# Dairy Wastewater Treatment and Electricity Generation Using Microbial Fuel Cell

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**Abstract -** *Microbial Fuel Cell (MFC) is feasible to use as an alternative to conventional wastewater treatment techniques. The compiled project work successfully represents the MFC as a significant technology in the dairy industry, uniting wastewater treatment and off-grid electricity production. The optimized design parameters are found out by evaluating the practicability of using different electrodes, varying detention time and increased electrode surface area. MFC in which stainless steel (15×5×0.1cm) is incorporated as electrode and Agar-NaCl salt bridge is used as proton exchange membrane is finally identified as the optimum design at 6 hours detention time with a power and electrical energy generation of 37.651µW and 0.0677W sec respectively. The percentage of removal efficiencies achieved in the optimized experimental setup for various parameters such as COD, Oil and Grease, BOD, EC and TDS are 93.98%, 83.82%, 90.63%, 73.06% and 72.66% correspondingly. Finally it has to be concluded that "Microbial Fuel Cell Technology" is efficient for dairy wastewater treatment and simultaneous energy recovery.*

***Key Words*: Microbial Fuel Cell, Dairy Industry, Proton Exchange Membrane, Off-Grid Electricity Production**

## 1. INTRODUCTION

Some of the biggest challenges the world is facing in the recent decades are energy crisis due to continuous depletion of fossil fuels, increasing price of fuels and global warming. Increasing pollution levels in terms of $CO_2$ emissions are not on track which causes global warming. As the world's population increases day by day, the demands such as water, food and energy sources are also increases. The Energy-Water-Food Nexus is the biggest challenge in the world. If it is possible to find a better solution to resolve one challenge could improve the others. To quench the world's energy demand, it is important to find alternative energy source which comes under renewable energy sources. As the availability of fossil fuels decreases, the market price gets increased. Numbers of researches are carrying out day by day related to renewable energy in order to find suitable technology which does not harm environment. Along with popular renewable energy such as solar and wind, biomass, bio-fuel etc have also gain attention in the recent decades. But more technological innovations are required to eliminate the limitations of all available renewable sources of energy. Industrialization results not only high production, but also increased water usage as well as waste generation. Energy recovery from waste is one of the interesting topics for research. Energy can be recovered in different forms such as electrical energy, heat or natural gas. Comparing with other forms of waste, wet waste (wastewater) is the one from which energy recovery can be done efficiently. Bio-electrochemical systems (BES) are those which generate electricity from biomass by spontaneous bacterial activity. Microbial fuel cells (MFC) are one of the major types of BES. Microbial fuel cell is a promising technology by which simultaneous wastewater treatment and energy generation can be accomplished without any energy input. Potential of microbial fuel cell to treat wastewater and to generate energy in pilot scale is yet to be evaluated.

It is important to evaluate the feasibility of using different substrates and different electrode materials for which the study can be extended to a pilot scale, and in the present study an attempt has been made to evaluate the effects of MFC with dairy wastewater for different variables such as different electrode configurations, varying surface area and detention time. Efficiency of microbial fuel cell in treating dairy wastewater is analyzed for all variable designs and effort is put to find out the optimum design. Along with treatment efficiencies, electrical properties of MFC is also studied in terms of power generation and electrical energy produced.

## 2. MATERIALS AND METHODOLOGY

Continuous flow type two chambered microbial fuel cell is fabricated from the locally available materials. Materials for fabrication are collected from the nearby shops. After material collection, fabrication is done and all the fabricated units are assembled in the laboratory.

### 2.1 Collection of Wastewater and Analysis

Dairy wastewater is used as substrate in MFC and it is collected from Shimul Dairy, Shimoga District. Wastewater is taken from the equalization tank present in the dairy premises. Collected wastewater is stored in the refrigerator at 4ºC in order to retard the microbial activity. This wastewater is non toxic and rich in organic matter and it is analyzed in the laboratory to find out the initial characteristics of the wastewater such as COD, $BOD_3$, pH, Oil and Grease, TDS and EC and the test results are shown in Table-1 below.

**Table -1: Initial Characteristics of Dairy Wastewater**

| Sl No. | Parameters | Results |
|---|---|---|
| 1. | COD (mg/l) | 8250 |
| 2. | Oil and Grease (mg/l) | 49.83 |
| 3. | $BOD_3$ (mg/l) | 6280 |
| 4. | EC @ 25ºC (µS/cm) | 837 |
| 5. | TDS (mg/l) | 462 |
| 6. | pH | 5.52 |

## 2.2 Seed Culture and Inoculums

Locally available cow dung is used to prepare the inoculums. 5g of cow dung and 100ml of dairy wastewater is mixed with 3 liters of water and introduced to anaerobic chamber. It is kept for continuous 7 days and a thin bio-film formation is observed after 7 days. Excess seed is removed and substrate was introduced after 7 days.

## 2.3 Working and Sample Collection from MFC

Before introducing in to the MFC, dairy wastewater is kept out from the refrigerator in order to bring its temperature back to the normal atmospheric temperature. Wastewater is stirred for 25 minutes in a mechanical stirrer for making it uniform. As pH and temperature are important parameters for efficient working of MFC, pH is adjusted to 6.5-7 by adding NaOH extra pure solution.

Two numbers of aspirating glass bottles are used as head balancing tanks to feed the sample in to the anaerobic chamber as the flow rate has to be maintained uniformly. 26.5cm head is maintained in the second head balancing tank to ensure uniform flow. Pinch cocks are used for maintaining the flow rate and there by maintaining the detention time. Anodic chamber is sealed for maintaining complete anaerobic condition and wastewater is fed at a fixed rate in to the chamber. Cathodic chamber is filled with distilled water and electrodes are fixed at a distance of 5cm from the salt bridge. Electrodes are attached to the copper wire by using crocodile clips and the wire is externally connected to the digital multimeter. After every half an hour voltage and current generated is noted down and the collected effluent samples are stored in refrigerator below 4ºC till analyzing. Salt bridges are changed for each variable as it gets saturated.

For the optimized experimental setup in which maximum power generation and treatment efficiency is obtained, filtration and aeration are provided and the effects in terms of treatment efficiency are found out. Filtration and aeration units are arranged in a manner so that continuous flow can be maintained. Uniform sized filter media is used and diffused aeration is achieved by using aquarium air pump with a maximum output of 3L/min. Additional effects of aeration is find out by varying the aeration time such as 1, 2 and 3 hours. Samples are collected after each aeration time and analyzed for different parameters. Over all optimized design is stated with removal efficiencies and electrical properties of MFC. The line diagram, pictorial view of overall experimental setup is shown in Fig-1.

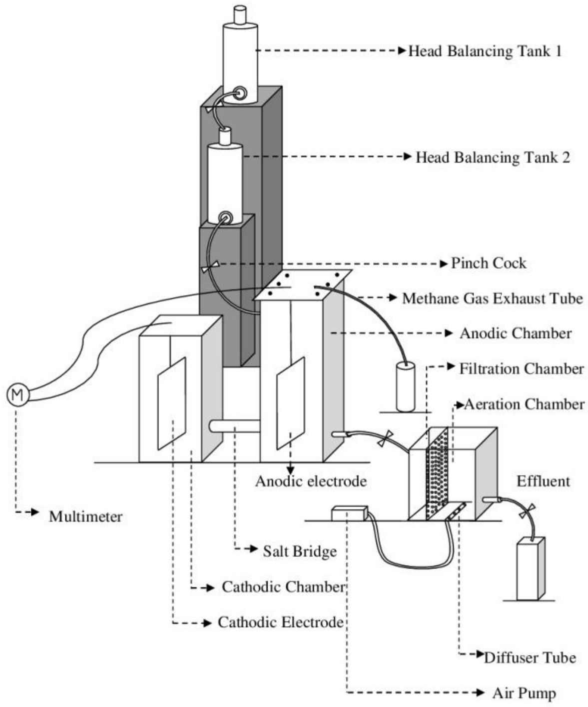


**Fig -1**: Line Diagram of the experimental Setup

## 2. RESULTS AND DISCUSSIONS

Removal efficiencies along with the electrical properties are monitored for each experimental setup and experimental setup with stainless steel of larger surface area showed higher removal efficiency and stable electrical properties. The extent of COD removal is noted as 93.98%, whereas BOD removal efficiency is 90.63% as comparing with all other results. Graphical representation of variation in COD removal efficiencies with respect to various experimental setups are shown in chart-1. As the surface area of stainless steel increased from 103 to 152cm², radical change in removal efficiencies are observed for all three detention times. When both anodic and cathodic surface areas are increased from 103cm² to 155cm², power and electrical energy delivered by MFC also increased more than 22µW. Highest voltage and current generation (502mV & 77µA) are obtained for 6 hours detention time. As detention time increased from 2 to 4 hours, maximum power generation is increased by 23mV and from 4 to 6 hours the hike is found more than 100mV. Graphical representations of the results of optimized design (Chart 2&3) show clear separations between the electrical properties and a gradual increase with respect to the detention time are visible.

Comparing with the results of experimentation with small stainless steel electrode (103cm$^2$), highest current and voltage generations are significantly increased from 41μA to 77μA and 412mV to 502mV respectively. For smaller surface area, highest electrical energy and power generation (0.0264798W-sec and 14.711μW) are obtained for 6 hours detention time and in case of increased surface area, highest electrical energy and power generation (0.067773W-sec and 37.651μW) are obtained for 6 hours detention time. Results clearly indicate that, increase in anodic and cathodic surface areas readily affects the electrical properties of MFC.

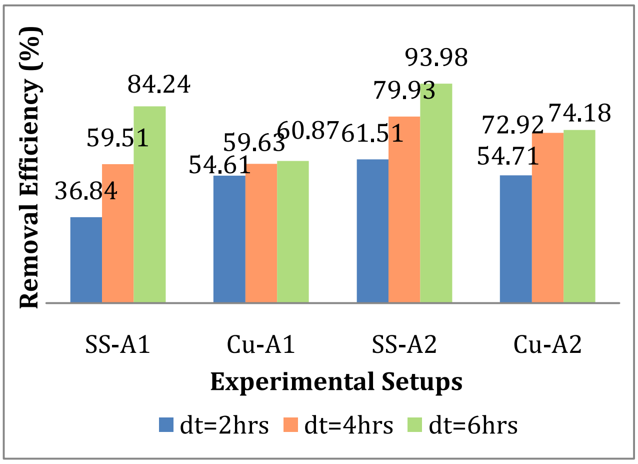


**Chart-1**: COD Removal Efficiencies

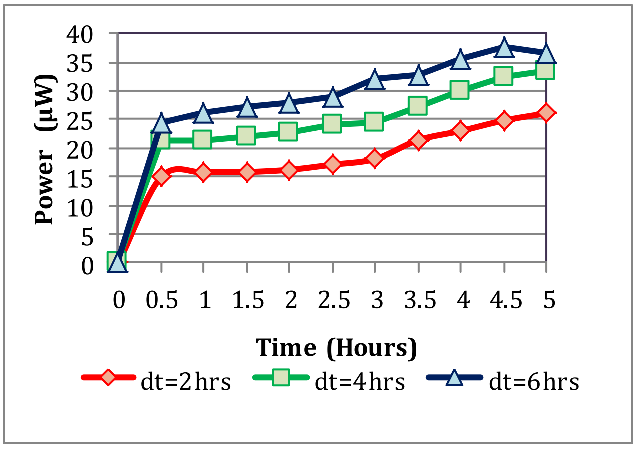


**Chart-2**: Power Generation (SS-A$_2$)

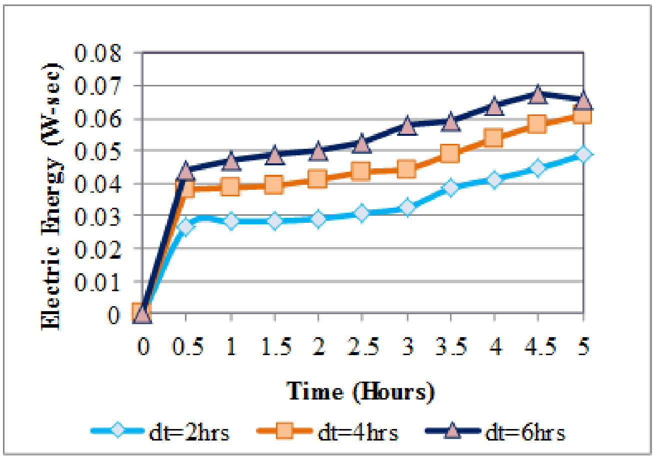


**Chart-3**: Electrical Energy (SS-A$_2$)

## 2.1 Additional Effects of Filtration and Aeration

For the optimized design, additional treatments such as filtration and aeration are provided and the removal efficiency of each parameter is monitored. The treated dairy wastewater from the anaerobic chamber is maintained at a flow rate of 0.65lit/hr, and allowed to get filtered through the filter media. After filtration, wastewater is collected in the aeration chamber and aeration is provided. Different parameters such as COD, Oil and Grease, BOD, EC, TDS and pH are found out in laboratory by following standard test procedures.

Removal efficiency of all parameters is increased after filtration and aeration. Highest removal efficiencies of COD, Oil and Grease, BOD, EC and TDS are 95.7%, 96.60%, 93.79%, 81.61% and 77.64% respectively observed when 3 hours aeration is provided. Results of 2 hours aeration is significantly good as the results of experimentation with 3 hours aeration time. And thereby 2 hours aeration is found optimum both in economic point of view and removal efficiency

## 3. CONCLUSIONS

From the experimentation named "Dairy Wastewater Treatment and Electricity Generation Using Microbial Fuel Cell", the following conclusions have been made:

- The present study successfully presents the MFC as an excellent resource recovery technology in the dairy industry; unite wastewater treatment and off-grid electricity production.
- The good outcomes and consequences of using two different types of electrodes (Stainless Steel and Copper) as anodic and cathodic electrodes in MFC are monitored and Stainless Steel is found significantly better in terms of both treatment efficiency and electricity generation.

- Copper is appreciably good in conducting electrons but the main drawback found in using copper electrode as anodic and cathodic electrode for MFC is the anaerobic corrosion and its antimicrobial characteristics.
- Surface area is found to be an important parameter as it vary from 103cm$^2$ to 152cm$^2$ noteworthy increase in percentage of removal efficiency and power generation are noticed.
- Even though maximum voltage (529mV), current(132μA), power(57.367μW) and Electrical Energy(0.103262W-sec) are obtained when copper is used as electrode in both the chambers, stainless steel is found as ideal electrode due to its stable electrical properties.
- An increase in removal efficiency is found after providing additional filtration and aeration. As both the experimental results of 2 hours and 3 hours aeration gives nearly same removal efficiencies, 2 hours aeration is found better in cost-effective aspect.
- Finally it has to be concluded that "Microbial Fuel Cell Technology" is efficient for dairy wastewater treatment and instantaneous energy recovery. MFC application in the dairy industry requires additional optimization in order to amplify power voltage and to decrease detention time.

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