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Production of Electricity Using Microbial Fuel Cell Utilizing Untreated Human Urine

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Abstract

To meet with the ever growing energy demands, many alternative sources of energy which are eco-friendly and non-polluting have been identified. To name a few- wind energy, bioethanol, biodiesel etc. So far, very few of them have been implemented in an industrial level mainly due to poor economic viability. Of all the known methods, Microbial fuel Cell (MFC) technology is one of them. MFCs makes use of the waste sources like effluents from industries, household waste water, lakes and even human urine and can directly convert it into electricity. MFCs are electrochemical cells which are capable of converting chemical energy into electrical energy. One of the most important things about MFCs is how the bacteria acts as a source of electricity. It is a two-step process. The first step is the removal of electrons from the source of organic matter (Oxidation), and the second step consists of giving those electrons to something that will accept them (Reduction). The bacteria can transfer these electrons to a carbon electrode if they are grown under anaerobic conditions. These electrons move across a wire to a cathode where they combine with the protons and oxygen to form water. When these electrons flow from the anode to the cathode, they generate current.

A wide range of substrates can be used as fuel for MFC and urine, being an abundant waste product can surely be utilized as a fuel for MFC. Carbon rods were used as anode and cathode due to its amorphous nature. The voltages across the electrodes were tabulated, initially without urine (substrate) observed over a period and later with urine, the readings thus obtained were compared for increase in voltage. Further, the one with better voltages can be connected in series with similar units. The change in the voltages across the electrode is observed and tabulated.

Keywords: *Microbial Fuel Cell, .Waste water, Carbon rods, Voltage, Current, Urine, Series, Substrate*

1. Introduction

The prime requirement for mankind along with food, clothing and shelter, has been energy since the start of civilization. From time immemorial, man has been finding new sources of energy, to sustain his needs. It started with using animals for farming and transport purposes, and with the discovery of fire, moved on to wood. Wood was the dominant source of energy for a long period of time because of its abundance and therefore cheap availability. However, the turn of the twentieth century brought with it the industrial revolution, and there was an exponential rise in the demand for energy globally. At the same time, coal was also introduced as a conventional solid fuel but was not sufficient to satisfy the energy requirements. These requirements were then satisfied by petroleum and liquid fuels which had a much higher calorific value than solids and this made it ideal for long term use. However, as the demand kept increasing at a rate much higher than the supply, and the depletion of these

energy sources at a faster rate has led to search for alternate resources. Another major advance was the invention of the hydrogen fuel cell. The major advantage being totally clean is that the only by product is water. However, the fuels needed are explosive and their storage and transportation is an issue. Also, although hydrogen is the most abundant element in the universe, currently the only known method by which it is harvested is by steam reforming of methane, which is an expensive process.

Thus, in the global race for total energy efficiency, the rising need for a new non-conventional source of power is being felt daily. Existing sources of power such as coal and other fossil fuels are being depleted and their continued usage contributes towards the increasing pollution, global warming and rising fuel prices. Scientists are trying to solve this issue by developing new techniques that can generate energy. One such technique is the microbial fuel cell.

In 1791 the earliest discovery between biology and electrical energy was demonstrated by Galvani showing the frog leg twitching from an electric current [1]. Grove in 1839 discovered the first fuel cell which involved electrolysis of water. Using the microorganism (E.coli) Potter at University of Durham demonstrated the first half-cell [2]. Cohen from University of Cambridge led to one of the major types of biofuel cells, i.e., microbial fuel cells which were connected in series and generated over 35volts [3]. Development of biofuel cells received a boost in the late 1950s and early 1960s by the USA space program, which led to application of microbial fuel cells as an advanced technology for waste disposals treatment in space flights. Microbial fuel cells were widely applied since 1970s by the concept of using them as biocatalyst [4]. And they also found that using electron mediators the power output could greatly be improved [5]. The instability and toxicity of mediators limited the cell performance. Then the mediator-less microbial fuel cells were first used in wastewater treatment and electricity generation by direct transfer of electrons to the electrodes [6]. Direct electron transfer by these microorganisms facilitates stable and high yield in coulomb efficiency [7]. Certain bio-electrochemically active microbes which transfer electrons directly through the membrane are Shewanella putrefaciens, Geobacteraceae sulfurreducens, Geobacter metallireducens and Rhodoferax ferrireducens [8]. In 1964, noticeable developments have been done in enzymatic biofuel cell in terms of power density, cell life-time and operational stability. Output potential generated from enzymatic fuel cells is still far beyond the demands of commercial applications. MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures. It is believed, based on the existing and new data that many new types of bacteria will be discovered that are capable of anodophilic electron transfer (electron transfer to an anode) or even interspecies electron transfer (electrons transferred between bacteria in any form). MFCs are being constructed using a variety of materials, and in an ever increasing diversity of configurations. These are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface area, reactor size, and operation time [9].

The main objectives of the study include evaluation of the organic matter content initially present in the sludge in terms of COD, To Design a microbial fuel cell that can generate electricity using sludge, graphite electrodes and salt bridge. To compare the voltage generation using sludge and urine with sludge as the raw material. To compare the voltages generated from the MFC after connecting the cells in series and parallel. To evaluate the organic matter content of the sludge after being used in the cell for about 30 days in terms of COD.

2. Materials and methods

2.1 Materials for MFC Construction:

2.1.1 Anode and Cathode Chambers

Union joints, 3/4 –inch, Sandpaper (1 sheet)□□Permanent Marker□□Adhesive like acrylic cement that can bond plastics, Straight sided plastic (acrylic) storage containers of capacity one and half liters, Drill with 3/4 inch space drill bit and 2mm drill bit, in addition to other diameters.

2.1.2 Electrodes

Graphite rods taken from Zn-C batteries, Wire strippers, Copper wires, Electrical Tape, Soldering rod with soldering wire and flux, Alligator clips.

2.1.3 Salt Bridge Construction

Petri dish□□Stove/Burner□□Glass rod□□Measuring cup□□Agar□□Table salt□□Short section of plastic pipe (polyethylene or PVC)□□□□□Weighing scale□□Beaker□□Distilled water.

2.1.4 Chemicals required

Potassium Dichromate, Sulphuric acid, Silver Sulphate crystals, Ferroin Indicator, Ferrous ammonium

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sulphate crystals, Mercuric sulphate crystals, Electrolyte solution, Agar medium.

2.2 MFC Assembly and Operation:

The microbial fuel cell was assembled using the following materials. Waste water sample, Measuring cup, Aquarium pump with tubing required for aeration, Trays, Alligator clip cables, Digital Multimeter, Straight sided plastic storage containers of capacity one and half liters

Two storage containers were connected with a salt bridge, a conductive salt solution of 1 liter capacity was prepared and it was filled in the cathode chamber. The waste water was collected from the ISRO Lake in ISRO layout, Bangalore and filled in the anodic chamber. The electrodes are submerged in the containers. An aquarium pump is attached to it to aerate the solution inside the chambers. External circuit is made by connecting the alligator clips to the bare end of the electrode from the anode and connecting the alligator clips to the free end of the electrode coming from cathode. The voltage is measured with a digital Multimeter. A prototype of the MFC is as shown in Figure 1.

Figure 1: **A prototype model of the MFC**

3. Results and Discussions

The initial experiments were conducted with waste water in the anodic chamber and conductive solution in the cathodic chamber. The values of voltage and current generated were recorded for a time period of 10 days. A graph of voltage generated against time was plotted and shown in Figure 2. Similar experiments were conducted with the substrate (Urine). 25ml of urine sample was added to the cathodic chamber containing the conductive solution. The readings were recorded and observed that there was sudden rise in the voltage values and the values were recorded for another 10 days. A comparative graph was plotted and shown in the Figure 3. It can be observed from Figure 3 that the voltage generated increased 1.5 folds when the substrate is added to the cathodic chamber showing improvement in the voltage generated.

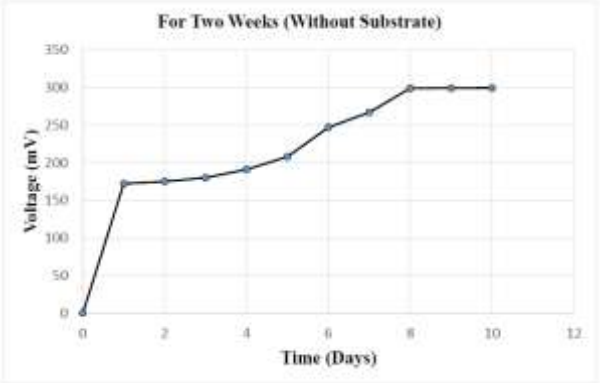

Figure 2: **Voltage v/s Time of MFC without Substrate**

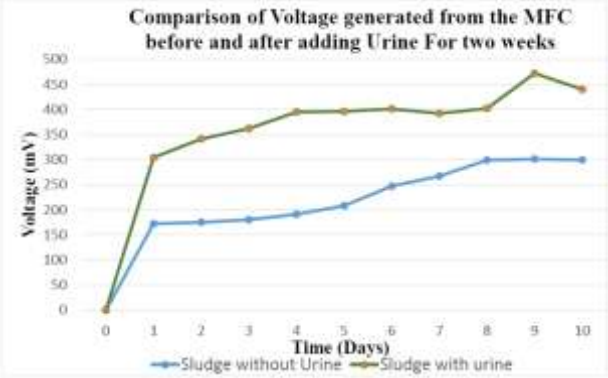

Figure 3: **Voltage v/s Time of MFC without and with Urine**

It can be seen that voltage values were higher in the MFC when urine was added as a substrate. To obtain better power output, the MFCs could be connected in different configurations such as series and parallel arrangements. So an effort was made to scale up the existing fuel cell with series and parallel arrangements. So, three similar MFCs were constructed and the voltages were recorded for 10 days (To ensure proper operation of each individual MFC). It was observed that similar readings were obtained for all the units. Then the individual cells were connected in series and parallel arrangements with 25 ml of urine and voltage was recorded. A graph of voltage generated with series and parallel arrangements was plotted with time as shown in Figure 4. It was observed that the series

arrangements gave better results compared to the parallel arrangements. After observation of voltages produced in the MFCs shown in Figure 4 for about 10 days each, the power was calculated using the power equation,

$$P = V*I \quad (1)$$

P = power in mW, **V** = voltage in mV, **I** = current in mA

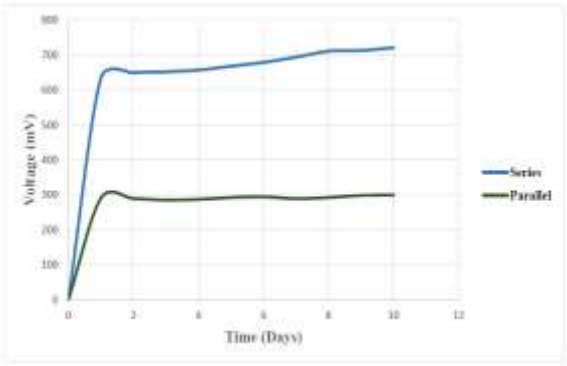

Figure 4: **Voltage v/s Time of Three Cells in Series and Parallel**

The average power value that is obtained from the MFCs' without adding urine and after adding urine was calculated using equation 1. It can be observed that after adding the substrate the power generated was increased to about 3 folds without the substrate. COD of Sludge (waste water) was estimated before and after use in the MFC. It was found that there was a decrease in the COD values and indicates that the Microbes are metabolizing the organic matter present in the wastewater. Initial COD value of the waste water sample was 573.6 mg/l and after 30 days usage it was reduced to 352.8 mg/l

4. Conclusions:

By extracting bioenergy from environments, the MFC technology exhibits a promising potential of powering sensors in remote locations where it is difficult to replace batteries. This experimental study investigates the performance of individual and different combinations of MFCs with and without substrate provides ways of increasing the efficiency for such an application. On the basis of the experimental results, we conclude that an individual MFC produces an average voltage of 300mV without substrate and 440mV with Urine as the substrate. An effort was made to improve the efficiency by connecting the MFC in different combinations like series and parallel combinations. 3 similar MFCs were designed and connected in series and parallel and measured the voltage generated. 720mV and 300mV was generated from series and parallel arrangements. The average power value that is obtained from the MFCs' without adding urine and after adding urine was calculated. The power generated was around 9mW without substrate and 25mW with substrate. It can be observed that after adding the substrate the power generated was increased to about 3 folds without the substrate. It was found that there was a decrease in the COD values and indicates that the Microbes are metabolizing the organic matter present in the wastewater.

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