Treatment of Dairy Wastewater using MFC Employing Zinc Electrode

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Abstract

Conventional wastewater treatment methods can be replaced by adopting MFC. The organized project conducted satisfactorily represents MFC as a convincing technology to treat dairy effluent along with generation of energy. The primary object of the existing paper "Treatment of Dairy Wastewater using MFC Employing Zinc Electrode" is to examine the efficiency of dual chambered MFC having continuous feed of substrate. The substrate employed is dairy effluent. The developed design parameters are established by checking out the responsibility of employing silver nanoparticles integrated salt bridges, Zinc electrodes and altering detention time. Zinc electrode having surface area of 123.4 sqcms is finding to be most stable performer. The detention time of six hours is found to be optimum for maximum output. For optimized experimental set up the maximum efficiencies obtained in removal of COD, BOD, EC, TDS and Oil and Grease were 77.58%, 75.02%, 65.95%, 57.96% and 67.32%. Maximum power and electrical energy generated were 21.483 μW and 0.0386694 Watt-sec respectively. From the results obtained the conclusion was MFC is efficient in replacing conventional method of treating dairy wastewater. It can treat efficiently along with energy generation.

Keywords- Microbial Fuel Cell, Dairy Wastewater, Silver Nanoparticles Integrated Salt Bridge, Zinc Electrode

I. INTRODUCTION

To meet the increasing energy demand caused due to population growth, modernization, industrialization and urbanization there is continuous extraction of fossil fuels as source of fuel because of which depletion of conventional sources is taking place. Regular usage of fossil fuels is leading to increase in levels of pollution, emission of carbon di oxide which is leading to Global warming. Day by day the requirement of energy goes on increasing. To reduce the burden as well as consumption of fossil fuels one has to find out the alternative energy sources which is derived from non-conventional references such as solar, tidal, wind, biomass, hydropower and bio fuels which have got no significant environmental impacts. In the current decades many research works are being carried out on utilization of generated biomass as main source of energy by which load on treatment plants will be reduced and proper maintenance of waste can be achieved. For continuous supply of energy from such sources, requires more innovative ideas and technological research works.

Industrial production requires huge amount of water supply thus large amount of wet waste is generated as a byproduct. It requires proper treatment methodologies before disposal. Energy reclamation from such waste effluent has got high efficiency and can overcome the difficulties caused due to energy crunch. In various forms energy can be recaptured from wet effluent say Natural gas, heat, generation of electric current. BES (Bio electrochemical System) is one of the most suitable methods for generating electric current by utilizing impulsive activities of microbes present in effluent. Without any intake of energy contemporarily effluent is treated and energy is generated from a technology based on Microbial fuel cells, which is highly promising. Possibility of treating the wet effluent and generation of electric current from such cells in large scale requires proper investigation.

It is essential to investigate the liability of adopting distinct substrates and electrode components for enhancing the analysis to a large scale and currently an effort is made to investigate the impact of MFC with dairy industry effluent for distinct detention time, Zinc electrodes and impacts of nanoparticle integrated salt bridges. Potentiality of microbial cells in handling Dairy effluent is examined for all variable conspiracies and an attempt is made to know the ideal conspiracy. Besides of handling the effluent, MFC electrical characteristics are considered for analyzing the generated electric current and power.

II. HISTORY OF MFC

In 1911 Potter was the first to find out the degradation of organic substance and generation of electrons from ERB (Electrode Respiring Bacteria). He identified that disintegration of organic substance by microbes was followed by discharging of electrons. Various factors influence this criteria say temperature, pH, concentration of nutrients and active microbes. Whole metabolic activities were not explained by Potter. Later in 1980's a remarkable research work continued on BES. After 1999 an effort was

applied to increase power generation from MFC's and it was found successful. It was noticed that for larger area cathodes the generation of power reached up to 6.9 Wm^{-2}.

By utilizing metals as catalysts, fuel cells act as substitute source of energy. BES consists of microbial fuel cells which convert chemical energy into electrical energy in an anaerobic condition by microbial activities. The main advantage of adopting MFC technology is, current is generated along with the treatment of wastewater. Usually in wastewater treatment process emission of methane is a big problem to be faced, but by adopting MFC treatment methodology this can be avoided as the gas generated is off gas which is harmless and no further monitoring of gas is required.

To generate high voltage current MFC's can be operated under different conditions of, say pH, size of reactor, time of operation, electron acceptor, electrodes surface area MFC mainly constitutes of Anodic and cathodic chambers, salt bridge, electrodes, substrate, digital multimeter, copper wire. Anode is maintained for anaerobic condition by proper sealing of container whereas cathode for aerobic condition and it is achieved by providing proper aeration system. Physically both chambers are made apart by connecting a proton exchange membrane in between. This helps in transfer of Hydrogen ions from anode to cathode. Usually Agar salt bridge is used as PEM. Electrodes are connected to external circuit by digital multimeter. The Hydrogen ions and electrons react with oxygen present in cathode to form water (reduction).

Microbes that are developed in anaerobic compartment require energy to sustain that is obtained in two steps. In first step, oxidation of food occurs by releasing electrons and in second, these electrons are passed to electron acceptors for reduction process, say nitrate or oxygen. Usually when organic matter is degraded by bacteria in aerobic condition they produce carbon dioxide and water but in absence of oxygen they produce H^+ (protons), carbon dioxide and electrons as shown in equation below.

A. Anodic Reaction

$$C_{12}H_{22}O_{11} + 13H_2O \longrightarrow 12CO_2 + 48H^+ + 48e^- \text{ (Oxidation)}$$

B. Cathode Reaction

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O \text{ (Reduction)}$$

The efficiency of MFC can be expressed interms of generation of current, power, voltages and by testing various parameters of the effluent collected at the outlet.

III. STUDIES AND FINDINGS

For simultaneous treatment of wastewater and generation of electric current two chambered MFC was used and it requires the following prerequisites for the development of cell. They are: Acrylic sheets for the development of anode chamber, Plastic container with half open lid as cathode chamber, Aspirator Bottles, Pinch clips to maintain flow rates, Zinc electrodes, Polyvinyl Chloride pipes, Copper wires, Flexible pipes, Digital multimeter with DT830 series.

A. Collection and Analysis of Wastewater

From Bathi Milk Dairy, Davangere District the substrate required was collected and the initial parameters were tested. After analysis the sample was stored in refrigerator to avoid degradation.

Table 1: Initial Characteristics of Dairy Effluent

Serial No.	*Parameters*	*Results*
1	*COD (milligram/litres)*	*7380*
2	*BOD_3 (milligram/litres)*	*5430*
3	*EC @ 25^0 C (µs/cms)*	*752*
4	*Ph*	*5.9*
5	*TDS (milligram/litres)*	*402*
6	*Oil and Grease (milligram/litres)*	*39.45*

Table 1 represents the Intial characteristics of wastewater collected from Dairy industry.

B. Nanoparticles Integrated Bridge Preparation

Prepare 0.002M concentration of $NaBH_4$ (Sodium Borohydride) solution along with that prepare 0.001M concentration $AgNO_3$ solution. On ice bar place container having 30ml of Sodium Borohydide solution and start stirring up to the formation of homogeneous solution, now add 2ml of 0.001 M AgNO3 at specified rate say 1 drop/sec. This solution is added to the mixture of Agar NaCl Bridge and then poured into pipe and kept in refrigerator for uniform setting. It is shown in Fig. 1.

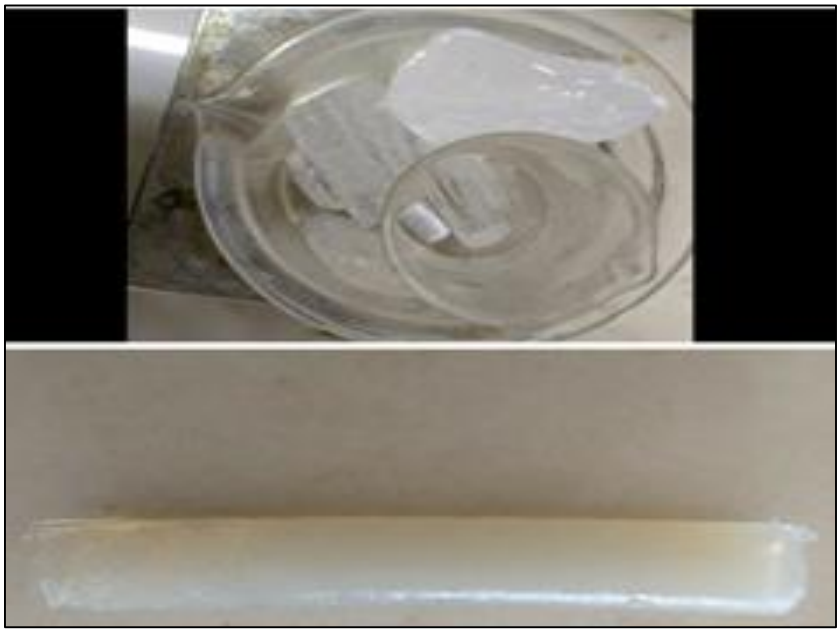

Fig. 1: Preparation of Silver Nanoparticles integrated Agar NaCl Bridge

C. Preparation of Inoculums and Seeding

Take 3litres of water in anode compartment add 100ml of dairy industrial wastewater and 5gms of cow dung and mix well. Set up the anaerobic condition by proper packing of lid and without causing any disturbances allow it to stay for 7 more days for the formation of thin biofilm layer. After this remove all excess seed and add substrate into anode compartment.

D. Working Principle

In order to maintain optimum pH and temperature the collected wastewater was kept outside and stirring was done for about 25min using magnetic stirrer instrument to obtain uniform wastewater composition.

In lab, the experiment set up was done, two aspirator bottles were used to store and supply substrate, they were connected by flexible pipes having pinch clips. 26cm head was maintained in one bottle to provide uninterrupted uniform flow of substrate. Through flexible pipes substrate was introduced into the completely packed anaerobic compartment at fixed rate to maintain Detention time. Pinch clips were fixed to adjust flow rate, distilled water was filled in cathode compartment. Distance between salt bridge and electrodes were kept as 5cm, using copper wire electrodes were connected to external circuit where mutimeter was placed. Digital readings of voltage in mV and current in micro amp were taken for every 30mins of duration of time and the treated effluent was collected and kept in fridge for further analysis.

IV. RESULTS AND DISCUSSIONS

Zinc electrode of 12x5x0.1 cm having surface area of 123.4 sqcms was used as electrode in both anode and cathode compartment. PEM was developed by Nanoparticle integrated salt bridge. Table 2 represents the intial and final effluent characteristics.

Table 2: Initial and Final Effluent Characteristics

Parameter	*Concentration of influent C_{in}*	*Concentration and Efficiency of effluent at distinct DT*					
		DT_1=2hrs		*DT_2=4hrs*		*DT_3=6hrs*	
		C_{eff}	*η%*	*C_{eff}*	*η%*	*C_{eff}*	*η%*
COD	*7380*	*3512*	*52.41*	*1994*	*72.98*	*1654*	*77.58*
BOD	*5430*	*2789*	*48.63*	*1722*	*68.28*	*1356*	*75.02*
EC	*752*	*422*	*43.88*	*349*	*53.59*	*252*	*65.95*
TDS	*402*	*245*	*39.05*	*218*	*45.77*	*169*	*57.96*
Oil and Grease	*39.45*	*20.82*	*47.22*	*14.56*	*63.09*	*12.89*	*67.32*
pH	*5.9*	*6.72*		*6.89*		*6.92*	

The efficiency of removal for different detention time is represented in the above Table. It was found that as the detention time increases efficiency increases. Maximum efficiency obtained for removal of COD, BOD, EC, TDS and Oil and Grease was 77.58%, 75.02%, 65.95%, 57.96% and 67.32% respectively.

Corresponding power and electrical energy generated for distinct detention time are represented in following Fig 2 and 3.

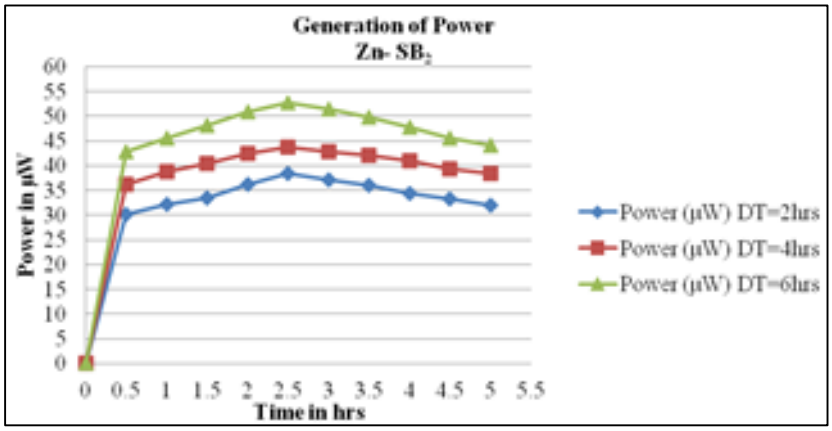

Fig. 2: Generation of Power (Zn- Nanoparticles Integrated Bridge)

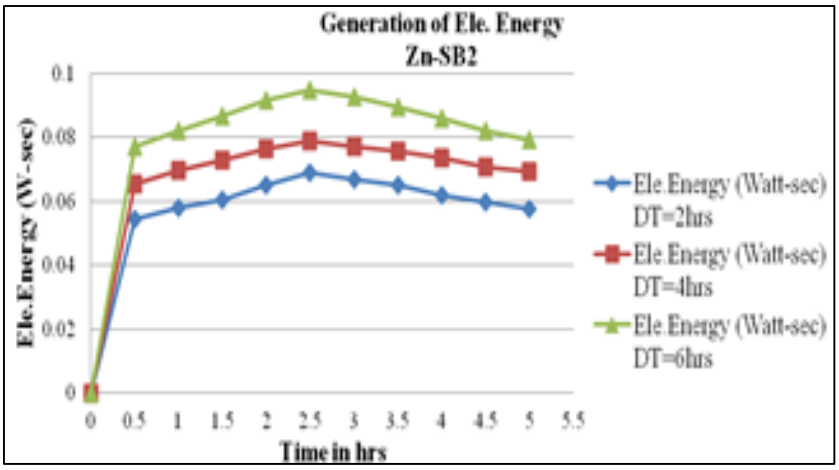

Fig. 3: Generation of Ele. Energy (Zn- Nanoparticles Integrated Bridge)

Maximum power and electrical energy generated was 21.483 µW and 0.0386694 Watt-sec respectively. From the graph it is found as H^+ ions transfer increased by nanoparticles more electrons are passed through circuit and more current is generated. But as the Silver particles shows the antimicrobial nature the degradation of organic matter decreased leading to lesser generation and transfer of electrons. Thus there is decrease in power and electrical energy generation.

V. CONCLUSIONS

- Microbial fuel cell proves itself to be successful in treatment and generation of power.
- Zinc proves to be a suitable electrode for MFC.
- Six hours detention is suitable for treatment as it has got high efficiency of removal as compared to two and four hours by employing Zinc electrode.
- For optimized experimental set up the maximum efficiencies obtained in removal of COD, BOD, EC, TDS and Oil and Grease were 77.58%, 75.02%, 65.95%, 57.96% and 67.32%.
- Lastly it is concluded by saying MFC can replace conventional treatment methods of treating wastewater along with off grid energy generation. It can be adopted in treating dairy wastewater. Some of the changes have to be done to increase the efficiency of treatment and generation of energy say by increasing the area of electrode.

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