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EXPERIMENTAL STUDY OF POWER GENERATION AND COD REMOVAL EFFICIENCY BY MICROBIAL FUEL CELL USING LACTOBACILLUS

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Abstract
Microbial fuel cells (MFCs) are a form of bioreactor that uses exoelectrogens to help produce electricity while simultaneously treating wastewater. The current study conducts two groups of trials to concentrate on the performance of acathode MFC in terms of its capacity to remove chemical oxygen demand (COD) and generate electricity.Using Lactobacillus as the biocatalyst, this research examines the air-cathode microbial fuel cell (MFC)'s dual ability to produce electricity and eliminate the chemical oxygen demand (COD) of wastewater. The substrate for the experiment was household wastewater in a single-chamber MFC with graphite electrodes. Over many batch cycles, the COD removal and voltage output were measured. The system produced bioelectricity steadily, reaching a maximum voltage of 0.55 V and an average chemical oxygen demand (COD) removal efficiency of 78%. The results highlight the promise of Lactobacillus-based MFCs for decentralized wastewater treatment and sustainable energy production. This strategy has potential for distributed applications in wastewater treatment facilities in rural and semi-urban areas. The overall efficiency and practicality of operation may be improved by further advances in electrode materials and system scalability.

Keywords: Lactobacillus, MFC, TDS, BOD, COD, pH, and Cathode.

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Introduction

A microbial fuel cell (MFC) is a bioelectrochemical device that transforms chemical energy found in organic or inorganic materials directly into electrical energy through the catalytic actions of microorganisms in anaerobic environments[1]. In an MFC, microorganisms break down organic substances at the anode, resulting in the release of electrons and protons. The electrons are transferred to the anode either directly or through mediators and subsequently travel through an external circuit to the cathode, producing an electric current, while protons move through a proton exchange membrane to reach the cathode[2][3]. At the cathode, electrons combine with protons and an electron acceptor, usually oxygen, to create water or other reduced substances, thereby completing the circuit. This mechanism effectively captures the biochemical energy from microbial metabolism to generate electricity[4]. MFCs generally comprise two compartments divided by a membrane: the anode compartment, where oxidation happens, and the cathode compartment, where reduction occurs. The technology has progressed from initial systems that utilized chemical mediators to contemporary designs where electrochemically active bacteria directly transfer electrons to electrodes[5]. These bacteria, known as exoelectrogens, facilitate effective electron transfer without the need for external mediators. Apart from generating electricity, microbial fuel cells (MFCs) hold great potential for sustainable wastewater treatment, biosensing, hydrogen production, and environmental cleanup, positioning them as a flexible and eco-conscious solution for clean energy and waste management. Nevertheless, issues like low power generation and elevated costs continue to be focal points for ongoing research and development[6]-8]. Microbial Fuel Cells (MFCs) have gained significant attention as an innovative bio-electrochemical technology that integrates wastewater treatment with clean energy production. MFCs utilize electroactive microorganisms to oxidize organic matter and transfer electrons to an anode, thus generating electricity [9]. Among various microbial species, *Lactobacillus*-a facultative anaerobe-offers metabolic flexibility and resilience, making it a promising candidate for MFC applications. cathode MFCs are preferred for their cost-effectiveness and simplicity in design, as they allow oxygen from the air to act as the terminal electron acceptor. This study focuses on the performance of acathode MFC inoculated with *Lactobacillus* and fed with domestic wastewater, aiming to evaluate its power generation capability and COD removal efficiency.

2.0 Materials and methods:

The present study sought to examine the efficacy of biological approaches for managing four different kinds of effluents. The experimental methods aimed to minimize factors like biochemical oxygen demand (BOD), pH, total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), chlorides, sulfides, and overall hardness. A Microbial Fuel Cell was utilized for the ongoing treatment of wastewater for 45 days, and samples were gathered at regular intervals for 5 days. Airtight 1.5-liter plastic bottles were employed to construct the dual-chamber MFC (anode and cathode sections). Each bottle had a side opening with a 1 cm radius connected to a Polyvinyl chloride (PVC) pipe placed at a height of 9 cm from the bottle's base (roughly at the midpoint). By heating 100 g of agar together with 100 g of sodium chloride (NaCl) in a 1000 ml water bath, the liquid agar was allowed to cool and subsequently moved into a PVC pipe, which was closed at one end with a plastic cap and tape. The agar was allowed to set undisturbed. The PVC tubing, joined with the salt-agar blend, was epoxy-attached between the two bottles and acted as a salt bridge, promoting proton transfer while the Microbial Fuel Cell was functioning. Copper electrodes with dimensions of 7 cm in length, 5 cm in width, and 0.3 mm in thickness were employed. The gap between the two chambers was maintained at distances of 5, 10, 15, 20, and 25 cm in the configuration of the Microbial Fuel Cell. The electrodes were linked to the circuit with copper wires. A digital multimeter recorded the values of an external resistance (R) of 100, 200, 330, 470, 500, and 1000Ω. The collected sample underwent analysis through standard industry techniques to observe the biodegradation process inside the Microbial Fuel Cell. Different parameters are employed to evaluate the properties of wastewater

In this research, biological oxygen demand, pH, total dissolved solids, total suspended solids, chemical oxygen demand, dissolved oxygen, chlorides, sulfates, and various other parameters were analyzed to evaluate the performance of the Microbial Fuel Cell. A wastewater sample is gathered and examined every 5 days to evaluate its various parameters. A multimeter is used to measure voltage and current during the operation.

3.0 Results and Discussion

A microbial fuel cell (MFC) signifies an innovative type of renewable energy by producing electricity from substances generally considered waste, such as industrial byproducts or sewage. A microbial fuel cell acts as a biological reactor, transforming the chemical energy in organic compounds into electrical energy through the activities of microorganisms in aerobic conditions. In a microbial fuel cell, the anode and cathode are connected via an external circuit and separated by a proton exchange membrane. Anodic materials must exhibit electrical conductivity, biocompatibility, and chemical stability when interacting with the substrate. Metal anodes can be made from noncorrosive stainless steel. Graphite plates or rods act as the primary substances for anode electrodes because of their affordability, simplicity in handling, and unique surface area. Graphite felt terminals are used to provide much larger surface areas.

The effect of salt extension concentration and the salt platform: The accumulation of salt in the proton exchange membrane is vital for the transfer of hydrogen ions. The first part of the research investigated KCl and NaCl to assess their viability as robust salts in proton exchange membranes. The research demonstrated that there were quite minor differences in the current yield among these salts. The isolated particles within the salt podium enable proton exchange via the salt podium, making molar convergence essential. The salt expansion created with 10M NaCl produced excellent outcomes. It provided an astonishing current of 859 mA.

3.1 Effect of pH

The pH of the Dairy Wastewater was determined using a pH meter. The range of pH of the sample collected during regular intervals of Days is presented in Figure 4.8. The results indicate that the pH of the Dairy Wastewater has decreased. Dairy wastewater demonstrated its capability to reduce pH from 8.61 to 7.2. In MFC, the anode reaction generates protons while the cathode reaction utilizes them. The buildup of protons caused by slow and incomplete diffusion and migration through the membrane will lead to a reduction in pH [10-11].

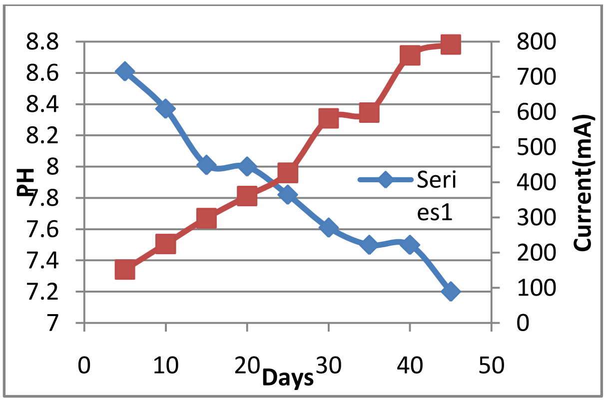

Figure 01: Variation of pH and Current with time

3.2 Effect of Chemical Oxygen Demand (COD):

The pH level of the Dairy Wastewater was determined using a pH meter. The range of pH from the sample collected at standard Chemical Oxygen Demand reflects the overall amount of oxygen needed to convert all organic material into carbon dioxide and water, without differentiating between readily available and inert organic matter. The waste is measured based on the amount of oxygen needed for the oxidation of organic matter to produce CO2 and water. Samples were kept with H2SO4 for Chemical Oxygen Demand verification and processed for Chemical Oxygen Demand verification after completing the full examination procedure. During the activity, the configuration was consistently monitored for waste (measured as Chemical Oxygen Demand) removal to assess the power module's ability to act as a wastewater treatment unit. Chemical Oxygen Demand of Dairy wastewater at different time intervals is presented, and Figure 4.9 illustrates the variation of Chemical Oxygen Demand and current over time [12-13].

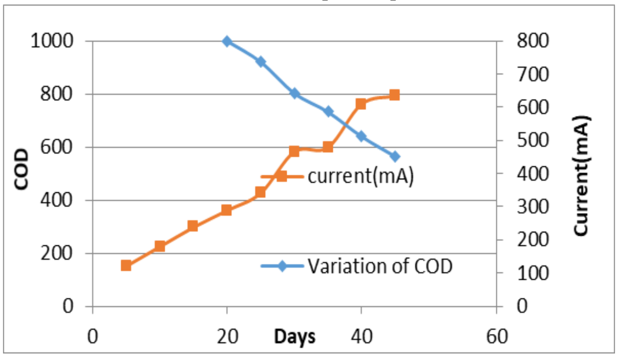

Figure 02 Variation of Chemical Oxygen Demand and Current with time

3.3 Effect of Biochemical Oxygen Demand (BOD):

Under active conditions, a creature's Biological Oxygen Demand is proportional to the amount of oxygen it would consume when breaking down natural materials. The figuredepicts the impact of a Microbial Fuel Cell on the Biological Oxygen Demand of dairy wastewater. The Biological Oxygen Demand efficiency for varied feed concentrations reached equilibrium after 4-5 days, with BOD decreasing from 511 mg/L to 260 mg/L over time [14-15].

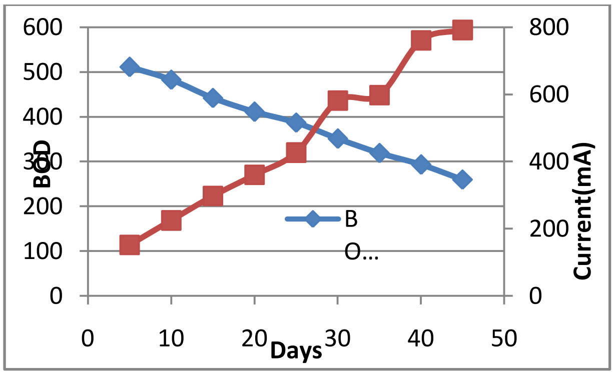

Figure 03: Variation of Biological Oxygen Demand and Current with time.

3.4 Effect of Dissolved Oxygen (DO)

Fish and other aquatic creatures require dissolved oxygen (oxygen in water) to flourish. Water temperature, the number of dregs in the stream, the amount of oxygen removed from the framework by breathing and decaying life forms, and the amount of oxygen returned to the framework by photosynthetic plants, the stream, and air circulation all have an impact on how much oxygen is broken down in streams. The amount of broken-up oxygen in a liter, measured in milligrams per liter (mg/L) or parts per million (ppm), went from 2.25 to 3.6 mg/L, indicating higher quality. Figure depicts how dissolved oxygen varies over time. This occurrence, along with the fact that the additional carbon source used more oxygen before the nitrification reaction, resulted in inadequate dissolved oxygen levels for completed nitrification [15-16].

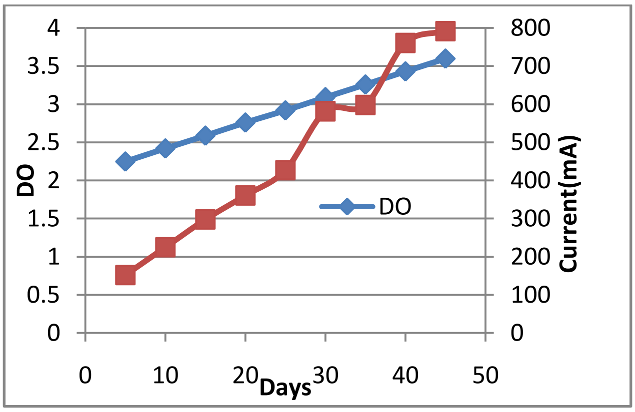

Figure 04: Variation of Dissolved Oxygen and Current with Time

3.5 Effect of Total Dissolved Solids (TDS):

All broken-up solids are composed of inorganic salts (mostly calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) and a small amount of natural matter destroyed in water. Total Dissolved Solids in drinking water come from a variety of sources, including sewage, urban runoff, mechanical effluent, synthetic compounds used in water treatment, and the design of the channeling or transportation equipment. The absolute disintegrated solids test provides a subjective proportion of the quantity of broken-down particles, but it does not indicate the type of particles or their relationships.The current Microbial Fuel Cell (MFC) demonstrated its potential for Total Dissolved Solids evacuation. Figure depicts the impact of MFC on the total breakdown of solids in dairy effluent over usual spans. Exploratory data revealed that broken-up solids were continuously reduced during the activity over 45 days. The total dissolved solids (TDS) of dairy wastewater reduced from 797 mg/L to 416 mg/L, respectively [17-18].

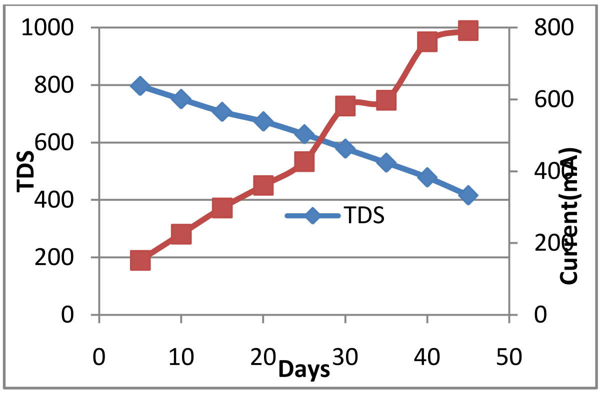

Figure 05: Variation of Total Dissolved Solids and Current with Time

3.6 Effect of Total Suspended Solids (TSS):

High concentrations of suspended particles can harm water quality because they capture light. At that point, the water gets hotter, reducing the ocean's ability to hold oxygen, which is required for sea-going life. Oceanic plants receive less light, which reduces photosynthesis and oxygen production. Certain types of life are harder to envision because of the combination of hotter water, less light, and less oxygen. Suspended particles have varying effects on humans. Figure wastewater test reduced from 688 mg/L to 391 mg/L, indicating that Total Suspended Solids were removed more efficiently [19-20].

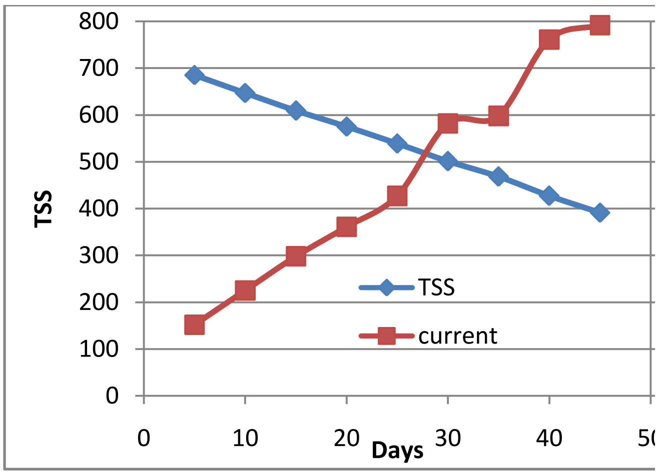

Figure 06: Variation of Total Suspended Solids and Current with Time

3.7 Effect of Chlorides:

Water and dairy effluent contain a lot of calcium, sodium, and potassium chloride salts. Chloride fixations in drinking water impart a strong flavor that varies with the water's composition. The two most important taste-delivering salts in water are sodium chloride and calcium chloride. Chloride is commonly found in water and dairy effluent as calcium, sodium, and potassium salts as a result of the breakdown of salt stores released by synthetic businesses, oil well activities, sewage release from compound ventures, and so on. Chloride fixations in drinking water impart a strong flavor that varies with the water's composition. The figure depicts the influence of a Microbial Fuel Cell on chlorides in a dairy wastewater test. The chloride concentration fell from 67 mg/L to 40 mg/L throughout time [21-22].

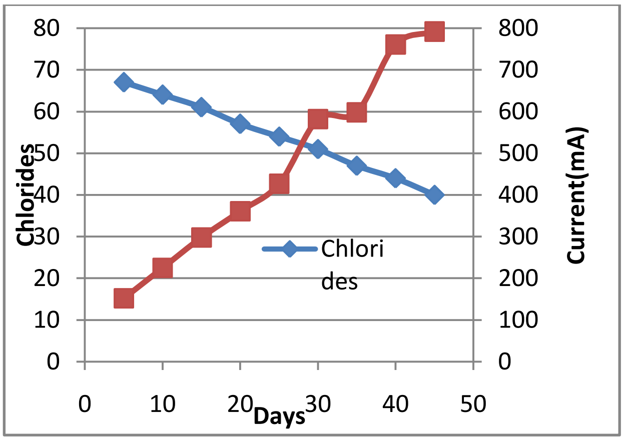

Figure 07: Variation of Total Chlorides and Current with Time

3.8 Effect of Sulphates:

Most surface and ground waters contain sulphate, a soluble form of sulfur. It is a stable and completely oxidized form of sulphur. Sulfate has never been a limiting factor in oceanic frameworks. The average sulfate level is high. Sulphate is commonly used as an electron acceptor for the breakdown of natural matter when water becomes overburdened with natural waste to the point that oxygen is reduced, resulting in H2S and a ruined egg stench. Up until day 40, COD elimination and power production increased while sulphates decreased in the effluent. When the sulphate concentration dropped to 34.12 mg/L, reactor performance deteriorated. The figure depicts the impact of MFC on sulphates. Sulphates fell from 51 mg/L to 32 mg/L over time [23-24].

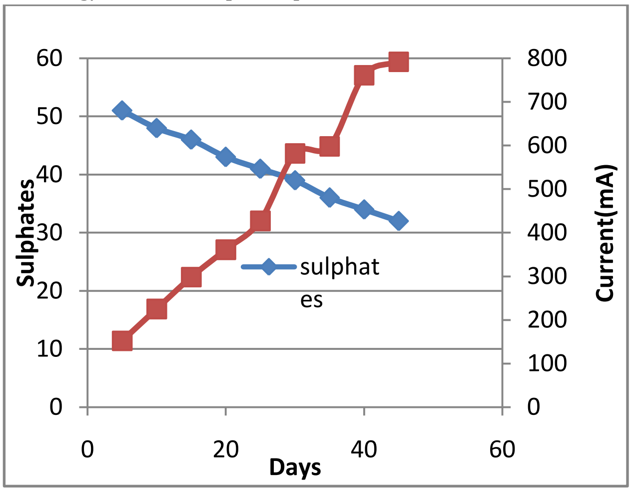

Figure 08: Variation of Sulphates and Current with Time

3.9 Effect of Treatment Efficiency:

Figure 9 illustrates how treatment effectiveness is impacted by MFC. The treatment efficiency improved from 63.144 mg/L to 81.588 mg/L when the Chemical Oxygen Demand concentration was 452 mg/L [25-26].

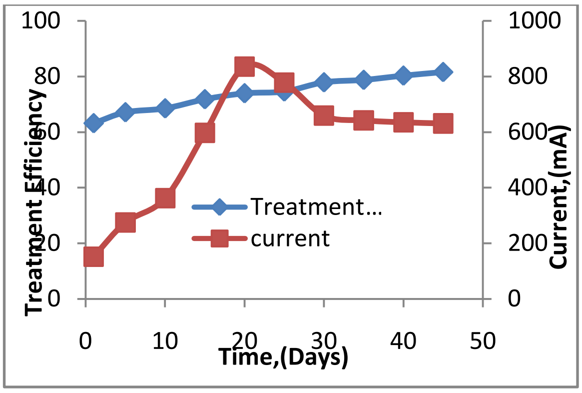

Figure 09: Variation of Treatment Efficiency and Current with Time

3.10 Coulombic Efficiency:

The Coulomb efficiency is often used to express the ability of a released cell. This is the ratio of the discharge capacity following a complete charge to the charging capacity of the same cycle. The coulombic efficiency began to improve with the length of operation after the start-up, reaching a peak of The coulombic efficiency then began to decrease with time. The low coulombic efficiency of microbial fuel cells indicates that the electron-transfer bacteria cannot convert all of the available organic material into electricity; as a result, the additional substrate creates a niche for organic growth in a conducive environment. The 25th day saw the highest Coulombic efficiency, which ranged from 0.005 to 9.484 [27-28].

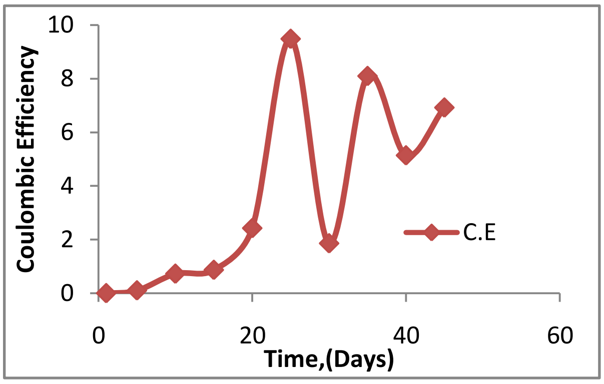

Figure 10: Variation of Coulombic Efficiency with Time

4.0 Conclusions

The purpose of the study was to investigate biological approaches used in wastewater management. Microbial Fuel Cells were chosen for this physical evaluation to improve wastewater quality. The key contribution is to improve alternative energy sources, and this MFC technology is excellent for wastewater treatment and energy production, delivering an extra benefit for environmental recovery from a chemical engineering standpoint.The levels of Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Sulphates, and Chlorides are lower than in the original wastewater. The Microbial Fuel Cell was efficient, inexpensive, simple to maintain, and did not require a skilled operator. They surely have the potential for energy recovery in wastewater treatment systems. They could occupy a market niche as an independent power source and for direct wastewater treatment.pH was reduced from 8.61 to 7.2, Chemical Oxygen Demand was reduced from 945 mg/L to 452 mg/L, Biological Oxygen Demand was reduced from 511 mg/L to 260 mg/L, Dissolved Oxygen was increased from 2.25 mg/L to 3.6 mg/L, Total Dissolved Solids was reduced from 797 mg/L to 416 mg/L, Total Suspended Solids was reduced from 685 mg/L to 391 mg/L, Total Chlorides were reduced from 67 mg/L to 40 mg/L, and Total Sulphates were reduced from 51 mg/L to 32 mg at room temperature.

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