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Generation of Electricity from the Dead Sea Mud by Using Microbial Fuel Cell (MFC)

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Abstract

Electricity was generated from the Dead Sea mud through constructing and operating microbial fuel cells(MFC's) that use geobacter, a very efficient type of bacteria. Carbon graphite electrodes were used in these batteries since carbon can withstand tough conditions of high or cold temperature and corrosion. The Dead Sea mud contains organic and inorganic materials that are suitable for geobacteria to decompose through anaerobic respiration.

For the first MFC, 4 electrodes were used in a trial to increase the surface contact area with microorganisms and then to accelerate the transfer of electrons. Electricity was generated and measured as voltage, 0.32 V was recorded on day 6. For the second MFC, 10 electrodes were used and the maximum voltage value was 0.653 V recorded on day 14. For the third MFC, 15 electrodes were used ina trial and the maximum voltage output was 0.74 V measured on day 17.

The second and third batteries were connected in series. For this combination, the measured output voltage was 1.19 V and the efficiency of connection was 86%. Also, the first, second, and third batteries were connected in series. The measured output voltage was 1.45 V and the efficiency of the connection was 88%.

Keywords: Microbial fuel cells, Geobacter, Graphite electrodes, Efficiency, Electricity.

1. Introduction

1.1 Generation of electricity

The Dead Sea mud, as a local source, has been suggested as a new renewable resource for electricity generation. The mud contains many kinds of microorganisms and substrates that undergoes fermentation (anaerobic oxidation). This degradation produces acetate which is converted to carbon dioxide, protons, and electrons.

Geobacter is one type of these organisms. It has the ability to oxidize organic compounds to CO_2 while transferring electrons to electrodes with high efficiency and without need for an exogenous mediator.[1,2]

Inserting a graphite electrode (anode) in the mud can collect the electrons from the outer surface of bacteria. The electrons flow through a copper wire connected to another graphite electrode (cathode) inserted in the sea water. Hence, producing an electrical voltage.

Although microbial fuel cells are unlikely to produce enough electricity to contribute to the national power grid in the short term, the cells may prove feasible in some specific applications that requires low voltages.[3,4]

1.2 Microbial fuel cell (MFC)

A microbial fuel cell (MFC) is a device that converts chemical energy from organic matters into electrical energy (electricity) through microorganisms (bacteria) as biocatalyst. [5]

A typical (MFC) consists of anode and cathode compartments separated by a cation specific membrane. In the anode compartment, fuel is oxidized by micro-organisms, generating electrons and protons. Electrons are transferred to the cathode compartment through an external electric circuit, and the protons are consumed in the cathode compartment, combining with oxygen to form water.

In microbial fuel cell operation, the anode is the terminal electron acceptor recognized by bacteria in the anodic chamber. Therefore, the microbial activity is strongly dependent on the redox potential of the anode.

Microorganisms is placed in a sealed chamber to stop oxygen entering, thus forcing the microorganisms to use anaerobic respiration. [6]

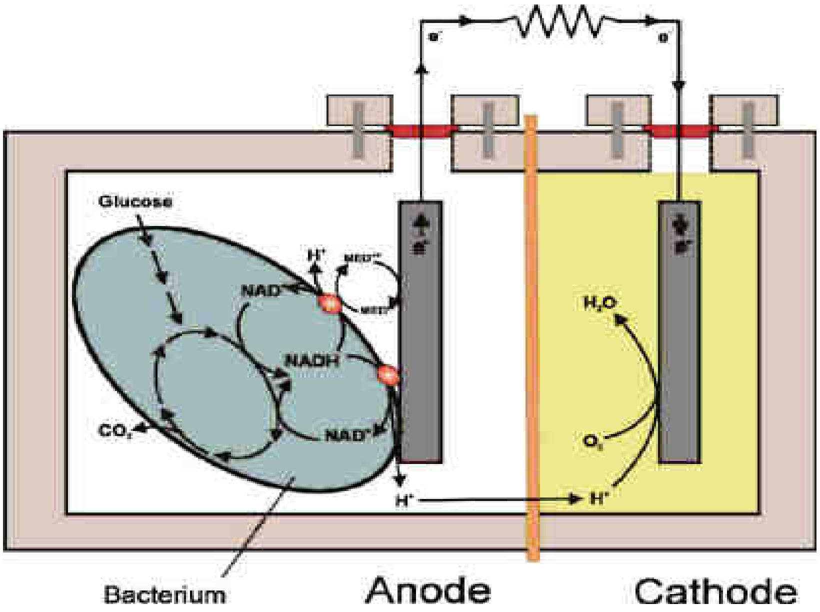

Fig (1-1): Microbial fuel cell (MFC)

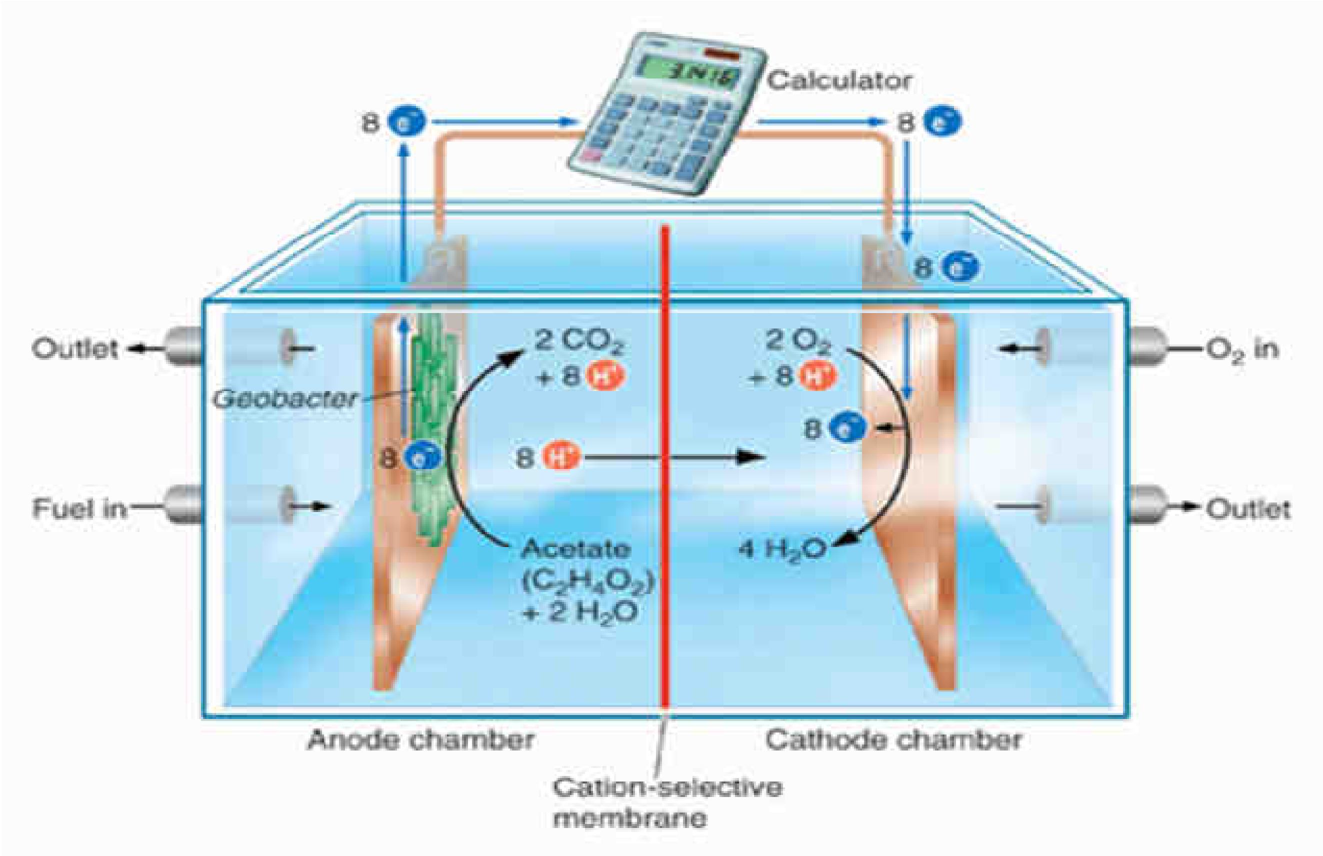

Fig (1-2): Chemical reactions taking place during the operation of MFC

1.3 Factors affecting the performance of MFC

Type of bacteria, type of substrate, material of electrodes, configuration of MFC are important factors that affect the performance of an MFC.

Microorganisms that has high respiration rate and large interact area with the anode can pump much more electrons that flows through the outer electric circuit and produce voltage.

In general, it is easier for the bacteria to decompose simple hydrocarbons than complex organic matters. However, Cellulose is being the hardest substance for any microorganisms to digest.[7]

Normally, both electrodes are made of carbon graphite since it withstand high temperature. The cathode can be made of some specific metals for some applications. For instance, an MFC with a magnesium cathode produces a higher electric voltage in comparison to a carbon graphite.

Increasing the interfacial contact between the anode (positive electrode) and the bacteria will increase the transfer rate of electrons flowing through the electrical circuit and hence producing more power. This can be achieved by increasing the outer surface area of a single electrode (anode), or dispersing several electrodes in the sediments and connecting them successively with a copper wire, so they serve as a positive electrode.

Connecting microbial fuel cells in series will produce a voltage that is, theoretically, equal to the summation voltages of the MFC's.

1.4 Distinctions between electricigens and other microbes employed in MFC

Electricigens are microorganisms that conserve energy to support growth by completely oxidizing organic compounds to CO_2 with direct electron transfer to the anode of MFC

Electricity production with electricigens has a number of advantages. Of great significance is the high coulombic efficiency, more than 90% in comparison to less than 10% for fermentative microorganisms. This results from electricigens being able to completely oxidize organic fuels to carbon dioxide with anode serving as the sole electron acceptor.

Another advantage of electricigen-powered fuel cell is its long-term sustainability. This results from the fact that electricigens conserve part of energy for maintenance and growth. Electricigen-based microbial fuel cell has been run for more than 2 years without a decline in power output.[8]

The ability of electricigens to directly transfer electrons to the anode surface also alleviates the need for unstable, and potentially toxic, mediators. This simplifies the design of microbial fuel cells and lower their costs. Furthermore, this makes it possible to employ electricigen-based fuel cells in open environments.

A number of electricigens are available in pure culture. The most heavily studied are electricigens in the family ***Geobacteraceae.***

Geobacter is a very small organism(about 1 µm), has a rod shape with flagellate. It is anaerobic respiration bacteria, and has capabilities for environment bioremediation.

It can destroy petroleum contaminant in polluted ground water by oxidizing this compounds to harmless carbon dioxide, and it is useful for removing radioactive metal contaminant from ground water.[9, 10]

Fig (1-4): Geobacter shape

2. Procedure

2.a First battery

1- A container was half-filled with Dead Sea mud.
2- Four carbon electrodes(as anode) were connected with a copper wire then were buried in the mud.

3- Sea water was poured over the mud.

4- Other four carbon electrodes (as cathode) were connected with another copper wire and were immersed in sea water. The top of electrodes were exposed to air

5- The other ends of copper wires were connected to a voltmeter.

6- The output voltage reading was periodically recorded.

2.b Second battery

1- Ten carbon electrodes were used to obtain a larger surface area than in trail one.

2- The same procedure applied in trail one was repeated.

2.c Third battery

1- Fifteen carbon electrodes were used to obtain a larger surface area than in trail Two.

2- The same procedure applied in trail one and two was repeated.

2.d Second and third batteries were connected in series.

2.e First, second, and third batteries were connected in series.

3. Results

Table 3.1: Voltage output from battery one

Days	1	4	6	11	15
Reading (v)	0	0.3	0.32	0.32	0.262

Table 3.2: Voltage output from battery two

Days	1	3	5	8	15	17
Reading (v)	0.5	0.519	0.589	0.604	0.623	0.653

Table 3.3: Voltage output from battery three

Days	1	3	5	7	12	14
Reading (v)	0.524	0.567	0.62	0.65	0.71	0.74

Table 3.4: Voltage output from battery two and three in series after reaching maximum value in each trail

	Trail two	Trail three	Actual value in series	Theoretical value in series
Reading (V)	0.653	0.74	1.192	1.393

Table 3.5: Voltage output from battery one, two and three in series after reaching Maximum value in each trail

	Trail one	Trail two	Trail three	Actual value in series	Theoretical value in series
Reading (v)	0.26	0.653	0.74	1.451	1.653

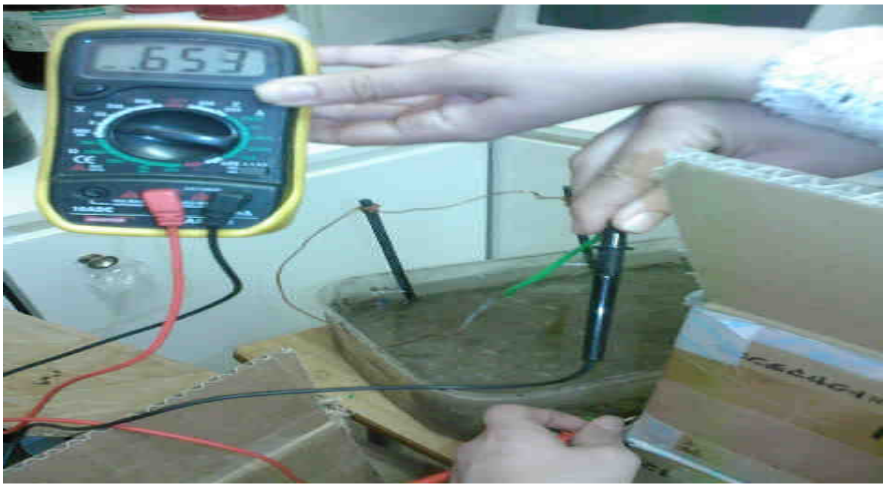

Fig (3-1): maximum voltage value reached in trail two

Fig(3-2): maximum voltage value reached in trail three

Fig(3-3): Voltage reading for trail two and three connected in series

Fig(3-4): Voltage reading for trail one, two, and three connected in series

4. Discussions

For the first battery that has 4 electrodes, the maximum voltage (0.32 V) wasreached after 6 days of operation. It remained constant until day 11, then it began to decline. This decline is due to consumption of fuel by geobacter, or decrease in metabolism activity of geobacter, since the operation temperature has been dropped during the experiment.

For the second battery that has 10 electrodes, the maximum voltage reached was 0.653 V after 17 days. However, for the third battery that has 15 electrodes, the maximum voltage reached was 0.74 V after 14 days. Assuming the same surface area for an electrode, the equivalent voltage per electrode for the second and third battery were 0.065 V and 0.049 V, successively. Therefore, the efficiency of configuration is higher for the second battery.

For the second and third batteries connected in series, the theoretical voltage is the sum of each individual battery(0.653V + 0.74 V = 1.393 V). The actual (measured) voltage for this combination was 1.192 V, so the efficiency of connection was 1.192/1.393 = 86%

For the first, second, and third batteries in series, the theoretical voltage value was 1.653 V. The actual voltage value was 1.451 V, therefore, the efficiency of this connection was 88%.

5. Conclusions

1. Constructing and operating MFC's from the Dead Sea mud, by using geobacteria, would give moderately higher voltage output in comparison to other MFC's. Moreover, the stability of voltage output is more since geobacteria reserves part of energy for metabolism and growth.

2. Increasing the surface area of electrodes should be done up to an optimum value, where the equivalent voltage output per electrode is highest. This instruct us that we should not distribute many electrodes in a certain volume of mud.

3. Connecting MFC's in series is a good technique for increasing the total voltage output even so the efficiency of connection is lower than 90%.

4. At stable normal weather conditions at which the temperature does not deviates steeply, the voltage output would be almost constant and stable to a long period of time.

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