# Impact of Nanoparticle Incorporated Salt Bridge on Bioelectricity Production and Treatment Efficiency of Microbial Fuel Cell

**Drisya C M[1] Manjunath N T[2]**
[1]M. Tech. Scholar [2]Professor
[1,2]Department of Civil Engineering
[1,2]University B. D. T. College of Engineering, Davangere, Karnataka India

*Abstract*— Bio electrochemical systems (BESs) have recently emerged as an exciting technology. In a BES, bacteria interact with electrode using electrons, which are either removed or supplied through an electrical circuit. The most described type of BES is Microbial Fuel Cells (MFCs). Microbial fuel cells (MFC) use the power of bacteria and convert energy released in metabolic reactions into electrical energy. Microbial fuel cells with nanoparticles incorporated salt bridge showed higher energy generation in the experimental setup with copper electrode due to the abiotic current production. Stainless steel without nanoparticles incorporated salt bridge is found as optimum design due to its stable properties.

***Key words:*** BES, MFCs

## I. Introduction

In developing country like India, waste generation and energy crisis are two most significant challenges. Wet waste (Wastewater) is very complex in nature and difficult to treat. Characteristics of wastewater changes from industries to industries related to the production process and material usage. Dairy industries are very active in India and bulk amount of wastewater is produced from each industry day by day. Fuel's demand and price are increasing due to the continuous depletion of non-renewable energy sources. So there is an urgent need to find a new renewable energy source of energy which is clean, easy to produce, economically viable and reusable. One of the techniques is the use of Microbial Fuel Cells (MFC) for simultaneous wastewater treatment and energy generation. It is really feasible to produce clean energy from wet waste as well as treating it to the best level, instead of using energy to treat wastewater.

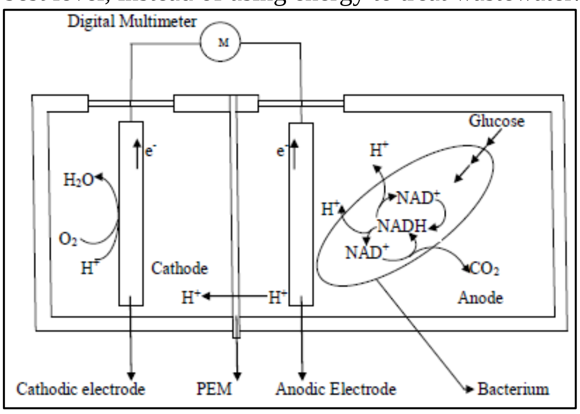


Fig. 1: Typical Two Chambers MFC

A typical MFC consist of two chambers namely anodic and cathodic chambers separated by a proton exchange membrane (PEM) like salt bridge. Both oxidation and reduction reactions are taking place in MFC. Microorganisms (Anaerobically active) help in oxidizing the organic matter and electrons generated by the reactions are transferred through outer circuit provided. The power output varies with respect to the operational conditions such as substrate concentration, bacterial growth, and specific conductivity of electrode, pH, temperature, Organic Loading Rate (OLR) and reactor configuration. A typical two chambered MFC is shown in Fig. 1 below.

To quench the present energy demand and to find concurrent method to treat wastewater, microbial fuel cells are the best alternative. For pilot scale application in any industrial wastewater treatment, it is practicable to select a continuous flow type MFC than batch type reactors for a continuous energy harvesting and wastewater treatment. The present study is to find out the performance of a continuous MFC for treating dairy wastewater at various working conditions.

### A. *Objectives*

The specific objectives of the present study are,

- To study the performance of continuous flow type two chambered microbial fuel cell using dairy wastewater as substrate.
- To compare the impact of Agar-NaCl salt bridge and silver nanoparticles incorporated salt bridge on power generation, electric energy generation and wastewater treatment efficiencies.
- To study the effects of two different electrodes (stainless steel & copper) used in microbial fuel cell.
- To find the impact of detention time on dairy wastewater treatment efficiency and bio-electricity generation.

## II. Materials and Methodology

### A. *Materials for Fabrication*

In the intended project two chambered microbial fuel cell is used for simultaneous dairy wastewater treatment and electricity generation. The main fabricating prerequisites are listed below,

- Aspirator Glass Bottles
- Anodic Chamber (Acrylic sheets)
- Cathodic Chamber (Plastic #7)
- Filter cum Aeration Chamber (Acrylic sheets)
- Pinch Cock
- Copper Electrodes
- Stainless Steel Electrodes
- PVC Pipes
- 16-Strands Copper Wire
- Crocodile Clips
- Filter Media (1cm diameter)
- Flexible Plastic Tubes
- Digital Multimeter (Series-DT830)
- Air Pump (Series-AP208)

 

### *B. Salt Bridge Preparation*

For the preparation of normal salt bridge following chemicals and materials are used.

– Agar
– Sodium chloride extra pure
– PVC pipe (Length=10cm, Diameter=2cm)
– Beaker (250 ml)
– Glass rod

For the preparation of nanoparticle incorporated salt Bridge following chemicals are used.

– Sodium borohydride
– Silver nitrate

### *C. Preparation of Agar-NaCl Salt Bridge*

To prepare the salt bridge, 3 grams of Agar is dissolved in 50 ml of 1M NaCl solution and the mixture is heated until a uniform solution is noticed. The mixture is then poured to a PVC pipe of 10cm length and 2cm diameter and refrigerates it for proper setting. Salt bridge after setting is shown in Fig.2 below.

Fig. 2: Normal Agar-NaCl Salt Bridge

### *D. Preparation of Nanoparticles Incorporated Salt Bridge*

Nanoparticles Incorporated Salt Bridge is prepared by the following procedure.

– 0.002M sodium borohydride solution ($NaBH_4$) is prepared
– Also 0.001M Silver nitrate solution ($AgNO_3$) is prepared
– 30 ml of prepared $NaBH_4$ solution is taken and placed it on an ice bar and stirring is done for about 30 minutes until it becomes homogenous solution.
– To this solution 2 ml of $AgNO_3$ solution is added at a rate of 1 drop per second.
– Normal salt bridge solution is prepared and reduced silver nitrate solution is added to it, this final mixture is then filled in a PVC pipe and refrigerated for proper setting.

### *E. Working and Sample Collection from MFC*

Fig. 3: MFC Experimental Setup

After seed culture, inoculums are introduced to the fabricated chamber, Excess seed is removed from it after 7 days. Dairy wastewater is introduced in to the anaerobic chamber in a controlled flow rate to maintain the detention time. Aspirating glass bottles are used as head balancing tanks. Bio-electricity generation and treatment efficiency of MFC is compared for both experimental setups such as MFC with normal Agar-NaCl salt bridge and nanoparticles incorporated salt bridge. The pictorial view of overall experimental setup is shown in Fig. 3 below.

## III. RESULTS AND DISCUSSIONS

### *A. Initial Characteristics of Dairy Wastewater*

Initial characteristics of dairy wastewater are analyzed according to the standard test procedure and the test results are shown in Table I below.

| Sl. No. | Parameters | Results |
|---|---|---|
| 1 | COD (mg/l) | 8250 |
| 2 | Oil and Grease (mg/l) | 49.82 |
| 3 | $BOD_3$ (mg/l) | 6280 |
| 4 | EC @ 25ºC (µS/cm) | 837 |
| 5 | TDS (mg/l) | 462 |
| 6 | pH | 5.51 |

Table 1: Initial Characteristics of Dairy Wastewater

### *B. Discussions*

For experimentation with Stainless steel as electrode, influent concentrations are monitored as reduced after treatment and the amount of removal efficiencies of each parameter varies with respect to the variation in detention time. The extent of COD removal is noted to be 84.84% which is less as comparing with the result of experimentation with normal salt bridge (93.98%) whereas BOD removal efficiency is observed to be decreased by 13.4%. Results therefore indicates that, the effect of silver nanoparticle is adverse for the microbial activities and thereby for wastewater treatment it is better to avoid the presents of metal ions which has antimicrobial characteristics. Highest voltage and current generation (355mV & 89µA) are obtained for 6 hours detention time. Graphical representation of power generation is shown in Fig. 4.

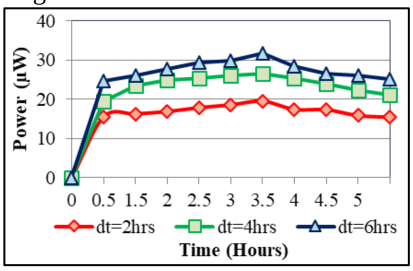


Fig. 4: Power Generation in MFC with SS, $SB_2$

Comparing with the results of experimentation with same stainless steel electrode and Normal Agar-NaCl salt bridge, a drop in the highest voltage generation is monitored from 384mV to 355mV. In comparison with that, highest current generation is increased from 81µA to 89µA. Nanoparticle incorporated salt bridge enhances the transport of $H^+$ ions and there by electron transport through the external circuit increases and thereby current generation increases. Electrical properties suddenly get suppressed due to the unavailability of electron as the microorganisms are unable to degrade the organic matter due to its toxic effect. For all three detention times, gradual fall in power and electrical energy is clearly visible in the graphical representations.

In the experimentation with copper electrode, when comparing with the results of experimentation with normal salt bridge, removal efficiencies decreased due to toxic outcome of metallic ions such as copper ions and silver ions. Only a slight increase in removal efficiency is noticed for COD and BOD, as comparing with the results with stainless steel electrode removal efficiency is less. The trend is maintained for EC and TDS removal also as for higher detention time (6 hours), due to the copper leaching removal efficiency is decreased. There is not much increase or decrease in pH is observed after treatment. Graphical representation of power generation is shown in Fig. 5.

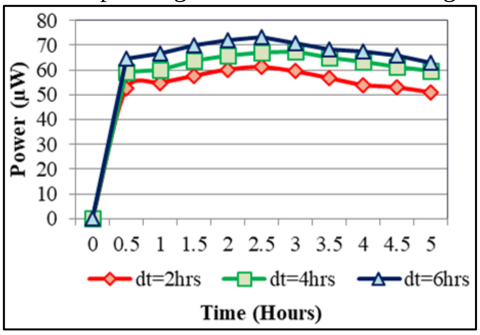


Fig. 5. Power Generation in MFC with Cu, $SB_2$

Electrical properties of MFC vary with respect to the salt bridge configuration. A sudden increase is noticed in the power and electrical energy generation but it decreased soon. When comparing with all electrode setups, stainless steel showed comparatively stable electrical properties. Even though corrosion is observed in copper, electrical properties are good and highest power generation and electrical energy generation is observed for copper electrode of larger surface area with 6 hours detention time. It is due to the combined effect of copper conductivity, biotic and abiotic current generation in copper and high $H^+$ ion conductivity of nanoparticle incorporated salt bridge.

## IV. Conclusions, Advantages, Limitations and Scope for Further Study

### A. *Conclusions*

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.

Agar-NaCl salt bridge is noticed as a fine choice than any other costly proton exchange membranes for lab scale studies. Silver nanoparticle incorporated salt bridge is a good conductor of $H^+$ ions but exhibits toxic effects to the electrode respiring bacteria and causes reduction in treatment efficiencies.

It is found that the removal efficiencies are decreased when nanoparticles incorporated salt bridges are used. It is due to antimicrobial characteristics of the silver incorporated in the salt bridge

### B. *Advantages*

- The main advantage of MFC is its operational firmness which offers self-regeneration of microorganisms and excellent resistance to ecological stress.
- In the economic point of view, the main advantages of MFC in wastewater treatment are energy recovery, low operational price and concurrent wastewater treatment.
- Although the energy that could be captured from wastewater is not enough to power a city, it is large as much as necessary to one day power a treatment plant. With progress, capturing this power could attain energy sustainability for the water infrastructure.

### C. *Limitations*

- Power produced by the cell may not be adequate to run a sensor or a transmitter constantly.
- Selection of anodic and cathodic electrode is a critical part in MFC operation. Electrodes have to select not only by considering economic viability but also after evaluating the metallic properties.
- MFCs cannot function at very low temperatures due to the fact that microbial reactions are slow at low temperatures.

### D. *Scope for Further Study*

- Different operational conditions can be analysed and effects of pH, temperature, different electrodes, organic loading rate and substrate concentrations can be find out.
- There is scope for combination of methanogenic, photo heterotrophic and electrochemically active bacteria in order to scale up removal, energy production and make the technology profitable.
- Single chamber MFC can also analysed for the same variables and the results can be compared with the results of present work.
- Feasibility of providing chemical treatment for the copper electrode to mitigate the problem of anaerobic corrosion can be studied and the improvement in removal efficiencies can be weigh against the present results.

## References

[1] M. C Potter (1911) "Electrical Effects Accompanying the Decomposition of Organic Compounds", 84(571): 260-276.

[2] Mostafa Rahimnejad, Arash Adhami, Soheil Darvari, Alireza Zirepour and Sang-Eun Oh (2015), "Microbial Fuel Cell as New Technology for Bioelectricity Generation

[3] Abdul Rehman Rizvi and Aftab Ahmed Almani, 2015, "Future of Green Energy: Innovation in Energy from Waste", International Journal of Engineering Research & Technology, 4(10), 83-89.

[4] Abhilasha S Mathuriya and V N Sharma, 2009, "Bioelectricity Production from Various Wastewaters through Microbial Fuel Cell Technology", Journal of Biochem Tech, 2(1), 133-137.

[5] Aishwarya D. Dalvi, Neha Mohandas, Omkar A. Shinde and Pallavi T. Kininge, 2011, "Microbial Fuel Cell for Production of Bioelectricity from Whey and Biological Waste Treatment", International Journal of Advanced Biotechnology and Research, 2(2), 263-268.

[6] Ana Faria, Liliana Gonçalves, Joao M. Peixoto, Luciana Peixoto, Ant_onio G. Brito and Gilberto Martins, 2017, "Resources Recovery in the Dairy Industry: Bioelectricity Production Using A Continuous Microbial Fuel Cell", Journal of Cleaner Production, 140, 971-976.

 

[7] Anand Parkash, 2015, "Generation of Bioenergy from Sewage Using Dual Chamber Microbial Fuel Cell", Bioprocess Biotech, 5(7), 242.
[8] Anand Parkash, 2015, "Impact of Salt Bridge on Electricity Generation from Hostel Sewage Sludge using Double Chamber Microbial Fuel Cell", Journal of Engineering and Technology, 13-18.
[9] Anand Parkash, Shaheen Aziz, Imran Nazir and Suhail A Soomro, 2015, "Utilizing Dairy Wastewater for Electricity Generation Using Environment-Friendly Double Chambered Microbial Fuel Cell", NUST Journal of Engineering Sciences, 8(1), 44-50.
[10] Andre Baudler, Igor Schmidt, Markus Langner, Andreas Greiner and Uwe Schroder, 2015, "Does it have to be carbon? Metal anodes in microbial fuel cells and related bioelectrochemical systems", journalof Energy & Environmental Science.
[11] Andrea G. Capodaglio, Daniele Molognoni, Sebastià Puig, M. Dolors Balaguer and Jesús Colprim, 2015, "Role of operating conditions on energetic pathways in a Microbial Fuel Cell", International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability", 74, 728 – 735.
[12] Animesh Deval and Anil Kumar Dikshit, 2013, "Construction, Working and Standardization of Microbial Fuel Cell", Journal of Biological Science, 5(1): 59 – 63.
[13] Ashley E. Franks and Kelly P. Nevin, 2010, "Microbial Fuel Cells, A Current Review", Energies, 3, 899-919.