BIOELECTRICITY PRODUCTION FROM WASTEWATER USING MICROBIAL FUEL CELL (MFC)

Chonde Sonal G\(^1\), Mishra A. S.\(^2\) and Raut P. D\(^3\).

\(^1,\(^2,\(^3\)\) Department of Environmental Science, Shivaji University, Kolhapur- 416 004- INDIA

ABSTRACT

Renewable source of energy is a need of developing countries to fulfill their present and future energy requirement. Electrical energy demand up to some extent can be fulfilled by Microbial Fuel Cell (MFC). Microbial Fuel Cell technology represents a new form of renewable energy by generating electricity from waste. In present study the feasibility and potential of bioelectricity production from sewage wastewater was observed. The sewage wastewater showed bioelectricity production up to 594 mV with COD removal of 60%. Bioelectricity production from growth enhancer like glucose and mediator i.e. methyl orange was also observed. Sewage wastewater efficiently produces bioelectricity and this also helpful to reduce wastewater pollution load.

Key words: - Bioelectricity production, Wastewater treatment, Microbial fuel cell.

INTRODUCTION

Bio-energy is renewable energy available from materials derived from biological sources. Biomass is any organic material which has stored sunlight in the form of chemical energy. As a fuel it may include wood waste, straw, manure, sugarcane and many other byproducts from a variety of agricultural processes. Wastewater generation create a big problem to environment. However wastewater can act as a source of energy by producing electricity from it. The idea of using microbial cells in an attempt to produce electricity was first conceived at the turn of the nineteenth century. M.C. Potter was the first to perform work on the subject in 1911. A professor of botany at the University of Durham, Potter managed to generate electricity from E. coli, but the work was not to receive any major coverage. In 1931, however, Barnet Cohen drew more attention to the area when he created a number of microbial half fuel cells that, when connected in series, were capable of producing over 35 volts, though only with a current of 2 milliamps.

The study of MFC was firstly performed by M.C Potter in 1911 to generate electricity from E.Coli. Hydrogen can be used in the MFC which is produced by the fermentation of glucose by Clostridium butyricum as the reactant at the anode of the hydrogen and air fuel cell [1],the current
design and concept of MFC is an ideal design to produce bioelectricity through microorganisms [2]. It is now known that the electricity can be produced directly from the degradation of organic matter in the microbial fuel cell. Sugar when consumed by the microorganisms under aerobic condition they produce carbon dioxide, water, but when oxygen is not present the end product is carbon dioxide, protons and electrons as described below.

\[
\text{C}_{12}\text{H}_{22}\text{O}_{11} + 13\text{H}_2\text{O} \rightarrow 12\text{CO}_2 + 48\text{H}^+ + 48\text{e}^-
\]

The experimental microbial cells were electrochemically inactive. So the electron transfer from microbial cells to the electrode was facilitated by mediators such as methyl orange. Microbial fuel cells use inorganic mediators to tap into the electron transport chain of cells and channel electrons produced. The mediator crosses the outer cell lipid membranes and bacterial outer membrane; then, it begins to liberate electrons from the electron transport chain that normally would be taken up by oxygen or other intermediates. The now-reduced mediator exits the cell laden with electrons that it shuttles to an electrode where it deposits them; this electrode becomes the electro-generic anode (negatively charged electrode). The release of the electrons means that the mediator returns to its original oxidized state ready to repeat the process. This can only happen under anaerobic conditions; if oxygen is present, it will collect all the electrons as it has greater electronegativity than mediators. In a 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. A number of mediators have been suggested for use in microbial fuel cells. These include natural red, methylene blue, methyl orange, thiamine, and resorufin. Among this the Methyl orange is used in this experiment.

Microbial fuel cells are not new – the concept of using microorganisms as catalysts in fuel cells was explored from the 1970s [2], and microbial fuel cells. Treating domestic wastewater was presented in 1991 [3]. A microbial fuel cell (MFC) is a device that uses bacteria to catalyze the conversion of organic matter into electricity [2]. Microbial fuel cell treating domestic wastewaters were presented in 1991[3]. A microbial fuel cell (MFC) is a device that uses bacteria to catalyze the conversion of organic matter into electricity [2], [4], [5], [6], [7]. Microbial fuel cell (MFC) employing low-cost materials (non-coated plain graphite electrodes) without any toxic mediators (aerated cathode and mediator less anode) was evaluated under acidophilic (anode pH of 5.5) conditions.

The function and efficiency of MFC with respect to power generation are generally dependent on factors such as nature of carbon source used [8], fuel cell configuration, dimension and volume, nature and type of electrode [9], electron acceptors (mediators) present in the cathode chamber, electrolyte used, operating temperature, culture used in the anode chamber and nature of proton exchange membrane [10].

**MATERIALS AND METHODS**

**MATERIALS:**
**Wastewater Samples:**
Wastewater was collected from various sources which are consisting of organic materials. For the better efficiency of MFC it is necessary that there should be sufficient amount of organic load in the wastewater so as to degrade it by using microorganisms in the MFC unit.

**Sewage wastewater from Jayanti Nallah, Udyam Nagar:**
Sewage water has good potential of electricity production and simultaneous reduction in the COD level of wastewater as it consists of natural micro flora.
Biomaterial for MFC:
Bio waste material used for the bioelectricity production is Cow dung. Cow dung consists of thermopiles microorganisms like Clostridium cellulosi sp. Clostridium cellulofermentans sp. are helpful in the degradation of the cellulose and other organic materials.

Apparatus and microbial culture used for Experiment:

Electrodes: In Microbial Fuel Cells, the anode is the negative terminal, while the cathode is the positive terminal. This is due to the convention which states that all anodes are terminals that undergo oxidation or release of electrons, and all cathodes are terminals which undergo reduction. Current departs at a cathode and enters a device at the anode, independent of the polarity of the voltage of the device. Electrode used in this experiment is cylindrical in shape having 5cm in length and 1cm in diameter, with a point at a top for external connection.

MFC Assembly: MFC assembly consists of two containers connected with the external circuit and proton pump. External circuit is completed with a copper wire. Containers are of 500ml each for cathode and anode. Proton pumps are molded hollow glass tube. This glass tube is field with the Agar gel so as to provide a channel for flow of electrons through the electrodes.

Digital Multi meter: The digital multi meter is used to measure the voltage in millivolts and ampere in miliamperes generated in the MFC unit.

Methodology:
The bioelectricity production was observed by following three steps i.e. Preparation of MFC assembly, Preparation of samples and Measurement of electricity produced per day. Measurement of COD removal is observed by carrying out COD analysis before and after the treatment of wastewater in MFC.

Preparation of MFC assembly.
Preparation of assembly requires two containers of 500 ml, copper wire, proton pump, electrodes (cathode and anode) and m-seal. Cathode and anodes are fixed to the cap of the container properly in erect position. Glass tube is then filled with a agar gel prepared aseptically by using 2% agar powder. Glass tube of proton pump is inserted to the half of the size of electrode in the container at both sides. The prepared sample of proton acceptor and waste sample is then filled in the cathode and anode respectively. Only 400 ml of sample are filled so as to keep air gap for the CO₂ produced in the container.
PREPARATION OF SAMPLES

Proton acceptor: The proton acceptor used in this experiment is 400ml 1N Potassium ferricyanide.

Sewage sample Set

Sewage sample is used directly for the experiment just by varying the pH to pH-6, pH-7, and pH-8.

Measurement of the electricity produced.

Measurement of electricity produced is done form next day of the inoculation for each set of MFC. Electricity is measured by digital multi meter in the units of millivolts and milliampere to calculate the voltage and current respectively. The monitoring of MFC is carried out for the 14 days for each set.

OBSERVATIONS

The experiment of bioelectricity was carried out for 336 hours i.e. 14 days in anaerobic conditions. The experiment showed bioelectricity production from sewage water which is composed of naturally occurring microorganisms and organic load from domestic, commercial and bio waste materials such as cow dung, growth enhancers like glucose when added to enhance the growth of microorganisms in the experiment and mediators such as methyl orange which was added to enhance the transport of electrons from cell to electrodes in MFC. In the sample of different sets there was production of electricity due to fermentation of organic materials in the anaerobic condition when incubated at room temperature. According to table given bellow it is seen that the highest efficiency to produce the electricity was from sewage wastewater with natural microbial cultures.

BIOELECTRICITY PRODUCED FROM SEWAGE SAMPLE

**Table 1.** Electricity in mill volts obtained from sewage wastewater sample.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Mill volts (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hrs 24 48 72 96 120 144 168 192 216 240 264 288 312 336</td>
</tr>
<tr>
<td>1</td>
<td>S1 198 229 463 584 590 615 619 661 674 658 638 630 536 490</td>
</tr>
<tr>
<td>2</td>
<td>S2 400 569 589 624 658 740 816 808 797 784 750 721 675 651</td>
</tr>
<tr>
<td>3</td>
<td>S3 441 517 675 759 807 818 826 807 803 799 770 754 601 575</td>
</tr>
</tbody>
</table>

**Table 2.** Electricity in milliampere obtained from sewage wastewater.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Hrs 24 48 72 96 120 144 168 192 216 240 264 288 312 336</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 0.1 0.03 0.06 0.08 0.11 0.14 0.17 0.19 0.21 0.24 0.24 0.21 0.18 0.18</td>
</tr>
<tr>
<td>2</td>
<td>S2 0.04 0.06 0.11 0.14 0.17 0.20 0.24 0.28 0.35 0.38 0.39 0.30 0.28 0.21</td>
</tr>
<tr>
<td>3</td>
<td>S3 0.06 0.10 0.12 0.21 0.21 0.22 0.41 0.44 0.45 0.50 0.54 0.59 0.47 0.41</td>
</tr>
</tbody>
</table>

- S1: Sample with pH 6
- S2: Sample with pH 7
- S3: Sample with pH 8

All the samples showed variation in electricity production as per their potential and ability of microorganisms to degrade the organic materials. As well as COD of wastewater was reduced. The graphical representation boldly shows the adaptability of microorganisms in the environment of
MFC. Some of the microorganisms showed delay in log phase, increasing their lag phase for about 7-8 days, whereas some microorganisms were best suited for that environment and showed rapid degradation of electricity production in 3-4 days.

The use of growth enhancers were done for enhancement of electricity production but the adaptability of microorganisms were very slow and showed late production of electricity in MFC. Use of mediators was carried out for increasing the rate of electron transport in Electron Transport Chain (ETC) in MFC; this resulted in increase in electricity generation but took long time for adaptability of microorganisms in MFC. The observations recorded on each days of experiment in tabular form are given below with their graphs.

**BIOELECTRICITY PRODUCED FROM SEWAGE SAMPLE**

**Graph 1.** Electricity in millivolts obtained from sewage wastewater sample

**Graph 2.** Electricity in milliampere obtained from sewage wastewater sample

- S1: Sample with pH 6
- S2: Sample with pH 7
- S3: Sample with pH
Table 3: percent (%) removal of COD while bioelectricity production from sewage wastewater samples

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Wastewater sample</th>
<th>Initial COD in mg/lit.</th>
<th>Final COD in mg/lit.</th>
<th>percent (%) removal of COD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>590</td>
<td>390</td>
<td>34%</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>590</td>
<td>450</td>
<td>24%</td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>590</td>
<td>240</td>
<td>60%</td>
</tr>
</tbody>
</table>

Graph 3: percent (%) removal of COD while bioelectricity production from sewage wastewater samples

RESULT AND DISCUSSION

Bioelectricity production was carried using microbial fuel cell using various domestic sewage water and cow dung. These waste materials were checked for their potential to generate bioelectricity under anaerobic condition using natural and additionally inoculated microbial cultures.

The bioelectricity generation was observed in the sewage wastewater sample, the pH of sample was adjusted to pH 6, pH 7 and pH 8. The highest electricity generation was observed with pH 8 with 60% COD removal (Graph 3). The experiment was performed at room temperature. The MFC was continuously monitored during experiments and readings were taken after each 24 hours of inoculation, inoculation time was considered as time ‘0’ and after 24 hours first reading was taken. Fuel cell was operated for 336 hours i.e. 14 days for each set of samples. The experimental data showed the feasibility of electricity generation from each wastewater as per there potential to degrade the organic matter in the MFC in the given room temperature.

Hence all sample showed the variation in electricity generation due to difference in potential of wastewater. The highest electricity generation in the sample S I was recorded after 216 hours of inoculation i.e. 674 mV and further it started decreasing gradually up to the 630 mV in next 120 hours. Whereas the highest current generation in sample S I was recorded at the same time i.e. after 261 hours and similarly like voltage, ampere also showed the decrease in current production the initial COD of sample was 590 mg/lit. And after treatment of wastewater in MFC during 14 days it was reduced to 390 mg/lit i.e. 34% reduction was observed. In sample S II there was good current
and voltage generation i.e. 0.39 mA and 816 mV respectively, which was recorded as maximum in 216 hours same as SI, the COD removal in sample S II was 24% reducing it to 240mg/lit. Sample S III showed the highest current and voltage generation as compared to S I and S II at pH 8 i.e. 0.59 mA and 826 mV in 216 hours. The reading obtained in this experiment was more than Barua[11].ie. 147 mV. The COD reduction of sample was only 60% i.e. 450mg/lit.

CONCLUSION

Present study focus on waste minimization as production of bioelectricity from sewage wastewater sample. The assembly of microbial fuel cell was run for 336 hours i.e. 14days at room temperature, and it was found that most of the set was capable generating bioelectricity in 3 to 4 days. The reason behind taking these days for starting degradation is nothing but the bacteria and fungus were in lag phase generating potential in them to adapt the environment. While the microorganisms from cow dung this was artificially added to sewage wastewater play an important role in degrading the organic matter. As it degrades organic matter so it reduces COD of waste water up to 60%. Which indicate that this method not only produce electricity but also reduce COD load of sewage wastewater. It was found to be very effective method as it minimizes the pollution load. It is concluded that bioelectricity can be produced from sewage wastewater sample and it also controls the water pollution problem.

ACKNOWLEDGMENT

Authors are thankful to authorities of Shivaji University, Kolhapur and Department of Environmental Science, Shivaji University, Kolhapur for experimental purpose.

REFERENCES

