Performance Comparison of Conventional Membrane Bioreactor and Moving Bed Membrane Bioreactor for the Treatment of Synthetic Textile Wastewater

Ayberk Soysaloglu¹, Betul Takatas¹, Hanife Sari Erkan¹,*, Abdulkadir Çaglak¹, Guleda Onkal Engin¹

Abstract

There is growing attention towards moving bed-membrane bioreactor (MB-MBR) technology due to their several advantages, such as improved MBR performance, reduced suspended solids (SS) concentrations, lower membrane fouling propensity and higher membrane flux. In MB-MBR technology, biofilm reactor with bio-carriers and membrane filtration are combined. In the present study, conventional MBR and MB-MBR were investigated for synthetic textile wastewater treatment in terms of chemical oxygen demand (COD) and color removal rates. For this purpose, MBR was operated without bio-carriers for about three months in order to determine the removal efficiencies and membrane fouling propensity. After completion, bio-carriers were added to be 20% of the total reactor volume and MBR was operated with bio-carriers for additional two months. As expected, the transmembrane pressure (TMP) in MB-MBR reduced approximately by half compared to conventional MBR. On the other hand, similar COD removal efficiencies (about 96%) were achieved in both operations, while higher color removal efficiencies were found in MB-MBR. The obtained results show that the MB-MBR improves reactor performance in terms of color removal and TMP.

Keywords: Textile wastewater, membrane bioreactor, moving bed membrane bioreactor, bio-carrier

1. INTRODUCTION

Textile industry is one of the most complex and oldest manufacturing industries with a series of interrelated processes. It requires high quantities of water and generates large volumes of wastewater [1]. Approximately 200 L of water are consumed in the production of 1 kg of textile products. This required water is used when the chemicals and dyes are applied on fabrics and also used during the rinsing of the final products [2].

Textile dyeing wastewater is high in color, SS, COD and biochemical oxygen demand (BOD) [3]. It also includes metals and salts [4, 5]. The textile wastewater may be also high in total organic carbon (TOC), ammonia (NH₄⁺), nitrate (NO₃⁻) and orthophosphate (PO₄³⁻) and these parameters should be monitored during the treatment process. Several treatment methods, such as physico-chemical, chemical and biological treatments and their combination, can be applied for textile wastewater in order to ensure discharge standards [6]. Membrane bioreactor technology has been investigated for the textile wastewater treatment by several

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authors [7, 8] and higher COD and color removal efficiencies were obtained in these studies. Jegatheesan et al. [9] reported in their review that COD and color removal efficiencies were found to be between 80 to 98% and 70 to 100%, respectively, for the treatment of textile wastewater using an MBR. The mixed liquor suspended solids (MLSS) concentrations in the MBR varied between 4 and 15 g/L in most of the studies and MBRs were operated between 0.1 to 0.5 bar TMP values. Membrane flux values were also varied from 5 to 30 L/m².h in these studies [9]. Recently, moving bed-membrane bioreactors (MB-MBR) have been studied for textile wastewater treatment. MB-MBR, which is an alternative to conventional MBR, is combining a biofilm reactor with membrane filtration process. MB-MBRs may ensure microbial diversity from the attached growth system compared with activated sludge systems, and MLSS concentration may be reduced as the attached growth on bio-carriers, thus membrane fouling propensity decrease and MBR performance can be improved [10].

The main purpose of this study was to compare conventional MBR and MB-MBR technology for synthetic textile wastewater treatment. For this purpose, COD and color removal efficiencies were monitored in order to determine treatment performance. TMP values were also monitored in order to determine the effects of bio-carriers on membrane fouling.

2. MATERIALS AND METHODS

The lab-scale MBR system consists of plexi-glass reactor having 5 L working volume and ceramic flat sheet membrane module (Cembrane, Denmark) with a nominal pore size of 0.1 µm and a total surface area of 0.057 m². Figure 1 shows the schematic presentation of MBR system. Initial seed sludge was taken from a municipal wastewater treatment plant in Istanbul. Oxygen was supplied with a stainless steel air diffuser located at the bottom of the reactor with an air pump. Temperature of mixed liquor was kept constant 22 ± 1 °C by a recirculating pump in the heat jacket of the reactor. The reactor was fed with synthetic textile wastewater and the composition of feed wastewater is shown in Table 1.

![Figure 1. MBR system used in the study (1- reactor, 2- flat sheet ceramic membrane, 3- peristaltic pump, 4- feed tank, 5- bio-carriers, 6-air pump, 7- Vacuum pump, 8- analytical balance, 9-a ile 9-b- automated valve, 10- computer)](image)

**Table 1. Feed wastewater characteristics**

<table>
<thead>
<tr>
<th>Added ingredient</th>
<th>Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₆H₁₂O₆H₂O</td>
<td>1000</td>
</tr>
<tr>
<td>NaHCO₃</td>
<td>1000</td>
</tr>
<tr>
<td>NH₄Cl</td>
<td>230</td>
</tr>
<tr>
<td>K₂HPO₄</td>
<td>37</td>
</tr>
<tr>
<td>KH₂PO₄</td>
<td>67</td>
</tr>
<tr>
<td>CaCl₂.2H₂O</td>
<td>4</td>
</tr>
<tr>
<td>MgCl₂.6H₂O</td>
<td>3.4</td>
</tr>
<tr>
<td>FeSO₄.7H₂O</td>
<td>5.92</td>
</tr>
<tr>
<td>MnSO₄.H₂O</td>
<td>0.4289</td>
</tr>
<tr>
<td>ZnSO₄.7H₂O</td>
<td>0.1053</td>
</tr>
<tr>
<td>Na₂SO₃</td>
<td>0.2811</td>
</tr>
<tr>
<td>CuSO₄.5H₂O</td>
<td>0.0556</td>
</tr>
<tr>
<td>NiSO₄.6H₂O</td>
<td>0.1</td>
</tr>
<tr>
<td>CoCl₂</td>
<td>0.5457</td>
</tr>
<tr>
<td>Reactive Red 390</td>
<td>10</td>
</tr>
</tbody>
</table>
The reactor was operated at a constant permeate flux under the sludge retention time (SRT) of 30 days. MBR was operated without bio-carriers for about three months, after completion of studies with conventional MBR, bio-carriers were added into the reactor, when the system reached steady-state condition. Additional two month operation was carried out in MB-MBR with bio-carriers. The bio-carriers are hollow cylinder with dimensions of 16.75 mm x 5 mm made by WARDEN Biomedia Bioflo+. The bio-carriers have density of 170 kg/m³ and the total and protected surface area of 1036 and 800 m²/m³, respectively. The measurements of COD and color in the feed wastewater and the effluent, and MLSS in the reactor systems were performed according to the Standard Methods (2005).

3. RESULTS AND DISCUSSION

In this study, membrane flux was tried to be kept approximately 5 L/m².h (LMH) throughout the operation. The MLSS concentrations of MBR system were monitored throughout the study (Figure 2). The MBR were operated for 47 days with synthetic textile wastewater without Reactive Dye 390. After the addition of dye, MBR was operated for an additional 40 days without bio-carriers. The MLSS value increased to approximately 6400 mg/L at 21st days of operation and it was almost stable at 71st days. Then, the MLSS value increased from 6400 to 10000 mg/L at 90st days although the operation was conducted at a constant membrane flux. After that, the reactor was filled with 20% (v/v) bio-carriers at 97th days of operation. There was not found an additional increase of MLSS in the reactor after the adding of bio-carriers in reactor. The MLVSS/MLSS ratio of activated sludge samples were found between 81.9% and 91.7% throughout the operation.

Membrane fouling was recognized by monitoring TMP variation with time. The variation of TMP values at constant flux for the MBR is presented in Figure 3. In the MBR, the TMPs increased slowly after the operation and the TMP values reached 0.65 bar at on day 21 of operation duration. After that, the TMP was not stable and increased rapidly to maximum pressure levels (0.6 bar) given by the membrane manufacturer. Physical membrane cleaning was applied using a sponge cleaner, when the TMP values reached 0.6 bar during the 97 days of operation without bio-carriers. After the addition of bio-carriers, TMP values decreased rapidly approximately to 0.4 bar, and then, the TMP values were found to be almost stable in the MBR.
The COD removal efficiencies in reactor were found as 95.6 ± 4.7% throughout the operation. Addition of bio-carriers did not affect the COD removal rates in the MB-MBR. On the other hand, color removal efficiencies were about 95% in MBR without bio-carriers. After the addition of bio-carriers, color removal efficiencies increased slightly from 95% to 98%.

CONCLUSION

In this study, two types of MBR (conventional submerged MBR and MB-MBR) were compared in terms of reactor performance and membrane fouling behavior. Obtained results show that there were no significant differences in terms of COD and color removal efficiencies between MBR and MB-MBR operations. In the study, TMP values were monitored day by day in order to recognize membrane fouling. The ceramic membrane was washed physically several times in order to decrease TMP values in conventional MBR operation. However, there was no need to clean membrane in MB-MBR operation as the bio-carriers affect positively ceramic membrane filtration. Moreover, cake layer formation did not occur on the membrane surface in MB-MBR when visual observation was performed compared to conventional MBR operation.

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