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Efficient single-stage autotrophic nitrogen removal with dilute wastewater through oxygen supply control

Wonji Kwak [a], Perry L. McCarty [a,b], Jaeho Bae [a], Yu-Tzu Huang [c], Po-Heng Lee [a,d,*]

[a] Department of Environmental Engineering, Inha University, Namgu, Yonghhyun dong 253, Incheon, Republic of Korea
[b] Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305, USA
[c] Chung Yuan Christian University and R&D Center for Membrane Technology, No. 200, Chung-Pei Road, Chung-Li 32023, Taiwan
[d] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

HIGHLIGHTS

- Efficient single-stage autotrophic nitrogen removal from dilute waster is possible.
- Over 90% total N removal by controlling oxygen supply to 0.75 mol O_2/mol NH_3 added.
- With this or less oxygen, nitrate formation held to 2% or less of ammonia removed.
- The efficient nitrogen removal obtained with 1 h HRT, 25 °C and 50 mg/L NH_3–N.
- Autotrophic nitrogen removal requires little oxygen and no organics.

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ABSTRACT

Autotrophic nitrogen removal via ammonia oxidizing (AOB) and anaerobic ammonium oxidizing (anammox) bacteria was evaluated for treatment of a dilute 50 mg/L ammonia-containing solution in a single-stage nitrogen-removal filter at 25 °C. Important was an external oxygenation system that permitted close control and measurement of oxygen supply, a difficulty with the generally used diffused air systems. Hydraulic retention time (HRT) was reduced in steps from 15 to 1 h. At 1 h HRT, total nitrogen (TN) removals varied between 73% and 94%, the maximum being obtained with a benchmark oxygenation ratio of 0.75 mol O_2/mol ammonia fed. At higher ratios, nitrate was formed causing TN removal efficiency to decrease. With lower ratios, TN and ammonia removals decreased in proportion to the decrease in BOR. When operating at or below the BOR, nitrate formation equaled no more than 2% of the ammonia removed, a value much less than has previously been reported.

1. Introduction

Growing populations along with diminishing supplies of energy and other resources has led to emphasis on energy-efficiency and resource recovery. Towards this end, complete anaerobic treatment of domestic wastewaters and simultaneous energy recovery in the form of methane is of growing interest (Kim et al., 2011; McCarty et al., 2011). However, anaerobic treatment does not remove ammonia nitrogen from wastewater. Ammonia removal by the conventional biological process, nitrification followed by denitrification, requires both extensive energy for aeration to carry out nitrification to nitrate and an external carbon source for denitrification. A much more energy-efficient process for this purpose is autotrophic nitrogen removal, which couples nitritation of a portion of the ammonia to nitrite by ammonium oxidizing bacteria (AOB), which is then used for anaerobic oxidation of the remaining ammonia to N_2 (anammox) (Third et al., 2001). The advantages of autotrophic nitrogen removal compared with conventional nitrification–denitrification are: (1) a 60% reduction in energy consumption for aeration (van Dongen et al., 2001; Siegrist et al., 2008); (2) no organic donor requirement for denitrification, which otherwise can be converted to methane for energy production (McCarty et al., 2011); (3) a 90% reduction in sludge handling and transportation costs (Mulder, 2003; De Clippeleir et al., 2011); and (4) less production of N_2O, a powerful green house gas (ICCP, 2006; Kampschreur et al., 2009). Fux and Siegrist (2004) estimated autotrophic nitrogen removal can achieve a 30–40% cost reduction for

* Corresponding author at: Department of Environmental Engineering, Inha University, Namgu, Yonghhyun dong 253, Incheon, Republic of Korea. Tel.: +82 32 860 9236; fax: +82 32 865 9236.
E-mail addresses: poheng76@inha.ac.kr, poheng76@gmail.com (P.-H. Lee).

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