Treatment of Textile Industry Wastewater using Microbial Fuel Cell

C.Marimuthu, S.Vidya, S. Diwakaran

Abstract: ***Recent research have found out that Bio Electrochemical Systems (BES) are proving to be efficient in both power generation and in waste disposal. The best example for a BES is a microbial fuel cell. The microbial fuel cell (MFC) uses the organic and the inorganic materials in the wastewater to produce electricity by the action of the microbes on them. Thus the MFC's can be used for both bio-electricity generation and wastewater treatment. The power generation and the efficiency of the MFC depends on various factors like the type of bacteria, type of electrode used and organic content in the effluent. Experiments were carried out to treat textile industry wastewater using Microbial Fuel Cell. Graphite was used as anode, stainless steel and aluminium mesh were used as cathode. Influence of cathodes on power production and COD reduction on process has been critically examined. The maximum power density and COD reduction were observed in graphite and stainless steel electrode system***

Keywords : Electricity, Electrode, Microbes, Microbial fuel cell, textile wastewater treatment.

I. INTRODUCTION

The major problem faced by a developing country is clean energy production1 and the disposal of waste. Many new methods have been developed for waste disposal and production of clean energy but most of them are not economically feasible and are still in research. The new methods proposed entail high operational costs or large of lands for the treatment [2].Thus, active research to find out alternate methods to treat wastewater and to find new sources of energy especially renewable sources of energy is a new trend [3]. The new systems called Bio Electrochemical Systems4 are new method of clean power generation. The microbial fuel cell are one such BES that can be used for the power generation. The MFC works on the anaerobic breakdown of the substrate or organic matter present in the wastewater by the bacteria present in it. Microbial fuel cell (MFC) is a novel device which can directly convert organic substrate into electricity [5]. Electricity producing microorganism are called as Electricigens.

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Electricigens make it possible to convert renewable biomass and organic wastes directly into electricity without combusting the fuel, which wastes substantial amounts of energy as heat [6].

Most basic fuel cell consist of two chamber, an anaerobic and anode and aerated cathode separated by membrane such as Naffion or salt bridge. Membrane or salt bridge allows hydrogen ions generated in the anode chamber to the cathode chamber [7]. Most biological fuel cells use mediator molecule to speed up produced electrons to electrode surface. Recently, mediator-less microbial fuel cells have been developed. These kinds of microbial fuel can directly transfer electrons to the electrodes [8–10].

Water based organic matters that can be used in an MFC can be simple carbohydrates, acetate and butyrate, and complex organic compounds, domestic wastewater, and manure sludge [11]. The wastewater is usually taken in the anode chamber and a cathode chamber is filled with water. The electrodes are inserted in the respective chambers. The external circuit is closed by connecting the electrodes. In anaerobic conditions the bacteria breakdowns the organic matter producing electrons and protons [12]. The electrons are transferred to the anode which passes it to the external circuit thus current is produced in the opposite direction of the electrons flow. The protons are exchanged through the proton exchange membrane, they reach the cathode compartment and combine with oxygen to form water. Microbial fuel cells use biocatalysts for the conversion of chemical energy to electrical energy [13–15].
The Schematic diagram of a MFC is represented in figure 1.

The basic reaction taking place I the anode and cathode chamber of an MFC are given below [16]

Acetate is used as substrate fuel for wastewater
Anode : $CH_3COOH + 2H_2O \rightarrow 2CO_2 + 8H^+ + 8e^-$
Cathode: $2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$
Overall: $CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$ + electricity

The various factors that affect the power production in MFC are [17]

- Electrode used
- Shape of the electrode
- Size of the cathode
- Types of microbes present in the wastewater
- Proton exchange membrane

Due to the breakdown of the organic matters in the waste water the COD level of the effluent decreases

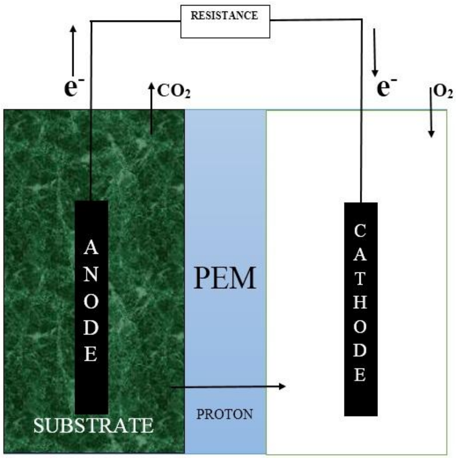

Fig 1. Schematic representation of an MFC

II. MATERIAL AND METHODS

A. Textile Industry Wastewater

Textile industry waste water was collected from a common effluent treatment plant in Tirupur district of Tamilnadu. The effluent was stored in refrigerator at 40°C to avoid the contamination. The test was conducted without any modifications to the wastewater like pH adjustments or addition of nutrients [18]. The figure 2 shows the textile effluent collected from industries.

Fig 2. Textile Industry Waste water

B. MFC configuration and operation

Experiment was carried out using fabricated two simple two chambered microbial fuel cell with the help of four 900ml airtight containers. Graphite anodes were used since it's the most abundantly used one and its cost is low approximately Rs. 80 per kg. [19]. Stainless steel mesh was used as cathode for MFC configuration -1 and aluminum mesh as cathode for MFC configuration-2. The properties of the electrode are given below in the table 1.

Table- I: Properties of Electrode

Electrode / Properties	Graphite Electrodes	Stainless Steel Electrode	Aluminium Electrode
Shape	Cylindrical	Rectangular Mesh	Rectangular Mesh
Effective area	12.26cm^2	60.37cm^2	60.52cm^2
Cathode/Anode	Anode	Cathode	Cathode
Dimensions	L=6cm,D=1.3cm	L=30cm, B =6.5cm	L=30cm, B=7cm

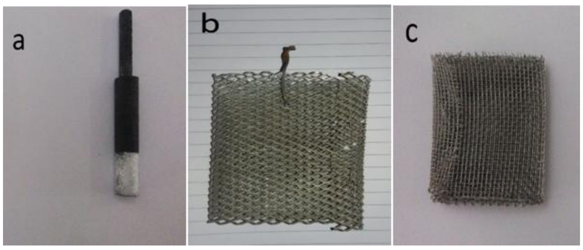

Fig. 3. (a) Graphite Electrode, (b) Aluminum Electrode, (c) Stainless Steel Electrode

An Agar salt bridge was used as a Proton exchange membrane. 800ml of the effluent was taken in the anode chamber and the cathode chamber was filled with 700ml ordinary tap water. The respective electrode was inserted in the respective chambers. The anode chamber was sealed air tight to maintain anaerobic condition and the cathode chamber was provided with a hole to supply air. The electrodes were externally connected to the multimeter with copper wires. No pre-treatment was done to the electrodes.

C. Analysis

The COD, pH, TSS, and TDS analysis of the effluent was done before the test. The results are as shown in the following table 2.

Table- II: Textile Effluent Characteristics

S.no	Property	Effluent characteristics
1	pH	7.2
2	COD	2960 ppm
3	Colour	Dark Green
4	TDS	6000 ppm
5	TSS	1200 ppm

The MFC was operated and the voltage was measured using the multimeter. The Current was measured across an external resistance of 470 ohm using the following formula [20].

Current = Voltage/External resistance ,

$I = V/R_{ext}$ (Ampere)

Current Density= Current/Area,

$J = I/A$ (Ampere/m^2)

The power was measured was calculated using the formula

Power = Voltage x Current , P = V x I (mWatt)

Power density = Current density x Voltage,

PD=J x V (mW/m^2)

III. RESULT AND DISCUSSION

The output of both MFCs were observed for 17 days based on the literature [1]. The corresponding current and power density was calculated using the above mentioned formulas. Graphs of Time vs Voltage, Time vs Power density and Voltage vs Power density were drawn for each MFC configurations

A. MFC configuration-1

The total power generated for 1m^2 area of the stainless steel electrode was 35626.77mW. The Actual power generated from the electrode area of 0.001225m^2 is 43.19mW.

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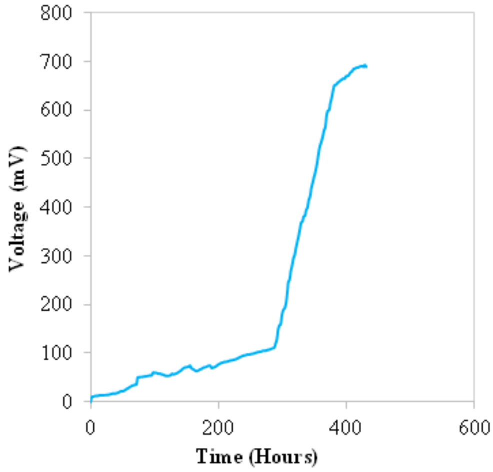

Fig 4. Voltage vs Time graph for Stainless Steel Cathode and Graphite Anode

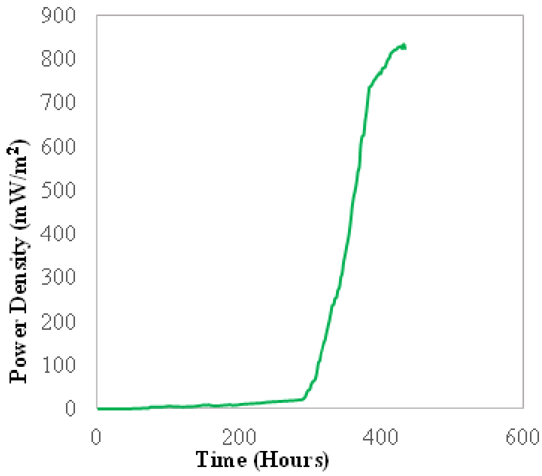

Fig 5. Power density vs Time graph I Stainless Steel Cathode and Graphite Anode

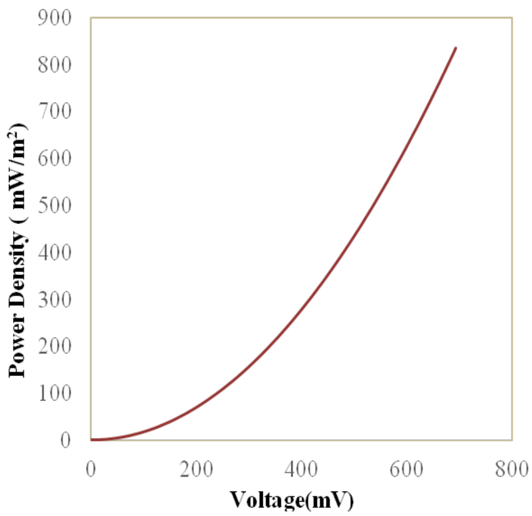

Fig 6. Power density vs Voltage graph I Stainless Steel Cathode and Graphite Anode

B. MFC configuration-2

The total power generated for 1m^2 area of the Aluminum electrode was 32050.31mW. The Actual power generated from the electrode area of 0.001225m^2 is 39.26mW.

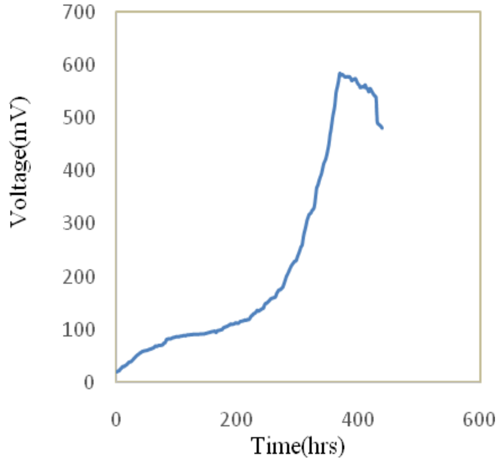

Fig 7. Voltage vs Time graph for Aluminum Cathode and Graphite Anode

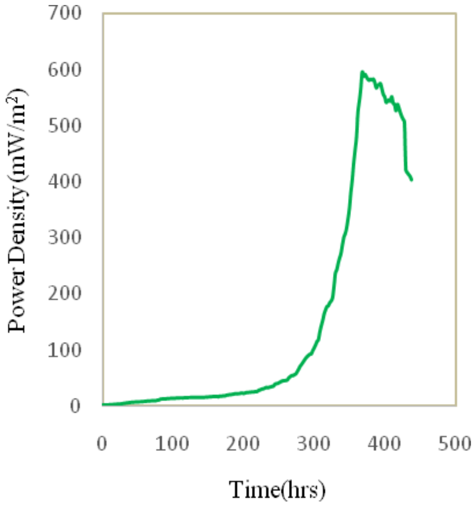

Fig 8. Power density vs Time graph for Aluminum Cathode and Graphite Anode

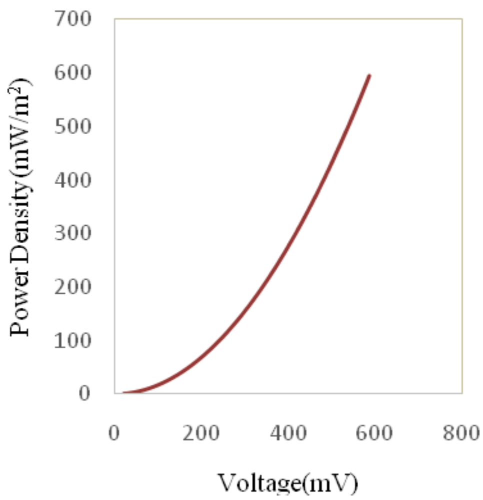

Fig 9. Power density vs Voltage graph for Aluminum Cathode and Graphite Anode

Table- III: Comparison of Effluent Characteristics

Characteristics	Inlet	After Treatment

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	Effluent	MFC SETUP-1	MFC SETUP-2
COD ppm	2960	678	992
TDS ppm	6000	10000	9650
TSS ppm	1200	1600	1435
pH	7.2	6.8	6.8
Color	Dark Green	Yellowish Green	Yellowish Green

From the above table it can be seen that there is 77.09% COD removal while using stainless steel electrode and 66.48% COD removal while using aluminum electrode. Total solids content has increased duo to bacterial activities in the effluent.

Fig 10. Effluent colour before and after treatment

C. Comparison of Electrode Material Output

Due to the varying properties of the electrode the output characteristics of the MFC setups also varied. The output of both the MFC setups was compared and is shown in the figure 11.

The variation in the output is due to the variation in the electrode potential of the electrodes and the electron accepting capacity of the electrodes.

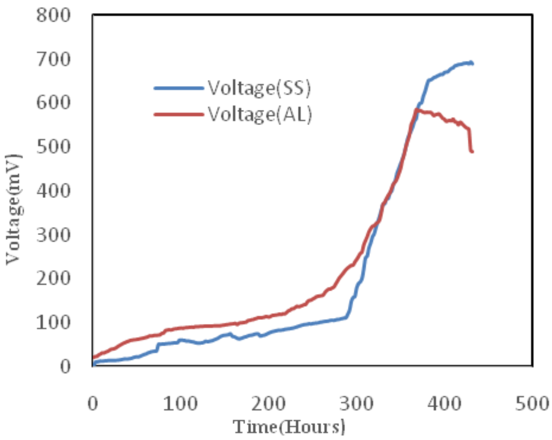

Fig 11. Comparison of output of SS and Aluminum electrode

The raw sludge and the sludge obtained from the treated effluent were collected and were given for SEM analysis. The SEM images are shown below

From the 20µm and 10µm SEM images it is observed that there is growth of bacterial layer on the sludge surface. From these images it is observed that the bacteria have anaerobically reduced the organic matter in the wastewater and have grown by feeding on it.

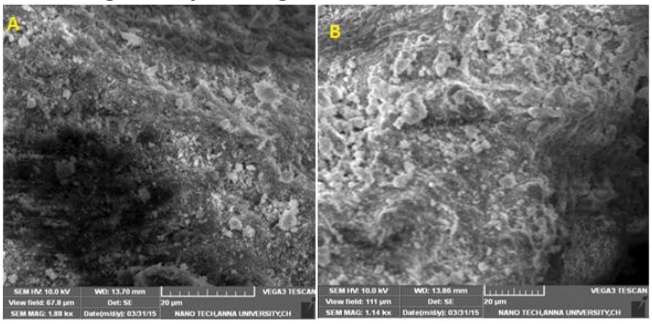

Fig 12. (A) SEM image of textile effluent raw sludge, (B) growth of bacterial layers on the surface of the sludge (20µm)

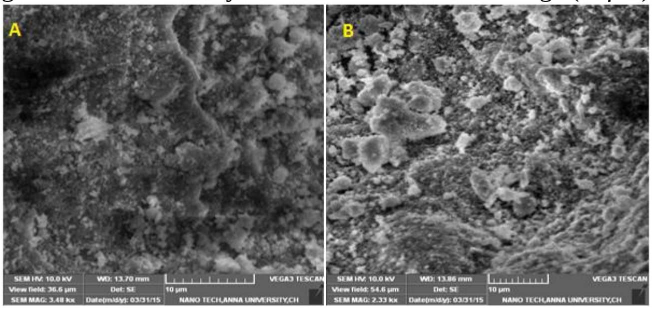

Fig 13. (A) SEM image of textile effluent raw sludge, (B) growth of bacterial layers on the surface of the sludge (10µm)

From the Table 3 it is observed that the COD level of the effluent has drastically decreased. About 77.09% of COD removal is achieved in Graphite-Stainless steel configuration and 66.08% of COD removal in Graphite-aluminum configuration. From the Obtained results it is observed that the removal of COD in Graphite-stainless steel electrode configuration (77.09) is comparatively higher than that of the Graphite-aluminum electrode configuration (66.08). Similarly the power produced in the Graphite-stainless steel configuration (35.63 W/m^2) is a little bit higher than graphite-aluminum configuration (32.05W/m^2). From Figure-10 it is observed that there is a reduction in the colour of the effluent. Hence from the experimental data it is observed that the MFC can be efficiently used to treat the textile effluent and to generate clean energy.

IV. CONCLUSION

Microbial fuel cell has been tested using textile effluent and the output of two different cathode material was compared. The current work has proved successful in implementing the textile effluent as a fuel source for the MFC and further has proven that the MFC help in the reduction of COD level of the effluent. Though the power produced was low there is scope for further improvement by using an electron mediator in the anode chamber and the use of catalyst in the cathode chamber for the easy oxygen facilitation to the protons. From the experimental data the maximum power density obtained from Graphite – stainless steel configuration was 35.63 W/m^2. The maximum voltage reached was 693mV. For the graphite – aluminum configuration the maximum power density was obtained as 32.05W/m^2. The maximum voltage reached was 585mV. There was a considerable decrease in the COD level of the effluent in graphite-stainless steel configuration 77.09% COD

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level reduction was seen as for the graphite-aluminum configuration it was 66.48%.Thus from the experimental data it is observed that the graphite-stainless steel electrode configuration is more efficient in COD removal than the graphite-aluminum electrode configuration.

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