Bioresource Technology 162 (2014) 373–378

Contents lists available at ScienceDirect

Bioresource Technology

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

Simultaneous organic carbon and nitrogen removal in an anoxic–oxic activated sludge system under various operating conditions

Kashif Rasool [a], Dae Hee Ahn [b,*], Dae Sung Lee [a]

[a] Department of Environmental Engineering, Kyungpook National University, 80 Daehak-ro, Buk-gu, Daegu 702-701, Republic of Korea
[b] Department of Environmental Engineering and Biotechnology, Myongji University, 116 Myongji-ro, Cheoin-gu, Yongin, Gyeonggi-do 449-728, Republic of Korea

HIGHLIGHTS

- A modified pre-denitrification anoxic-oxic process was proposed.
- Efficient pre-denitrification using returned activated sludge was achieved.
- Sludge concentration, dissolved oxygen, pH and alkalinity profiles were monitored.
- Proposed process was suitable for achieving COD and nitrogen removal.

ARTICLE INFO

Article history:
Received 25 September 2013
Received in revised form 17 March 2014
Accepted 21 March 2014
Available online 1 April 2014

Keywords:
Activated sludge
Anoxic–oxic
Nitrification
Recycling sludge
Wastewater treatment

ABSTRACT

This study investigated a bench-scale anoxic–oxic activated sludge system for integrated removal of COD and nitrogen. The experimental unit includes four chambers and continuous feeding in first chamber without recycle of nitrified liquid from aerobic to anoxic chamber unlike the conventional anoxic–oxic process. Recycled excessive sludge was used for the purpose of recycling nitrified mixed liquor. Synthetic wastewater with average loading rates of 0.53 kg COD/m^3/d and 0.067 kg NH_4^+-N/m^3/d was fed to the reactor system at hydraulic residence times (HRT) of 24 and 18 h. The results of 100 days operation showed high removal efficiencies of organic matter of about 97% as total COD and more than 99% removal of ammonia–nitrogen. In anoxic–oxic operation phase, total inorganic nitrogen (TIN) removal was about 66% by pre-denitrification. Moreover, the solid liquid separation through final clarifier was excellent without any suspended solid in the effluent.

1. Introduction

The contribution of nutrient-rich wastewater to the eutrophication of inland and coastal waters has resulted in increased demands for COD, and nutrient removal from municipal and industrial wastewater (Chen et al., 2006; Klees and Silverstein, 1992). Nitrogen is becoming increasingly important in wastewater management because nitrogen can have many adverse effects on the environment (Iqbal et al., 2010; Xiankai et al., 2008). Moreover, nitrates in wastewater streams have raised concerns due to severe impacts on human and animal health. Different agricultural land uses in the suburban areas cause a distinct difference in NO_3^- contamination and the anoxic subsurface system associated with the geological settings and pavement coverage function to buffer NO_3^- contamination due to active denitrification and less nitrification.

Activated sludge process, being cost effective, is normally adopted for treatment of organics and nutrients rich industrial and domestic wastewater (Kulkarni, 2013; Naseer et al., 2013). Biological nitrogen removal process uses nitrifiers and denitrifiers to achieve nitrogen removal from the wastewater. Nitrification demands a very efficient oxygen supply coupled with adjustment for changes in the alkalinity of the wastewater due to the formation of hydrogen ions, whereas, denitrifying bacteria essentially need a carbon source as an electron donor. The primary nutrients which should be removed to prevent deterioration of water bodies are carbon, nitrogen and phosphorous. Carbon is not considered difficult to remove biologically. On the contrary, one of the most significant problems with treatment of many wastewaters is a lack of organic carbon, as the removal of both nitrogen and phosphorous involve heterotrophic conversions, requiring an electron donor. Thus, treatment plants treating wastewaters containing low COD:N ratios experience difficulties in removing residual nitrogen and phosphorous due to a shortage of organic substrate (Naseer et al., 2013). This has led to an increased interest in the

* Corresponding author. Contact address: Department of Environmental Engineering and Biotechnology, Myongji University, Republic of Korea. Tel.: +82 31 330 6692; fax: +82 31 336 6336.

E-mail addresses: dhahn@mju.ac.kr (D.H. Ahn), daesung@knu.ac.kr (D.S. Lee).

http://dx.doi.org/10.1016/j.biortech.2014.03.108
0960-8524/

optimization of the various microbial steps involved in biological removal, aimed at a reduction of investment and operating costs for treatment plants. As a consequence, research into control strategies to conserve organic substrate has gained attention in recent years (Cao et al., 2013; Guo et al., 2013; Liu et al., 2013) and is the subject of research in this investigation.

The wastewater influent is generally mixed with returned activated sludge (RAS) as it enters the treatment reactor. Nitrification followed by denitrification requires careful control because denitrification requires reducing equivalents that do occur in wastewater, but are difficult to preserve through the necessary preceding nitrification step. Unlike other studies where nitrified water is pumped back to the anoxic zone to make it in contact with the incoming wastewater for anoxic feeding or predenitrification (Canals et al., 2013; Wang et al., 2009), this study focused on the use of recycled sludge as a nitrified water source. Operating reactor without pumping the water from oxic to anoxic zone could significantly decrease the operating cost. The purpose of this work was to present the design and functionality of a bench scale dynamic activated sludge system for biological removal of organic substrate and nitrogen applying anoxic–oxic process. Also the changes and effect of different operating conditions like hydraulic retention time (HRT), sludge retention time (SRT), alkalinity, pH, and substrate concentrations were studied.

2. Methods

2.1. Experimental design and operating conditions

Fig. 1 shows the schematic diagram of bench scale anoxic–oxic activated sludge system made of Plexiglas. The bench scale reactor had total operational volume of 150 L, with four chambers each having a working volume of 37.5 L. Denitrification took place in the first anoxic chamber, whereas nitrification and carbon oxidation was accomplished in the following three aerobic chambers. Finally, a secondary sedimentation tank (ST) of 40 L was used for sludge separation and recycling nitrified liquid into first chamber of the reactor. Sludge wastage and recycle was controlled by a timer that switches on/off by magnetic three-way valve. Wastewater transfer was performed by peristaltic pumps. In particular, the reactor configuration was made in such a way that the wastewater or mixed liquor suspended solids (MLSS) were introduced and withdrawn from the top of each reactor. Aeration was performed by the diffused aeration method, i.e., air was introduced at the bottom of the aerobic chambers through special porous material. Air flow meters were used for manual control of air flow rates in each aerobic chamber. All tanks were gently stirred to completely mix the biomass.

The Reactor was fed with synthetic wastewater. All experiments were performed at room temperature. The characteristics of the system varied with respect to HRT, SRT and influent wastewater strength. HRT of the activated sludge system was altered from 24 to 18 h and was calculated excluding the ST. Sludge recycling rate was maintained equal to each influent flow rate. The reactor was operated with SRT of 10, 18 and 30 d. The pH was maintained at 7.3–8.3 in the reactor. The average influent concentrations of COD and ammonia–nitrogen (NH_4^+-N) were about 450 and 60 mg/L, respectively. The bench-scale plant was operated for 100 d. For the first 77 d all the four chambers were operated in aerobic mode to study the effect of HRT and SRT on nitrification. After day 77, the first chamber was made anoxic to study pre-denitrification.

2.2. Reactor inoculation

All the four chambers were inoculated by aerobic sludge taken from the Yongin wastewater treatment plant (Gyeonggi Province, Korea) with initial total suspended solid (TSS) concentration of 3000 mg/L in each chamber. Synthetic wastewater contained mainly ammonium and COD and its composition is described in Table 1. Glucose and NH_4SO_4 were used as a sole source of carbon and ammonia. Sufficient alkalinity in the form of Na_2CO_3 and $NaHCO_3$ was provided to fully support the nitrification. The influent pH was adjusted in the range of 8.5–9.5. After the operational conditions (i.e., influent flow rate, HRT, SRT) were set, the reactor was run until it reached steady state conditions. In order to assure steady state conditions, samples were taken periodically to check the stability of the unit efficiency. When steady state conditions were confirmed, change of operational conditions for the next run was performed. Table 2 shows the operational conditions and loading rates for organic and nitrogenous substrate.

2.3. Analytical procedure

The parameters chosen to characterize the liquid fraction and to monitor the performance of the reactor were: pH, dissolve oxygen (DO), MLSS, mixed liquor volatile suspended solids (MLVSS), COD, NH_4^+-N, nitrate-nitrogen (NO_3^--N), nitrite-nitrogen (NO_2^--N) and alkalinity. Under steady state conditions, samples from influent, all the four chambers and effluent were collected and centrifuged at 5000 rpm for 5 min. Supernatant obtained was filtered through 0.45 μm filter paper (GF/C-Whatman) and was used for further analysis. NH_4^+-N was measured by selective electrode method (Ammonia Selective Electrode ORION®). NO_3^--N and NO_2^--N were measured by colorimetric method. COD was analyzed by closed reflux method. The pH was examined by pH meter (inoLAB WTW). MLSS, MLVSS, and alkalinity were performed in accordance with the standard methods for the examination of water and wastewater (APHA, 2005).

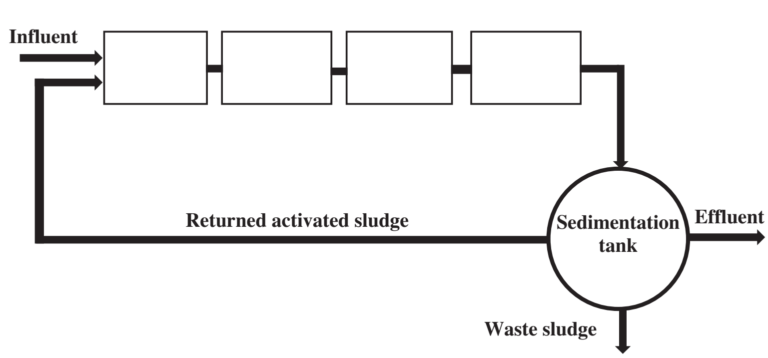

Fig. 1. Schematic diagram of a lab scale activated sludge system.