Bioresource Technology 118 (2012) 526–535

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

High rate biological nutrient removal from high strength wastewater using anaerobic-circulating fluidized bed bioreactor (A-CFBBR)

Mehran Andalib, George Nakhla *, Jesse Zhu

Department of Chemical and Biochemical Engineering, The University of Western Ontario, London, Ontario, Canada N6A 5B9

HIGHLIGHTS

- Development of an integrated system for biological nutrient removal from high strength WW.
- High rate C and N removal at a high OLR of 35 kg COD/m^3 d and NLR of 1.1 kg N/m^3 d.
- High rate biogas production per reactor volume of 16 L gas/$L_{reactor}$ d.
- A very low overall system sludge yield of 0.017 g VSS/g COD.

ARTICLE INFO

Article history:
Received 21 March 2012
Received in revised form 13 May 2012
Accepted 14 May 2012
Available online 23 May 2012

Keywords:
Biological nutrient removal
Anaerobic
Aerobic
Anoxic
Fluidization

ABSTRACT

Biological nutrient removal (BNR) from high strength wastewater was investigated using a newly developed integrated anaerobic fluidized bed (AF) with circulating fluidized bed bioreactor henceforth called A-CFBBR. The A-CFBBR showed 99.7% COD removal, 84% nitrogen removal, with a very low sludge yield of 0.017 g VSS/g COD while treating a synthetic wastewater containing 10,700 mg COD/L and 250 mg NH_3–N/L over a period of 6 months. The system was operated at an organic loading rate (OLR) of 35 kg COD/m^3_{AF} d and nitrogen loading rate (NLR) of 1.1 kg N/m^3_{CFBBR} d at a hydraulic retention time (HRT) of less than 12 h in the A-CFBBR. Microbial communities analysis using DGGE confirmed the presence of both AOBs and NOBs in the riser and downer. *Pseudomonas putida* and *Pseudomonas fluorescence* were the dominant denitrifiers present in the downer. Methanogenic activity was accomplished by a microbial mixture of archaea and bacteria in the anaerobic column.

1. Introduction

High strength wastes produced by fertilizer production, explosive manufacturing, and recovery of nuclear fuels as well as landfill leachate contain in addition to organic matter, nitrogen in the forms of ammonia, nitric and nitrous acids (Chen and Lin, 1993). Similarly, many food processing wastewaters such as rendering wastes also contain high ammonia concentrations as a result of protein digestion. Nitrogen removal from such wastes, which require anaerobic processes to recover energy, can be challenging. Although simultaneous denitrification and methanogenesis (SDM) in a single anaerobic reactor has been studied, the toxic effects of NO_3–N, NO_2–N, and N_2O on methanogenesis at different loading rates makes it less attractive than using the sequence of anaerobic, anoxic, and aerobic systems (Andalib et al., 2011a).

The Circulating Fluidized Bed Bioreactor (CFBBR), introduced and developed by Nakhla and his coworkers (Cui et al., 2004), was tested for biological nutrient removal (BNR) from municipal wastewaters in both lab and pilot scales at OLR of 5 kg COD/m^3 d and NLR of 0.5 kg N/m^3 d (Chowdhury et al., 2010). The CFBBR consists of an anoxic riser and an aerobic downer with fast and conventional fluidization regimes respectively. More than 90% organic, 70–80% total nitrogen and 50–70% phosphorous removal were reported, at hydraulic retention times (HRTs) of 2–3 h and an observed biomass yield of 0.12–0.16 g VSS/g COD. The CFBBR was reported to treat high strength wastewater such as landfill leachate and septage as well at the aforementioned OLR and NLR (Eldyasti et al., 2010). However, in order to accomplish high rate biological nutrient removal from high strength waste containing nitrogen, a newly developed bioreactor referred to henceforth as anaerobic-circulating fluidized bed bioreactor (A-CFBBR) was designed and tested to treat synthetic high strength wastewater with TCOD of 10,600 ± 270 mg/L, NH_3–N of 250 ± 10 mg/L. The advantages of the A-CFBBR over conventional anaerobic treatment

* Corresponding author. Tel.: +1 519 661 2111x85470; fax: +1 519 850 2921.
E-mail address: gnakhla@eng.uwo.ca (G. Nakhla).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.05.068