Treatment of distillery wastewater using single chamber and double chambered MFC

Hampannavar U.S.1, Anupama2, Pradeep N.V.3.

1- Assistant Professor, Civil Engineering Department, K.L.E Society’s College of Engineering and Technology, Belgaum, Karnataka.
2, 3- M.Tech Scholar, K.L.E Society’s College of Engineering and Technology, Belgaum, Karnataka.
uday_hamp@rediffmail.com
doi:10.6088/ijes.00202010012

ABSTRACT

Distillery wastewater was treated in Microbial Fuel Cell (MFC) at ambient room temperature which varied between 27-32°C. Microbial Fuel Cells can be simultaneously used for the treatment of wastewater and generation of electricity. In this study single chamber MFC and double chambered MFC were compared for the distillery wastewater treatment and generation of electricity. Microorganisms present in distillery wastewater and sewage were used as inoculum, and distillery wastewater acted as substrate. Single chamber MFC was efficient and found to be producing maximum current of 0.84 mA, power density of 28.15 mW/m² where as double chambered MFC produced a maximum current of 0.36 mA and power density of 17.76 mW/m². Double chambered MFC was efficient in the removal of COD (64% removal) when compared with single chamber MFC which attained 61% COD removal efficiency. The removal of dissolved solids in both single and double chambered MFC was found to be 48%. Five varied feed concentrations were loaded to both the single and double chambered MFC and the systems were stable. The COD and dissolved solids removal observed in distillery wastewater might be attributed to the microbial catalyzed electrochemical reactions occurring in the anodic chamber of single and double chambered MFC.

Keywords: Microbial fuel cell (MFC), bioelectricity, distillery wastewater, organic waste, energy recovery, air cathode.

1. Introduction

Organic wastes released from many process industries are of prime concern to the environment. Their handling, treatment and disposal are the major challenges to such industries. Distillery spent wash is unwanted residual liquid waste generated during alcohol production and pollution caused by it is one of the most critical environmental issue. This poses severe threat to human health and environment when not managed properly. A number of clean up technologies have been put into practice and novel bioremediation approaches for treatment of distillery spent wash are being worked out (Mohana et al., 2009). Anaerobic treatment produces small amount of sludge and energy can be recovered (Hampannavar and Shivayogimath, 2010).

Microbial fuel cells (MFC) are unique devices that can utilize microorganisms as catalysts for converting chemical energy directly into electricity, representing a promising technology for simultaneous energy production and wastewater treatment (Liu et al., 2004; Logan and Regan, 2006). To make this technology feasible, power densities should to be increased and reduce
the cost of construction materials (Logan et al., 2007; Logan, 2006; Clauwaert et al., 2008). In MFC electrons generated in anode cell reach the cathode and combine with protons that diffuse from anode through the membrane or agar salt bridge (Logan et al., 2006; Min and Logan, 2004).

MFCs have wider applications including wastewater treatment, production of electricity, bioremediation, hydrogen production, and as environmental sensors (Logan and Regan, 2006). MFCs have been used to treat various kinds of wastewater such as domestic sewage (Ahn and Logan, 2010; Liu et al., 2004), brewery (Feng et al., 2008; Abhilasha and Sharma, 2009), distillery (Mohanakrishna et al., 2010), sugar (Abhilasha and Sharma, 2009), paper and pulp (Huang and Logan, 2008), rice mill (Behera et al., 2010), swine wastewater (Kim et al., 2008) and phenolic wastewater (Luoa et al., 2009). An additional advantage of using MFCs for wastewater treatment is the potential for reducing solids production compared to aerobic processes (Ahn and Logan, 2010). MFCs have some disadvantages, including the high costs of materials (platinum-catalyst and proton exchange membrane), the low efficiency of organic treatment, among others (Kubota et al., 2010). MFCs operated using mixed microbial cultures currently achieve substantially greater power densities than those with pure cultures (Logan et al., 2006). Very less study has been done on the comparison of single and double chambered MFC for distillery wastewater treatment.

In this study, the treatment efficiency and electricity generation using single and double chambered MFC was undertaken and comparisons were made between single and double chambered MFC. Both the MFC reactors were operated at identical ambient environmental conditions.

2. Materials and Methods

2.1 Electrode Materials

Graphite rods from pencils were used as both anode and cathode (Logan and Regan, 2006; Logan et al., 2007). The arrangement of the graphite rods was made in such a way as to provide the maximum surface area for the development of biofilm on anode. The length and diameter of the graphite rods were 90 mm and 2mm respectively. Pre-treatment was not provided for the electrode materials.

2.2 MFC Reactors

Two MFC reactors were constructed, one was single chamber MFC and the other was double chambered MFC. The reactors were constructed using non-reactive plastic containers with dimensions of 8 X 8 X 12 inches. The electrodes were connected by using copper wire as reported by Logan (2005). The agar salt bridge was used as the proton exchange medium (Momoh and Naeyor, 2010). The electrodes were placed in the chambers, then were sealed and made air tight. Both the reactors were checked for water leakage.

2.2.1 Double chambered MFC

Two non-reactive plastic containers were used for Double chambered MFC. One plastic container was used as anode chamber (to be fed with wastewater) and the other as cathode chamber as shown in Figure 1. The wastewater was fed to the anode chamber and Potassium permanganate (catholyte) was fed to the cathode chamber (Lefebvre et al., 2008; Behera et
The cathode and anode chambers were connected using agar salt bridge. The length and diameter of agar salt bridge was 5 inches and 1.5 inches respectively.

![Figure 1: Double chambered MFC.](image)

### 2.2.2 Single chamber MFC

A plastic container was used as the anode chamber. The agar salt bridge was joined to anode chamber. The length and diameter of agar salt bridge was 5 inches and 1.5 inches respectively as shown in Figure 2. The graphite rods were placed on the agar salt bridge and left open to air which acted as cathode (Logan et al., 2007).

![Figure 2: Single Chamber Air Cathode MFC.](image)
2.3 Distillery Wastewater and Microbial Inoculum

The distillery wastewater was used as substrate and sewage as source of inoculum. No any additional nutrients were given for micro-organisms except the nutrients present in the distillery wastewater.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.1</td>
</tr>
<tr>
<td>Colour</td>
<td>Dark Brown</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>42000</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>102500</td>
</tr>
<tr>
<td>Total Solids (mg/L)</td>
<td>73980</td>
</tr>
<tr>
<td>Dissolved Solids (mg/L)</td>
<td>59740</td>
</tr>
<tr>
<td>Chlorides (mg/L)</td>
<td>6900</td>
</tr>
<tr>
<td>Conductivity (mS/cm)</td>
<td>19.5</td>
</tr>
</tbody>
</table>

2.4 Experimental Conditions

The anode chamber was filled with distillery wastewater so that micro-organisms in the wastewater could colonize the electrodes and produce electricity. The samples were drawn from the chambers periodically and analysed. The ambient room temperature during most of the period of study varied between 27 °C and 32 °C. When the reactor reached steady state conditions, the reactor was loaded with distillery wastewater of higher concentration.

2.5 Analyses

The voltage (V) and Current (I) in the MFC circuit was monitored at 24hour intervals using a multimeter (UNI-T ®, Model Number- DT830D) (Kim et al., 2005). Analytical procedures followed in this study were those outlined in Standard Methods (1995).

3. Results and Discussions

The single and double chambered MFC were run parallel. The whole study was conducted under ambient environmental conditions. Different feed concentrations were given for single and double chambered MFC. The increase in feed concentration showed a positive effect on the current and voltage. Five feed concentrations from 2.1 g COD/L to 6.1 g COD/L with an increment of 1g COD/L were given. The study is under progress for higher feed concentrations.

3.1 COD removal efficiency

At every increment in feed concentration, the improvement in COD removal efficiency was observed. Distillery wastewater showed its potential for COD removal indicating the function of microbes, present in wastewaters in metabolizing the carbon source as electron donors. It is evident from experimental data that current generation and COD removal showed relative compatibility. Continuous COD removal was observed in both the MFCs. In double chambered MFC, COD removal efficiency increased from 52% to 64% as the feed concentration increased from 2.1 g COD/L to 6.1 g COD/L respectively (Figure 3). In the
case of single chamber MFC, the COD removal efficiency increased from 55% to 61% for the same feed concentrations (Figure 4). The findings of this study are near to Feng et al (2008) who conducted the studies on brewery wastewater treatment using air-cathode MFC. Liu et al (2004) conducted the studies on domestic wastewater treatment using single chamber MFC and observed 50% to 70% COD removal efficiency. Liu and Logan (2004) reported a COD removal efficiency of 55% using the MFC with a proton exchange membrane (PEM), and 75% using the MFC without a PEM.

![Figure 3: COD reduction in double chambered MFC.](image1)

![Figure 4: COD reduction in single chamber MFC.](image2)

The COD removal efficiency was almost similar in single and double chambered MFC but single chamber MFC showed more consistent COD removal than double chambered MFC.

3.2 Dissolved solids removal efficiency

Distillery-based wastewater characteristically contains higher concentration of solids. During the operation considerable reduction in dissolved solids concentration was observed in both the reactors. The reduction of dissolved solids increased with the increase in feed concentration. As the feed concentration increased from 2.1 g COD/L to 6.1 g COD/L, the
dissolved solids removal efficiency increased from 41% to 48% respectively in both of the reactors (Figure 5 and Figure 6). Mohanakrishna et al (2010) have reported 24% reduction in total dissolved solids (TDS) while treating distillery wastewater using continuous flow single chamber air-cathode MFC.

**Figure 5:** Dissolved solids reduction in double chambered MFC.

![Graph of dissolved solids reduction in double chambered MFC](image)

**Figure 6:** Dissolved solids reduction in single chamber MFC.

![Graph of dissolved solids reduction in single chamber MFC](image)

In single and double chambered MFC, the dissolved solids reduction was efficient and almost similar.

### 3.3 Current and Power Density

The average values of current and power density for each feed concentration are as given in the Figure 7 and Figure 8 respectively. The current and power density showed a gradual increase with respect to the increase in feed concentration. The similar observation was reported during the treatment of distillery wastewater by Mohanakrishna et al (2010).
Treatment of distillery wastewater using single chamber and double chambered MFC

![Graph showing current and power density against feed concentration](image)

**Figure 7:** Average values of current obtained at each feed concentration.

![Graph showing power density against feed concentration](image)

**Figure 8:** Average power density obtained at each feed concentration.

The current and power densities were much higher in single chamber MFC when compared with double chambered MFC. Logan *et al.*, (2007) have reported the advantage of air-cathode MFC (compared with the cathode suspended in water) as oxygen transfer to the cathode occurs directly from air, and thus oxygen does not have to be dissolved in water. The abundant electron acceptors i.e., oxygen availability in air is the reason for the higher current generation.

The current and power density of MFCs with various types of wastewaters and the present study are as given in Table 2.
Table 2: Performance of MFCs with various types of wastewaters.

<table>
<thead>
<tr>
<th>Type of wastewater</th>
<th>MFC Configuration</th>
<th>Operating pH</th>
<th>Current in mA (Max)</th>
<th>Power density in mW/m²</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic wastewater</td>
<td>Single chamber air cathode</td>
<td>7.3 to 7.6</td>
<td>0.92</td>
<td>28</td>
<td>Liu and Logon., 2004</td>
</tr>
<tr>
<td>Domestic wastewater</td>
<td>Two chamber</td>
<td>6 to 7</td>
<td>1.03</td>
<td>72</td>
<td>Min and Logon., 2004</td>
</tr>
<tr>
<td>Rice mill wastewater</td>
<td>Dual chamber (PEM)</td>
<td>7</td>
<td>1.07</td>
<td>15.57</td>
<td>Behera et al., 2010</td>
</tr>
<tr>
<td>Distillery wastewater (Different feed concentrations)</td>
<td>Two chamber</td>
<td>6</td>
<td>0.34</td>
<td>17.76</td>
<td>Present study</td>
</tr>
<tr>
<td></td>
<td>Single chamber air Cathode</td>
<td>6</td>
<td>0.84</td>
<td>28.15</td>
<td>Present study</td>
</tr>
</tbody>
</table>

4. Conclusions

The study demonstrated effective treatment of distillery wastewater of feed concentrations from 2.1 g COD/L to 6.1 g COD/L simultaneously generating electricity. The single chamber air cathode MFC proves to be more reliable because of the reduced cost of construction, low maintenance and higher electricity generation when compared with double chambered MFC. Both the reactors exhibited stable operation.

5. References


Treatment of distillery wastewater using single chamber and double chambered MFC


