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Wastewater Treatment and Electricity Generation using Microbial Fuel Cell

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ABSTRACT:

Microbial Fuel Cells (MFCs) offer a sustainable solution for wastewater treatment while simultaneously generating electricity. This study explores the design, fabrication, and performance of a dual-chamber MFC using organic wastewater as a substrate. The MFC utilizes electroactive bacteria to degrade organic matter, producing bioelectricity. Experimental results indicate a significant reduction in wastewater contaminants and a measurable electrical output. This study highlights MFCs' potential for eco-friendly energy generation and wastewater remediation.

Keywords: Microbial Fuel Cells, Organic matter, Waste water treatment,Generating electricity

1. INTRODUCTION:

While the world population is growing, energy and water resources are becoming limited. An additional challenge associated with population growth is the increase in wastewater generation and environmental pollution. While water scarcity and energy demand are continuously increasing in the world, alternative sources are needed to meet the requirement of a growing population. Microbial Fuel Cell (MFC) is a sustainable technology that converts organic matter in wastewater into electricity, thus it can be a potential alternative source for water and energy. Although significant studies in MFC research have been accomplished in the last few years, improvement in power generation and decrease in material cost are still necessary to bring MFC into Practical application.

Basic types of MFC

Two basic types are

1) Single chamber MFC

2) Double chamber MFC

Single chamber MFC

Single chambered MFC are basic anode compartments where there is no complete cathode compartment and may not contain proton trade films. Permeable cathodes shape one side of the mass of the cathode chamber using oxygen from air and letting protons diffuse through them. They are very easy proportional to the two fold chambered Fuel Cells and hence have discovered broad use and research interests recently. The anodes are ordinary carbon terminals yet the cathodes are either permeable carbon terminals or PEM fortified with adaptable carbon fabric anodes. Cathodes are regularly shrouded with graphite in which electrolytes are poured in a relentless design which carries on as catholyte and keeps the film and cathode from drying. Therefore water administration or better liquid administration is a critical issue in such single chambered power devices. Composed a solitary chambered MFC consisting of a rectangular anode chamber combined with a permeable air cathode that is presented straightforwardly to the air.

Double chamber MFC

It is a classic type of technology that consists of two or dual chambers, which are separated by an exchange membrane. It runs in batch mode and works in continuous mode. This MFC design is widely used in laboratories. To generate electricity, it uses acetate or glucose as a substrate. It is available in cylindrical, rectangular, up flow with cylindrical, miniature, and U-shaped cathodes

Aim

The aim of this project is to design a Microbial Fuel Cell (MFC) system for efficient waste water treatment and electricity generation.

Objectives

- To fabricate double chambered MFC
- To generate electricity using Domestic waste water
- To generate electricity from microbial activity
- To ensure treated water is safe for the environment
- To create a sustainable system for both energy and waste water treatment

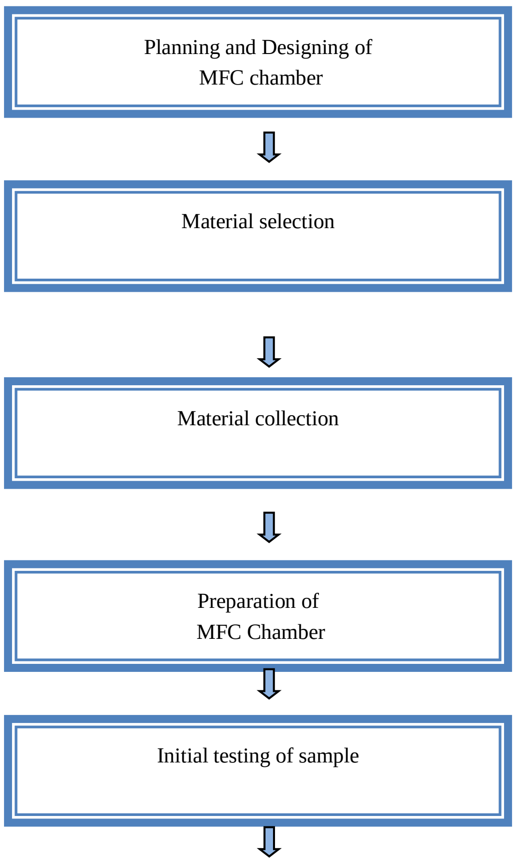
2. LITERATURE REVIEW:

R Bishnoi et al(2018) Investigated the catalytic activities of microbes for converting the chemical energy stored in organic rich streams for bioelectricity production. MFCs represent an auspicious technology to treat landfill leachate and generate bioelectricity. The Box-Behkin Design model of response surface methodology was found suitable for the determination of optimal conditions for the removal of chemical oxygen demand. The study revealed that the integration of coagulation with MFC technology enhanced the treatment efficiency as well as power generation for landfill leachate.

SimengLi(2018); Discussed the different applications of bio electrochemical system to effectively minimize wastes and treat wastewater while simultaneously recovering electricity, bio hydrogen and other value added chemicals via specific redox reactions. The review study is based on an extensive literature research regarding agriculture related bio electrochemical studies(BESs).BES have the potential to recover considerable amounts of electric power and energy chemicals from agricultural wastes and wastewater .The recovered energy can be used to reduce the energy input into agricultural systems. Other resources and value added chemicals such as biofuels, plant nutrients and irrigation water can also be produced in BESs. The possible applications to produce food without sunlight and remediate contaminated soils using BESs have also been discussed. Agricultural wastes can also be processed into construction materials or biochar electrodes electro catalysts for reducing the high costs of current BESs.

Bk Pandey V Mishra et al : In this journal production of bio electricity during waste water treatment using a single chamber microbial fuel cell is discussed. Microbial fuel cells (MFCs) represent a completely new long term, affordable, accessible and ecofriendly approach to waste water treatment with production of sustainable energy. The power generation efficiency in microbial fuel cells (MFCs) is based on bioreactors, which may represent a completely new approach to wastewater treatment. In our experimental test we found that it is possible to generate electricity using bacteria while accomplishing waste water treatment in process based on microbial fuel cell technologies. Tests were conducted using a single chamber microbial fuel cell (SCMFC) containing eight graphite electrodes (anodes) and a single cathode.

3. METHODOLOGY:



Final testing

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Analysis of result

COLLECTION OF MATERIALS

The different materials procured for this study are

1. Waste water as sample

2. Aluminium as anode

3. Copper as cathode

4. KMNO4 as catholyte

5. Waste water as anolyte

6. Agar agar as proton exchange membrane

FABRICATION OF MFC CHAMBER

Dual chambered MFC were fabricated using polypropylene of 2mm thickness. Length of cathodic and anodic chamber was 7.5cm and the middle chamber was 6cm. A proton exchange membrane made of Agar is cast in the central chamber. Copper electrode with 15 cm length and breadth 5cm as cathode. Aluminium electrode with 15cm length and breadth 5cm as anode potassium permanganate solution was loaded in the cathodic chamber .The system was analysed with regard to parameters such as open circuit voltage, short circuit current.

Fig 3.1 Acrylic sheet used for chamber

The electrode system consisted of aluminium as the working electrode , copper as the counter electrode. To determine electrical current produced by the MFC, measure the deflection of opposite sides of the multimeter. Multimeter deflection shows the produced voltage.

Fig 3.2 Completion of chamber

ALUMINIUM AS ANODE

The aluminium placed in the waste water reacts and utilize the organic constituents for its function and thereby reducing the BOD and COD concentration .Aluminium of length 15m and breadth 5cm is used as anode. Aluminium is a scarificial electrode but has less outcome with the period. Fig 3. shows aluminium as anode used in the MFC cell

Fig 3.3 Aluminium as anode

COPPER AS CATHODE

Copper act as counter electrode , copper with 15cm length ,breadth 5cm was used as cathode working electrode which is dipped in waste water while copper electrode acted as counter electrode which was introduced into potassium permanganate solution .

Electrons are transferred to the cathodic chamber through an external circuit, while proton travelled to the other side through proton exchange membrane. Electrons and protons are consumed in the cathode compartment reducing permanganate to manganese dioxide. Fig 3.4 shows copper as cathode

Fig 3.4 Copper as cathode

$KMNO_4$ AS CATHOLYTE

Potassium permanganate solution (0.3%) was loaded in the cathodic chamber and is used as oxidising agent . cathodic chamber was filled $KMNO_4$ Solution of 600 ml. The cathode electrode is dipped in this solution and act as an oxidising agent. Fig 3.4 shows $KMNO_4$ which is used as catholyte

Fig 3.5 $KMNO_4$ as catholyte

AGAR AGAR

Agar agar is used as proton exchange membrane. The MFC consists of three modular units constituting the three chambers. A PEM made of agar is initially cast in the central chamber and then retrofitted into the system with flanking anode and cathodic chambers

4. EXPERIMENTAL STUDY

BOD TEST

The Biochemical Oxygen Demand (BOD) test is a crucial analysis conducted in wastewater treatment to determine the amount of oxygen required by microorganisms to break down organic matter in a water sample over a specific period, usually 5 days at 20°C. It is a key indicator of water pollution and helps assess the effectiveness of wastewater treatment processes.

1.Must be free of chlorine. If chlorine is present in the sample, a dechlorination chemical (e.g, sodium sulfite) must be added prior to testing.

2.Needs to have an existing adequate microbiological population. If the microbial population is inadequate or unknown, a “seed” solution of bacteria is added along with an essential nutrient buffer solution that ensures bacteria population vitality.

3.Specialized 300 mL BOD bottles designed to allow full filling with no air space and provide an airtight seal are used.

4.The final DO reading is then subtracted from the initial DO reading and the result is the BOD concentration (mg/L). If the wastewater sample required dilution, the BOD concentration reading is multiplied by the dilution factor.

Fig 4.1 BOD sample

pH TEST

The pH test helps determine whether wastewater is acidic or alkaline, which is crucial for environmental monitoring and treatment processes. Litmus paper provides a quick and simple way to check the pH level.

Procedure for pH Test Using pH Indicator Paper

1. Take a small sample of the liquid to be tested in a clean container.

2. Immerse a strip of pH indicator paper into the sample for a few seconds.

3. Change: Remove the strip and wait for the color to stabilize.

4. Match the color of the strip with the provided pH color chart.

5. Read the corresponding pH value to determine acidity or alkalinity.

ALKALINITY TEST

The alkalinity test helps determine the buffering capacity of wastewater, which is vital for microbial growth and stable pH in MFC systems. Maintaining appropriate alkalinity ensures efficient electricity generation and wastewater treatment.

Procedure

1. Take 50 mL of the wastewater sample in a conical flask.

2. Phenolphthalein Alkalinity (P Alkalinity)

Add 2–3 drops of phenolphthalein indicator.

If the solution turns pink, titrate with 0.02 N H_2SO_4 until the pink color disappears.

Record the volume of acid used (P Alkalinity).

3. Total Alkalinity (T Alkalinity)

Add 2–3 drops of methyl orange indicator to the same sample.

Continue titrating with 0.02 N H_2SO_4 until the color changes from yellow to orange.

Record the total volume of acid used (T Alkalinity).

Fig 4.2 Indicators used

Fig 4.3 solution turns pink

Fig 4.4 Titration process

5. RESULT AND DISCUSSION :

THE INITIAL CHARACTERISTICS OF SAMPLE

The Domestic waste water collected is tested for the following test before the working of mfc setup.

SI.NO	CHARACTERISTICS	RESULT
1	COLOUR	YELLOWISH ORANGE
2	ODOUR	MUSTY ODOUR
3	pH	7.9
4	ALKALINITY	500mg/L
5	BOD	650 mg/L

Table 5.1 Initial characteristic of sample

EVALUATION OF ELECTRICITY GENERATION

MFC was generated consecutively for 5days.DC voltage was measured using a multimeter and noted it. Table below voltage generated from day 1-5

Day	**Voltage (v)**
1	**1.68**
2	1.52
3	1.39
4	1.18
5	0.97

Fig 5.1 Initial reading day - 1

Fig 5.2 Final reading day – 5

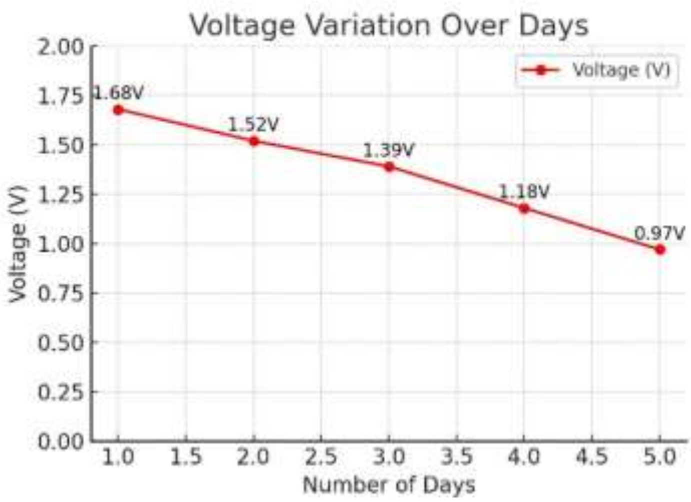

Fig 5.3 Graphical representation of voltage generated from day 1 – 5

THE FINAL CHARACTERISTICS OF SUBSTRATE

The treated sample after being kept consecutively for 5 days has been tested with the following results.

SI.NO	CHARACTERISTICS	RESULT
1	COLOUR	YELLOWISH ORANGE
2	ODOUR	MUSTY ODOUR
3	pH	6.5
4	ALKALINITY	400 mg/L
5	BOD	500 mg/L

Table 5.3 Final characteristic of sample

6. CONCLUSION

The project on wastewater treatment and electricity generation using Microbial Fuel Cells (MFCs) successfully demonstrates the potential of bio electrochemical systems in addressing two major environmental challenges: waste management and renewable energy production. By harnessing the metabolic activities of microorganisms, this study showcases how organic pollutants in wastewater can be broken down while simultaneously generating electrical energy. The initial tests on wastewater samples, which included BOD, pH, alkalinity, and dissolved solids, revealed high levels of organic contamination, making it a suitable substrate for microbial fuel cell applications. Over a period of five days, noticeable improvements in water quality were observed, particularly in the reduction of BOD levels, confirming that microbial metabolism played a significant role in breaking down organic matter and reducing pollution. The potential benefits of MFC technology extend beyond energy savings and pollution reduction. In the future, MFCs could play a crucial role in sustainable development by contributing to circular economy models where waste is converted into valuable resources. With continued innovation, policy support, and investment, MFC technology can be a game-changer in wastewater management and renewable energy production, paving the way for a cleaner and more sustainable world.

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