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Study on Performance Characteristics of Different Microbial Fuel Cells

Md. Moniruzzaman[1*], Md. Hedaetul Alam[1], Md. Zahid Bin Haq[1], Md. Washim Akram[1], M. Ahasan Habib[2], Dr. Kazi Mohammad Anamoul Haque[3]

[1]Department of Mechanical Engineering, Bangladesh Army University of Science and Technology, Saidpur, Bangladesh
[2]Department of Industrial & Production Engineering, Bangladesh Army University of Science and Technology, Saidpur, Bangladesh
[3]Department of Arts and Sciences, Bangladesh Army University of Science and Technology, Saidpur, Bangladesh

emails: *[1]*moniruzzamanshuvo@icloud.com;* [2]*headipe@baust.edu.bd; ('*' - corresponding author)*

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ABSTRACT

Microbial Fuel Cells (MFC) is a bio-electrical devices that using microorganisms as the catalysts convert into the chemical energy present in organic or inorganic component into electric current. In this research double chamber MFC was used to find the appropriate electrode, appropriate salt bridge and better source of microorganism for better electricity production. Using the NaCL with Agar Agar salt bridge better result found. Using Graphite electrode instead of copper and Zinc in the cathode chamber, a high and stable voltage output was found where the maximum voltage was shown which was 2.076V. Rice field clay when used as anodic materials source of microorganism can produce higher voltage compared with top soil clay and drain clay because it causes enough amount of microorganism.

1. INTRODUCTION

Microbial fuel cells (MFC) are the first and the most widely studied microbial Electrochemical Technologies (METs) and Bio-Electrochemical systems. In MFC, an ion exchange membrane separated anodic and cathodic chambers [1]. In an exceedingly divided MFC, microorganisms catalyze substrate chemical reaction reactions within the anodal compartment and synchronic chemical and microorganism substrate reduction reaction happens within the electrode compartment as shown in Figure 1(a) [2]. In Figure 1(b) represent the practical laboratory construction where different components of MFC are mentioned. Anode and cathode compartments are normally separated by a proton exchange membrane and are both side connected electrically in an external circuit with a resistor. Carbon dioxide, protons, and electrons are produces on anaerobic substrate oxidation by microorganisms. Through a separator the protons ions are transferred to the cathode chamber. The electrons are transferred first to the anode and then flow to the cathode via an external circuit thereby producing electricity as the main product. These electrons produce water as the end product and finally reduce oxygen in the cathode chamber. Here electrons donor as acetate and oxygen as electron terminal acceptor, the reactions develop on MFCs can be shown as below [1].

Anode: $CH_3COOH + 2H_2O \rightarrow 2CO_2 + 8^- + 8H^+$
Cathode: $2O_2 + 8^{e-} + 8H^+ \rightarrow 4H_2O$
Overall: $CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O + Biomass + Electricity.$

Any biodegradable substrate is potentially being explored as the ability of MFCs to produce electricity from wastewater treatment applications. The positioning of MFC as an eco-friendly alternative or complementary technology to conventional anaerobic digestion and energy-consuming activated sludge wastewater treatment processes that technology is attractive because of its application in energy harvesting from wastes [2]. Advantages of MFCs such as high tolerance to salinity, low sludge production, suitability for low COD containing waste streams, pH and temperature changes and most importantly it can help in establishing an energy-positive or energy-neutral wastewater treatment process [3].

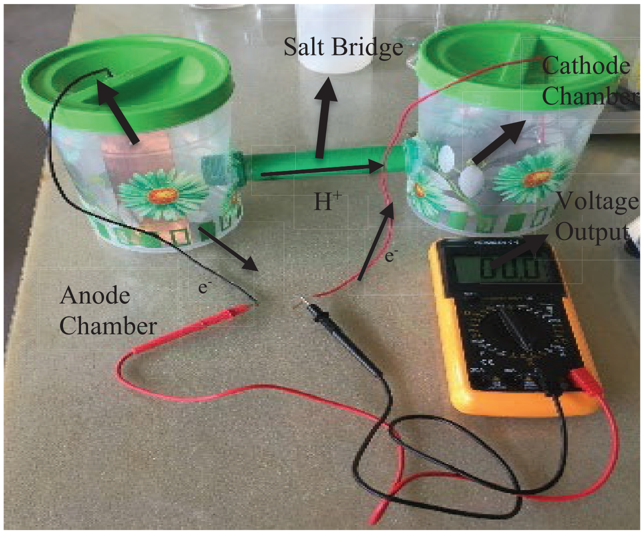


Figure 1(a): Typical two chambered single bridge MFC [2]

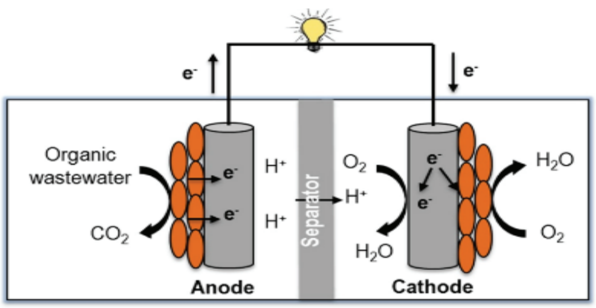


Figure 1(b): Moderated two chamber single bridge MFC

2. MATERIALS AND METHODS

Anode:

In the reactor solution, Anodic materials have to be conductive, chemically and stable biocompatible. Metal anodes consisting of noncorrosive, it's used carbon, Copper and Zinc. Surface modification of the anode materials additionally contribute to the boosted-up performance of the MFCs. The standard current enters into a polarized device through an anode is an electrode. Contradict with a cathode; current leaves an electrical device through an electrode [4].

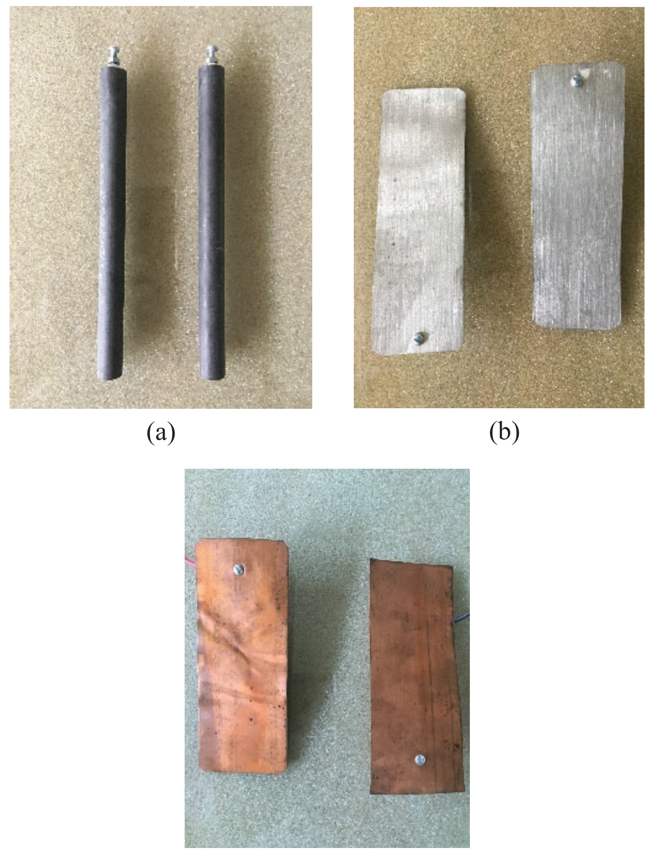
Cathode:

Basically, cathode is a kind of electrode where electrons can move. Formula of the anode collects electrons (has the positive charge) and the cathode type of electrode delivers electrons (negative charge). Cathode has negative charge and Anode has positive charge. For an aqueous solution the cation moves towards cathode coz it has negative charge (opposite charge attraction) and in aqueous solution the anions move towards anode which is positively charged. In a MFC, the oxidation and reduction of metals occurs at the electrodes. There are two electrodes in a MFC, one in each half cell. Reduction takes place at the cathode and at the anode, oxidation takes place hence the ions are reduced [4].

Electrode:

An electrode is an electrical conductor used to make part of a circuit. Electrodes are usually made of metals, such as silver, lead, copper, and zinc etc. Negative ions or anions migrate in the cell through the anode as the electrode. Lose of electrons is the negative ions when oxidation takes place. The anode is known as an electrode where electrons or current leave the cell [4].

Performance of associate MFC is additionally ruled by numerous conductor parameters like biocompatibility, active expanse, high physical phenomenon, nature of conductor surface etc.



(a) (b)

(c)

Figure 2(a): Graphite Electrodes, (b): Zinc Electrodes (c): Copper Electrodes

Proton Exchange Membrane (PEM):

In MFCs, Electrochemical performance influences by the proton exchange membrane that is a core component in the cell. The PEM has a structure which enables only hydrogen ions or protons to pass through as illustrated in fig. 3. Next generation alternative energy is the Hydrogen with proton exchange membrane fuel cells (PEMFCs) which is the high energy density and high abundance of hydrogen in nature that considered as a great potential technology. The most widely used polyelectrolyte for proton exchange membrane is the Agar Agar Solution which increases the three-dimensional zone of catalytic activity [5].

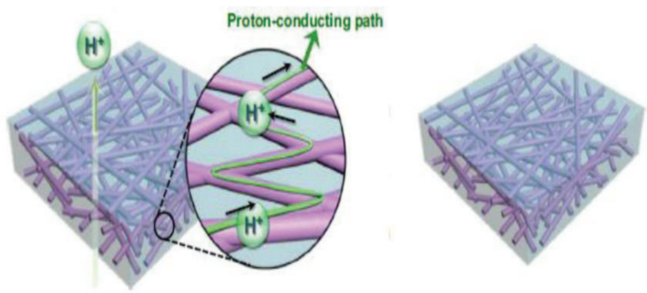


Figure 3: PEM structure which allows hydrogen ions to pass through [7]

In the reduction processes, it forms water and carbon dioxide with the electrons as the hydrogen ions passes through the membrane and completing the circuit.

A tube containing an electrolyte (typically in the form of a gel which shown at Figure (4) which are providing electrochemical contact among two solutions. Especially on different parts of a large molecule such as a proton, a path establishes between electrically charged acidic and basic groups. The electrons are moving from one half cell to the other because the purpose of a salt bridge is not to move electrons from the electrolyte, but also maintain charge balance. For that reason, the proton or hydrogen ions flow from the anode to the cathode.

In a salt bridge, it used KCL and NaCL with Agar Agar because it provides positive K+ and Na+ ions and negative CL- ions because the salt bridge has to maintain the neutrality balance in the system during oxidation by providing enough negative ions equal to the positive ions. The salt bridge contains a salt resolution, by doing this the electrons within the salt are absolve to move (ionic compound), alongside any electrons that would like to try and do constant. This is because, the salt bridge allows the electrons to flow back to the beaker they came from, and it completes the circuit [6].

MFC Construction

Salt Bridge immersed at between Anode and Cathode chamber that consisted of a plastic container of capacity 1.5 liter which served as the maintain charge balance. The anodic and cathodic compartment contained the substrate and the copper electrode (65cm2), Zinc electrode (65cm2), Graphite Electrode (63cm2). In molten stage, the salt cathode was immersed in the salt bridge to ensure complete surface contact. Salt bridge employed here was made with 1M, KCL or NaCL and 10% Agar. The salt bridge was cast in an elegant PVC pipe. Necessary steps were taken for complete protection at anodal chamber by applying epoxy and wax to confirm anaerobic conditions.

Figure 4: PEM (Salt Bridge) in the form of a gel

3. RESULTS AND DISCUSSIONS

Microbial fuel cell can be used in production of electricity by using microorganism. This is a green process of production of electricity [1]. In this research we used rice field clay, top soil clay and drain water as electrolyte in anodic chamber, mineral water used as electrolyte in the cathode chamber. In both case for anode and cathode we used Cu, Zn and Graphite in different experiment. Figure 5 represent the plot of time verses voltage produced using different electrodes for rice field clay as anodic material and KCL Agar Agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 2.023V compared with zinc and copper electrode.

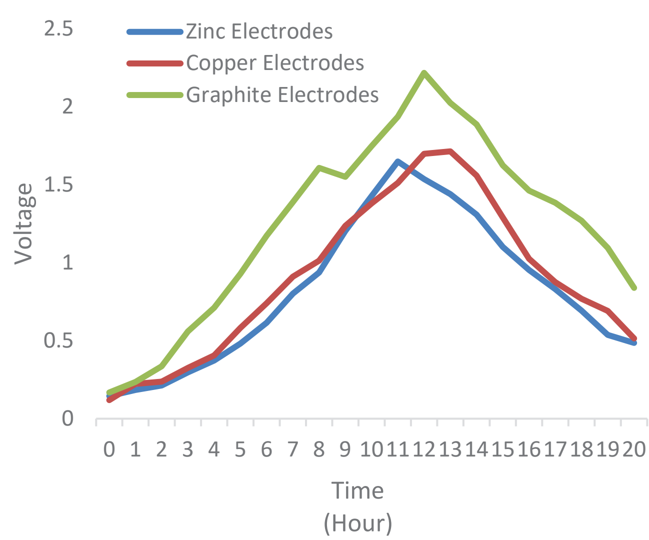


Figure 5: Rice field clay with KCL salt bridge

Figure 6 represent the plot of time verses voltage produced using different electrodes for rice field clay as anodic material and NaCL Agar Agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 2.076V compared with zinc and copper electrode.

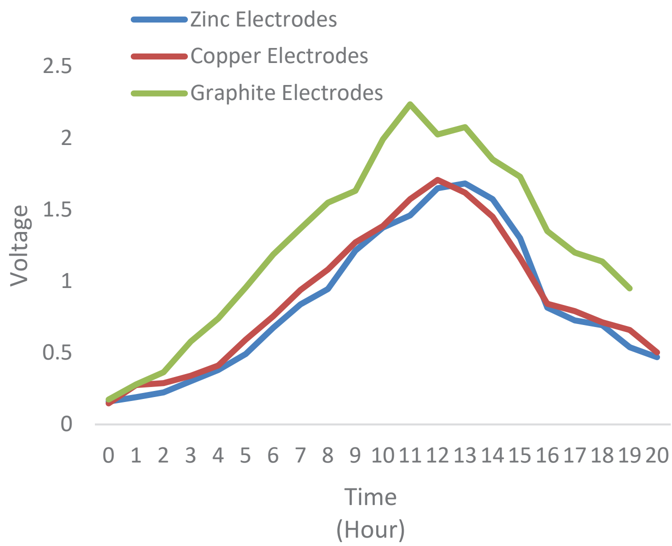


Figure 6: Rice field clay with NaCL

Figure 7 represent the plot of time verses voltage produced using different electrodes for top soil clay as anodic material and KCL Agar Agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 1.647V compared with zinc and copper electrode.

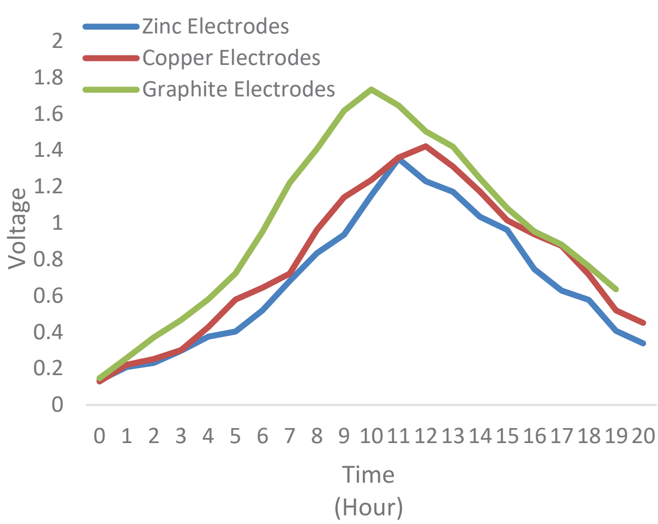


Figure 7: Top soil Clay with KCL salt bridge

Figure 8 represent the plot of time verses voltage produced using different electrodes for top soil clay as anodic material and NaCL Agar Agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 1.938V compared with zinc and copper electrode.

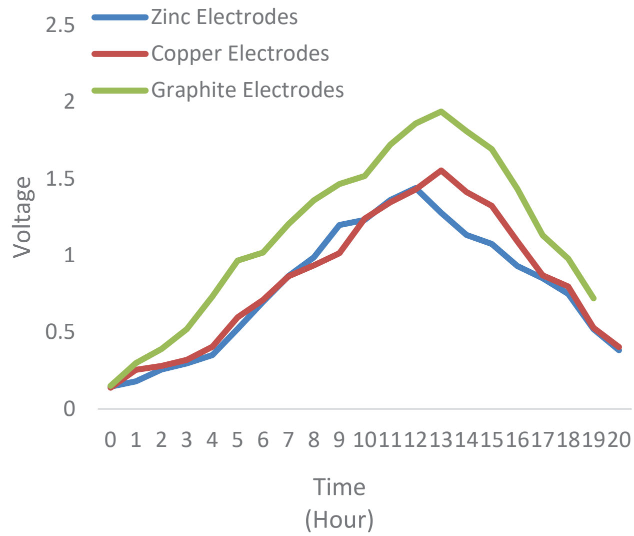


Figure 8: Top Soil with NaCL Salt Bridge

Figure 9 represent the plot of time verses voltage produced using different electrodes for drain water, as anodic material and NaCL agar agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 1.192V compared with zinc and copper electrode.

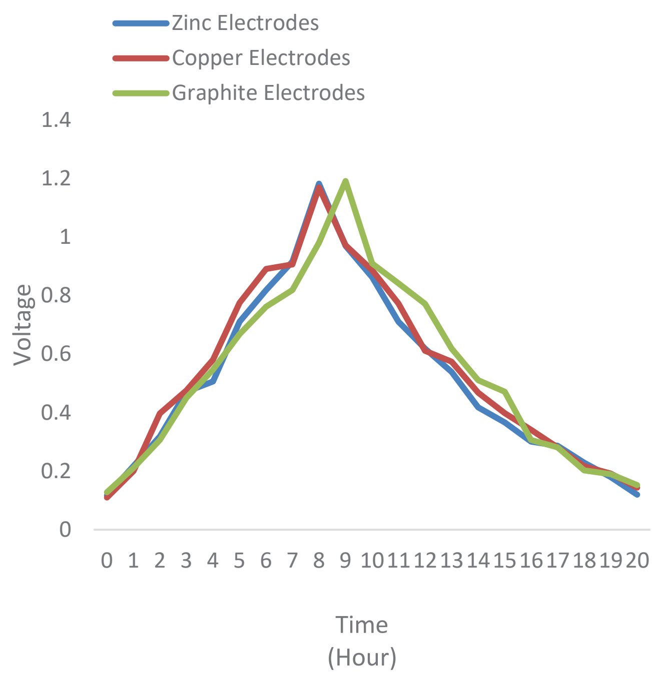


Figure 9: Drain water with NaCL

Figure 10 represent the plot of time verses voltage produced using different electrodes for drain water as anodic material and KCL Agar Agar salt bridge. From this figure we can say graphite electrode can produce highest voltage 1.123V compared with zinc and copper electrode.

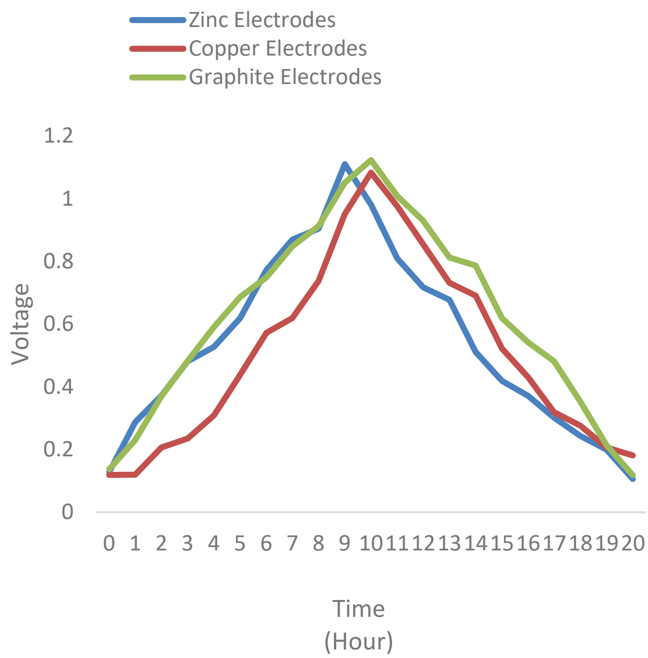


Figure 10: Drain water with KCL

From the experimental results we can say Graphite electrode can produce heights voltage compared with different phenomena as Zinc and Copper electrode. In this research work, we used different types of salt bridge or PEM names NaCL with Agar Agar and KCL with Agar Agar. Experimental result shows that production of voltage is higher when NaCL with Agar Agar salt bridge used instead of KCL with Agar Agar salt bridge. This is because of the higher movability of Na+ ion than the K+ ion. Among the three anodic materials, (rice field clay, top soil clay and drain water) rice field clay produce more voltage than top soil clay and drain water clay because rice field clay contains more microorganism compared with top soil clay and drain water clay.

Environmental Effects of MFC

Microbial Fuel cell is very beneficial for our environment because it can use any bacterial water to generate electricity. It does not emit any kind of emissions, does not remove any contaminants to environment. It can generate electricity at very low cost. Such eco-friendly power plants are very important to meet our needs in the future. For generate electricity, we can collect all the raw material for these power plants for free from our surroundings. If this production process can be started commercially, we can get environmentally friendly electricity at low cost [8, 9].

4. CONCLUSIONS

A study on Microbial Fuel Cell with graphite, copper and zinc electrodes with different anodic materials was conducted in this research. The MFC was fabricated following a proper methodology and several experiments were then conducted to test the effects of different kinds of anodic materials, different Salt Bridge and different electrodes. Types of electrodes for better electricity production was identified, Graphite electrode can produce more electricity. Among three anodic materials rice field clay can produce more electricity because it contains enough microorganism. Among two salt bridge, NaCL with Agar Agar can produce more electricity. Effect of the amount of anodic materials and the volume of the anodic or cathodic chamber is a future plan of this research.

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