

# **Characterization of generated Voltage, Current, Power and Power Density from *Cow Dung* using Double Chamber Microbial Fuel Cell**

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

**BACHELOR OF TECHNOLOGY  
IN  
BIOTECHNOLOGY**

By  
**PRIYABRATA THATOI**  
110BT0632

Under the guidance of

**Prof. Krishna Pramanik**



**DEPARTMENT OF BIOTECHNOLOGY AND MEDICAL ENGINEERING  
NATIONAL INSTITUTE OF TECHNOLOGY  
ROURKELA - 769008**

**May- 201**



## **National Institute of Technology, Rourkela**

### **CERTIFICATE**

---

This is to certify that the thesis entitled “**Characterization of generated Voltage, Current, Power & Power density from Cow Dung using Double Chamber Microbial Fuel Cell**” submitted by Sri Priyabrata Thatoi (Roll No. 110BT0632) in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biotechnology at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not formed the basis for the award of any Degree or Diploma or similar title of any University or Institution.

**Date:**

**Prof. Krishna Pramanik**  
**Professor and Head**  
**Department of Biotechnology and Medical Engineering**  
**NIT, Rourkela-769008**

# **ACKNOWLEDGEMENT**

---

I would like to express my profound gratitude and indebtedness to Prof. K.Pramanik, Professor, Department of Biotechnology and Medical Engineering, NIT, Rourkela for her guidance and valuable suggestions. This work would not have been possible without his encouragement and constructive criticism. I sincerely thank him for the time and patience he devoted for this work.

I am also thankful to all the faculty members for their valuable suggestions.

I am immensely thankful to Mr. Bikram Nayak (Technical assistant Attendant) for their help in carrying out laboratory experiments.

I would like to acknowledge the authors of different research paper referred in the work, which were a valuable source for understanding the subject.

Lastly, I am thankful to all my friends who have encouraged and helped me in accomplishing this project.

**PRIYABRATA THATOI**

110BT0632

Department of Biotechnology and Medical Engineering

NIT, Rourkela

# CONTENT

<b>SUBJECT</b>	<b>PAGE NO.</b>
<i>CERTIFICATE</i>	2
<i>ACKNOWLEDGEMENT</i>	3
<i>LIST OF FIGURES</i>	6
<i>LIST OF TABLES</i>	8
<i>LIST OF ABBREVIATIONS</i>	9
<b>ABSTRACT</b>	<b>10</b>
<b><i>CHAPTER 1: GENERAL</i></b>	<b>11</b>
1.1 Background	12
1.2 Advantage of Microbial fuel cell	15
<b><i>CHAPTER 2: LITERATURE REVIEW</i></b>	<b>17</b>
2.1 Source of Biomass for fuel cell	18
2.2 Experiment with Cow Dung	19
<b><i>OBJECTIVE</i></b>	<b>22</b>
<b><i>CHAPTER 3: MATERIALS AND METHODS</i></b>	<b>23</b>
3.1 MFC construction prerequisites	24
3.2 MFC construction	25
3.3 Salt Bridge Construction	25
3.4 Calculations	25
<b><i>CHAPTER 4: EXPERIMENTAL RESULTS</i></b>	<b>27</b>
4.1 Generated voltage in an open circuit	28
4.2 Maximum generated voltage from day 1-6.	31
4.3 Generated current in an open circuit	32
4.4 Maximum generated current from day 1-6	35
4.5 Generated power in an open circuit	36
4.6 Maximum generated power from day 1-6.	36

4.7 Generated SPD in an open circuit	39
4.8 Maximum generated SPD from day 1-6.	40
	43
<b>CHAPTER 5: DISCUSSION</b>	44
5.1 Generated voltage	45
5.2 Generated current	45
5.3 Generated Power	45
5.4 Generated Surface power density	46
5.5 Comparative analysis of generated voltage, current, power and SPD	46
<b>CHAPTER 6: CONCLUSION</b>	48
6.1 conclusion	49
<i>FUTURE SCOPE</i>	49
<i>REFERENCES</i>	51

## **LIST OF FIGURES**

<b>SL NO.</b>	<b>TITLE</b>	<b>PAGE NO</b>
1	<b>Schematic Representation of Microbial fuel cell</b>	12
2	<b>The mechanism of electron transfer from the cell surface to electrode in MFC</b>	13
3	<b>Diagrammatic representation of step wise construction of Doube chamber MFC device.</b>	26
4	<b>Generated voltage characteristics in Day 1</b>	28
5	<b>Generated voltage characteristics in Day 2</b>	28
6	<b>Generated voltage characteristics in Day 3</b>	29
7	<b>Generated voltage characteristics in Day 4</b>	29
8	<b>Generated voltage characteristics in Day 5</b>	30
9	<b>Generated voltage characteristics in Day 6</b>	30
10	<b>Maximum Generated voltage characteristics from Day 1- 6.</b>	31
11	<b>Generated current characteristics in Day 1</b>	32
12	<b>Generated current characteristics in Day 2</b>	32
13	<b>Generated current characteristics in Day 3</b>	33
14	<b>Generated current characteristics in Day 4</b>	33
15	<b>Generated current characteristics in Day 5</b>	34
16	<b>Generated current characteristics in Day 6</b>	34

17	<b>Maximum Generated current characteristics from Day 1- 6.</b>	<b>35</b>
18	<b>Generated power characteristics in Day 1</b>	<b>36</b>
19	<b>Generated power characteristics in Day 2</b>	<b>36</b>
20	<b>Generated power characteristics in Day 3</b>	<b>37</b>
21	<b>Generated power characteristics in Day 4</b>	<b>37</b>
22	<b>Generated power characteristics in Day 5</b>	<b>38</b>
23	<b>Generated power characteristics in Day 6</b>	<b>38</b>
24	<b>Maximum Generated power characteristics from Day 1- 6.</b>	<b>39</b>
25	<b>Generated SPD characteristics in Day 1</b>	<b>40</b>
26	<b>Generated SPD characteristics in Day 2</b>	<b>40</b>
27	<b>Generated SPD characteristics in Day 3</b>	<b>41</b>
28	<b>Generated SPD characteristics in Day 4</b>	<b>41</b>
29	<b>Generated SPD characteristics in Day 5</b>	<b>42</b>
30	<b>Generated SPD characteristics in Day 6</b>	<b>42</b>
31	<b>Maximum Generated SPD characteristics from Day 1- 6.</b>	<b>43</b>
32	<b>Maximum generated Voltage, Current, Power and SPD characteristics from Day1- 6</b>	<b>47</b>

## **LIST OF TABLES**

<b>SL NO</b>	<b>TITLE</b>	<b>PAGE NO</b>
1	<b>List of different electrodes and their characteristics</b>	16
2	<b>List of experiments conducted for the production of electricity using cow manure/dung as a substrate.</b>	21
3	<b>Change of Maximum generated Voltage from day 1-6.</b>	31
4	<b>Change of Maximum generated Current from day 1-6.</b>	35
5	<b>Change of Maximum generated Power from day 1-6.</b>	39
6	<b>Change of Maximum SPD from day 1-6.</b>	43
7	<b>Maximum generated voltage, current, power and surface power density from day 1- 6</b>	46



## LIST OF ABBREVIATIONS

<b>Sl.no</b>	<b>abbreviations</b>	<b>words</b>
1	$\mu$	Micro
2	$^{\circ}\text{C}$	Degree Centigrade
3	A	Ampere
4	BOD	Biological oxygen demand
5	C.S.A	Cross sectional area
6	cm	centimeters
7	COD	Chemical oxygen demand
8	KCl	Potassium chloride
9	Kg	Kilogram
10	L	Liter
11	M	molarity
12	MFC	Microbial fuel cell
13	ml	Milliliter
14	NaCl	Sodium chloride
15	PEM	Proton exchange membrane
16	V	Voltage
17	W	watt

## **ABSTRACT**

The present work deals with the fabrication of a laboratory scale double chamber microbial fuel cell (MFC) to generate energy from waste. The experiment was performed to generate electricity from locally available cow dung as substrate using the fabricated MFC. The device was operated under anaerobic condition at varying time duration of 6 days. PVC pipe was used to make a salt bridge using agarose and potassium chloride. The experimental reading was recorded at an interval of 1 & 1/2 hrs.

The performance of MFC was evaluated by characterizing the generated voltage, current, power and surface power density. It was observed that despite of high impedance of the substrate, all the generated parameters have shown maximum values at day 5 and then a decline in trend was observed on 6 days onwards. The corresponding maximum values of the generated parameters are 0.804V, 0.0105 $\mu$ A, 0.008442 $\mu$ W and 0.000938mW/m<sup>2</sup>. The obtained graphs of voltage, current, power and surface power density were also found to have similar pattern. Thus this study has demonstrated that the fabricated MFC can be used for electrical energy generation from cow dung and other biowaste.

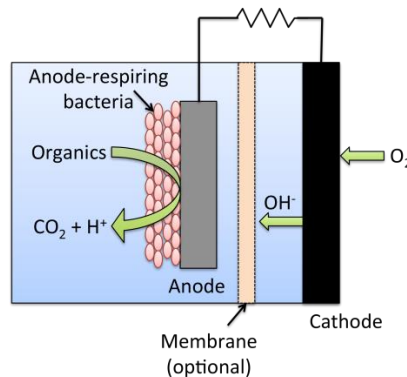
**Key words- Renewable source, MFC, Microbes, Cow dung**

# **CHAPTER 1**

## **GENERAL**

## 1.1 Background

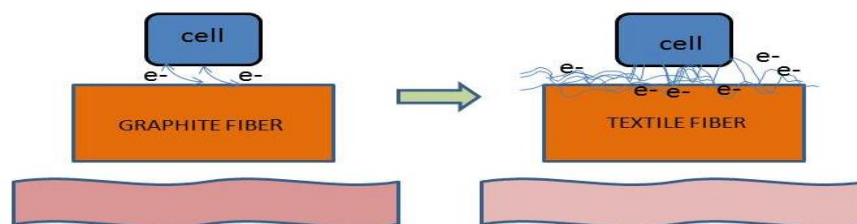
With increasing crisis of energy in world, MFC has taken over the top position in the queue of energy production. Being a complex system, MFC has given prominent results in solving energy crises at a small scale. It is defined as a device that provides a shell to microorganism, so as to carry out their metabolism and in lieu, produces electrons that are carried out through external circuit. The whole system of production of energy i.e. production of electrons is actuated by the consumption of right source of food. It indicates the organic food sources those are rich in sugar, carbohydrates, vitamins, proteins, fats etc. this concept of using microbes for the production of electricity was first used by a professor in botany named M.Poter. In the year of 1931, he generated electricity by using *E. coli*. It was initially not given much importance, but for his attempt of producing 35 volts and 2 milliamps, he got his recognition and the work of MFC got world class fame later. Technically, it is a device that uses microbes to convert chemical energy to electrical energy. The mechanism behind the production of electrons is that when microbes like electro genic bacteria consumes sugar in the presence of oxygen they produce carbon dioxide and water while in the absence of oxygen they produce carbon dioxide, electrons and protons. When these electrons are carried through a conductive wire to anode chamber where it completes the circuit forming a conduit of electrons and protons across the proton exchange membrane, electricity is produced. The overall reaction in anaerobic condition is given by equation 1.



**Fig1. Schematic Representation of Microbial fuel cell.**(<http://www.thevoltreport.com/microbial-fuel-cell-to-clean-water-while-making-clean-energy/>)

The anaerobic chamber is connected to aerobic chamber via conductive wire. Electrons pass through it and protons pass through proton exchange membrane (PEM) or salt bridge. Generally, chemotropic

microbes consume organic and recyclable compounds under extreme condition that results in the production of electrons via oxidation. Then produced electrons transport pass to right electron acceptor via appropriate mediators. The electrons are translocating across the cell membrane to generate adenosine triphosphate (2). Generally oxygen acts a good and readily available acceptor of electrons in the cathode chamber but other sources are nitrate and Fe (III) (2). It also has been proposed that the microbial cells like *G.sulferreducens* have cytochrome c on its surface and remains close to anode. Through this mediator, electrons are directly transferred to anode surface. In some species like shewanella oneidesis have soluble electrons shuttles that transfers electrons to anode surface whereas microbes like E.coli produces metabolites that transfers electron to anode



**Fig.2 The mechanism of electron transfer from the cell surface to electrode in MFC.**

Therefore, microbes having the most promising results in the field of MFC are:

- *G. sulferreducens*
- *Shewanellaoneidesis*

Several members of the family *Geobacteraceae*, including *Geobacter sulfurreducens* and *G. Metallireducens* have been shown to be capable of transferring electrons to an anode through direct contact. It uses some form of electrochemically active protein present on outer surface of the cell, and electrically conductive Pili facilitate the process of electron transfer. (4) MFC uses PEM (proton exchange membrane) or salt bridge to aid the movements of protons to cathode. PEM is a semipermeable layer made up of ionomers and is designed to conduct transfer of molecules but remain impermeable to oxygen and hydrogen. (5) Hydrogen molecules get split into protons and electrons. The electrons travels externally while protons travels internally. They both meet in the presence of oxygen to produce water. The reaction at cathode is given by equation2.



While the overall reaction for the process is given by equation 3.



Instead of proton exchange membranes, salt bridges can be used to transfer the protons from the anode chamber to cathode. For the salt bridge, generally 1M KCl or 1M NaCl solutions are used. These solutions are mixed with agar or agarose to form solidified salt bridge. It is an inexpensive component of microbial fuel cell. Different types of catholytes like water, ferricyanide, potassium permanganate, manganese dioxide are used in two chambered microbial fuel cell. (6) Many types of MFC have been built depending upon the requirement of mediator for the transport of electrons. These are characterized as follows.

#### 1. **Mediator MFC**

In this system, electrons transfer to electrodes is done by different kinds of chemical mediators like thionine, methyleviologen, methyl blue, humic acid etc.

#### 2. **Mediator-free microbial fuel cell**

In this microbial fuel cell, electrons are transferred by electrochemically active bacteria directly to the electrodes. Bacteria like *Shewanella putrefaciens*, *Aeromonas hydrophila*, and others act as an efficient microbes for this system.

#### 3. **Soil-based microbial fuel cell**

It is a type of mediator less MFC, in which the anode is placed inside the soil and the cathode is exposed to atmospheric oxygen. Soil contains large number of electrogenic microbes that consumes complex sugar out of accumulated animal and plants thereby releasing out electrons to the electrodes.

#### 4. **Phototrophic biofilm microbial fuel cell**

In this, MFC's anode has a phototrophic biofilm that consist of microorganism like chlorophyta, cyanophyta etc. that carry out photosynthesis and thus produces both organic metabolites as well as donates electrons.

On the basis of structure of microbial fuel cell, it has been divided into 2 types of microbial structures.

#### 1. **Single chamber microbial fuel cell**

## 2. Double chamber microbial fuel cell

The single chamber MFC consists of a single chamber containing substrate in it and two electrodes at the other ends of the chamber. While in case of double chamber microbial fuel cell, there are two chambers called cathode and anode and are separated either by proton exchange membrane or saltbridge.

### 1.2 Advantages of microbial fuel cell

- Generating energy out of waste- This technology is used mostly for waste matter treatments. Like waste water, sewage treatments, human wastes etc. it also produces hydrogen gas, that is a good source of fuel.
- Direct conversion of substrate into electricity- It consumes mostly sugar of the substrates and produces energy out of it. Hence, making the substrates biodegradable. (7)
- Availability of raw materials- This technology uses microbes as raw materials that are abundant and ample.
- Unlike chemical fuels, MFC does not require complex systems or devices in its process of producing energy. (8)

Electrodes also play an important role in determining the current, voltage, power and their respective densities. Different types of electrodes are used for the microbial fuel cell. Most commonly used one is graphite electrode. They come in different shapes and structures like-

- *Graphite rod*
- *Graphite fiber*
- *Graphite paper*
- *Graphite cloth*
- *Graphite felt*

Different characteristics of electrodes like surface area, conductivity, chemical stability, mechanical strength, cost etc. determines the frequency of their use (9). Some researchers have proved that without a catalyst, MFC can work properly as compared to the one with catalyst (10). Carbon based electrodes and other non-corrosive metals fulfill the criteria (11). List of different electrodes and characteristics are shown in table 1.

**Table 1. List of different electrodes and their characteristics. (10)**

<b>Electrode</b>	<b>Configuration</b>	<b>Electrode size</b>	<b>Reactor configuration</b>	<b>Max Power</b>
<b>Carbon cloth</b>	Plane	22.5 cm <sup>2</sup>	Two-bottle	600 mW/m <sup>2</sup>
<b>Carbon cloth</b>	Plane	7cm <sup>2</sup>	Single chamber	3290 mW/m <sup>2</sup>
<b>Graphite plate</b>	Plane	1.92 cm <sup>2</sup>	Two chamber	893 mW/m <sup>2</sup>
<b>Carbon felt</b>	Packed	156 ml (anode chamber)	Two chamber	356 W/m <sup>3</sup>
<b>Carbon cloth</b>	Brush	12 cm <sup>2</sup>	Single chamber	2400 mW/m <sup>2</sup>



# **Chapter two**

## **LITERATURE REVIEW**

## 2.1 Source of biomass for fuel cell

It is one of the important biological factors that affect the production of electricity. Different types of substrate are used for this purpose from simple substrate to complex matter present in waste water. Every kind of biomass can be used for generating electricity. Researches are using waste water, varieties of crops, cow dung, glucose containing components, starch containing components, acetate, rice water etc.

### 2.1.1 Experiment with simple substrates

- **Logan et al., (2007)** used acetate as their source for power generation, having concentration of 1g/L. They used pre acclimated bacteria from MFC and cube shaped single chamber MFC having graphite fiber brush anode. The maximum current density generated was 0.8 mA/cm<sup>2</sup>. (12)
- **Catal et al., (2008)** used arbutol as one of the substrate for single chamber, air-cathode microbial fuel cell, producing current density of 0.68 mA/cm<sup>2</sup>. They used pre acclimated bacteria from MFC (13)
- **Dumas et al., (2008)** used sodium fumarate and *G.sulferreducens* for his stainless steel cathode based MFC and succeeded in producing current density of 2.05 mA/cm<sup>2</sup>. (14)
- **Luo et al.(2009)** used phenol of concentration 400mg/ml for his two chamber and air-cathode MFC. He successfully produced current density of 0.1 mA/cm<sup>2</sup>. (15)
- **Niessen et al. (2004)** experimented his two chambered MFC having woven graphite anode and ferricyanidecatholyte, using starch of concentration g/L as it's substrate and *ClostridiumButyricum* as it's microbe. He successfully produced current density of 1.3 mA/cm<sup>2</sup> (16)

### 2.1.2 Experiment with complex substrates

- **Rodrigo et al. (2007)** used real urban waste water of concentration of 330mg/ml in two chamber MFC and successfully generated current density of 0.018 mW/cm<sup>2</sup>. (17)
- **Oh and Logan (2005)** used Food processing waste water for two chamber MFC, having graphite electrode and generated a current density of 0.05 mW/cm<sup>2</sup>. (18)

- **Wang et al (2009)** used domestic waste water of concentration of 600mg/L for his two chambered mediator less MFC having graphite electrodes. The device generated the current density of 0.06 mW/cm<sup>2</sup> (19)
- **Zhao et al. (2011)** used cattle dung as the substrate for his MFC and was able to generate 0.22 W/m<sup>3</sup> of volumetric power density. (20)

## 2.2 Experiments with Cow Dung as a substrate

Cow manure, known also as cow dung, is the feces of the bovine species. These species includes the cow, buffalo, ox, and bullock. Cow dung is basically the digested residues of herbs and other plants that they eat. The resultant fecal matter is rich in minerals. Color of the manure ranges from greenish blackish and sometimes it turns yellow due to chemical changes, fastened by sunlight. Cow dung in India is known as *gobar*. It is largely used for goobar gas plant, biogas plant, production of fertilizers, manures and many other organic products and cooking fuels. The biogas from cow dung is rich in methane and is used in rural areas of India/Pakistan providing a renewable and stable source of electricity.(21) it is a cheap alternative source of fuel for cooking and production of electricity. It is also used as a plaster in rural areas. Biologically, it has anti-bacterial properties. It is a vital source for chemical free farming.

Despite of having plethora of advantages, it also has a darker part. Chakraborty et al. have exposed the arsenic poisoning by cow manure that have affected many districts in Kolkata. They have found significant amount of arsenic's presence in air, water etc. The poisoning leads to respiratory problems like chronic bronchitis, coughing, X-ray abnormalities etc. This adds to environmental disadvantages.(22). Still, many researchers have worked on the application of cow manure in microbial fuel cell, biogas plants, fuel production etc, keeping aside its demerits.

- **Jiannajia et al. (2013)** in order to dispose food wastes (FWs) and process them into a waste-to-energy form used a MFC through which the maximum power density of ~18 W/m<sup>3</sup> (~556 mW/m<sup>2</sup>) at COD of 3200 ± 400 mg/L and the maximum columbic efficiency (CE) of ~27.0% at COD (Chemical Oxygen Demand)of 4900 ± 350 mg/L was obtained. COD of the pretreated FWs was 50,000–80,000 mg/L, it were further diluted by the additional nutrient medium containing 11.55 g Na<sub>2</sub>HPO<sub>4</sub>•12H<sub>2</sub>O, 2.77 g NaH<sub>2</sub>PO<sub>4</sub>•2H<sub>2</sub>O, 0.31 g NH<sub>4</sub>Cl, 0.13 g KCl, 12.5 ml mineral solution and 12.5 ml vitamin

solution. They used a single chamber and air cathode MFC with anode volume of 28 ml and electrodes of carbon clothes of 7cm<sup>2</sup> and nickel catalyzed. The voltage was measured across 500 ohms. Reactions are carried out in fed batch (23)

- **Yokoyama et al** measured the capacity of dairy cow waste slurry in generating electricity. They used the cow slurry of COD 1g/L for treating MFC that produced 0.34 mW/m<sup>2</sup> of power density. It was found that after using 84% biological oxygen demand (BOD), nitrogen, phosphorous and potassium were retained. (24)
- **Zheng et al.(2010)** developed a new 21 scale MFC was to treat cattle dung by The device was able to produce 0.5V in open circuit and 0.4V under the resistance of 470 ohms (25)
- **Khare and Bundela(2013)** via the application of Single chamber MFC, have generated electricity using different waste water mixed with vermicomposting from Jabalpur. Carbon electrodes were used as both the anode and cathode along with salt bridge having 3% agar and 1M KCl solution for proton transfer to cathode. MFC used was a single chamber mediated device. Methylene blue served as an electron shuttle. Maximum generated voltage was 232 mV over a period of 7 days. (26).
- **Lee et al. (2011)** made two different MFCs to treat solid waste that includes cow manure and was run in the batch mode. One was of single compartment type and other one is of twin compartment type. Voltage of 0.38 was recorded by using 470 ohm resistance. The power density was measured as 36.6 mW/m<sup>2</sup>. Electrodes used had 20% platinum catalyst and Nafion 117 was used as proton exchange membrane.(27)
- **Zhang.G et al. (2011)** tested the electricity generating potential of cow manure by three chambered MFC and biocathods. He was able to produce maximum voltage of 0.502 V with an external resistance of 100 ohm. The volumetric power density of 8.15 W/m<sup>3</sup> was obtained throughout the process of production of electricity. (28)

**Table2. List of experiments conducted for the production of electricity using cow manure/dung as a substrate.**

<b>Sl</b>	<b>Author</b>	<b>Year</b>	<b>Substrate</b>	<b>V<sub>max</sub></b>	<b>P.Density<sub>max</sub></b>
<b>1</b>	<b>Yokotama et al.</b>	2006	Dairy cow waste slurry	---	0.34 mW/m <sup>2</sup>
<b>2</b>	<b>Zheng et al.</b>	2010	Cattle dung	0.5 V in open circuit & 0.4 in 470 ohms	----
<b>3</b>	<b>Khare&amp;Bundela</b>	2013	Waste water+vermicompost	385 mV	---
<b>4</b>	<b>Lee et al.</b>	2011	Solid waste	0.38 V	36.6 mW/m <sup>2</sup>
<b>5</b>	<b>Zhang et al.</b>	2011	Cow Manure	0.502 V	8.15 W/m <sup>3</sup>

# Objectives

- **To observe and find the characteristics of Maximum generated voltage for a time period of 6 days**
- **To observe and find the characteristics of Maximum generated current for a time period of 6 days**
- **To observe and find the characteristics of Maximum generated power for a time period of 6 days**
- **To observe and find the characteristics of Maximum generated surface power density for a time period of 6 days**

# **Chapter three**

## **MATERIALS AND METHOD**

A double chamber microbial fuel cell with substrate cow dung in the anode chamber will be run for 6 days to observe the characteristics of generated voltage, current.

### **3.1 MFC construction prerequisites**

The construction of double chamber MFC device requires the following materials and instruments-

- no of 2.5L bottles-2
- 5 cm PVC pipe
- 1M KCl solution (25 ml)
- no of 5X5 graphite plates of width 2cm-2
- no of m-seal (adhesive)-2
- 0.5 kg of cow dung
- 0.5 m copper wire
- aluminum clips-2
- desktop multimeter(Fluke 8845A 6-1/2 Digital precision Multimeter)

### **3.2 MFC construction**

Two 2.5 L bottles were prepared as anode chamber and cathode chamber. Two small holes were made in the caps of the bottles so as to insert wires through it. Wires using aluminum clips were attached to graphite electrodes. The anode chamber was filled with substrate (0.1kg of cow dung mixed with 1



L of water) while the cathode chamber was filled with plain water of 1L. Other two ends of wires were attached to desktop multimeter.

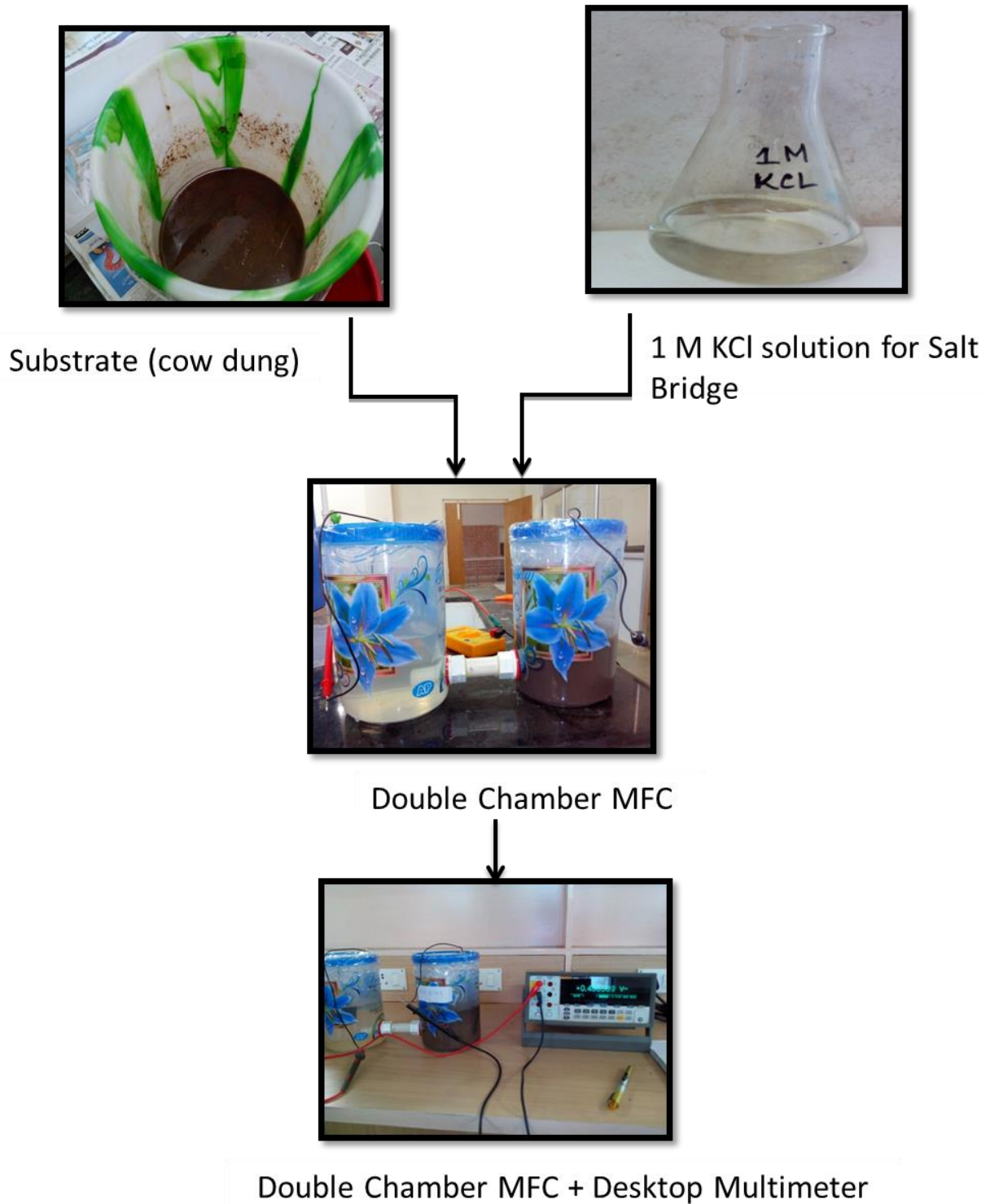
### **3.3 Salt bridge construction**

The PVC pipe used in salt bridge construction had dimensions of 5 cm length and 2 cm diameter. Volume  $15.7 \text{ cm}^3$  was calculated using the formula  $\pi r^2 h$ .

Salt bridge was prepared using 20 ml of 1M KCl solution and 3% agarose. The solution was first subjected to heat for blending, which in return gave a clear solution of agarose and KCl. The same was poured into the PVC pipe and was kept in the freezer at  $-4^\circ\text{C}$  for solidification. The solidified salt bridge was attached to the chambers using araldite adhesive which makes them leak proof.

### **3.4 Observation**

The generated voltage and current was recorded from the desktop multimeter at an interval of 1.5 hrs. for 6 days. While the corresponding power and surface power density was calculated by using formula  $P=V.I$  and  $P/a$  ( $a=\text{total surface area}=90\text{cm}^2$ ) respectively.



**Fig 3.**Diagrammatic representation of step wise construction of Double chamber MFC device.

# **Chapter four**

## **EXPERIMENTAL RESULTS**

MFC was operated for 21 hours, consecutively for 6 days and DC voltage and current was measured using Desktop multimeter. The data collected was graphed using OriginPro 8.0 software.

## 4.1 Generated voltage in an open circuit

### Result obtained on day one

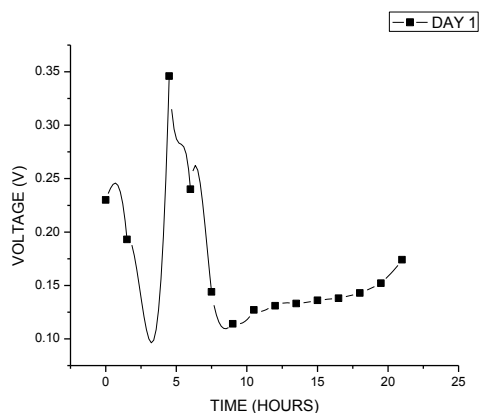


Fig4. Generated voltage characteristics in Day 1

### Result obtained on day two

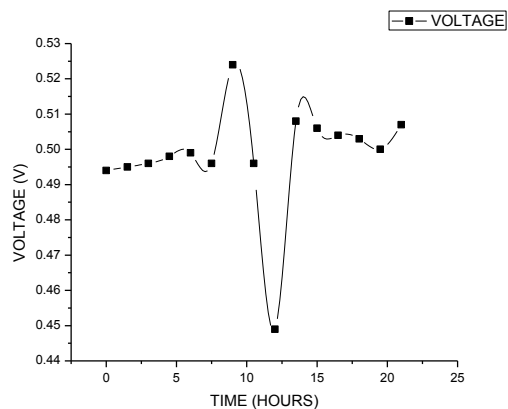
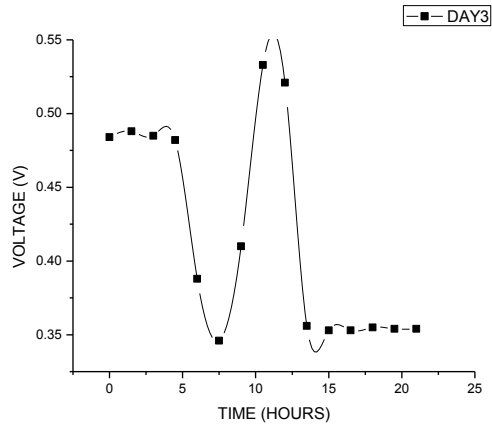
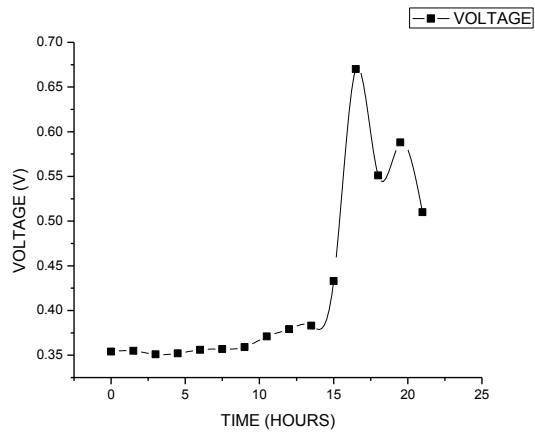


Fig 5. Generated voltage characteristics in Day 2



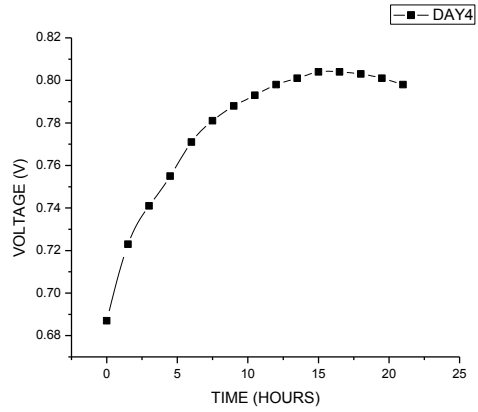
**Fig 6. Generated voltage characteristics in Day 3**

**Result obtained on day four**



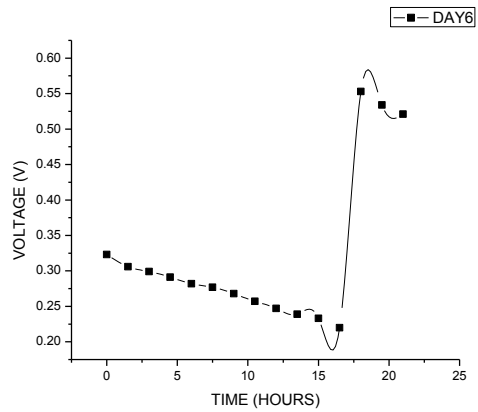
**Fig 7. Generated voltage characteristics in Day 4**

**Result obtained on day five**



**Fig 8.Generated voltage characteristics in Day 5**

**Result obtained on day six**



**Fig 9.Generated voltage characteristics in Day 6.**

## 4.2 Maximum generated voltage from day 1-6.

Table 3.Rte of Maximum generated Voltage from day 1-6.

DAY	MAX.VOLTAGE (V)
1	0.478
2	0.524
3	0.533
4	0.67
5	0.804
6	0.553

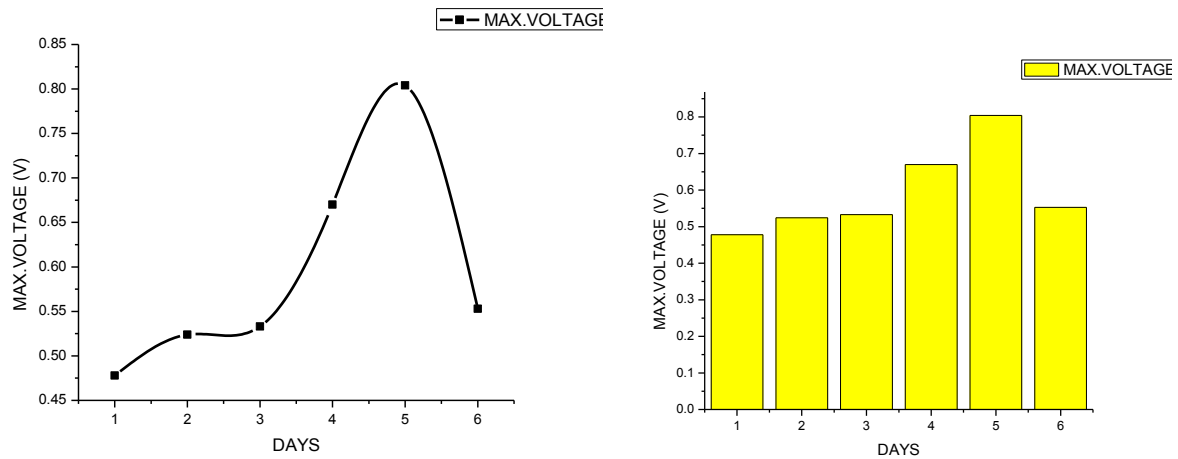


Fig 10.Maximum Generated voltage characteristics from Day 1- 6.

### 4.3 Generated current in an open circuit

#### Result obtained on day one

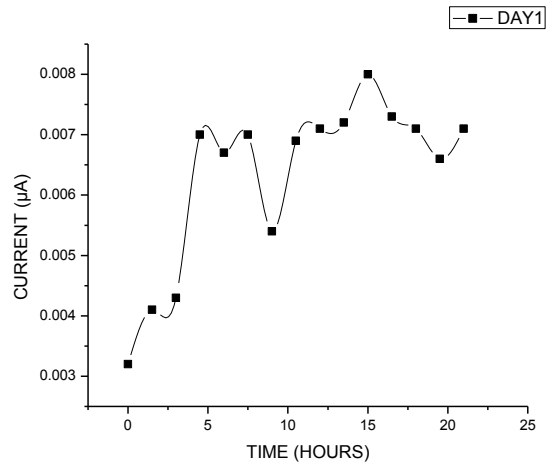


Fig 11. Generated current characteristics of Day 1.

#### Result obtained on day two

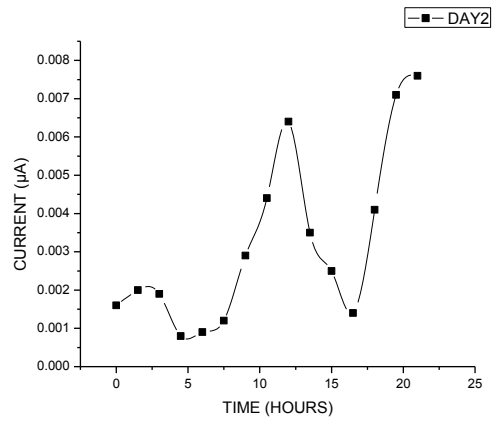
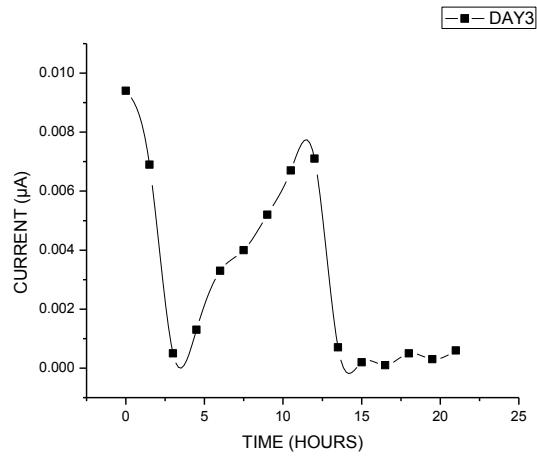


Fig 12. Generated current characteristics of Day 2

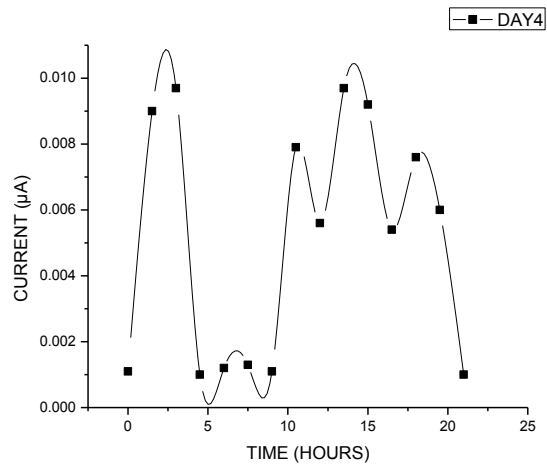


### Result obtained on day three



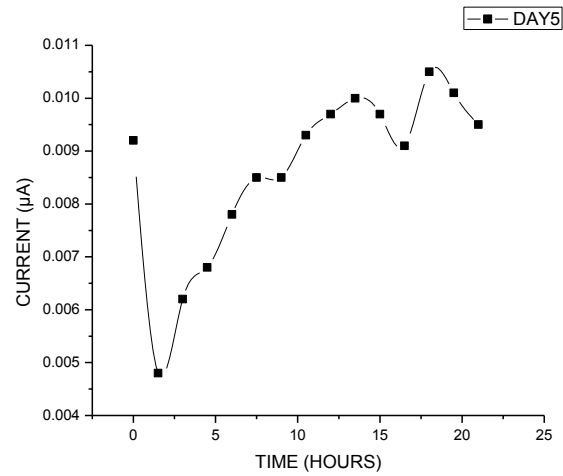
**Fig 13. Generated current characteristics of Day 3**

### Result obtained on day four



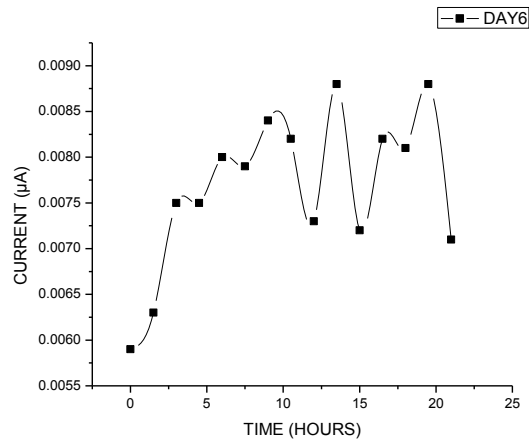
**Fig 14. Generated current characteristics of Day 4**

## Result obtained on day five



**Fig 15. Generated current characteristics of Day 5**

## Result obtained on day six



**Fig 16. Generated current characteristics of Day 6**

#### 4.4 Maximum generated current from day 1-6.

Table 4. Rate of change of Maximum Current from day 1-6.

DAY	MAX.CURRENT ( $\mu\text{A}$ )
1	0.008
2	0.0076
3	0.0094
4	0.0097
5	0.0105
6	0.0088

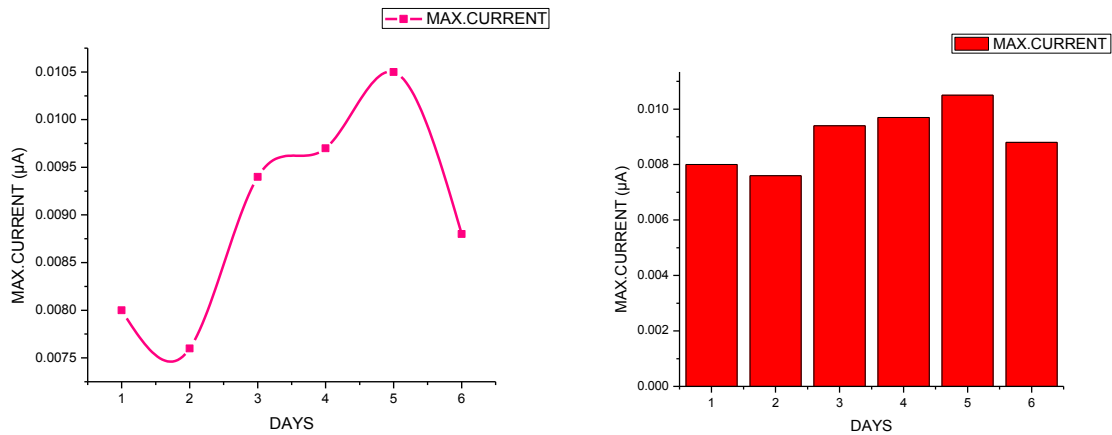


Fig 17. Maximum generated current characteristics from Day1- 6

## 4.5 Generated power in an open circuit

### Result obtained on day one

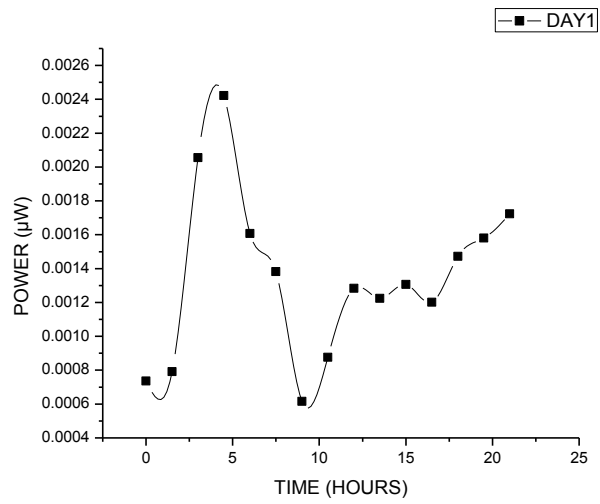


Fig 18.Generated power characteristics of Day1.

### Result obtained on day two

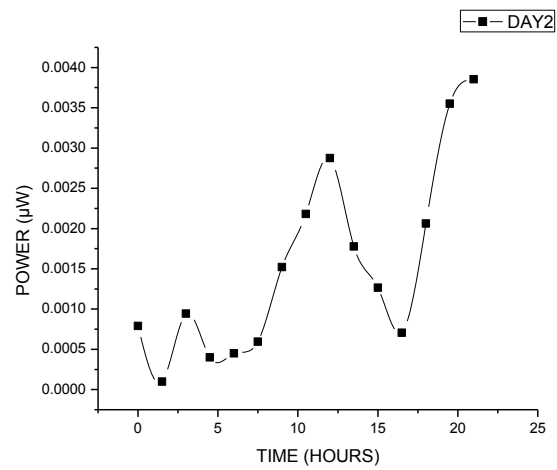
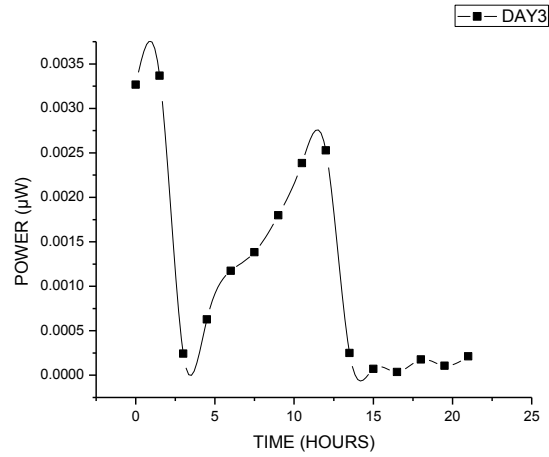


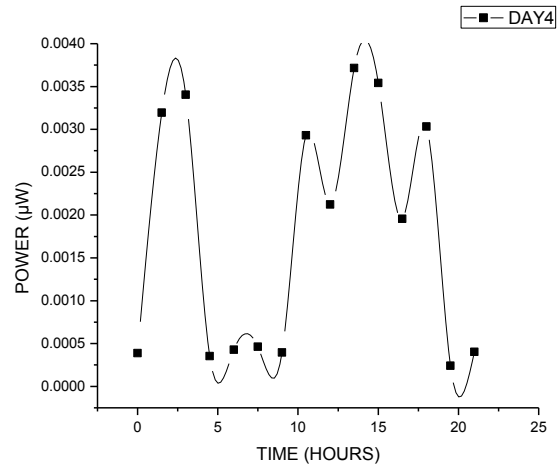
Fig 19.Generated power characteristics of Day2.

**Result obtained on day three**



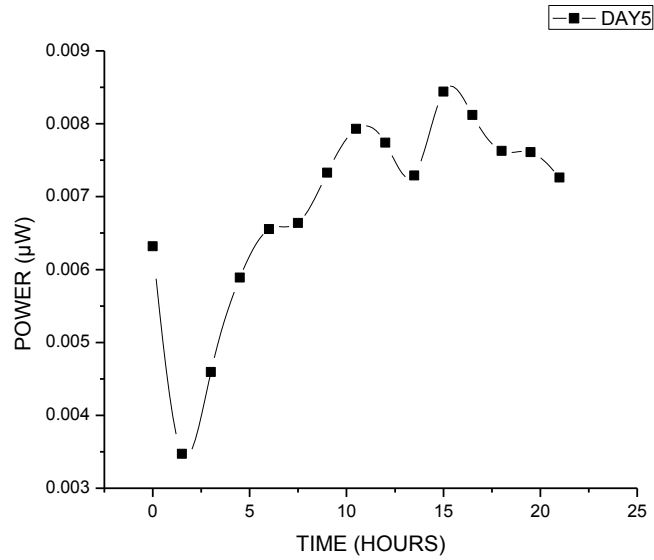
**Fig 20. Generated power characteristics of Day 3.**

**Result obtained on day four**



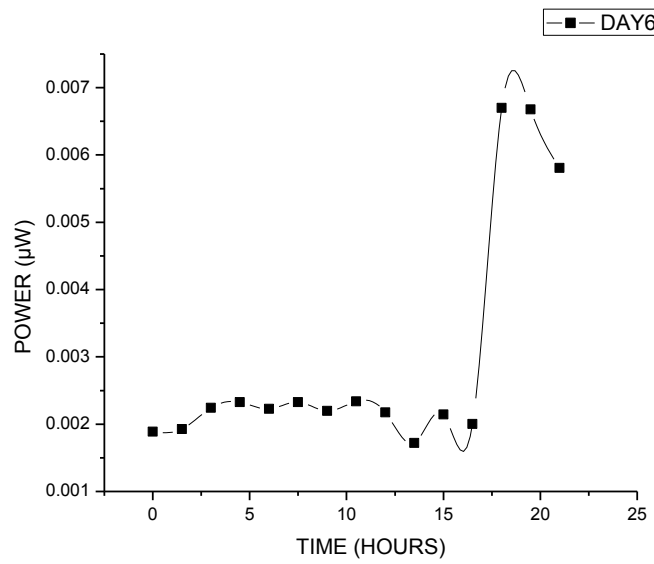
**Fig 21. Generated power characteristics of Day 4.**

**Result obtained on day five**



**Fig 22.Generated power characteristics of Day5.**

**Result obtained on day six**



**Fig 23.Generated power characteristics of Day6**

## 4.6 Max generated power from day 1-6

Table 5. Rate of change of Maximum generated power characteristics from Day1- 6

DAY	MAX.POWER ( $\mu$ W)
1	0.002422
2	0.003853
3	0.003367
4	0.003715
5	0.008442
6	0.0067

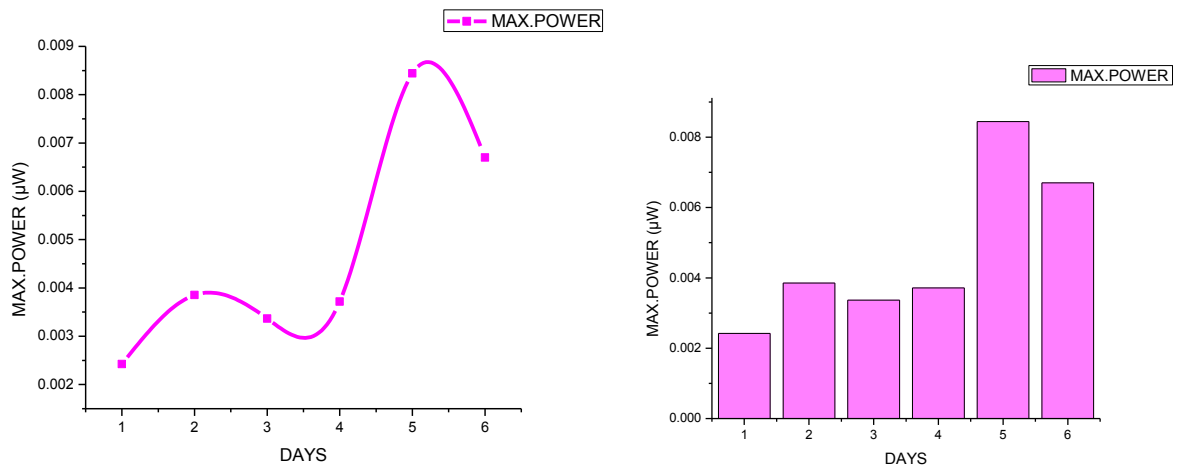


Fig 24. Maximum generated power characteristics from Day1- 6

## 4.7 Surface power density

### Result obtained on day one

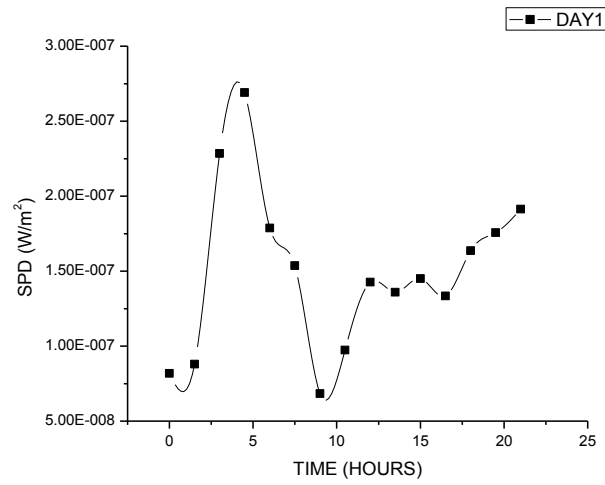


Fig 25. Generated surface power density characteristics of Day1.

### Result obtained on day two

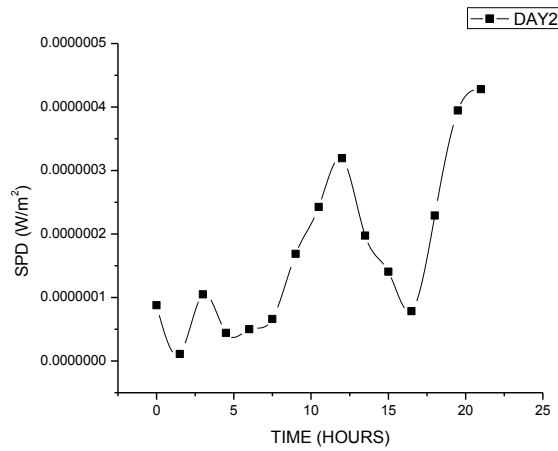
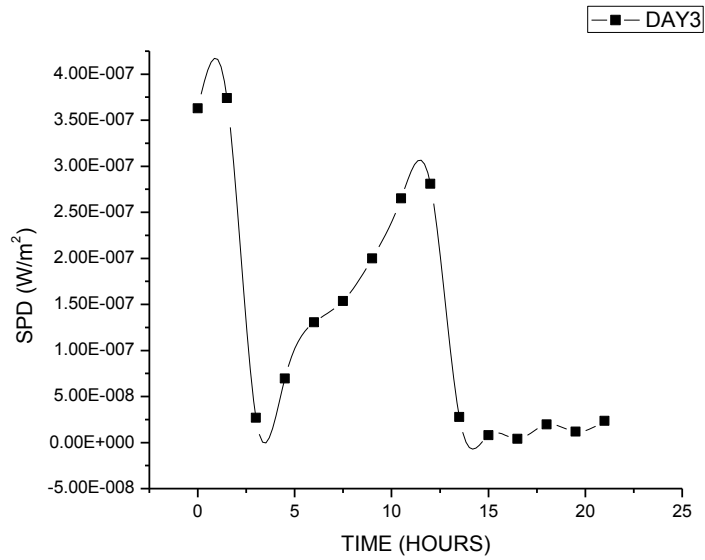


Fig 26. Generated surface power density characteristics of Day2

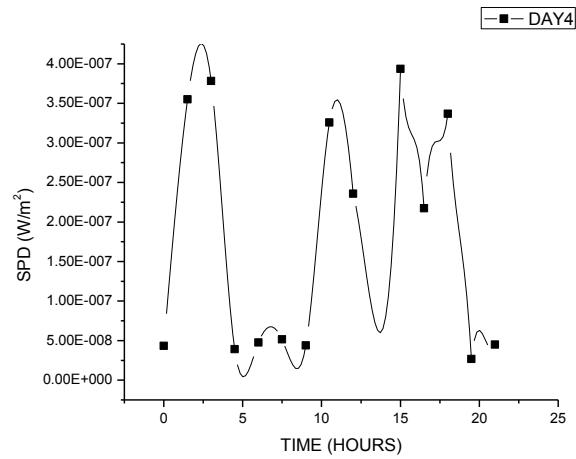


### Result obtained on day three



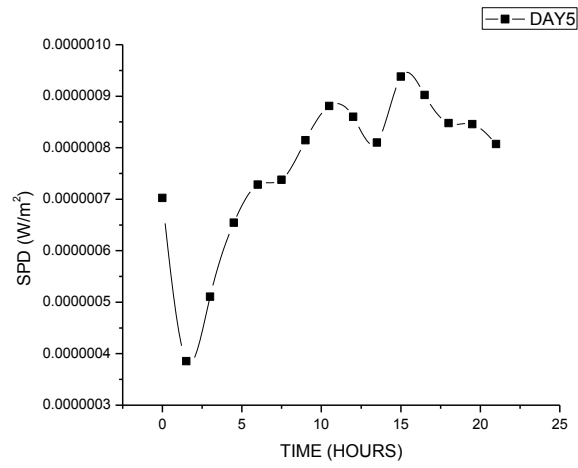
**Fig 27.**Generated surface powerdensity characteristics of Day3.

### Result obtained on day four



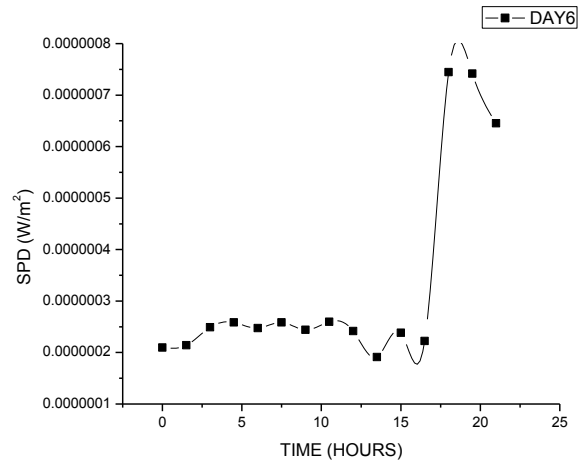
**Fig 28.** Generated surface powerdensity characteristics of Day4.

## Result obtained on day five



**Fig 29. Generated surface power density characteristics of Day5.**

## Result obtained on day six

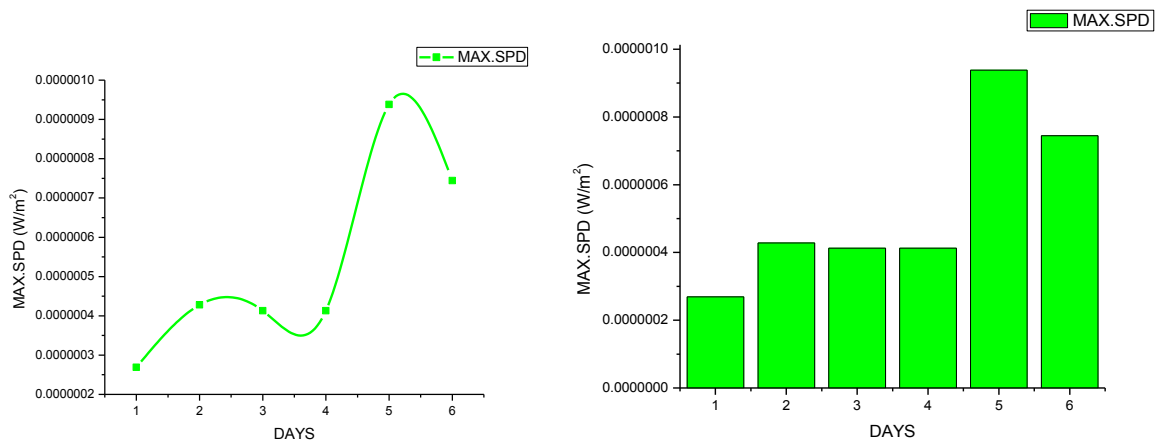


**Fig 30. Generated surface power density characteristics of Day6**

## 4.8 Maximum generated SPD from day 1-6

**Table 6. Rate of change of Maximum generated SPD characteristics from Day1- 6**

DAY	MAX.SPD (W/m <sup>2</sup> )
1	2.69111E-07
2	4.28133E-07
3	3.74133E-07
4	4.12789E-07
5	0.000000938
6	7.44444E-07



**Fig 31. Maximum generated SPD characteristics from Day1- 6**

# **Chapter Five**

## **DISCUSSION**

## 5.1 Generated voltage

Voltage generated by cow dung using double chamber MFC was recorded at an interval of 1&1/2 hr per day for the entire time period of 6 days as shown in Fig 4-9. The maximum generated voltage in each of the six days is depicted in Table 3. It is observed that there was a definitive increase in the generated voltage from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated voltage at day 5 was **0.804V** and the minimum generated voltage of **0.478 V** was observed on day 1. The voltage measured was open circuit voltage since the external resistance is not used. Hence the voltage generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

## 5.2 Generated current

Current generated by cow dung using double chamber MFC was recorded at an interval of 1&1/2 hr per day for the entire time period of 6 days as shown in Fig 11-16. The maximum generated current in each of the six days is depicted in Table 4. It is observed that there was a definitive increase in the generated current from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated current at day 5 was **0.0105μA** and the minimum generated current of **0.076 μA** was observed on day 1. The current measured was open circuit voltage since the external resistance is not used. Hence the voltage generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

## 5.3 Generated power

Power generated by cow dung using double chamber MFC was recorded at an interval of 1&1/2 hr per day for the entire time period of 6 days as shown in Fig 17-22. The maximum generated current in each of the six days is depicted in Table 5. It is observed that there was a definitive increase in the generated voltage from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated current at day 5 was **0.008442μW** and the minimum generated voltage of **0.003853 μW** was observed on day 1. The power measured was open circuit power since the external resistance is not used. Hence the power generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

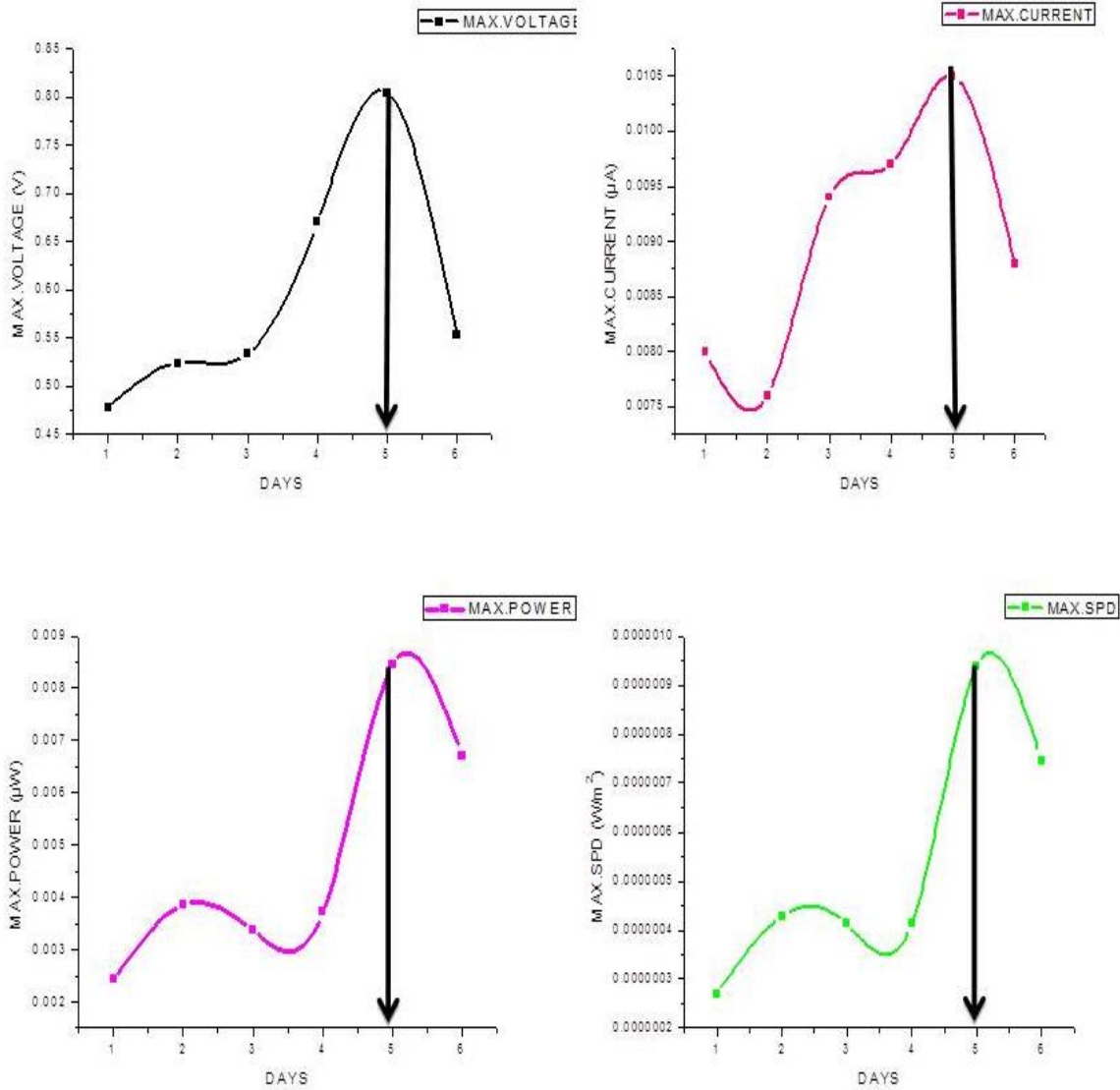
## 5.4 Generated surface power density

Power density generated by cow dung using double chamber MFC was recorded at an interval of 1&1/2 hr per day for the entire time period of 6 days as shown in Fig 23-28. The maximum generated power density in each of the six days is depicted in Table 4. It is observed that there was a definitive increase in the generated power density from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated power density at day 5 was **0.000000938W/m<sup>2</sup>** and the minimum generated power density of **2.69111E-07W/m<sup>2</sup>** was observed on day 1. Power density measured was open circuit voltage since the external resistance is not used. Hence the power density generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

## 5.5 Comparative analysis of generated voltage, current, power and surface power density

Table 7. Maximum generated voltage, current, power and surface power density from day 1- 6.

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6
Max.Voltage (V)	0.478	0.524	0.533	0.67	0.804	0.553
Max.Current (μA)	0.008	0.0076	0.0094	0.0097	0.0105	0.0088
Max.power (μW)	0.002422	0.003853	0.003367	0.003715	0.008442	0.0067
Max.SPД (W/m <sup>2</sup> )	2.69111E-07	4.28133E-07	3.74133E-07	4.12789E-07	0.000000938	7.44444E-07



**Fig 32. Maximum generated Voltage, Current, Power and SPD characteristics from Day1- 6**

The maximum generated voltage, current, power and surface power density is observed to have similar characteristics from day 1-6. The pattern of their increase and decrease are also follows the similar trend. On day 5, all the parameters measured are observed to have maximum value while on day 1 the minimum values are obtained except in the case of maximum current which might be due to high impedance of substrate resulted because of improper mixing of substrate and water.

# **Chapter Six**

## **CONCLUSION**



## 6.1 Conclusion

Due to rapid depletion and escalation of prices of conventional fossil fuel, the whole world is urgently looking for an alternative source of energy, which is renewable and can be produced in an economical manner. In this context, energy produced from a potential organic biowaste is an attractive option. Keeping this view, the present work has been undertaken to produce electrical energy from cow dung as biowaste in microbial fuel cell. The main outcomes of this project work is described below-

In the first phase of project work, a microbial fuel cell was successfully constructed using two 1.5 L bottles, which were operated as cathode and anode chambers. The salt bridge was made using KCl and agarose. Graphite plates were used as electrodes in MFC.

In the second phase, experiment was conducted to generate energy from locally available cow dung, which was used as a substrate for MFC. The whole system was connected to desktop multimeter for obtaining précised readings of voltage and current.

In the last phase, characterization of generated voltage, current, power and surface power density was done. The maximum values of these parameters obtained were 0.804V, 0.0105 $\mu$ A, 0.008442 $\mu$ W, and 0.000000938 W/m<sup>2</sup>.

Overall, this study has shown that the constructed the fabricated microbial fuel cell can be used for the generation of electricity from cowdung and possibly other waste.

### Suggested Further Study

The study and development of MFC is still in initial phase. The fabricated MFC has produced satisfying amount of voltage, though there is wide scope for development of MFCs in terms of design and power output as for now the power density is too low for their use in automobiles, electronic devices, medical appliances and other industrial applications. Modification in design components will provide improved results. High quality substrates can be used in MFC that can provide high power to run electrical appliances. The microorganisms which supply electrons can be modified genetically to provide more efficient electron transfer to electrodes. Optimizing the process parameters involved production of electricity can be increased. It is the matter of proper electrodes, salt bridge, volume of anode chamber

and an appropriate resistance to produce high power. Since the use of catalyzed electrodes have added most of the cost of fabrication and maintenance, different innovations like bio cathodes can be applied as a substitute. High quality proton exchange membranes can effectively increase the ion exchange without hindrance in the electricity production. Nanoparticles may be incorporated in salt bridge, cathode chamber or anode chamber which might boost up the output values.

A mathematical model may be developed for explaining the similarity and pattern recorded in this study, which might help to find the rate of reactions responsible for maximum and minimum values of the observed parameters.

# References

- (1) **Z.guodong et al.**, biocathode MFC for efficient electricity recovery from dairy manure, biosensors and bioelectronics, volume 31, issue 1, 15 january 2012, pages 537–543
- (2) **karmakar,S et al.**, design and development of microbial fuel cells, current research, technology and education topics in applied microbiology and microbial biotechnology,
- (3) **Lovley.D et al.** the microbe electric: conversion of organic matter to electricity, current opinion in biotechnology, vol 19, 2008, pp.1-8
- (4) **M. venkatamohan et al.**, harnessing, bioelectricity through microbial fuel cell from wastewater, renewable energy, april 2012, volume 5, issue 5
- (5) **lilingwei et.al**, effects of cathodic electron acceptors and potassium ferricyanide concentrations on the performance of microbial fuel cell, international journal of hydrogen energy, 2012, pp. 1-7
- (6) **Rabaey, k.et al.**, microbial fuel cell, performances and perspectives”, biofuels for fuel cells: biomass fermentation towards usage in fuel cells, 2005.
- (7) **kumari. S et al.** studies on marine microbial fuel cell, e-thesis, 2012. pp. 1-54
- (8) **Zhou.M et al.** an overview of electrode materials in microbial fuel cells, journal of power sources, 2011, volume 196, issue 10, pp. 4427–4435
- (9) **Logan.B.** e. microbial fuel cells. (wiley, hoboken new jersey. 2008
- (10) **Wei.J et al.**, recent progress in electrodes for microbial fuel cells, bioresource technology, vol.11, 2011, pp. 1-47
- (11) **Jia.J et al.**, electricity generation from food wastes and microbial community structure in microbial fuel cells, bioresource technology, volume 144, september 2013, pages 94–99
- (12) **Logan .B et al.**.Electricity generation and treatment of paper recycling wastewater using a microbial fuel cell. Appl. Microbiol. Biotechnol. Vol.80, pp. 349–355.
- (13) **Catal, T et al.**, Electricity production from polyalcohols in single-chamber microbial fuel cells. Biosens.Bioelectron.2008, Vol.24, pp. 855–860
- (14) **Dumas, C et al**, Microbial electrocatalysis with *Geobactersulfurreducens* biofilm on stainless steel cathodes. Electrochem.Acta, 2008, Vol. 53, pp. 2494–2500.

- (15) **Luo, H et al.**, Phenol degradation in microbial fuel cells. *Chem. Eng. J.*, 2008, Vol. 147, pp.259–264.
- (16) **Niessen, J et al**, Exploiting complex carbohydrates for microbial electricity generation – a bacterial fuel cell operating on starch. *Electrochem.Comm.*6, 2004, pp.955–958.
- (17) **Rodrigo, M.A et al.**, Production of electricity from the treatment of urban waste water using a microbial fuel cell. *J. Power Sources* , 2004, Vol. 169, pp. 198–204
- (18) **Ohet al.**,Hydrogen and electricity production from a food processing wastewater using fermentation and MFCtechnologies. *Water Res.*, 2005, Vol. 39, pp. 4673–4682.
- (19) **Wang, X. et al.**, Accelerated start-up of two-chambered microbial fuel cells: effect of positive poised potential. *Electrochem.Acta*, Vol. 54, pp. 1109–1114.
- (20) **Zhao.G et al**, electricity generation from cattle dung using MFCtechnology during anaerobic acidogenesis and the development of microbial populations, *waste management*, 2012,volume 32, issue 9, pages 1651–1658.
- (21) <http://denmark.dk/en/green-living/sustainable-projects/cow-dung-a-source-of-green-energy/>
- (22) **Henrian,H et al.**,harvesting electrical energy from cellulose using cow manure microorganisms as biocatalysts in a two-chamber, 4<sup>th</sup> national science and mathematics congress of regional science high schools, 2008
- (23)H. Liu, B.E. Logan, Electricity generation using an air–cathode single chamber MFCin the presence and absence of a proton exchange membrane, *Environ. Sci. Technol.*,2004, pp. 4040–4046
- (24) **Yokoyama.H et al**, treatment of cow-waste slurry by a MFCand the properties of the treated slurry as a liquid manure, *animal science journal*, animal science journal, 2006, volume 77, issue 6, pp. 634–638,
- (25) **X. zheng et al**, cattle wastes as substrates for bioelectricity production via microbial fuel cells, *biotechnology letters*, 2010, volume 32, issue 12, pp 1809-1814
- (26) **Khare. A et al.**, generation of electricity using vermicompost with different substrates through single chamber mfc approach, *international journal of engineering trends and technology* ,2013,vol 4. .
- (27) **lee.Y et al.**, electricity production in membrane-less MFCfed with livestock organic solid waste, *bioresource technology*, volume 102, issue 10, may 2011, pages 5831–5835.
- (28) **Zhang.G et al**, Biocathode Microbial Fuel Cell for Efficient Electricity Recovery from Dairy Manure, *Biosensors and Bioelectronics*, 2011.