TEST Engineering & Management

*July – August 2020*
*ISSN: 0193-4120 Page No. 77 - 83*

# Construction of Low-Cost Microbial Fuel Cells with Different Electrodes, Feed and Microorganism

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***Article Info***
***Volume 83***
***Page Number: 77 - 83***
***Publication Issue:***
***July - August 2020***

***Article History***
***Article Received**: 06 June 2020*
***Revised**: 29 June 2020*
***Accepted**: 14 July 2020*
***Publication**: 25 July 2020*

## Abstract

The generation of renewable energy from waste water has been demonstrated using a simple batch Microbial Fuel Cell (MFC) primarily from domestic waste water obtained from Khan River water/sediment in Madhya Pradesh State, India and the results were expanded to distillery/dairy industry generating wastewater with high organic content. Various electrodes were used in MFC. In the preliminary experiment, cheap iron electrodes were used for anode and cathode chamber with E-Coil bacteria where obtained efficiency was only 35%. In order to achieve better efficiencies, construction of MFC was changed and iron electrodes are replaced with the electrodes made up of Copper and graphite electrodes for better conductivity of electrons at 23 0C.The efficiency increased but not sufficiently.The commercialization of MFC requires high powerdensity per unit area ,this barrier could be overcome by increasing surface area which is possible by using nano-particle based electrodes and higher electro catalytic activity compared to the conventional carbon materials.Simple hummer method is used to prepare Graphene oxide nano. The synthesized nano particles were characterized by the SEM and, FTIR. Further these nano particles were coated on carbon electrodes to improve the power density. A substantial improvement in the maximum power density was achieved with graphite electrodes and nafion membrane. Proper enhancement was done by coating Nano materials and thereby increasing electron transfer and hence electricity generation. Bacteria's such as Escherichia Coli and Shewannellaputrificians were also employed to generate electricity. The efficiency increased to 85%.Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were decreased considerably.MFC is the novel solution to treat wastewater.

**Keywords;** *Microbial Fuel Cell (MFC) Electrodes, nano-particles, carbon based Graphene Oxide (GO),biological oxygen demand (BOD), chemical oxygen demand (COD), X-Ray Diffractometer (XRD, Fourier Transform- Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM)*

## I. INTRODUCTION

Economic growth and social development are continually increasing gap between the availability of fossil fuels and energy demands. Actual energy needs are farmore larger than energy readily available. In recent years the use of fossil fuels, particularly petroleum, has driven up a global energy crisis (Papaharalabos Get al., 2015). Furthermore, the combustion of fossil fuels releases CO2 to the atmosphere and causes global climate change. Consumption of the natural energy sources due to increasing human activities are leading to depletion of fossil fuels .The existing-time scenario of exhaustion energy sources in India and all over the globe is precarious, that indicating to search carbon-neutral, renewable and sustainable energy sources as alternatives to fossil fuels is needed to lighten the global energy crisis and climate change .Presently used methods to produce energy are not sustainable and leading to climate change, which



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require to develop sustainable methods those produce energy using renewable and carbon-neutral sources (Bullen et al., 2006). Biomass is one of the future energy sources, since it is carbon neutral. Treatment of biomass such as waste water is a continuing issue, especially in undeveloped countries, where the infrastructure is not present and the energy demands cannot be met. Fossil fuel reserves are low and their use to produce energy has adverse environmental impact. It leads to a search for novel renewable energy technologieslike Microbial fuel cells (MFCs) where waste water is used to generate electricity

## EXPERIMENTS AND RESULTS

Two main aspects of the MFC, substrate and parameters affecting anode biofilms were investigated in order to enhance the anode performance for the production of electricity and for waste/wastewater clean-up. Firstly, system design aspects such as, each MFC component, reactor designs as well as anode and cathodes were looked into. Through comparing nine commercially available ion exchange membranes, a Nafion membrane was chosen for the rest of the work. Secondly, three different parameters affecting anode biofilms, temperature, type of electrode material and feedstock, were investigated to analyze and understand the energy production and waste reduction.

Microbial Fuel Cell is made up of low cost materials with the design as shown in the figure 1 .MFC consists of one anode and one cathode compartments of equal volume (500 ml ) , length of MFC is 19 cm, breadth 15 cm and height of 7.5 cm.and distance between the anode and cathode was 20 cm. The wastewater was supplied to the anode and salt water was placed in the cathode compartment. The anode and cathode chambers were separated by Nafion membrane and electrodes were connected via copper wire to multimeter.

**Figure 1: Typical Microbial Fuel Cell**

Initially experiments were started at 230C in the laboratory, at this temperature three electrodes were used namely Copper rod, Graphite rod and Iron rod with Khan River wastewater as substrate and E-Coil for bacteria. After 15 days experiments it is found that power density is very low i.e maximum 0.45924 (mW/m2), COD reduction is only about 35 % and efficiency is 30%

Experiments are continued further by changing temperature, substrate and electrode design and results are compared for the nine MFCs in terms of power density, COD and BOD as shown in table 1.

Three MFC setups are prepared , experiments are started at 23 0C, wastewater as feed, E-Coil microbes and electrodes materials are Copper (MFC 1), Graphite rod (MFC 2), Iron rod (MFC 3).In this set of experiments maximum efficiency was only 23% , because of the low temperature biofilm formation at the anode was very low.To increase efficiency temperature changed to 35 0C and graphite rod design is changed to plate, two microbe groups are used namely ShewannellaPutrificians (MFC 4) and E-Coil (MFC 5).Out of these two experiments MFC 4 has given maximum power density of 11.28 mW/m2 and efficiency of 45% as shown in the figure 2. COD reduced to 52 %.

Efficiencies are very low, in order to improve efficiency anode surface area is increased by nano particle coating. Graphene oxide nanoparticles are prepared using hummer method. Electrode surface


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area plays a very important role to increase the production of electricity , hence electrodes are coated with graphene oxide (GO) nanoparticles for better surface area , nanoparticles are synthesised by hummer method and particles are characterised by FTIR and SEM technologies. The results are shown in figure 2 and 3 respectively.

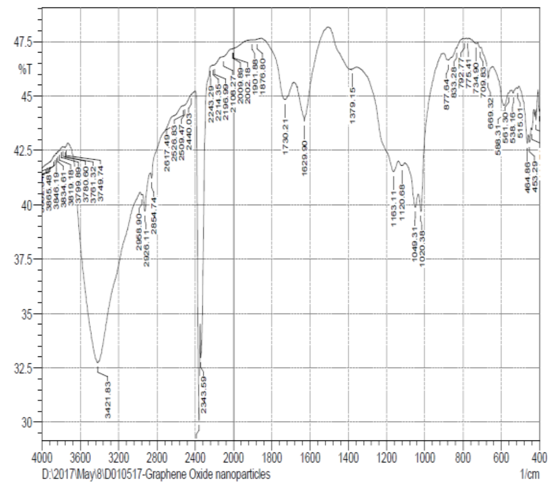


**Figure 2. FT-IR spectrum of Graphene oxide nanoparticles**

The characteristic FTIR spectrum of GO nanoparticles is depicted in Figure. 6. It is seen with oxygen-containing groups in which the main absorption band at 3421 cmí1 is assigned to the O-H group stretching vibrations. The two absorption peaks at about 1020 cmí1 and 1049 cmí1 are assigned to the C–O stretching vibrations. This C=O group found in GO would facilitate the attachment of biomolecule.

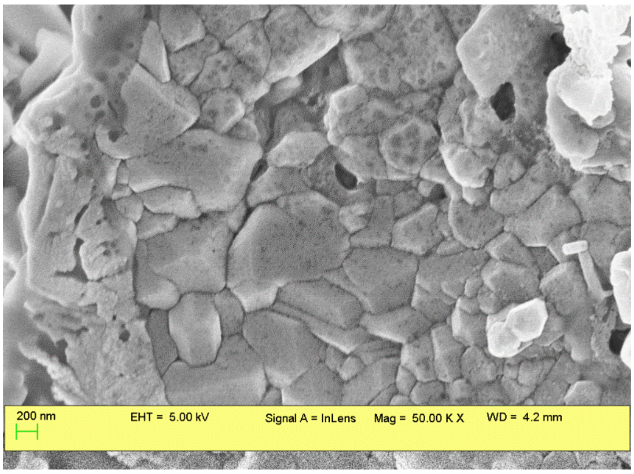


**Figure 3. The SEM image of surface GO nanoparticles obtained by a chemical exfoliation technique**

It was found that GO nanoparticles consists of randomly aggregated and crumpled thin sheets which also observed with wrinkles and folds on the surface of GO nanoparticles. This result confirmed that two-dimensional nanosheets of GO can be produced from exfoliation of suspended graphite oxide.

Graphite plates are coated with GO nanoparticles and two experiments are conducted with E-Coil (MFC 5) and shewannellaPutrificians (MFC 6) as microbes to analyze .Temperature maintained at 35 0C. Experiments are conducted for 15 days , maximum power density achieved was 29.04 mW/m2 and efficiency increased to 67% for MFC. COD and BOD also reduced considerably. It shows shewannellaPutrificians forms biofilm better than E-Coil at the electrode.

Organic content in the feed is one of the important factors to improve the power density, Khan river wastewater is changed to Dairy waste water to test the reults.Three experiments are conducted with Dairy wastewater as substrate , Graphite with GO particles coating ,E-Coil as microbe (MFC 7), with same electrode and shewannellaPutrificians microbes (MFC 8) and the last one copper plate electrode (MFC 9) with same operating conditions.

It was very evident that MFC 8 was giving good results from the day one . The maximum power


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density achieved was on day 7 itself i.e 35.69 mW/m2 and efficiency of 81%, it is maintained till 3 days and started reducing.COD is reduced up to 80-85%.

In all operating experiment, the MFCs were able to achieve high biological oxygen demand (BOD) and chemical oxygen demand (COD) reduction up to 85% and 80% with dairy wastewater and domestic wastewater respectively. In both the cases Shewanellaputrfaciens are used as electron carriers for the transfer of electrons from bio film to electrodes. Comparison of power density and efficiency results for MFC 4, MFC 6 and, MFC 8 are shown in the figure 4 and 5 respectively.

MFC with dairy wastewater substrate, shewannellaputrificiansmicrobes ,grahite plate with graphene oxide nanoparticles at 350C has showed that voltage production is good but power density can be increased by increasing the current production, so it can be achieved by stacking the more no of MFCs in series.

## CONCLUSION

MFC is a novel and promising technology to overcome the problems of wastewater treatment and bioelectricity production. Power density can be improved by surface area and with carbon based electrodes. Commercialization needs more research on cost effective materials with stacked MFC designs.Some companies (mfc tech, Opencel) have emerged to use MFC technology for fuel and other potential applications including remote power, bioremediation and biosensors proving that this technology could have greater impact in development of clean energy within a few years. MFCs can be considered seriously in developing countries where wastewater treatment is only on paper not in use because of the high cost involved where industries and municipal corporations can earn money by generating electricity while treating wastewater.

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**Table 1. MFCs with different configurations including electrode material, design, temperature and in feed substrate**

| MFC No | Feed | Electrode Material | Bacteria Used | Temperature ($^0C$) | Electrode Design |
|---|---|---|---|---|---|
| MFC 1 | Domestic wastewater | Copper | E-Coil | 23 | Rod |
| MFC 2 | Domestic wastewater | Graphite | E-Coil | 23 | Rod |
| MFC 3 | Domestic wastewater | Iron | E-Coil | 23 | Rod |
| MFC 4 | Domestic wastewater | Graphite | Shewanellap utrefaciens | 35 | Plate |
| MFC 5 | Domestic wastewater | Graphite with graphene Oxide coat | E-Coil | 35 | Plate |
| MFC 6 | Domestic wastewater | Graphite with graphene Oxide coat | Shewanellap utrefaciens | 35 | Plate |
| MFC 7 | Dairy wastewater | Graphite with graphene Oxide coat | E-Coil | 35 | Plate |
| MFC 8 | Dairy wastewater | Graphite with graphene Oxide coat | Shewanellap utrefaciens | 35 | Plate |
| MFC 9 | Dairy wastewater | Copper | Shewanellap utrefaciens | 35 | Plate |


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*July – August 2020*
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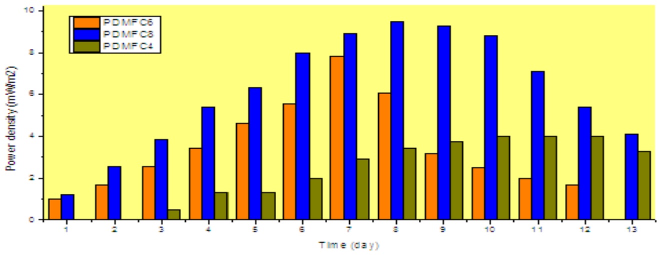


**Figure 4. Maximum Power density of 35.69 mW/m2 for MFC 8 on day 8 when comparing to MFC 6 and MFC 4**

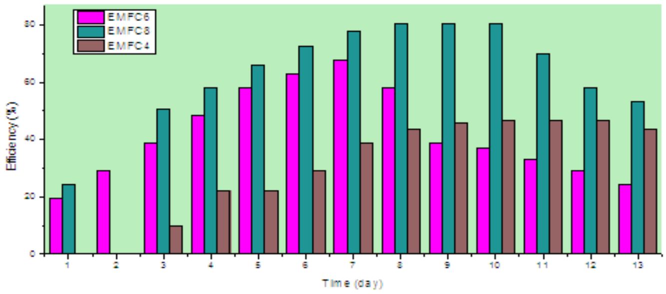


**Figure 5. Maximum efficiency of 80% for MFC 8 on day 8 when comparing to MFC 6 and MFC 4**