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Designing and Optimization of Microbial Fuel Cell Using Bio-Waste

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Abstract:- A microbial fuel cell (MFC) or biological fuel cell electrochemical system drives an electric current by using bacteria found in nature. MFC's can be grouped into two general categories i.e. mediated MFC and unmediated MFC. There are two chambers in the fuel cell i.e. the anodic chamber and the cathodic chamber. Both the electrodes are immersed in the respective chamber for the flow of electrons. Moreover, a salt bridge can be set-up in between the chambers for the flow of protons or a proton exchange membrane (PEM) can also be used. Various types of electrodes can be used according to the requirement. The pencil lead type graphite electrode provides more surface area which results in higher voltages as compared to wire mesh type carbon paper electrodes. Performing different trials for different types of water, electrodes and NaCl concentration an appropriate result can be concluded. By comparing the time and voltages data of trials on a graph, the economical and feasible trial can be selected. The fuel cells can be used for various applications like waste water treatment, generation of current using organic waste as well as can be used as bio-sensors for the determination of Biochemical Oxygen Demand (BOD). The advantages of MFC's are many but its use for production of electric current from waste is driving people's attention. Humanity has just touched the surface of MFC's and there is a vast scope of future development.

Keywords:- *MFC, Mediated and Unmediated, Salt Bridge, Electric Current, Applications.*

I. INTRODUCTION

A microbial fuel cell or MFC is a device that converts the chemical energy into the electrical energy by the action of microorganisms.[1] Most MFC's contains a membrane, that separates the compartments as the anode or oxidation part and the cathode or reduction part. The electrons produced during oxidation are transferred directly to an electrode or to the redox mediator species. Most microbial cells are electrochemically inactive. To facilitate the electron transfer mediators such as thionine, methyl blue, humic acid, and neutral red are used. But most available microbial fuel cells use electrochemically active bacteria to transfer electrons to the electrode.[2][3] The electron flux is moved to the cathode. The charge balance of the system is compensated by ionic movement inside the cell, usually across an ionic membrane i.e. salt bridge. Most MFCs use an organic electron donor that oxidizes to produce CO_2. However, there is no net carbon release because the carbon dioxide in the renewable biomass which originally comes from the atmosphere in the photosynthesis process. Unlike in a direct combustion process, the electrons are absorbed by the anode and are transferred to the cathode through an external circuit. Other electron donors have been reported, such as sulfur compounds or hydrogen.[4] After crossing a PEM or a salt bridge, the protons enter in the cathodic chamber where they join with oxygen to form water. Generation of electric current is made viable by keeping microbes separated from oxygen or any other end terminal acceptor other than the anode and this requires an anaerobic anodic chamber. For the present and future context, microbial fuel cells technology may present a sustainable and an environmentally friendly route to meet the water sanitation needs. Microbial fuel cell based on wastewater systems employ bioelectrochemical catalytic activity of microbes to produce electricity from the oxidation of organic, and in some cases inorganic substrates present in urban sewage, agricultural, dairy, food and industrial wastewaters. This article represents the potential for energy generation and economic waste water treatment in microbial fuel cells. Three special features i.e. energy saving, less sludge production and less energy production makes MFCs outstanding compared with the existing technologies. Multiform wastewater could be efficiently degraded through advancing MFCs alone or integrating the MFCs with other processing units.[5]

II. MATERIALS AND METHODS

The setup is designed cost-effective and to built from inert material to avoid inhibition of microbial activity. So, the material of construction used is 10 mm thick acrylic sheet for lighter weight and better handling. The silicone gel is used to avoid any leakage in the model.

It was more important to gain considerable output at very first attempt. Volume of MFC is decided to be 1 liter in each compartment. Dimension is determined such that the electrodes and inlet-outlet of material can be effectively positioned. From the literature survey, solid graphite electrodes are found cheap at the same time efficient as well as compared to other typed of electrodes.

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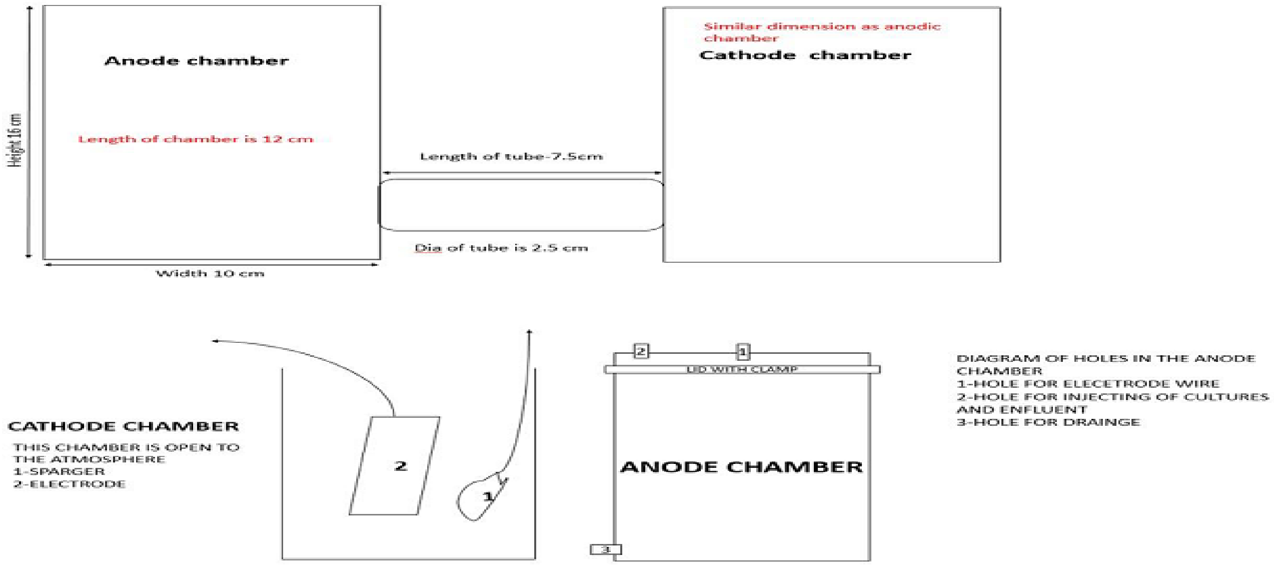

Fig 1:- Design of a cell

Inoculum was first filled in the anodic chamber. The beginning trails were done on synthetic wastewater by changing Chemical Oxygen Demand (COD) concentrations. COD concentration is manipulated by removing old wastewater which is done by settling and keeping sludge as it is. COD concentration is optimized to give maximum voltage. Surface area of electrodes is also changed by changing electrode materials during different trial operation for checking the consequences of surface area of electrodes on voltage generation. Wastewater COD is varied by changing the concentration of glucose in synthetic wastewater. Final trials were done on the distillery wastewater to check the feasibility of treatment. It is diluted to achieve optimum COD. Experimentation is carried out for 6 hours. Wastewater remains the same during the whole operation. Initial and final biomass concentrations are measured.

Two types of electrodes were used for the variation in surface area and to analyze the effects of surface area on electricity production. One electrode used was made from pencil graphite lead and another electrode was mesh carbon electrode.

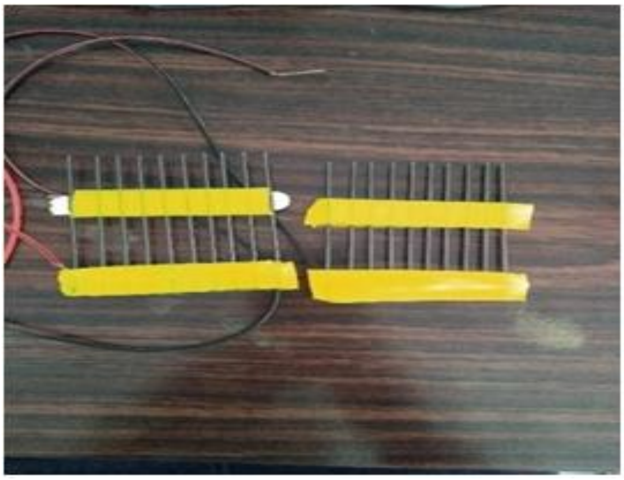

Fig 2:- Graphite electrode (pencil lead)

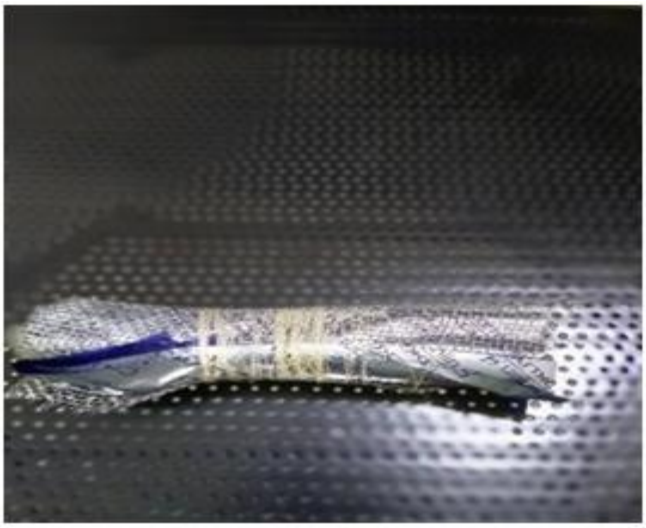

Fig 3:- Carbon electrode (Wire mesh + Carbon Paper)

Sr. No.	Items	Quantity
1	Agar	5 gram
2	KCl	5 gram
3	NaCl	200 gram
4	K_2HPO_4	1 gram
5	Distilled Waste water	1 litre
6	Pond Sediments	5 litre
7	Cotton Plugs	100 gram

Table 1:- Chemicals and Materials required

A. Salt Bridge Preparation

Salt bridge is a cheaper and more durable alternative as compared to proton exchange membrane. But it must be prepared from pure agar.

Salt bridge is prepared from mixture of agar and salt. Take 100ml of distilled water in 500ml beaker and put on the heating at 70°C, now add 0.1g KCl as a salt and dissolve it. Provide it a continuous stirring and add 5 g of agar slowly till the viscosity of the solution reach to solid.

Cotton plugs are placed to the side opening of the salt bridge casing pipe and solution is immediately transferred into the opening as shown in figure 4. Don not use until the agar salt bridge gets solidified completely for 2 to 3 hours. Now salt bridge is up to the task for the operation.

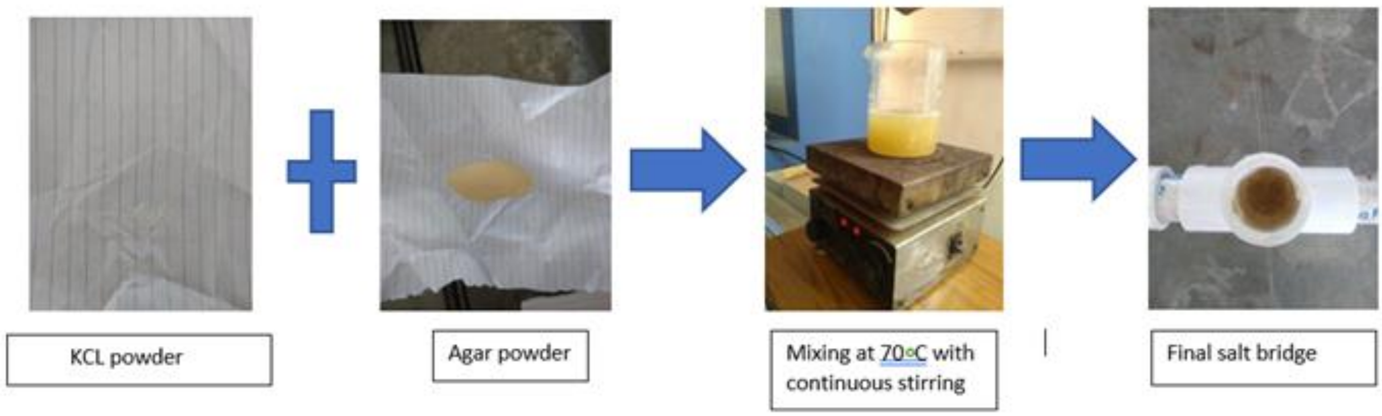

Fig 4:- Preparation of Salt Bridge

B. Anodic Chamber

Anodic chamber has a lid arrangement to seal the chamber completely, so as to provide anaerobic system. Lid has a hole to introduce wastewater and electrode wire. The anodic reaction is:

$CH_3COO^- + H_2O \rightarrow 2CO_2 + 2H^+ + 8e^-$

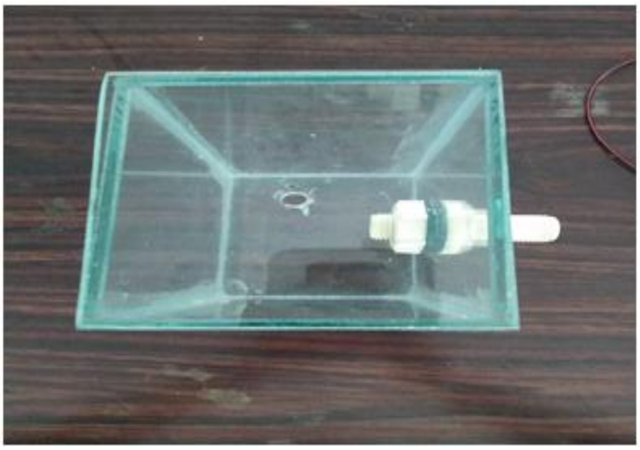

Fig 5:- Anodic chamber with glass lid

C. Preparation of Inoculum for Anodic Chamber

Inoculation is done with the help of two sources of mixed consortia i.e. pond sediments and activated sludge. Activated sludge cannot be used because the microbes were not that efficient as of pond sediments.

Inoculum is prepared by the given method, pond sediments (from the deep down bottom ensuring anaerobic microbes present) or mixed consortia (prepared from pond sediments) and activated sediments is taken to centrifuge at 5000 rpm and 22°C. It washed thrice with saline buffer (2g NaCl, 0.30 g K_2HPO_4, 0.084 g KH_2PO_4 in 250ml of distilled water, pH 7.0) and centrifuged every time at same rpm. The pellet stays at bottom after washing away raffinate. It was rich in synthetic wastewater consists of 0.5 g/l NH_4Cl, 0.25 g/l KH_2PO_4, 0.25 g/l K_2 PO_4, 0.3 g/l $MgCl_2$, 25 mg/l $CoCl_2$, 11.5 mg/l ZnCl2, 10.5 mg/l $CuCl_2$, 5 mg/l $CaCl_2$, 15 g/l $MnCl_2$, 3 g/l Glucose, pH 5.5 and COD 3.4 g/l.

During the enrichment, bottles are kept covered to provide anaerobic environment at 10 rpm, room temperature and acidophilic pH 5.5 is maintained to sustain the acidogenic or hydrogen producing bacteria, which also inhibits the activity of methanogenic-bacteria in return which will enhance the hydrogen production, which is highly required for MFC operation. Before using it in MFC, the prepared inoculum is subjected to pH adjustment to 7.0 ± 0.5 under complete anaerobic environment.

D. Cathodic Chamber

Cathodic chamber consists of distilled water and electrode which are open to atmosphere. Aerobic chamber is open and have air pump to provide circulation and electrode. The cathodic reaction is:

$O_2 + 4e^- + 4 H^+ \rightarrow 2 H_2O$

E. Operating pH and Tempeature

During the operation, the pH is maintained at 7.0 ± 0.5. The retardation in pH is directly proportional to the output voltage. The whole experiment is carried out at room temperature i.e. 25 ± 5 °C.

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III. ANALYSIS

- COD analysis is carried out by the standard open reflux method.
- Voltage results are measured by standard multimeter of sensitivity up to 1 mV.

A. Trial- 1
- 10 grams of NaCl added at interval of 5 minutes
- Distilled wastewater was used
- Graphite electrode(pencil lead) was used

Sr. No.	Time Interval (Minutes)	Voltage (mV)
1	0	65
2	5	67
3	10	70
4	15	74
5	20	76
6	25	77

Table 2:- Trial 1 results

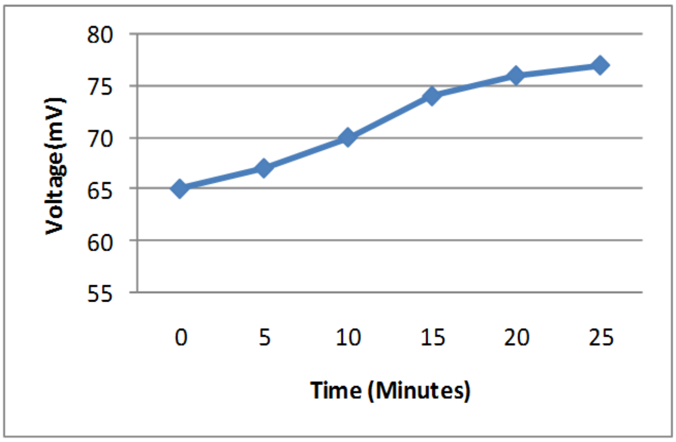

Fig 6:- Voltage (mV) v/s Time (Minute) graph for trial 1

B. Trial- 2
- 15 grams NaCl added after every 15 minutes
- Distilled wastewater was used
- Graphite electrode(pencil lead) was used

Sr. No.	Time Interval (minutes)	Voltage (mV)
1	0	245
2	15	339
3	30	356
4	45	458
5	60	420
6	75	441
7	90	425
8	105	430

Table 3:- Trial 2 results

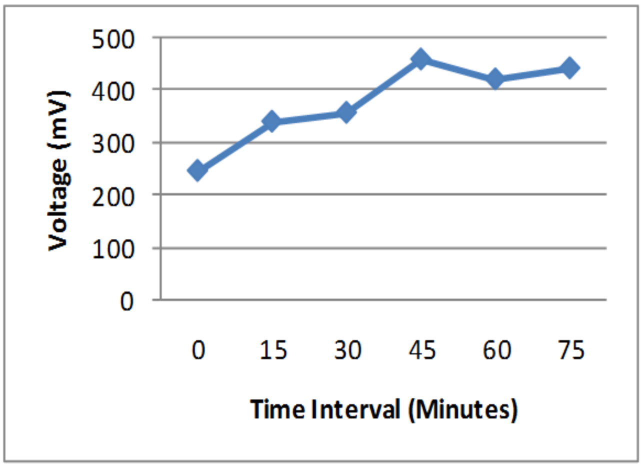

Fig 7:- Voltage (mV) v/s Time (Minute) graph for trial 2

C. Trial- 3
- 20 grams NaCl added after every 30 minutes
- Tap water was used
- (Wire-mesh + carbon paper) electrode was used

Sr. No.	Time Interval (Minute)	Voltage (mV)
1	30	156
2	60	144
3	90	154
4	120	139
5	150	137
6	180	141
7	210	134
8	240	132

Table 4:- Trial 3 results

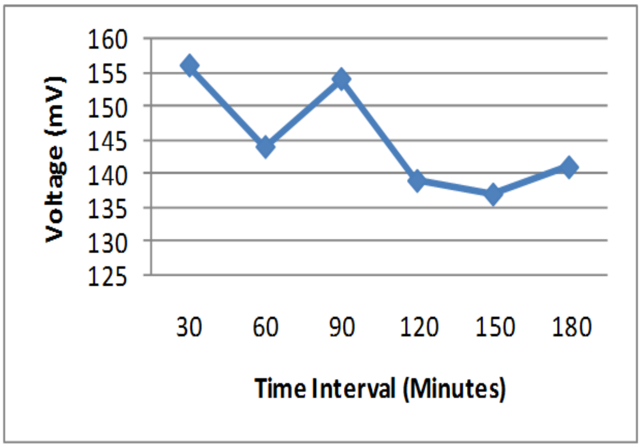

Fig 8:- Voltage (mV) v/s Time (Minute) graph for trial 3

D. Trial- 4.
- 300 gram of NaCl was added initially
- Air pump was installed for continuous agitation.
- Distilled wastewater was used.
- Graphite electrodes were used

Sr. No.	Time Interval (Minute)	Voltage (mV)
1	60	248
2	120	320
3	180	360
4	240	460
5	300	470
6	360	485

Table 5:- Trial 4 results

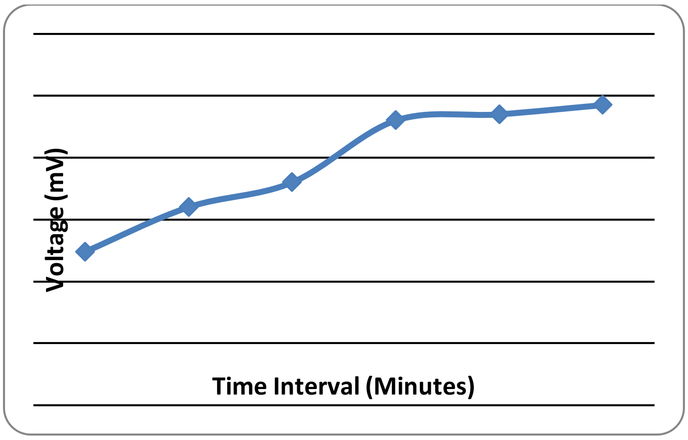

Fig 9:- Voltage (mV) v/s Time (Minute) graph for trial 4

IV. CONCLUSION

The Microbial Fuel Cell is an advantageous method for the wastewater treatment. After performing the experiment, it is clear that MFC technology will be explored in future. There are many types of MFC designs which are feasible but the salt bridge MFC is proved to be the best in terms of cost effective, voltage output and pollution free. It is also feasible to obtain power with mediator less MFC.

In the distilled wastewater trials, it was observed that 10000 to 15000 mg/l COD is sufficient for maximum power output. For that, the distillery (industrial) wastewater is diluted to 14400 mg/l COD from its original concentration. Synthetic water (tap water) trial also gives the idea of increasing surface area of electrode. The lower surface area yields lesser power output and higher surface area yields higher power output generation. It also accelerates the current density.

On performing various trails it can be conclude that the voltage obtained by using distilled wastewater with the sediments obtained from the pond waste water the results obtained were better compared to others. Moreover, it can also be noted that the graphite electrodes are better as compared to the carbon paper and wire mesh electrodes. Also the voltage generation depends on the salt addition. It shows positive results up-to certain data and than after remains constant. Continuous stirring is required to dissolve the salt for that of air pump is used in the last trial.

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