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

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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 countries 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 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

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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.

D. Preparation of Nanoparticles Incorporated Salt Bridge
Nanoparticles Incorporated Salt Bridge is prepared by the following procedure.
- 0.002M sodium borohydride solution (NaBH₄) is prepared
- Also 0.001M Silver nitrate solution (AgNO₃) is prepared
- 30 ml of prepared NaBH₄ 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 AgNO₃ 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
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.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COD (mg/l)</td>
<td>8250</td>
</tr>
<tr>
<td>2</td>
<td>Oil and Grease (mg/l)</td>
<td>49.82</td>
</tr>
<tr>
<td>3</td>
<td>BOD₃ (mg/l)</td>
<td>6280</td>
</tr>
<tr>
<td>4</td>
<td>EC @ 25ºC (µS/cm)</td>
<td>837</td>
</tr>
<tr>
<td>5</td>
<td>TDS (mg/l)</td>
<td>462</td>
</tr>
<tr>
<td>6</td>
<td>pH</td>
<td>5.51</td>
</tr>
</tbody>
</table>

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, SB₂
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, SB2](image)

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


