Bioresource Technology 136 (2013) 155–162

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Systematic analysis of biomass characteristics associated membrane fouling during start-up of a hybrid membrane bioreactor using worm reactor for sludge reduction

Zhipeng Li [b], Yu Tian [a,b,*], Yi Ding [b], Yaobin Lu [b]

[a] State Key Laboratory of Urban Water Resource and Environment, Harbin Institute of Technology (SKLUWRE, HIT), Harbin 150090, China
[b] School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, China

HIGHLIGHTS

- ▶ The effect of the worm reactor on microbial community development was investigated.
- ▶ The viability of sludge was slightly weakened with the predated sludge recycle.
- ▶ The microbial community was shifted with the predated sludge recycle.
- ▶ Changed EPS and SMP might be closely associated with microbial community.
- ▶ Microbial community shift might be responsible for improved membrane permeability.

ARTICLE INFO

Article history:
Received 12 November 2012
Received in revised form 21 February 2013
Accepted 22 February 2013
Available online 4 March 2013

Keywords:
Membrane bioreactor (MBR)
Worm reactor
Membrane fouling
Denaturing gradient gel electrophoresis
Microbial community

ABSTRACT

This study focused on the effect of predated sludge recycle on microbial community development in MBR coupled with Static Sequencing Batch Worm Reactor (SSBWR-MBR). The microbial activities and community were evaluated. The results indicated that the SSBWR-MBR fed with the predated sludge obtained excellent wastewater treatment performance and membrane permeability. In addition, the LIVE/DEAD staining analyses clearly showed that the viability of sludge in SSBWR-MBR was slightly lower than that in Control-MBR, indicating that SSBWR-MBR had a good ability to digest predated sludge. Changed EPS and SMP characteristics and low EPS production, as the major contributors for the mitigated membrane fouling, were closely associated with microbial community development. Denaturing gradient gel electrophoresis (DGGE) analysis revealed that the bacterial communities in the two reactors were different. Further identification of the bacterial populations suggested that decrease of *Betaproteobacteria* and *Gammaproteobacteria* and change in *Alphaproteobacteria* might be responsible for membrane fouling mitigation.

1. Introduction

Membrane bioreactors (MBRs) have been increasingly and widely used for wastewater treatments in the last decade (Hwang et al., 2010; Meng et al., 2009). However, membrane fouling is a major obstacle to the wide application of MBRs. Additionally, the excess sludge withdrawn from the MBR creates a concurrent sludge management problem (Oh et al., 2007). Recently, a MBR coupled with a Static Sequencing Batch Worm Reactor (SSBWR-MBR) was designed, in which excellent sludge reduction efficiency and membrane permeability were obtained (Tian et al., 2012a–c). Moreover, the improved membrane permeability of the mixed liquor was attributed to the changed biomass characteristics due to the predated sludge recycle (e.g., extracellular polymeric substance (EPS) level reduction, floc shape spheroidization and floc size homogenization) (Tian et al., 2012b,c).

The contributions of biomass characteristics in suspended mixed liquor to membrane fouling were reported largely depending on bacterial population in the MBR (Wu et al., 2011b). Several researchers have confirmed the significant role of the microbial community structure on membrane fouling. Ahmed et al. (2007) demonstrated that reduced membrane fouling at higher sludge retention time (SRT) was related to dominant growth of bacterium associated with a low EPS content in biomass. Li et al. (2012) reported that the shift in bacterial community during start-up period would be responsible for the severe membrane fouling. Wu et al. (2011a) found microbial community structure in the cake layer was highly similar with the

* Corresponding author at: School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, China. Tel.: +86 451 8628 3077/13804589869; fax: +86 451 8628 3077.
E-mail address: hittianyu@163.com (Y. Tian).

0960-8524/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2013.02.082

Nomenclature

CLSM	confocal scanning laser microscope
C-MBR	membrane bioreactor without static sequencing batch worm reactor
COD	chemical oxygen demand
DGGE	denaturing gradient gel electrophoresis
DI	de-ionized
DO	dissolved oxygen
dTMP/dt	rate of TMP increase (or fouling rate)
EPS	extracellular polymeric substance
MBR	membrane bioreactor
MLSS	mixed liquor suspended solids
OTU	operational taxonomic unit
PCR-DGGE	polymerase chain reaction-denaturing gradient gel electrophoresis
PVDF	polyvinylidene fluoride
S-MBR	membrane bioreactor with static sequencing batch worm reactor
SMP	soluble microbial product
SRT	sludge retention time
SSBWR	static sequencing batch worm reactor
SSBWR-MBR	membrane bioreactor coupled with a static sequencing batch worm reactor
TMP	transmembrane pressure

suspended mixed liquor. After the introduction of worm reactor to the MBR processes, nutrients released by worm predation may alter the influent characteristics of the entire system with the predated sludge recycle. Furthermore, each of the microorganisms has different growth patterns, growth rates and dependence on the environmental conditions (Yan et al., 2009). Thus the predated sludge recycle may influence the microbes in the bioreactor. However, there have been few in depth analyses of the biological performance and microbial communities associated with the combined MBR process.

Severe membrane fouling had been observed in the initial phase in which biomass was not fully acclimated and stabilized in new culture environment (Le-Clech et al., 2006). Obviously, the predated sludge recycle would lead to a dynamic shift in microbial living environment in MBR. However, it should be noted that the predated sludge recycle could cause less membrane fouling in our previous study (Tian et al., 2012b,c). Thus, the role of microbial community structure on membrane fouling during start-up of the combined system should be taken into account. The motivation of this research was, therefore, to investigate the microbial community development with the return of predated sludge in a hybrid MBR system and its influence on MBR performance and membrane fouling rate. It can be expected that this study would be useful for further developing an effective biofouling control strategies in MBR.

2. Methods

2.1. SSBWR-MBR system

Two bench scale MBRs, without (C-MBR) and with SSBWR (S-MBR), were operated for simultaneous wastewater treatment and sludge reduction (Fig. 1). The set-ups of the two systems were similar to that described in previous studies (Tian et al., 2012b,c). The SSBWR with the working volume of 39 L was made of Lucite so that the experiment was easily observed, and a complete description of this SSBWR unit was provided in (Tian et al., 2010). The two MBRs, each with a working volume of 40 L, were fed with synthetic wastewater (glucose 200 mg/L; starch 200 mg/L; $NaHCO_3$ 300 mg/L; $CO(NH_2)_2$ 32.1 mg/L; NH_4Cl 95.5 mg/L; KH_2PO_4 47 mg/L; $MgSO_4$ 40 mg/L; $CaCl_2$ 5 mg/L). A water level sensor was used to keep a constant liquid level in each reactor. One membrane module which was made of hollow fibers of polyvinylidene fluoride (PVDF) with an effective area of 1 m^2 and a mean pore size of 0.22 μm (Motimo, China) was immersed in each MBR. An aeration system was placed at the bottom of each MBR to maintain desired dissolved oxygen (DO) concentration. A suction pump was used to collect the effluent from the membrane module, and a manometer was fixed between the membrane module and the suction pump to monitor the TMP. The membrane flux was maintained at 8 L/(m^2 h) with a suction mode of 8 min "on" and 2 min "off". Once a day, 4.5 L of the mixed liquid withdrawn from the S-MBR was collected, and then was fed to the SSBWR. After predation, the worms consumed approximately one third of the sludge withdrawn from the S-MBR. As for the non-consumed sludge and possible metabolites, they were recycled to the S-MBR. Meanwhile, 1.5 L of the mixed liquor in the C-MBR which contained the amount of sludge equal to that of predated by worms was removed. Thus the mass of excess sludge discarded from the two systems was almost the same to maintain the SRT of the two MBRs at the same level. The C-MBR and S-MBR were operated for 105 days which can be considered as the start-up period in this study.

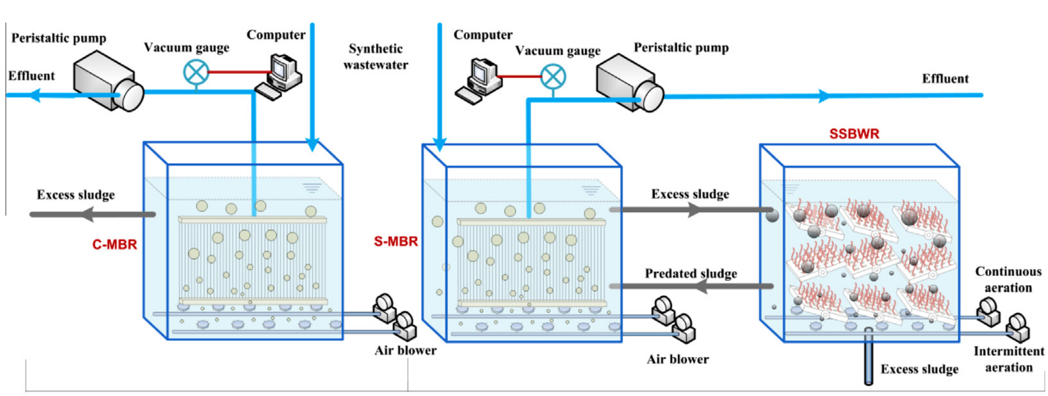

Fig. 1. A schematic representation of the Control-MBR and SSBWR-MBR.