International Biodeterioration & Biodegradation 85 (2013) 491–498

Contents lists available at SciVerse ScienceDirect

International Biodeterioration & Biodegradation

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

Fouling characterization and nitrogen removal in a batch granulation membrane bioreactor

Bui Xuan Thanh [a,*], Chettiyapan Visvanathan [b], Roger Ben Aim [c]

[a] Faculty of Environment, Ho Chi Minh City University of Technology, Building B9, 268 Ly Thuong Kiet Str., District 10, Ho Chi Minh City 70000, Viet Nam
[b] Environmental Engineering and Management Program, School of Environment, Resources and Development, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
[c] Université de Toulouse, INSA, UPS, INP, LISBP, 135 Avenue de Rangueil, F-31077 Toulouse, France

ARTICLE INFO

Article history:
Received 16 November 2012
Received in revised form
19 February 2013
Accepted 21 February 2013
Available online 19 March 2013

Keywords:
Aerobic granules
Membrane bioreactor
Extracellular polymeric substances
Fouling

ABSTRACT

A submerged membrane bioreactor (MBR) combined with aerobic granulation reactor was investigated for the simultaneous organic/nitrogen removal and membrane fouling control. Total nitrogen (TN) removal was 59% (1.76 mg TN/g VSS h) in the aerobic granulation reactor. The filtration of granulation effluent or low operating F/M condition of the MBR could extend the filtration period of up to 78 days without any need for physical cleaning The soluble fraction was the main contributor to fouling compared to colloids and solids. The soluble polysaccharides (sPS) had more adverse effects than that of soluble protein (sPN). The deposition on a unit of the membrane's surface area was 11 mg sPS/L m^2 and 8 mg sPS/L m^2. As a result, the BG-MBR could be an alternative treatment process for simultaneous organic/nitrogen removal and fouling control.

1. Introduction

The aerobic granular sludge process has been known to have many advantages as compared to the conventional activated sludge operations for about a decade. The aerobic granule possesses a compact spherical structure, excellent settling ability, dense biomass structure, high biomass retention, ability for simultaneous nitrification-denitrification and removal of toxic substance (Beun et al., 2002; Carvalho et al., 2006; Thanh et al., 2008; Shi et al., 2011). The sludge is more stable in batch reactors due to the existence of feast and famine conditions in each cycle (Beun et al., 2002). The organic and nitrogen removal in the granulation system is high compared to that of conventional activated sludge process (Arrojo et al., 2004; Tay et al., 2007; Thanh et al., 2009; Lotito et al., 2012). However, the single granular sludge reactor was not able to meet the effluent standards due to the high suspended solids content in the effluent. The suspended solids (SS) concentrations in the effluent of the granulation reactor were high, ranging from 75 to 250 mgVSS/L (Beun et al., 2002) and 200 to 450 mgTSS/L (Arrojo et al., 2004). Thus, a post treatment such as membrane filtration could be an add-in polishing step for complete treatment and water reuse.

Membrane technology has been proven to be the most effective wastewater treatment system in recent decades. The advantages are less footprint requirements due to a high substrate loading rate, good treated water quality which can be reused for appropriate operations, less sludge production rate, high biomass retention, and microbial diversity, among others (Visvanathan et al., 2000).

Membrane fouling could be due to the deposition of suspended solids/flocs (cake/gel formation, pore blocking), colloids (Bouhabila et al., 2001) and solutes (Shane Trussell et al., 2006; Jarusutthirak and Amy, 2006; Miyoshi et al., 2012). Recently, it has been found that the fouling mechanism of the submerged MBR is mainly caused by the deposition/accumulation of soluble extracellular polymeric substances (sEPS) on the membrane if reversible fouling (cake formation) is well controlled. The sEPS mainly comprises of soluble polysaccharide (sPS) and soluble protein (sPN). The fouling potential of sPS, sPN or both of them is still unclear. Both sPS and sPN were some of the factors which influenced membrane fouling (Shane Trussell et al., 2006; Liang et al., 2007; Miyoshi et al., 2012) where the sPS played a major role as membrane foulant (Rosenberger et al., 2006; Jarusutthirak and Amy, 2006; Kim and DiGiano, 2006).

* Corresponding author. Tel.: +84 907866073.
E-mail addresses: bxthanh@hcmut.edu.vn (B.X. Thanh), visu@ait.ac.th (C. Visvanathan).

0964-8305/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ibiod.2013.02.005

At the moment, there exists very limited published information related to the fouling behavior of the aerobic granular reactor effluent. Some researchers studied the filterability of MBR seeding with pre-cultivated aerobic granules for a short operation period. The granules used in the MBR were taken from a batch reactor. Li et al. (2005) reported that the permeability of the MBR seeding with pre-cultivated granules was 50% higher than that of the conventional MBR during 16 days of operation. The author proposed that the compact and round shaped structure of the granule might cause less fouling due to the contact of less floc particles with the membrane's surface. Additionally, Tay et al. (2007) also reported that the filterability of pre-cultivated granules was much better than that of conventional sludge flocs. Granular sludge had a membrane permeability loss of 1.68-fold less than conventional sludge flocs during the constant pressure test.

In this study, a hybrid system includes a submerged MBR following a sequencing batch airlift reactor (SBAR) to filter the effluent. This is named as a batch granulation membrane bioreactor (or BG-MBR). This combination was selected instead of inserting the membrane inside the granulation reactor because granular sludge was not stable in the continuous operation mode. It is clearly proven that granules could be stable with the cyclic feast and famine conditions in a batch reactor (Beun et al., 2002; Tay et al., 2007). The advantages of this hybrid system include high organic and nitrogen removal efficiencies and fouling control. This paper focuses on the investigation of high loading simultaneous organic and nitrogen removal and the fouling characteristics of the BG-MBR system. Further, the fouling behavior of sludge fractions was also investigated.

2. Materials and methods

2.1. Experimental setup

Fig. 1 describes the BG-MBR system including a SBAR (granulation reactor), a settler and a submerged MBR. The SBAR which operated in batch mode consisted of four cycles of operation. Air was supplied through a porous stone diffuser from the bottom of the reactor. Each batch of operation consisted of four stages namely feeding (6 min), reaction (high aeration rate: 3 h; and low aeration rate: 48 min), settling (3 min) and withdrawal (3 min). The high aeration rate is to achieve oxidation of organic and nitrogen compounds and granule stability. Further, it was followed by low aeration to reduce the aeration cost and to enhance the nitrogen removal through the denitrification process occurring inside the core of the granule. The denitrification process might be enhanced by limitation of oxygen diffusivity into the core of the granule. The SRT was not controlled in this study because the suspended solids from SBAR effluent fluctuated according to time. The second unit was the settler. The settler is a dual purpose tank to function as both holding and settling tank (denoted as "settler"). The effluent of SBAR was transferred into the settler which was then fed into the MBR in a continuous mode of operation. Settled sludge of 500 mL/d (twice, each 250 mL) from the settler was removed periodically. The final unit, the submerged MBR was used for the separation of liquid and solid fractions. The remaining substrate, unsettled colloids and pin flocs could be further biologically degraded in the MBR. All these systems were controlled automatically by programmable logic controller. Table 1 shows the operating conditions of BG-MBR system.

2.2. Wastewater and support media

The feeding wastewater contained 260 mg TOC/L (700 mg COD/L as glucose), 190 mg N/L of NH_4Cl, 50 mg/L of KH_2PO_4, 30 mg/L of $CaCl_2 \cdot 2H_2O$, 12 mg/L of $MgSO_4 \cdot 7H_2O$, and 4 mg/L of $FeCl_3$ throughout the experiment. Trace elements were added at the rate of 1 mL/L of wastewater as described by Thanh et al. (2008).

The shell carrier produced from the shell of white rose cockle was added to act as a support for microbial granule formation. The carrier was used to enhance the structure, round shape, and physico-chemical characteristics of the granules. The shells were dried, ground and sifted with sieve Nos. 70 and 100, to reach a fraction between 150 and 212 μm. The powder obtained was

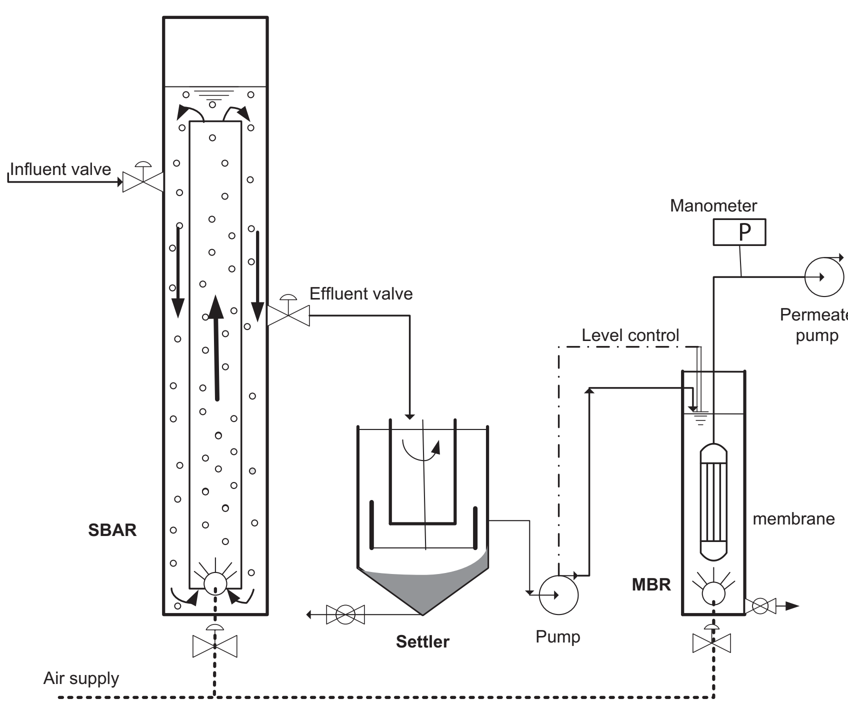

Fig. 1. Experimental set-up of BG-MBR system.