Partial Nitrification from Domestic Wastewater by Aeration Control at Ambient Temperature*

PENG Yongzhen(彭永臻)[a,], GAO Shouyou(高守有)[b], WANG Shuying(王淑莹)[a] and BAI Lu(白璐)[a]**
[a] Key Laboratory of Beijing for Water Environment Recovery Engineering, Beijing University of Technology, Beijing 100022, China
[b] Beijing General Municipal Engineering Design & Research Institute, Beijing 100045, China

Abstract The objective of this paper was to examine the feasibility of partial nitrification from raw domestic wastewater at ambient temperature by aeration control only. Airflow rate was selected as the sole operational parameter. A 14L sequencing batch reactor was operated at 23℃ for 8 months, with an input of domestic wastewater. There was a programmed decrease of the airflow rate to $28L\cdot h^{-1}$, the corresponding average dissolved oxygen (DO) was $0.32mg\cdot L^{-1}$, and the average nitrite accumulation rate increased to 92.4% in 3 weeks. Subsequently, further increase in the airflow rate to $48L\cdot h^{-1}$ did not destroy the partial nitrification to nitrite, with average DO of $0.60mg\cdot L^{-1}$ and nitrite accumulating rate of 95.6%. The results showed that limited airflow rate to cause oxygen deficiency in the reactor would eventually induce only nitrification to nitrite and not further to nitrate and that this system showed relatively stability at higher airflow rate independent of pH and temperature. About 50% of influent total nitrogen was eliminated coupling with partial nitrification, taking the advantage of low DO during the reaction.
Keywords partial nitrification, oxygen-limiting condition, ambient temperature, domestic wastewater

1 INTRODUCTION

Currently many municipal wastewater treatment plants (WWTPs) in China encounter the problem of ammonia overload, especially those that mainly cater to treatment of domestic wastewater. At the same time, many small WWTPs are being set up to treat the domestic wastewater decentralized *in situ* from residential areas. As a result of low C/N ratio in domestic wastewater, there is a deficiency of carbon sources, which are essential for the nitrification-denitrification process. As a result, improving the efficiency of processes currently in use or exploiting new process to convert nitrogen into harmless forms has been the target of recent researches on nitrogen removal.

Partial nitrification to nitrite, which is the oxidation of ammonium to nitrite as the end-product of nitrification (*i.e.*, nitritation), has been reported to be technologically feasible and economically viable, especially when wastewaters have high concentrations of ammonium and/or low levels of organic carbon for the process of denitrification. The main advantages of partial nitrification when compared with complete nitrification are lower oxygen demand during aeration, less requirements of organic substrates for sequent heterotrophic denitrification, and less biomass production[1]. Through appropriate regulation of the factors such as free ammonia concentration (FA), pH, temperature, sludge retention time (SRT), and dissolved oxygen (DO) concentration, nitritation can be enhanced by providing a favourable environment for growth of ammonium oxidizing bacteria (AOB), thereby conferring on them growth advantages, and selectively inhibiting the growth of nitrite oxidizing bacteria (NOB)[2]. It has been reported that FA at concentrations of $1—5mg\cdot L^{-1}$ inhibited nitrification but not nitritation[3]. Cecen and Gonenc[4] stated that the combined effects of high ammonia and high pH led to nitrite accumulation by Nitrobacter inhibition. Hellinga *et al.*[5] described the SHARON process at 35℃ without sludge retention for sludge liquor treatment. At elevated temperatures and relative high ammonia concentration (more than 500mg NH_4^+-$N\cdot L^{-1}$), nitrite oxidation was permanently prevented and denitrification with nitrite could begin. Ruiz *et al.*[6] examined the effects of pH and DO on partial nitrification and achieved a nitrite accumulation rate of 65% from simulated industrial wastewater containing 610 mg NH_4^+-$N\cdot L^{-1}$ at DO around $0.7mg\cdot L^{-1}$, whereas pH was not a useful operational parameter to indicate nitrite buildup. Wang and Yang[7] found that the optimal operational parameters to realize partial nitrification were as follows: pH, 7.5; DO, $1.5mg\cdot L^{-1}$; and temperature, 30℃, based on ammonia oxidation and nitrite accumulation rate.

However, many researchers have focused on the combined use of the above-cited methods. Some of the conditions under which nitrite accumulation can occur are as follows: ammonium-enriched feed inputs, high temperatures (often above 30℃), and high pH values (over 7.5). However, in practise, the temperature is not susceptible to be modified and controlled in full-scale reactors, mainly due to economic considerations. Increasing the pH will result in increased operation costs and complexities. To date, little attention has been paid to the exact effect of DO alone on partial nitrification, especially when the conditions in the

Received 2005-11-21, accepted 2006-04-28.
* Supported by Funding Project for Academic Human Resources Development in Institutions of Higher Leading under the Jurisdiction of Beijing Municipality [PHR(IHLB)], the National Natural Science Foundation of China (No.50478040) and the National Key Technologies R&D Program of China (No.2006BAC19B03).
** To whom correspondence should be addressed. E-mail: pyz@bjut.edu.cn

reactor are independent of pH and temperature. Furthermore, there are few reported studies on nitrite accumulation in domestic wastewater.

It is vital to achieve a state of stable partial nitrification to nitrite for the efficient functioning of the shortcut nitrification/denitrification nitrogen removal process *via* nitrite, so in this study a greater emphasis was laid on the nitrification process. The objective of this research was to study the effects of concentration of DO (realized by varied airflow rates) on partial nitrification to nitrite from raw domestic wastewater at ambient temperature (23℃). Experiments were conducted for 8 months to examine the stability of nitritation developed through limited aeration.

2 MATERIALS AND METHODS

2.1 Operation of sequencing batch reactor

A sequencing batch reactor (SBR) with working volume of 14L was used in this study (Fig.1). The height and diameter of this cylinder reactor were 0.8 and 0.18m, respectively. The operation mode of the SBR system consisted of five phases: fill, aeration, settling, decanting, and idle. Two cycles were performed each day. In each cycle, 9L of wastewater at a flow rate of $5L\cdot min^{-1}$ was fed to the reactor using a pump such that the volumetric exchange ratio in the reactor was 64%. Suppressed air was supplied just after the fill phase. The airflow rate in the reactor was controlled and kept constant in each cycle by a mass-flow controller, and gas was diffused into the reactor using an air-diffuser installed at the bottom of the reactor. A mixer was used to prevent sludge settlement during aeration. The temperature controller in the reactor maintained the desired temperature by switching on either the electronic heater in cold weather or the cooling water recycling system around the reactor in hot weather. The clarified supernatant was discharged at the end of the 30-minute settling phase.

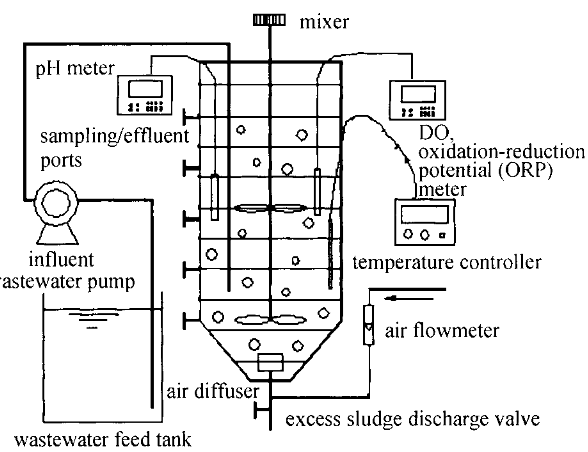

Figure 1 Schematic diagram of the SBR

2.2 Seeding and feeding

The reactor was inoculated with sludge from a municipal WWTP in Beijing, which exhibits biological nutrient removal. The initial concentration of the mixed liquor suspended solids (MLSS) in the reactor was $3000\ mg\cdot L^{-1}$. Four weeks of operation cultivating with domestic wastewater was done before the experiments started. The domestic wastewater from the septic tank in a residential area of Beijing University of Technology was ideal for this experiment because of the low ratio of chemical oxygen demand (COD) to total nitrogen (TN), the values averaging to 2.8. Every morning, the wastewater was regularly collected from the septic tank only between 8:00 a.m. and 9:00 a.m. to ensure that the influent characteristics (see Table 1) at the time of collection of the sample were as constant as possible.

Table 1 Characteristics of the raw domestic wastewater

Parameters	Min-max, $mg\cdot L^{-1}$	Mean, $mg\cdot L^{-1}$
NH_4^+	58—108	79
TN	59—110	80
PO_4^{3-}	5—9.5	8
BOD_5	100—165	115
COD	160—310	220

2.3 Experiment design

SRT was controlled at 20 days by sludge wasting at the end of the aerobic phase. The concentration of MLSS fluctuated between 2800 and $3500mg\cdot L^{-1}$, depending on both the operation condition and the influent strength. The reactor temperature was maintained at (23 ± 1)℃. The pH of the influent varied from 6.85 to 7.62, and during the experiment, no action was taken to regulate pH, which fluctuated between 6.90 and 7.85.

Different airflow rates were used to study the nitrification process in the reactor under oxygen-deficient conditions. Altogether, seven groups of experiments with air fluxes decreasing from 60 to $28L\cdot h^{-1}$ were carried out to follow up the process of nitritation. The length of the aerobic phase was determined by the DO concentration: when it exceeded $2.5mg\cdot L^{-1}$, the aeration was turned off and the settling phase began. A summary of the experiments is shown in Table 2. Sufficient cycles were carried out to achieve a quasi-steady state.

Table 2 Scheme of experimental conditions

Condition	Airflow rate, $L\cdot h^{-1}$	Day elapsed	Operation days
I	60	1—20	20
II	40	21—35	15
III	32	36—80	45
IV	28	81—115	35
V	32	116—130	15
VI	40	131—210	80
VII	48	211—240	30

2.4 Analytical methods

Daily chemical analyses of COD (using potassium