International Biodeterioration & Biodegradation xxx (2017) 1–6

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

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

Stability of partial nitritation in a sequencing batch reactor fed with high ammonium strength old urban landfill leachate

Phan The Nhat, Ha Nhu Biec, Truong Thi Thanh Van, Doan Van Tuan, Nguyen Le Hoang Trung, Vo Thuy Khanh Nghi, Nguyen Phuoc Dan*

Faculty of Environment and Natural Resource, Ho Chi Minh City University of Technology, Vietnam

ARTICLE INFO

Article history:
Received 31 March 2017
Received in revised form
23 June 2017
Accepted 23 June 2017
Available online xxx

Keywords:
Old landfill leachate
Partial nitritation
Sequencing batch reactor
Fed batch mode
Nitrogen removal

ABSTRACT

The aim of this study is to investigate the stability of partial nitritation in a lab-scale sequencing batch reactor (PN-SBR) fed with high ammonium strength old municipal landfill leachate without pH adjustment, bicarbonate addition and low dissolved oxygen control. Long sludge retention of over 120 days was applied for the PN-SBR. The PN-SBR, which run over 250 days used the old urban landfill leachate containing 3096 mg NH_4^+-N l^{-1}, 12960 mg HCO_3 l^{-1}, and influent HCO_3^-:NH_4^+ molar ratio of 1.06. After 75 days of operation, the partial nitritation achieved stability when the effluent nitrite to ammonium molar ratio obtained in the range of 1.0–1.32, which were suitable for feeding to an anammox reactor. The effluent NO_3^--N concentration was always below 20 mg N l^{-1}. The maximum FA concentration reached 506 mg NH_3-N l^{-1} at hour 26th during the cycle of 73 h. Even though old land fill leachate mainly contained refractory COD, COD removal efficiency achieved about 11%. The OUR tests show that the maximum growth rate μ_{max}, K_o, K_s and yield coefficient $Y_{X/N}$ of AOB were 0.12 day^{-1}, 1.35 mg O_2 l^{-1}, 53 mg NH_4^+-N l^{-1} and 0.26 mgVSS mg^{-1} NH_4^+-N, respectively.

1. Introduction

Old landfill leachate contains high ammonium (NH_4^+-N) and low biodegradable COD concentrations (Kjeldsen et al., 2002). Indeed, Nhat et al. (2014) found that the average TKN, bicarbonate concentrations, BOD_5:COD ratio and pH value of leachate from Go Cat old municipal landfill, which was closed in 2007 were 3263 ± 120 mg N l^{-1}, 12960 ± 1530 mg HCO_3^- l^{-1}, less than 0.15 and 7.8 ± 0.30, respectively. Free Ammonia (FA) formation originated from high strength of ammonia coupled with high pH value in the old landfill leachate can result in strong inhibition on nitrifying bacteria including AOB and NOB (Zhu et al., 2008; Ganigué et al., 2009). In fact, nitritation process running at the NLRs over 1.0 kg NH_4^+-N m^{-3}.d^{-1} inhibited AOB growth at FA concentration of about 150 mg N l^{-1} (Anthonisen et al., 1976; Kurniawan et al., 2006; Van Hulle et al., 2007). In the other hand, high ammonium strength wastewater causes a problem over the long-term operation by nitrite accumulation, which results in free nitrous acid (FNA) formation at low pH value or alkalinity (Lai et al., 2004; Yamamoto et al., 2008).

Two stage partial nitritation-Anammox process, that is fully autotrophic biological nitrogen removal has become the most preferable technology for treatment of wastewater containing high ammonium concentration and low biodegradable organic matter content such as old landfill leachate (Cema et al., 2007; Ruscalleda et al., 2008; Ganigué et al., 2009) or sludge digester supernatant (Van der Star et al., 2007; Wett, 2007). This process can mitigate aeration energy consumption for nitrification and external carbon source addition for denitrification in comparison with the conventional two-sludge nitrification-denitrification process that widely uses for high ammonium strength wastewater treatment. In the two-stage process, the partial nitritation provides the effluent suitable for feeding the subsequent anammox reactor that requires the influent molar ratio of nitrite to ammonium of about 1.3 (Strous et al., 1997). The previous studies (Ganigué et al., 2009; Li et al., 2014; Nhat et al., 2014; Assis et al., 2017) demonstrated using the SBR is a feasible option for the separate partial nitritation due to ease of real-time monitoring to reach to the desired molar ratio of nitrite to ammonium.

Ganigué et al. (2009) claimed that the stable long-term operation of a partial nitritation SBR (PN-SBR) much depended on NOB inhibition by FA or FNA. Even though AOB are better than NOB in terms of high tolerance to FA and FNA (Vadivelu et al., 2007), high

* Corresponding author.
E-mail address: npdan@hcmut.edu.vn (N.P. Dan).

http://dx.doi.org/10.1016/j.ibiod.2017.06.017
0964-8305/© 2017 Published by Elsevier Ltd.

FA and FNA concentrations that generate from old urban landfill leachate with high ammonium content could suppress AOB growth. The molar ratio of bicarbonate to ammonium, ammonium loading rate and pH value of the influent are the key operation parameters for controlling FA and FNA in the partial nitritation (Ganigué et al., 2012). In order to restrain AOB from the inhibition of FA and FNA, the PN-SBR with anoxic-oxic step-feed operation mode was recommended by Ganigué et al. (2009; 2012), who conducted long-term run with old landfill leachate containing extremely high mean ammonium concentration of 3772 ± 956 mg NH_4^+-N l^{-1}. Moreover, the strategy to achieve successfully a stability of partial nitrification is to promote NOB inhibition (Assis et al., 2017). The factors, which can adversely effect on NOB growth are high pH value, low dissolved oxygen (DO) concentration (less than 0.5 mg l^{-1}), high temperature (over than 35 °C), bicarbonate substrate limitation, higher growth rate of AOB or short sludge retention time (Prá et al., 2012; Viancelli et al., 2011; Sun et al., 2010; Zhu et al., 2008). To maintain low DO concentration, intermittent aeration is a favorable option for partial nitritation due to nitrite accumulation during the transition from anoxic to aerobic condition (Yoo et al., 1999; Pollice et al., 2002; Hidaka et al., 2002). However, maintenance of low DO concentration or short SRT may slow down AOB growth in the nitritation, which is fed with high ammonium strength wastewater. Besides, high bicarbonate alkalinity in old urban landfill leachate may be enough for carbon assimilation of AOB in the partial nitritation. Therefore, this study aimed to evaluate the stability of partial nitritation in a sequencing batch reactor with fed-batch operation mode, without pH adjustment or bicarbonate addition and without low DO control, which was fed with old municipal landfill leachate containing extreme high ammonia concentration and high bicarbonate alkalinity. The study also investigated variation of FA, FNA, alkalinity and pH value in a cycle of the PN-SBR that achieved stable performance of the partial nitritation.

2. Methods

2.1. Feed leachate

The study used leachate collected from Go Cat municipal landfill site, at Binh Tan District, Ho Chi Minh City, Vietnam, which was close in 2007. Characteristic of the feed leachate are illustrated in Table 1.

2.2. Reactor

A sequencing batch reactor with a working volume of 190 l (60 cm internal diameter by 100 cm total height) was used for the partial nitritation. The operating minimum volume was 40 l, which is equivalent to the volume exchange ratio (VER) of 79%. Complete mixing achieved by using an air compressor (RESUN AVO-006, 88 l min^{-1}) and an air diffuser (GREATECH GTD-270), which were fixed at the reactor bottom. The old landfill leachate was stored in a 1000-liter influent tank.

Table 1
Characteristic of the feed leachate in the study (n = 35).

Parameter	Average value ± std
pH	7.8 ± 0.3
Alkalinity, mg$CaCO_3$ l^{-1}	12960 ± 1530
NH_4^+-N, mg l^{-1}	3096 ± 542
TKN, mg l^{-1}	3263 ± 120
NO_2^--N, mg l^{-1}	0.74 ± 1.31
NO_3^--N, mg l^{-1}	0.70 ± 1.11
COD, mg l^{-1}	2770 ± 85
SS, mg l^{-1}	39 ± 12

2.3. Seed sludge

The PN-SBR was inoculated with 1660 mg MLVSS l^{-1} of AOB sludge taken from the study of Nhat et al. (2014), in which a lab scale system including a PN-SBR followed by an anammox reactor was used for nitrogen removal from the same Go Cat old landfill leachate.

2.4. Operational conditions

The PN-SBR was continuously run for 250 days at the room temperature ranging from 28 to 32 °C. No pH adjustment was occurred. The complete mixing by aeration provided DO concentration equal or higher than 2.0 mg l^{-1}. The reactor operated with fed-batch mode with each 73-hour cycle consisting of 10 min of feeding without aeration, 72 h of aeration, 40 min of settling and 10 min of supernatant decanting. Thus, at the volume exchange ratio (VER) of 79%, the reactor was run at the fixed hydraulic retention time (HRT) of 3.85 days during the whole experiment. The average suspended solid concentration in the decanted supernatant was 100 ± 25 mg TSS l^{-1}, whereas the average concentration of mixed liquor suspended solids (MLSS) was maintained 3200 ± 70 mg TSS l^{-1} with a volatile fraction of about 72%. The sludge retention time was not controlled because no sludge withdrawal was done during the whole study period. However, it is based on the average effluent SS concentration and MLSS maintained in the reactor, the average SRT of the whole experiment was 122 days.

2.5. Analytical methods

Chemical oxygen demand COD, total kjeldahl nitrogen (TKN), ammonium (NH_4^+-N), nitrite (NO_2^-N), nitrate (NO_3^--N), mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were measured according to Standard Methods for examination of Water and Wastewater (APHA, 1998). Free Ammonia (FA) and Free Nitrous Acid (FNA) concentrations were calculated as a function of pH, temperature, and total Ammonia Nitrogen (TAN) for FA determination, or Total Nitrite (TNO_x) for FNA determination (Anthonisen et al., 1976).

According to the method developed by Ciudad et al. (2006), the specific oxygen uptake rate (SOUR, mg O_2 g^{-1} VSS l^{-1}) was determined by on-line measurement of the drop in dissolved oxygen when no air flow was supplied. The SOUR of nitrifying bacteria, which is much dependent on substrate and DO concentrations was simulated by a double-substrate Monod expression (Equation (1)). Determination of OUR of AOB were carried out in a 2-liter respirometer using diluted leachate at NH_4^+-N concentrations of 5, 10, 200, 800, 1600 and 3200 mg l^-. The OUR test was triplicated. The experimental data obtained in the test were fitted to Eq. (1) by using nonlinear regression method in SIGMAPLOT software to determine the maximum SOUR and half saturation coefficient of AOB.

$$SOUR = SOUR_{max}\left(\frac{[DO]}{[DO]+K_O}\right)\left(\frac{[S]}{[S]+K_S}\right) \quad (1)$$

Where SOUR is specific oxygen uptake rate for nitritation (mg O_2 mg^{-1} VSS h^{-1}), $SOUR_{max}$ is the maximum SOUR for nitritation, [S] is ammonium concentration (mg NH_4^+-N l^{-1}), [DO] is DO concentration (mg O_2 l^{-1}), K_S is half saturation coefficient for substrate (mg NH_4^+-N l^{-1}), and K_o is half saturation coefficient for oxygen (mg O_2 l^{-1}).

Please cite this article in press as: Nhat, P.T., et al., Stability of partial nitritation in a sequencing batch reactor fed with high ammonium strength old urban landfill leachate, International Biodeterioration & Biodegradation (2017), http://dx.doi.org/10.1016/j.ibiod.2017.06.017