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Microbial fuel cell an alternative for COD removal of distillery wastewater

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ABSTRACT:

Microbial fuel cell (MFC) is a type of renewable technology for electricity generation since it recovers energy from renewable materials that are difficult to dispose of, such as organic wastes and wastewaters. In the present study, mixed consortia from domestic sewage were used in Double Chambered Microbial Fuel Cell for the treatment of distillery wastewater. Distillery wastewater was diluted to get different concentrations from 1100 mg COD/L to 10100 mg COD/L and this was given as feed to microbes present in MFC. The COD removal efficiency increased with the increase in feed concentrations until 6100 mg COD/L and further increase in feed concentration led to deterioration in the COD removal efficiency and current generation. The maximum COD removal of 64% was achieved at the feed concentration of 6100 mg COD/L. MFC produced a maximum current of 0.36 mA and power density of 18.35 mW/m^2.

Keywords:
Distillery wastewater, Microbial Fuel Cell, Agar salt bridge, COD, Catholyte.

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INTRODUCTION

Distilleries generate large volumes of high-strength wastewater that is of serious environmental concern. Spentwash handling, treatment and disposal are of great importance and needs special attention. Various physico-chemical and biological treatment options are available for the treatment of distillery wastewaters.

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). 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 are being constructed using a variety of materials, and in an ever increasing diversity of configurations. These systems are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface areas, reactor size, and operation time (Logan *et al*., 2006).

MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures. Community analysis of the microorganisms that exist in MFCs has so far revealed a great diversity in composition (Logan *et al.,* 2006).

Microbial fuel cells (MFCs) have gained a lot of attention in recent years as a mode of converting organic waste including low-strength wastewaters and lignocellulosic biomass into electricity (Pant *et al*., 2010). There has been great interest in using MFCs for wastewater treatment and power generation has been shown using a variety of wastewaters including both domestic and industrial wastewaters (Ahn and Logan, 2010). MFCs have been developed to generate electricity directly from complex organic wastewater such as food processing wastewater, brewery wastewater, domestic wastewater, chemical wastewater, starch wastewater, swine manure slurry, manure waste, landfill leachate, meatpacking wastewater, palm oil mill effluent, paper mill effluent and for denitrification of domestic wastewater (Behera *et al*., 2010).

MFCs were first used to produce power from the electrical current generated by bacteria, but there has been an evolution in these systems resulting in applications such as wastewater treatment, biosensors for on-line monitoring of organic matter and secondary fuel production such as hydrogen gas (Das and Mangwani, 2010). Very less study has been done on COD removal of distillery wastewater using double chambered MFC.

In the present study double chambered MFC was constructed for the generation of electricity and COD removal of varied feed concentrations of distillery wastewater using the mixed consortia present in domestic sewage.

MATERIALS AND METHODS

MFC Reactor Setup

Double chambered MFC was constructed using non-reactive plastic containers with dimensions of 8 x 8 x 12 inches. One plastic container was used as anode chamber (to be fed with wastewater) and the other as cathode chamber as shown in Fig 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 al*., 2010). The agar salt bridge was used as the proton exchange medium (Momoh and Naeyor., 2010). Hence the cathode and anode chamber was connected using agar salt bridge. The length and diameter of agar salt bridge was 5 inches and 1.5 inches respectively. The electrodes were placed in the chambers, then were sealed and made air tight. The electrodes were connected by using copper wire as reported by Logan (2005). 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, so as to provide the maximum surface area for the development of biofilm on anode. The length and

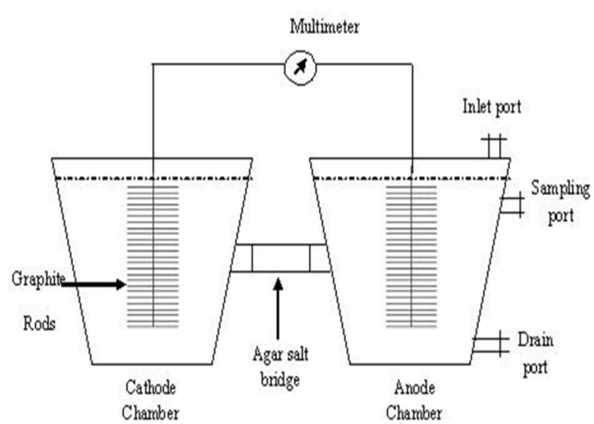

Fig 1: Double chambered MFC.

diameter of the graphite rods were 90 mm and 2mm respectively. Pre-treatment was not provided for the electrode materials.

Distillery Wastewater and Microbial Inoculum

The distillery wastewater was used as a substrate as well as source of inoculum. No other nutrients were given for micro-organisms except the nutrients present in the distillery wastewater.

Table 1: Characteristics of distillery wastewater

Characteristics	Average Value
pH	3.99
Colour	Dark Brown
BOD_3 (mg/L)	36666
COD (mg/L)	89833
Total Solids(mg/L)	74033
Dissolved Solids (mg/L)	59733
Chlorides (mg/L)	6933
Conductivity (mS/cm)	20.2

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 anode chamber 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.

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). Analysis of COD was performed as prescribed in Standard Methods (1995).

RESULTS AND DISCUSSIONS

COD Removal Efficiency

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. COD removal efficiency increased from 45.4% to 64% as the feed concentration increased from 1100 mg COD/L to 6100 mg COD/L respectively as shown in Fig 2. The increase in feed concentration from 6100 mg COD/L to 9100 mg COD/L slowly reduced the COD removal efficiency from 64% to 38.6%.

The microorganisms started to become inactive or rather they went into decline phase because of higher feed concentration of 10100 mg COD/L. The findings of this study are nearer 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. Mathuriya and Sharma (2010) obtained 85.8% COD removal efficiency at pH 7 when they utilized plain diluted beer brewery wastewater. They added 10% glucose and sucrose solution to the diluted beer brewery wastewater, and obtained the highest COD removal efficiencies of 93.8 and 91.92% respectively. Mohanakrishna *et al.,* (2009) have reported 72.84% COD removal efficiency while treating distillery wastewater using continuous flow single chamber air-cathode MFC.

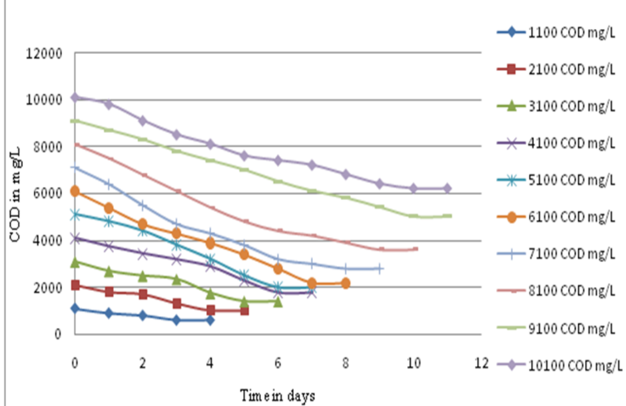

Fig 2: COD Reduction at various feed concentrations.

Current Generation and Power Density

The average values of current and power density for each feed concentration in MFC is as given in the Fig 3 and 4. The current and power density showed a gradual increase with respect to the increase in feed concentration until 6100 mg COD/L and later showed a gradual decrease in both current and power density. The highest average value of current obtained was 0.27 mA at 6100 mg COD/L feed concentration. Similarly the highest power density value obtained was 18.35 mW/m^2 at 6100 mg COD/L feed concentration.

Mohanakrishna *et al.,* (2009) reported the maximum current generation of 2.14 mA at 3600 mg COD/L in single chamber air cathode MFC

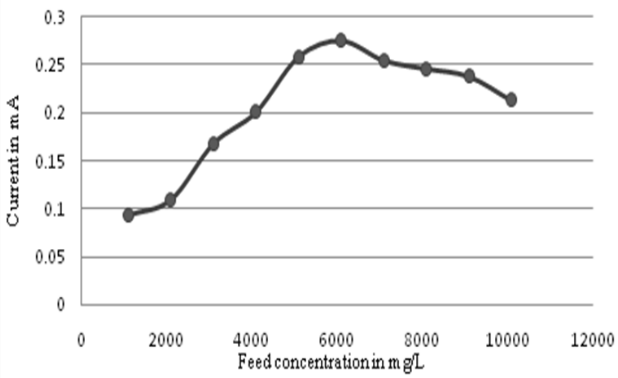

Fig 3: Current generation in MFC.

using distillery wastewater. Rabaey *et al.,* (2003) reported power density up to 3.6 mW/m^2 using different feed rate of glucose solution. Borole *et al.,* (2008) used two- chamber air sparged fuel cell and obtained a power output of 12.7 mW/m^2.

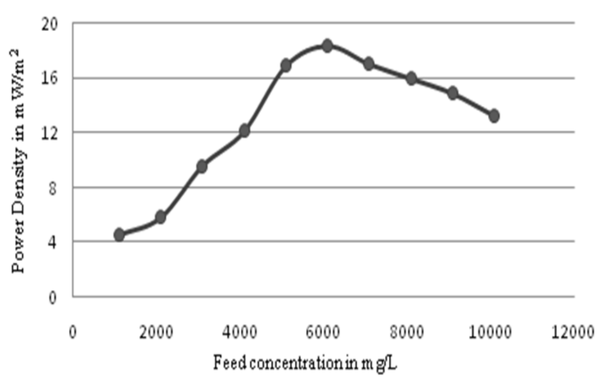

Fig 4: Power density in MFC.

COD reduction for various feed concentrations of distillery wastewater was observed along the power generation (Mohanakrishna *et al.,* 2009).

CONCLUSIONS

The results of the study demonstrate that MFC was able to treat spent wash successfully. The conclusions drawn from the study are as follows:

1. MFC produced maximum current of 0.34 mA and voltage of 824 mV at the feed concentration of 6100 mg COD/L.
2. Average power density of 18.35 mW/m^2 was observed in MFC at the feed concentration of 6100 mg COD/L.
3. The optimal feed concentration for MFC was 6100 mg COD/L.
4. The performance of MFC deteriorated at the feed concentration of 10100 mg/L COD.

Acclimatization of microbes to higher feed concentration of distillery wastewater might lead to good efficiency of COD removal even at higher feed concentrations.

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