Journal of Membrane Science 379 (2011) 434–439

Contents lists available at ScienceDirect

Journal of Membrane Science

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

Performance of the submerged membrane electro-bioreactor (SMEBR) with iron electrodes for wastewater treatment and fouling reduction

Khalid Bani-Melhem*, Maria Elektorowicz

Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, QC H3G 1M8, Canada

A R T I C L E I N F O

Article history:
Received 14 February 2011
Received in revised form 1 June 2011
Accepted 11 June 2011
Available online 12 July 2011

Keywords:
Membrane fouling
Submerged membrane electro-bioreactor
Electrocoagulation
Wastewater treatment

A B S T R A C T

This paper presents the results of the performance of a novel technology called submerged membrane electro-bioreactor (SMEBR). The SMEBR treats wastewater by combining membrane filtration, electrokinetic phenomena, and biological processes in one reactor, and improves treatment performance while helping to control membrane fouling. The newly designed SMEBR system was based on applying an intermittent direct current (DC) field between immersed circular perforated electrodes around a membrane filtration module. The SMEBR system significantly reduced the fouling rate when iron worked as electrodes and an intermittent DC with an operational mode of 15 min ON–45 min OFF was applied. In terms of effluent quality, the SMEBR system enhanced the removal of COD and PO_4-P up to 96% and 98%, respectively.

© 2011 Elsevier B.V. All rights reserved.

1. Introduction

Conventional wastewater treatment technologies are no longer responding to new standards, and there is an increasing desire for the development of innovative, more effective and inexpensive techniques for wastewater treatment [1]. Recently, a new technology was developed at Concordia University, Montreal, Canada, called submerged membrane electro-bioreactor or SMEBR [2–4]. The principal objectives of designing the SMEBR were to generate a high-quality effluent, while minimizing membrane fouling, which has been considered a major challenge to the widespread application of membrane bioreactor (MBR) technology [5,6].

The design of SMEBR technology was based on applying an intermittent direct current (DC) field between immersed circular perforated electrodes around an immersed membrane filtration module (Fig. 1). The treatment of wastewater with the SMEBR system involves the simultaneous application of biodegradation, electro-coagulation and filtration through a membrane module. The design of the SMEBR system consists of two zones being in contact (Fig. 1): Zone I (electro-bioreactor) extends from the internal wall of the bioreactor to the cathode, and Zone II is located between the cathode and the membrane module. Generally, Zone I is dominated by the processes of biodegradation and electro-coagulation, while Zone II is responsible for further biodegradation and membrane filtration.

The treatment performance with SMEBR is affected by electrode design and material, and the applied direct current field between the electrodes [3]. Designing the electrodes in SMEBR should allow effective distribution of aeration and should not hinder mixed liquor circulation [3].

The SMEBR design is the first attempt to combine electrokinetic principles, using electro-coagulation (EC) processes and submerged membrane bioreactor (SMBR) in one reactor vessel [3]. Contrary to other designs [7–9], the electrocoagulation unit combining with MBR permits a direct interaction with biological processes and membrane filtration. Bani-Melhem and Elektorowicz [3] reported a number of advantages of the designed SMEBR system.

In the previous paper [3], a detailed description of the design constraints and criteria of the new developed method was reported. The main objective of this study is to show the results of performance of the SMEBR system for fouling reduction and wastewater treatment in terms of COD, NH_3-N and PO_4-P removal when iron mesh was applied as electrodes.

2. Materials and methods

2.1. Experimental setup

A laboratory scale setup was used in this study (Fig. 2). The setup consisted of an electro-bioreactor with a working volume of 13.4 L, a membrane module ZeeWeed-1 (GE Power & Water/Zenon Mem-

* Corresponding author. Current address: Environmental Engineering Program, School of Sciences and Engineering, The American University in Cairo, Cairo, Egypt. Tel.: +20 2 2615 3711.

E-mail addresses: kmelhem@aucegypt.edu, k_banime@encs.concordia.ca, k_banimelhem@yahoo.com (K. Bani-Melhem), mariae@civil.concordia.ca (M. Elektorowicz).

0376-7388/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.memsci.2011.06.017

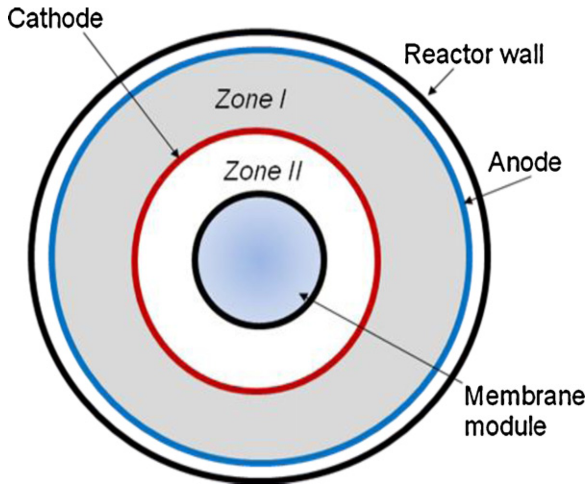

Fig. 1. Basic idea of the SMEBR system: top view.

brane Solutions, Canada), a wastewater supply system, an aeration system, and a DC supply system. The membrane module consisted of 80 fibers of 0.2 m in length and a pore size of 0.04 μm, with a total surface area of 0.047 m^2. The membrane module was fixed vertically in the centre of the electro-bioreactor. The effluent from the membrane module was withdrawn via a peristaltic pump (Model: 13-876-2, Fisher Scientific, Canada) operated at a constant suction pressure. A level sensor was connected to the feeding pump via a level controller system to maintain constant volume in the bioreactor. A cylindrical iron mesh anode (effective surface area = 93 cm^2) and a cathode (effective surface area = 106 cm^2) were fixed in the centre at a distance of 5.5 cm. The electrodes were connected to a digital external DC power supply maintained at a constant voltage gradient of 1 V/cm. The power supply was connected to a timer to regulate the intermittent DC at an operational mode of 15 min ON–45 min OFF. The aeration was continuous in both zones for maintaining the required dissolved oxygen in the bioreactor (>5 mg/L). In Zone II, an air diffuser was located at the bottom of the membrane module to create a shear stress for effective scouring of the membrane surface, and in Zone I, an aeration tube was used to provide good mixing of the sludge suspension in the bioreactor.

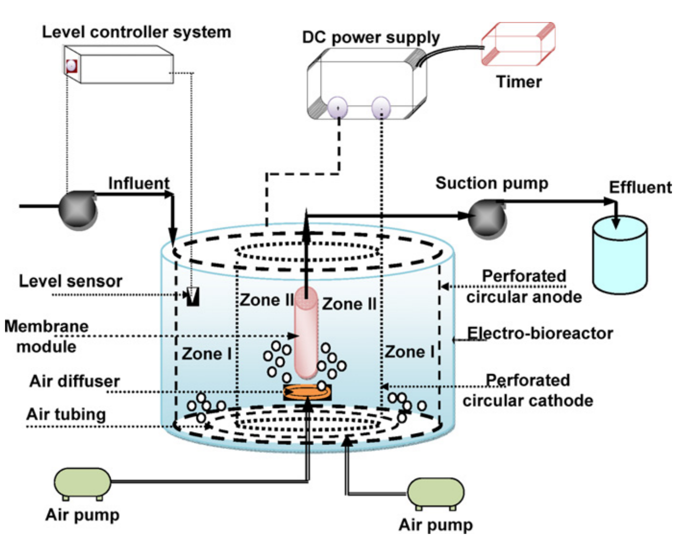

Fig. 2. Experimental setup of the SMEBR system.

Table 1
Characteristics of the prepared synthetic wastewater.

Water quality index	Average value ± (standard deviation)
pH	6.35 ± (0.36)
Temperature (°C)	20.4 ± (0.5)
COD (mg/L)	334 ± (23)
Ammonia-nitrogen (NH_3-N) (mg/L)	30.8 ± (2.1)
Nitrate (NO_3-N) (mg/L)	Not detected
Phosphorus (PO_4-P) (mg/L)	27.2 ± (1.9)

2.2. Wastewater characteristics

To obtain a consistency in the chemical and physical properties of the influent (wastewater composition) during the experimental period, the reactor was fed continuously with a synthetic wastewater mixture. The composition of synthetic wastewater contained (in mg/L): glucose (310), peptone (252), yeast extract (300), $(NH_4)_2SO_4$ (200), KH_2PO_4 (37), $MgSO_4{\cdot}7H_2O$ (40), $MnSO_4{\cdot}H_2O$ (4.5), $FeCl_3{\cdot}6H_2O$ (0.4), $CaCl_2{\cdot}2H_2O$ (4), KCl (25), and $NaHCO_3$ (25). Table 1 shows the characteristics of the prepared synthetic wastewater. The sludge for inoculation was taken from the secondary clarifier in the municipal wastewater treatment plant in the City of Saint-Hyacinthe (Quebec, Canada). The sludge was acclimatized for 60 days prior to membrane filtration experiments. The fill-and-draw technique was used to cultivate the activated sludge [10].

2.3. Analytical methods

Influent, effluents and supernatants in both Zones were sampled daily and analyzed by Hach methods (Hach, DR 2800, USA) for COD, ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), and orthophosphate (PO_4-P). Mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were performed according to Standard Methods [11]. The dissolved oxygen (DO) concentration was measured using a DO meter (YSI, Model 52, US). The values of pH and temperature were measured using a pH meter model 215 (Denver Instrument, US).

Other parameters (zeta potential and specific resistance to filtration (SRF)), which give an indirect indication about the fouling behavior, were also measured. A 50-mL sample of mixed liquor was taken every two days from each zone. Furthermore, the sampled supernatant was taken for zeta potential measurement (Zeta-Meter 3.0$^+$, US) after settling for 30 min. Each sample was measured ten times and the average value was taken as zeta potential with a standard deviation 2–6%. The sample was returned to the electro-bioreactor after taking the measurement. Additionally, about 100 mL were sampled from each zone of the elector-bioreactor every 10 days or at the end of each stage for the SRF tests. The SRF tests were performed as described by Ng and Hermanowicz [12].

2.4. Experimental procedure

The strategy of this study was based on operating the SMEBR at a constant transmembrane pressure that was created by withdrawing the effluents via a peristaltic pump operated at a constant suction pressure.

The SMEBR system was working continuously at room temperature without control for a period of 53 consecutive days. For comparison purposes, the SMEBR system was operated in two stages: (i) in Stage I, the bioreactor ran for a period of 26 days without electrokinetics (electrodes were disconnected); (ii) in Stage II, which lasted for 27 days, the SMEBR was connected to the power supply with an operational mode of 15 min ON–45 min OFF at voltage gradient of 1 V/cm. The fouling behavior was evaluated phenomenalogically by measuring the decline of permeate flux

Download English Version:

https://daneshyari.com/en/article/635564

Download Persian Version:

https://daneshyari.com/article/635564

Daneshyari.com