Available online at www.sciencedirect.com
ScienceDirect
Separation and Purification Technology 51 (2006) 173–179
Separation Purification Technology
www.elsevier.com/locate/seppur

Filtration capability and operational characteristics of dynamic membrane bioreactor for municipal wastewater treatment

Libing Chu *, Shuping Li

School of Light Chemistry and Environmental Technology, Shandong Institute of Light Industry, Jinan 250100, China

Received 7 October 2005; received in revised form 23 January 2006; accepted 23 January 2006

Abstract

This paper introduced an approach that used an industrial filter-cloth material instead of the conventional MF/UF membrane to build a membrane bioreactor (MBR) for wastewater treatment. The formation and filtration capacity of the dynamic membrane and the performance of the dynamic MBR for treating municipal wastewater were investigated. The results of the batch tests showed that the dynamic membrane could be formed on the filter-cloth surface quickly and developed steadily. It played an essential role to reject particulate matter. Higher sludge concentration could contribute to the formation of dynamic membrane, but lead to elevated SS concentration in the effluent and lower permeation flux. For treating municipal wastewater sequentially, in the permeate turbidity was less than 9 NTU and SS was zero at the most operation time under the MLSS concentration of less than 6000 mg L^{-1}. At hydraulic retention time (HRT) of 6.9 h and temperatures of 9–13 °C, the total COD and ammonia removal ranged 72–89% and 66–94%, respectively. The total resistance of the dynamic membrane was lower than that of the MF/UF membrane 2–3 numeral classes. Cake layer resistance was the major resistance.

Keywords: Filter-cloth; Dynamic membrane; Membrane bioreactor; Municipal wastewater

1. Introduction

The membrane bioreactor (MBR) process has recently been developed for wastewater treatment. Advantages of using membranes include improved effluent quality, higher mixed liquor suspended solids, reduced system volume, and perfect sludge retention time control [1,2]. However, MBR needs further improvement for a more widespread application. The high costs in investment for the membrane module and the unavoidance membrane fouling are believed to be the main hindrances. The dynamic membrane process would be one of the methods to settle the problems.

Dynamic membrane was also called secondary membrane or formed-in-place membrane [3]. It was formed when filtering a solution of one or more specific colloidal components or the substances that exist in the mixture liquid to be filtered. For creating dynamic membrane, the cheaper materials, such as mesh, nowoven fabric and filter-cloth were used as the filter media [4–6]. Moreover, dynamic membrane could be formed and re-formed in situ and once the membrane was severely fouled, the dynamic layer can be replaced by a new deposited layer. Thus, the costs of purchasing and physically replacing new membrane are spared.

So far, most of studies focused on the use of mashes as the filter material for sludge separation in wastewater treatment. Kiso et al. [4] compared the filtration performance of meshes having pore sizes of 100, 200 and 500 μm and found that a mesh having a pore size of 100 μm effectively rejected activated sludge and that the reactor retained SS of up to 9000 mg L^{-1} with a flux of 0.5–0.76 m day^{-1} at very low pressure (5–10 mm H_2O). The studies by Fan and Huang [7] demonstrated that the biomass layer of the dynamic membrane consisted of a cake layer and a gel layer. The gel layer had structures like conventional membranes and acted the key role in the dynamic MBR. Fuchs et al. [8] examined the performance of a mesh filtration system for municipal sewage treatment. The main results showed that the process was very effective under most of the operation conditions. The SS concentration in the effluent was below 12 mg L^{-1}.The average COD was in the range of 24–45 mg L^{-1}. Park et al. [9] investigated the sludge thickening performance of a mesh filtration system with the mesh opening sizes of 100–500 μm, and the sludge (3000–9000 mg SS L^{-1}) obtained from a domestic wastewater treatment facility. The

* Corresponding author. Tel.: +84 531 88626172; fax: +84 531 88619806.
E-mail address: chulibing@yahoo.com.cn (L. Chu).

1383-5866/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.seppur.2006.01.009

results showed that the sludge reduction rates were in the range of 85–95% for 6–7 h. The effluent contained very low SS and could be directly discharged into the environment.

Due to the much larger size of the mesh, the effluent was not of the same excellent quality as in the conventional MBR, especially during the initial forming process. In this work, a fine and close in texture material, industrial filter-cloth was used as the membrane module. As same as the mesh, the cost of the filter-cloth is much cheaper than that of the MF/UF membrane. But its capacity of retaining suspended solids is better than that of the mesh. The formation process and filtration capability of the dynamic membrane on the filter-cloth were studied. Moreover, the performance of the dynamic MBR for treating municipal wastewater was also investigated in order to evaluate its application potential for wastewater treatment.

2. Materials and methods

2.1. Experimental set-up

Fig. 1 presents the schematic diagram of the experimental set-up of a Plexiglas reactor, in which a flat-sheet type filter module is submerged. The working volume of the reactor is 14 L and the effective area of the membrane module is 660 cm^2. The filter module is made of terylene with a density of 232 threads in longitude and 190 threads in latitude per 10 cm. The aeration units were placed at the lateral parts of the reactor serving both for aeration and inducing circulation flow in the reactor. In addition, another air diffuser was installed under the filter module for aeration cleaning. The filtration was only driven by water level difference between the bioreactor and the effluent port.

2.2. Wastewater and seeds

The raw wastewater used in the experiment was derived from Shandong Institute of Light Industry. It was sampled two or three times per week after screening. The typical composition of the wastewater is listed in Table 1.

The bioreactor was inoculated with digested sludge taken from the local municipal sewage treatment plant. The ratio of MLVSS to MLSS and the sludge SVI were 0.75 and 130 mL g TSS^{-1}, respectively. The volume weight mean (mean particle size based on volume weight) was 30.6 μm.

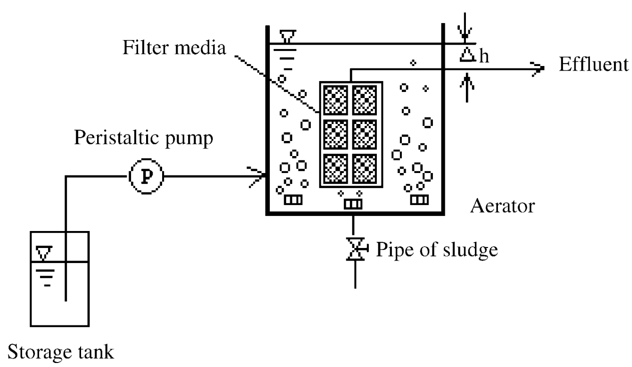

Fig. 1. Schematic diagram of the dynamic MBR.

Table 1
Main characteristics of the domestic wastewater

Items	Concentration		
	Low	High	Average
pH	7.6	8.0	7.7
COD (mg L^{-1})	236	410	328
NH_4–N (mg L^{-1})	7.6	62.8	30.5
Turbidity (NTU)	186	378	276
TSS (mg L^{-1})	48	136	70

2.3. Analysis

The COD, ammonium, TSS and VSS contents were determined according to the Chinese NEPA Standard Methods [10]. COD was analyzed using the $K_2Cr_2O_7$ oxidation method and ammonium was measured using the Nessler reagent method. Turbidity was evaluated using a WGZ-200 Photoelectric Turbidity Instrument.

Microbial composition and structure of the new and used filter-cloth module were observed with an environment scanning microscopy (ESEM, QUANTA 2000). The floc size distribution was measured using a Particle Size Analyzer (Mastersizer 2000, Malvern).

2.4. Experimental procedure

The experiments were divided into two portions. Firstly, preliminary batch assay was conducted to study the formation process and filtration capacity of the dynamic membrane. The activated sludge and raw wastewater with a certain volume were fed into the reactor. The concentration of MLSS was controlled at 3100, 5500, 8000 and 10000 mg L^{-1}. The changes of the fluxes and turbidity in the effluent were measured at 2 cm water head drop, where the pressure was adjusted by controlling the level of the effluent port and the effluent was recycled into the reactor in order to keep a constant water level in the reactor.

Then, the reactor was filled with the standard turbidity solution: polymer of hexamethylenetetramine and sulphate hydrazine with concentration of 80 NTU. The formed dynamic membrane module was placed in. The changes of the effluent turbidity with time were recorded. As a comparison, the same test was also conducted with a new membrane.

Secondly, in the wastewater treatment experiments, the raw wastewater flowed into a storage tank and then was fed into the bioreactor continuously by a peristaltic pump after screening. The effluent was withdrawn also continuously. The initial sludge concentration was 2900 mg L^{-1}. The HRT was set at 7.9–5.9 h. The SRT was controlled at 46–56 days. The organic loading rate and sludge loading rate were 0.8–1.4 kg COD m^{-3} day^{-1} and 0.2–0.5 kg COD kg^{-1} MLSS day^{-1}, respectively. A temperature control system was not installed and temperature fluctuated between 9 and 13 °C according to ambient conditions.

The routine monitoring items included pH, SS, COD, turbidity and ammonium in the influent and effluent. The sludge concentration in the reactor was measured after a certain period. The lateral aeration rate was in the range of 100–150 L h^{-1}. The