Utilization of microbial fuel cells (MFCs) for generating Bioelectricity in wastewater treatment plant

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Abstract:**Production of energy resource while minimizing the waste is one of the best ways for sustainable energy resource management practices.Application of Microbial Fuel Cells (MFCs) is the innovative techniques in wastewater treatment with production of sustainable clean energy. Theincrease in energy demand can be fulfilled by Microbial Fuel Cell (MFC) infuture. In recent years, researchers have shown that MFCs used for producing electricityfrom water containing glucose, acetate or lactate. Studies onelectricity generation using organic matter from the wastewater as substrateare in progress. Waste water is a inexpensive and fairly huge source ofelectrons for microbes able to produce electrical current in external cell. Theincreasing development in microbial electrochemical technologies in microbialfuel cells are diverse platform for ensuing sustainable energy and chemical production technologies. It is the contemporary study for the production ofsustainable energy source from waste water. Microbial fuel cells (MFCs) meana new abiding, economical, available and eco friendly proposal to waste watertreatment with creation of sustainable energy.******Keywords: Shell and helical coil heat exchanger, Pin fin arrangement***

I. INTRODUCTION

Many researches in the fields of Biological and Environmental Engineering exposed a real opportunities to pertain microbial fuel cell technology to wastewater treatment. Stimulating their work based on economic, environmental, and social needs for sustainable wastewater treatment systems and renewable energy. This cells are directly convert chemical energy to electricity through catalytic activities of microorganisms, and electricity has been generated in MFCs form various organic compounds including Carbohydrates, proteins and fatty acids. The major benefits of MFCs over conventional fuel cells such as hydrogen and methanol fuel cell are in various range of organic substance used as fuels.

A microbial fuel cell (MFC) is a device that transform chemical energy to electrical energy with the help of microorganisms. The study of MFC was firstly performed by M.C Potter in 1911 to generate electricity from E.Coli. Sugar when consumed by the microorganisms under aerobic condition they releasing the carbon dioxide and water, but when oxygen is not present the end product is carbon dioxide, protons and electrons as described below.

$$\mathbf{C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^-}$$

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. But the mediators MFC not needed mediator also it will uses electrochemically active bacteria and fungus for transferring electrons to electrode (electrons are carried directly from the respiratory enzyme to the electrode).

1.1 Aim and Objectives

1. Removal of undigested organic matter using microbes.
2. Generation of electricity, fuels and chemicals in the waste water.
3. Traditional method requires more electrical energy to digest the dissolved matter
4. The only technology has capable of extracting the energy from wastewater on a large scale.

II. MATERAIALS AND METHODS

Many microorganisms possess the ability to transfer the electrons derived from the metabolism of organic matter to the anode. A list of them is shown in Table 1.1 together with their substrates.

Table.1 List of materials used

Items	Materials
Anode	Graphite plate, Graphite felt, carbon paper, carbon cloth
Cathode	Graphite plate, Graphite felt, carbon paper, carbon cloth
Anodic chamber	Acrylic sheet
Cathodic chamber	Acrylic sheet
Proton exchange system	Nafion membrane

2.1 Collection of wastewater

Dairy waste waters are generally having higher organic content. If it is discharged without proper treatment severely pollute receiving water bodies and cause serious environmental problems. The sample is collected from the dairy factory which is located at oddanchatram.

Figure.1. Dairy Wastewater

2.1.1 MFC Chamber

An MFC chamber is a two chambered rectangular shape made from acrylic sheet with elastic tape. Dimensions are (18*10.5*10.5* cm) with a total volume 1500 ml and working volume of 750 ml from one side.

2.1.2 Electrodes

Electrode is the conducting materials which perform in transfer of electron from anode chamber causing useful flow of electron. According to surface area and type material performance of electrode varies(5).

In MFC, the substrate is oxidized at the anode cause generation of carbon dioxide, protons and electrons, which are transferred to the electrode. Microorganisms act as the biocatalysts in an analogy to chemical fuel cell.

2.1.3 Electrode materials

The electrodes are designed based on the size of the MFC chamber these electrodes are located inside the chamber both anode and cathode. MFC anode material are made from Graphite felt and cathode material are made from Graphite flat plate .Graphite felt is the most stable from of a carbon under standard condition. Graphite is an electric conductor. It can conduct electricity with the plane of layers. Electrolyte solution used in MFCs Potassium sulphate, Potassium dihydrogen phosphate, Potassium permanganate.

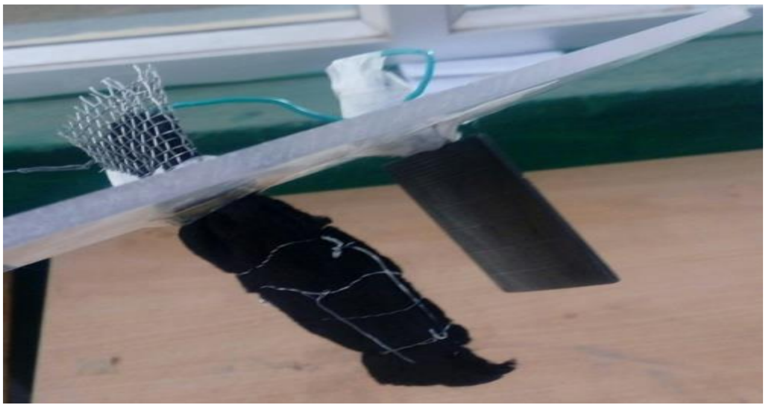

Figure.2. Electrode Material

2.1.4 Proton exchange membrane

Proton exchange membrane named as the polymer electrolyte membrane fuel cell being made for transporting the stationary fuel cell applications and portable fuel cell applications. It is a semi permeable membrane formed from ionomers and assigned to conduct protons when act as an electronic insulator and reactant barrier, e.g. oxygen and hydrogen gas. PEMs are primarily characterized by proton conductivity, methanol permeability and thermal stability.

2.1.5 Multimeter

The device is measurement of current in the electrical circuit. Current (I) measurements are recorded using a Digital Multimeter during standardization of MFC with anaerobically digested wastewater by connecting with external circuit.

2.2 Working process MFC

The MFC for wastewater treatment is made to create a non mixed culture of microbes in the anode chamber. These MFCs conduct (treat) organic substrates (in wastewater) through oxidation reduction reactions and conduct electrons through an electric circuit for the production of electric power. The oxidation reactions occur in the anode compartment where bacteria metabolize organic substrates to generate energy for cell maintenance and biomass synthesis. Bacteria, which are capable of extracellular electron transfer (called elec-tricigens), can respire with the solid electrode, while conserving energy by oxidizing organic molecules, such as acetate, completely to carbon dioxide.

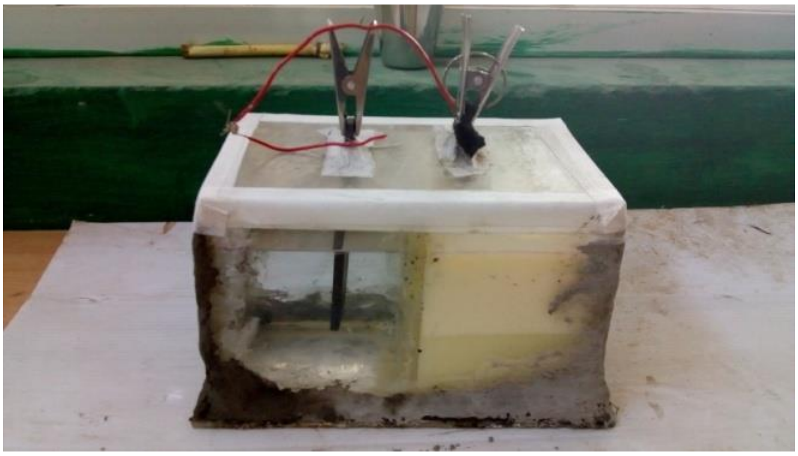

Figure.3. Working of MFC

III. ANALYTICAL PROCEDURE

3.1 Determination of PH and temperature

PH can be viewed as an abbreviation for power of hydrogen or more completely, power of the concentration of hydrogen ion. It says that the PH is equal to the negative log of the hydrogen ion concentration or PH = -log [H+].

$$PH = -\log [H3O+]$$

3.2 Determination of BOD

Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

3.3 Determination of COD

The COD is considered mainly the representation of pollution level of domestic and industrial wastewater or combination level of surface, ground and potable water. This is determined in terms of total oxygen required to oxidize the organic matter to CO2 and water.

3.4 Determination of TDS, TSS

A well-mixed filtered through a standard glass fibre filter, and the filtrate is evaporated to dryness in weighted dish and dried to constant weight at 179-181ºC. The increase in dish weight represents the total dissolved solids.

A well-mixed sample is filtered through a weighed standard glass fibres filter and the residue retained on the filter is dried to a constant weight at 103-105ºC.

3.5 Determination of alkalinity

The alkalinity of the water is a measure of its capacity to neutralise acids. The alkalinity waters due primarily to the salts of week acids.

3.6 Determination of acidity

Acids contribute to corrosiveness and influence chemical reaction rates, chemical specification and biological processes. Acidity of water is its quantitative capacity to react with a strong base to a designated PH. The measured value may vary significantly with end point PH used in the determination.

3.7 Determination of electricity conductivity

Conductivity of a substance is defined as the ability or power to conduct or transmit heat, electricity or sound. When an electrical potential difference is placed across a conductor, its removal charges flow, giving rise to an electric current. This property is called conductivity.

IV. CHARACTERISTICS OF DAIRY WASTEWATER

The selected dairy wastewater characteristics were tested and tabulated in table.2. Initial characteristics showed that the selected waste has high BOD and COD value of 3875.11 mg/l and 8564.22 mg/l respectively.

Table. 2 Initial characteristics of diary wastewater

S.No.	Name of the parameter	Concentration
1	Odour	Agreeable
2	Temperature	32°C
3	P^H	4.31
4	BOD(mg/l)	3875.11
5	COD(mg/l)	8564.22
6	Total Suspended solids(ppm)	8.77
7	Total Dissolved solids(ppm)	29.23
8	Oil and grease(mg/l)	260
9	Electrical Conductivity(mS)	240
10	Resistance(kilo ohm)	148.2
11	Sodium Chloride(ppT)	26.22

4.1 Electricity Production

The amount of electrons produced was measured by the external closed circuit. Day wise electrons production in the MFC system due to anaerobic treatment is tabulated in Table 3.

Table.3 Power generation of dairy wastewater

DAYS	POWER in mV
1	15.2
2	33.47
3	48.22
4	65.34
5	87.34
6	102.34
7	116.72
8	145.1
9	125.32
10	110.48
11	85.96
12	76.99

4.2 Comparison of power generation

The Production of electrons in the reactor mainly depends on the F/M ratio. The electron has been produced as soon as the microbial action on the wastewater. The anaerobic bacteria present in the system rapidly multiplies to form new cells. During the process of cell division it releases the electrons. The protons formed in the process transferred to other compartment via Proton Exchange membrane which allows only proton. The electrons produced in the process were measured daily. As the day progressed the electricity production was also increased Figure.4.

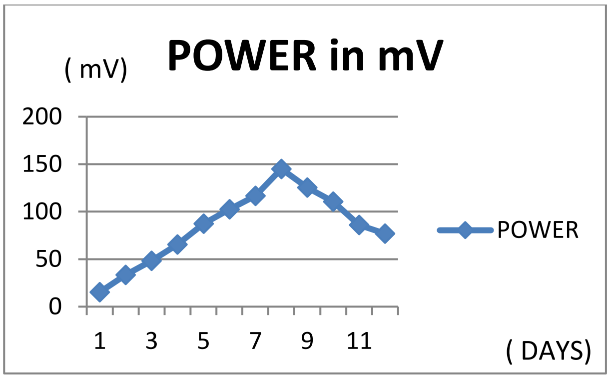

Figure 4. Power generation

4.3 Performance of MFC

Dairy effluent from the MFC system was tested for their final characteristics. The results shows that BOD and COD values were reduced considerably. Other physical and chemical characteristics of wastewater also reduced in the system (Table 4).

Table.4 Final treatment of diary wastewater

S.No.	Name of the parameter	Concentration
1	Odour	Agreeable
2	Temperature	32ºC
3	P^H	3.9
4	BOD(mg/l)	1519.22
5	COD(mg/l)	4367.12
6	Total Suspended solids(ppm)	4.77
7	Total Dissolved solids(ppm)	16.13
8	Oil and grease(mg/l)	143.44
9	Sodium Chloride(ppT)	18.67

V. CONCLUSIONS

- We conclude that by using MFC's we can generate power from wastewater, for our future use. The combination of wastewater treatment along with electricity production might help in compensating the cost of wastewater treatment.
- The membrane less MFC, its effectiveness as a wastewater treatment process along with electricity production, without incorporating any costly component, such as mediator and membrane. The COD, BOD removal were achieved at varying levels. Maximum power density was observed spacing between the electrodes and optimizing microorganisms.
- Further studies would be necessary to optimize the electricity production from this MFC. With further improvements and optimization, it could be possible to increase power generation. Also MFC as a continuous reactor can also be used. Going further toward the condition to be maintained in the reactor, aerated condition produces more electricity and it is instantaneous.
- In case of unaerated chamber, the current production is delayed by some time, due to inability of the reactor to complete the reaction in both chambers. Thus, the combination of wastewater treatment along with electricity production might help in compensating the cost of wastewater treatment.

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