IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
ISSN: 2278-1676 Volume 4, Issue 2 (Jan. - Feb. 2013), PP 47-51
www.iosrjournals.org

Utilization of Waste Water and Production of Electricity Using Non Mediated Microbial Fuel Cell

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***Abstract**: Renewable energy will one day be a large portion of global energy production and usage. Microbial fuel cell (MFC) technology represents a new form of renewable energy by generating electricity from what would otherwise be considered as waste. According to this technology it uses the bacterium already present in wastewater as catalysts for generating electricity while simultaneously treating wastewater. Application of microbial fuel cell (MFC) for wastewater treatment is an attractive alternative to reduce the cost of treatment of waste water and generation of electricity.*

Studies were conducted in the laboratory scale using membrane less MFCs for treatment of industrial wastewater. These MFCs performed well for COD and BOD removal from the wastewater, demonstrating the effectiveness of this device for wastewater treatment with COD and BOD removal efficiency about 90%.

Using graphite electrodes in the MFCs the electricity was generated and the observations were made. Thus, power can be produced from membrane less MFC using organic matter from wastewater as source of energy. This technology of generation of electricity using MFCs has leaded a great path of applicability from laboratory scale to industrial scale.

***Key Words**:Non mediated MFC, Waste water, graphite electrodes, Indigenous microorganisms, Microbial database. Microbial kinetics, resistance, power generation*

I. Introduction

The high energy requirement of conventional sewage treatment systems are demanding for the alternative treatment technology which will require less energy for its efficient operation and recover useful energy to make this operation sustainable. In past two decade high rate anaerobic processes are finding increasing application for the treatment of domestic as well as industrial wastewaters. In addition, due to global environmental concerns and energy insecurity there is emergent interest to find out sustainable and clean energy source with minimal or zero use of hydrocarbons. Microbial fuel cells, used for wastewater treatment, are capable to provide clean energy, apart from effective treatment of wastewater. The enriched microbial culture in these MFCs have capabilities to use organic matter present in the wastewater as energy source and produce electrons and protons, through which electricity can be recovered.

Microbial fuel cell (MFC) is a device which converts chemical energy to electrical energy during substrate oxidation with the help of microorganisms.

Microbial fuel cell is made up of two compartments, anode and cathode, separated with proton/cation exchange membrane. Microorganisms oxidize the substrate and produce electrons and protons in the anode chamber of MFC. Electrons collected on the anode are transported to cathode by external circuit and protons are transferred through the membrane internally.

In a mediator-less MFC, the membrane separates the anode from the cathode and the membrane functions as an electrolyte that plays the role of an electronic insulator and allows protons to move through. These functions of the membrane are believed to be indispensable in the operation of an MFC. Application of MFCs for wastewater treatment is very attractive due to energy recovery from waste as well as reducing production of excess sludge, disposal of which is very expensive. It is expected that this process would generate much less excess sludge than a conventional activated sludge process, since the major part of energy available from the oxidation of the organic contaminants is converted to electricity, and the remaining energy is used for microbial growth. In this study attempts were made to develop a mediator-less MFC without using a membrane. Membranes are the major cost for the construction of an MFC. A membrane-less MFC could improve the economic feasibility of the process to treat wastewater by reducing not only the capital investment but also the operation cost for the membrane maintenance. In this study a fuel cell was used to treat wastewater in a continuous mode.

Objectives Of The Project

➔ Collection of waste water from various sources.
➔ Construction and design of the non-mediated Microbial Fuel Cell.

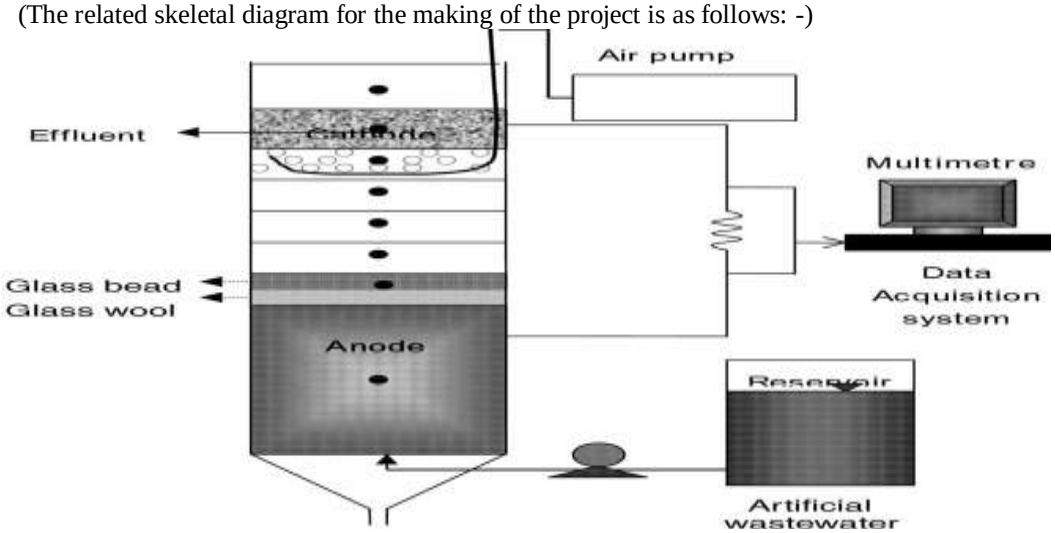
➔ Comparative analysis between the various sources.
➔ Isolation and identification of indigenous micro-organisms responsible for generating electricity and thus creating a database.
➔ Scanning Electron Micrograph of the biofilm growth on the surface of the electrodes**.**
➔ Optimizing the process for generation of electricity.
➔ A process involving lab scale to semi-pilot industrial scale operation for commercial utilization of waste water and generation of electricity.

SOURCES
The various sources used in the study of production of electricity from waste water using membrane-less MFCs are as follows:-
(i) Sewage water
(ii) Domestic waste water
(iii) Industrial waste water
Using the sewage water sources the experiment was carried out at laboratory scale and the various observations was noted down.

II. Construction

➔The microbial fuel cell chamber was made of plastic bottles.
➔The anode was at the bottom, and the cathode at the top of cylinder-shaped reactor.
➔ The anode and the cathode chamber were separated with the help of Glass wool and glass Bead .
➔Graphite plates were used as the anode, and the cathode of the same material.
➔The fuel (waste water) was supplied to the bottom of the anode, which was stored in the Reservoirs and was pumped in to the anode.
➔The cathode compartment at the top was left for the effluents.
➔The electrodes were connected with platinum wire to the supplied load and a multimeter.
➔The cathode compartment was aerated at various rates with the help of air-pumps, for the Cathode reaction.
➔For accelerating the cathode reaction we used saline water at the bottom of the cathode.

(The related skeletal diagram for the making of the project is as follows: -)



WASTE TAKEN TO SEWAGE TREATMENT PLANT

(SKELETAL REPRESENTATION OF THE USE OF MFC FOR ELECTRICITY PRODUCTION)

(PICTORIAL REPRESENTATION OF MFCs USED IN ELECTRICITY PRODUCTION)

PROCEDURE

➔The waste water was fed into the anode compartment from the waste water reservoir.
➔Microorganisms present in the waste water oxidize the substrate and produce electrons and protons in the anode chamber of MFC.
➔Then the metal reducing bacteria present in the waste water directly transfer electrons to electrodes (anode), using electrochemically active redox enzymes.
➔ Electrons are transferred to the cathode compartment through the external circuit, and the protons through the membrane (Glass wool & Glass bead).
➔The cathode chamber is supplied with oxygen (air) from the air pump.
➔ Electrons and protons are consumed in the cathode compartment reducing oxygen to water.
➔The reactions taking place at the cathode chamber is as follows

$4H+ + 4e- + O_2 \rightarrow 2H_2O$ or
$4H+ + 4e- + 2O_2 \rightarrow 2H_2O_2$ (oxygen in excess)

(The above carried process is detailed described in the figure below.)

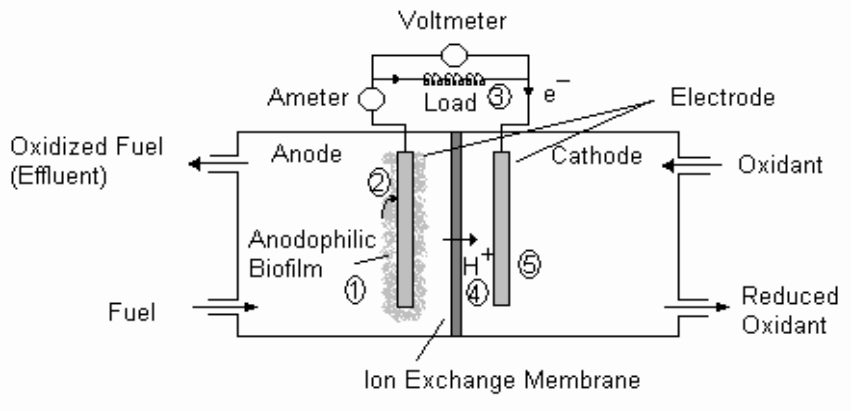


Figure 1: Mediator less Microbial Fuel Cell

(1) Oxidation of Fuel, (2) Electron transfer from the microbial cells to the electrode, (3) Electric load in the circuit, (4) Proton supply into the cathode compartment, (5) Oxygen supply and reduction at the cathode.

➔Due to the potential difference maintained at both anode and cathode chambers, and due to the flow of electrons through the external circuit, electricity is produced which is collected across the load.
➔The effluent and the subsequent waste water from the chambers are being drained out and is sent to the sewage treatment plant for further treatment of waste water.
➔Again fresh waste water (substrate) is supplied to the anode chamber from the reservoir. And, thus the process continues.
➔It was found that a mixed culture of substrates (Industrial waste + Domestic waste) generated a current that was six fold higher than that generated by a pure culture.

III. Results

➔ After inoculation and feed application in continuous mode, increase in current was observed in the MFCs with duration of operation.
➔The potential was measured using a digital multimeter and converted to power according to

$P = iV$

Where
P = power (W),
i = current (A),
V = voltage (V).

➔ The COD removal efficiency after two weeks of continuous operation was greater than 80% with average COD removal efficiency of 86.5% and that of BOD was 88.46%.
➔ The COD and BOD removal efficiencies observed in the MFCs demonstrated its ability to be used as the effective wastewater treatment process.
➔ The cathode compartment of the MFCs was aerated by supplying compressed air.
➔The DO (dissolved oxygen) in the effluent observed was in the range 3.75 to 4.88 mg/L.

➔ Even with continuous aeration, the lower values of DO in the cathode compartment and in the effluent were observed due to utilization of DO for the cathode reaction, where oxygen is reduced and thus due to the decreased value of DO it showed higher BOD and COD removal efficiency.
➔The observation was made across the duration of operation as shown in the table

Days	Current (mA)	Voltage (V)	Resistance (ohm)	Power (mW/m^2)	Joule (J/d)	HRT (hrs)
0-15	0.091 (±0.011)	0.116 (±0.007)	100	2.29 (±0.39)	0.92	24
16-35	0.175 (±0.007)	0.188 (±0.003)	10	6.73 (±0.44)	2.72	24
36-55	0.148 (±0.007)	0.175 (±0.007)	25	5.46 (±0.39)	2.20	24
56-78	0.121 (±0.008)	0.151 (±0.005)	50	3.96 (±0.46)	1.597	24

SCOPE OF THE PROJECT

➔Microbial fuel cells have a number of potential uses. The most readily apparent is harvesting electricity produced for use as a power source. Virtually any organic material could be used to feed the fuel cell, including coupling cells to wastewater treatment plants. Bacteria would consume waste material from the water and produce supplementary power for the plant. The gains to be made from doing this are that MFCs are a very clean and efficient method of energy production. Chemical processing wastewater and designed synthetic wastewater have been used to produce bioelectricity in dual and single chambered mediator less MFCs (non-coated graphite electrodes) apart from wastewater treatment. Since the current generated from a microbial fuel cell is directly proportional to the energy content of wastewater used as the fuel, **an MFC can be used to measure the solute concentration of wastewater (i.e. as a biosensor system).**

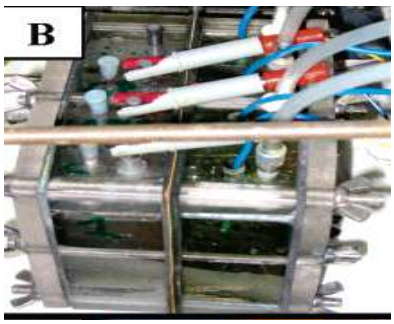
➔The strength of wastewater is commonly evaluated as biochemical oxygen demand (BOD) values. BOD values are determined incubating samples for 5 days with proper source of microbes; usually activate sludge collected from sewage works. When BOD values are used as a real time control parameter, 5 days' incubation is too long, **thus an MFC-type BOD sensor can be used to measure real time BOD values.**

➔**A number of companies have emerged to commercialize Microbial Fuel Cells**. These companies have attempted to tap into both the remediation and electricity generating aspects of the technologies.

➔**This technique of electricity production and waste water treatment using microbial fuel cells can further be researched to be of great use at industrial scale.**

➔**Many MFCs can be configured into one unit for more power generation and to increase the efficiency and effectiveness of the proposed project.**

The related fig. is as follows:-



IV. Conclusion

Performance of the mediator less microbial fuel cell demonstrated its effectiveness for the treatment of wastewater with COD and BOD removal about 90%. The electricity can be recovered from the MFC during treatment of wastewater. Increase in current and voltage production was observed with decrease in resistance between the electrodes, reducing the substrate diffusion limitations.

The production of current in the MFC depends on several factors. With continuous improvements in microbial fuel cell, it may be possible to increase power generation and reduce production and operating cost of MFCs and the treatment of waste water. **Thus, the combination of wastewater treatment along with electricity production paved a great way in compensating the cost of wastewater treatment, thus making it sustainable.**

And the further studies would help in the large scale use of this technique in industries.

References

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