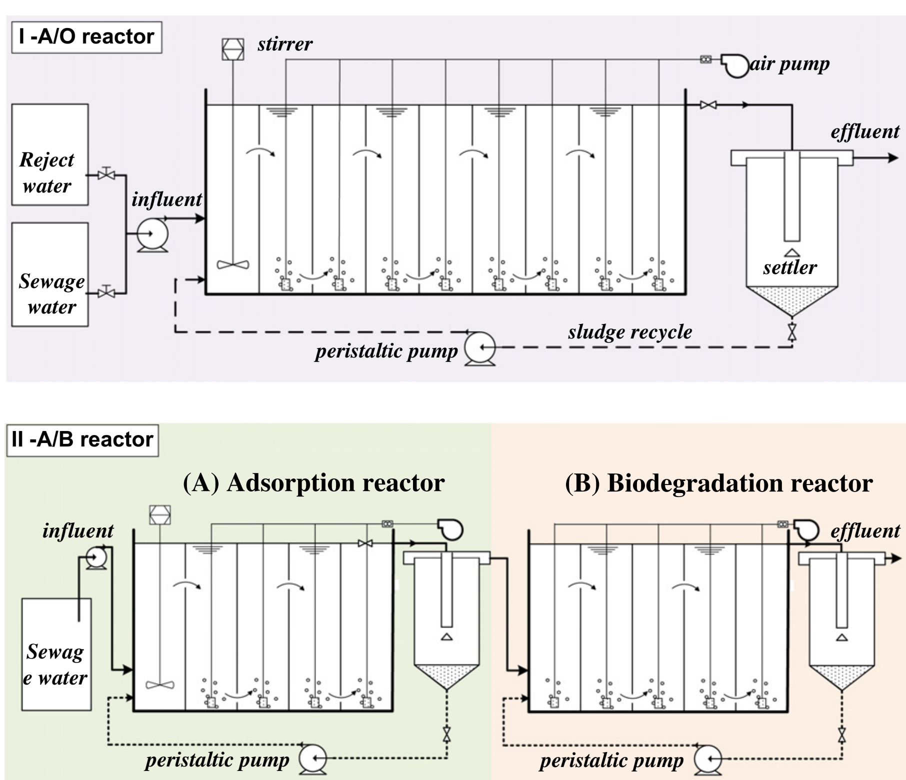

Fig. 1. Schematic diagrams of the bioreactor reactors used in the experiment. I: anoxic/oxic reactor; II: adsorption/biodegradation reactor.