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Research Article

Oil Palm Biomass Sap-Rotten Rice as a Source to Remove Metal Ions and Generate Electricity as By-Products through Microbial Fuel Cell Technology

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Microbial fuel cell (MFC) is a new and interesting technology that can be used to treat wastewater without using electricity. The current research focuses on electron generation, which is one of the technique's major challenges. According to the latest literature, the study was planned to successfully remove the metals from artificial wastewater at high concentrations and generate electricity. On average, after 18 days of operation, it offered 610 mV with 1000 Ω constant external resistance. The internal resistance was found to be 520 Ω. The achieved power density was 3.164 mW/m^2 at an external resistance of 1000 Ω. The achieved removal efficiencies of Pb^{2+}, Cd^{2+}, Cr^{3+}, and Ni^{2+} were 83.67%, 84.10%, 84.55%, and 95.99%, respectively. The operation lasted for 25 days. The cyclic voltameter studies show that there is a gradual oxidation rate of organic substances, while on day 25, the removal efficiency reached its maximum. The specific capacitance was found to be high between days 15 and 20, i.e., 0.0000540 F/g. It also indicated that biofilm was stable around day 18. Furthermore, the biological characterization also demonstrated that MFC operation was very smooth throughout the process, even at high concentrations (100 mg/L) of metal ions. Finally, there is the MFC method, as well as some new challenges and future recommendations.

1. Introduction

Considering the introduction of the modern revolution, the most major issue affecting the environment has been the production of water pollution and the need for energy [1]. The primary cause of water pollution is the excessive quantity of heavy metals released into sources of drinking water. Rapid technological advancement, the expansion of the chemical industry, and rising urbanization have all contributed to a rise in the toxicity of water sources worldwide by metal ions [2, 3]. One of the problems and limitations associated with heavy metals is the body's incapacity to digest them. This inability is one of the most basic problems. It is a cause of water pollution that is incapable of degrading naturally and has detrimental effects on both the lives of ecological systems and human populations [4, 5]. Many diseases and problems may arise from heavy metal precipitation in bones, fat, skeletal muscle, and ligaments [6]. The metals' high concentration impacts on organisms were identified in the 19th century and well explained in the

20th century. Concerns about the metals' possible negative effects on humans and other living things were raised briefly [7–9]. Since then, techniques for accurately identifying heavy metals have been developed, and their distribution, occurrence, and eventual destiny have been monitored [10]. The issue of heavy metal contamination is essential because heavy metals are extremely difficult to remove from polluted water using conventional treatment techniques like photocatalysis, chlorination, sun decontamination, water boiling, adsorption, desertion, and many more [11, 12]. In spite of all the advancements that have been made in the realm of wastewater treatment, there are still problems that persist. There are a few technologies that are up-to-date that have been developed, but they have a high energy consumption requirement, and some of them produce harmful by-products in the form of sludge that are difficult to dispose of. According to the most recent literature survey that we conducted, there have been two in-depth review papers written on heavy metals that have been published [13, 14]. These studies both made valuable efforts to explain how heavy metals continue to have an influence on both the ecosystem and human beings. What is the progress and what are the possible future research directions?

As we mentioned, the energy crisis is also a critical issue; therefore, the world cannot afford to use energy to treat wastewater. Although the treatment of wastewater is in growing demand, the world cannot ignore it. On the other hand, energy demand is very high in the modern world, especially after the industrial revolution. Over the course of history, the world's population has made use of a wide variety of sources of energy, such as coal, oil, gas, and renewable sources such as hydro, sun, and wind. However, the world's population growth has increased energy consumption, causing an energy crisis that has serious consequences for the environment, economy, and society [15]. According to these two conditions, scientists have recently directed their attention to renewable energy sources while simultaneously treating wastewater technology. After comprehensive efforts with last-era information, a system known as a microbial fuel cell (MFC) has been reported to the entire scientific community [16]. With this technique, the catalytic mechanism of microorganisms is applied to switch biological energy into electrical energy. On the other hand, during the electrochemical reduction process, the metals are converted into insoluble forms simultaneously [17, 18]. The MFC has an anode and a cathode electrode. Both the electrons and the protons that are generated in the cell as a consequence of the breakdown of organic matter are transferred to the cathode [19, 20]. The electrons are transported to the cathode via the external circuit, while the protons are transported through the proton exchange membrane. This process is known as cathodogenesis [21]. Even though the MFC cell lacks oxygen, the biochemical pathway that separates the organic compound releases highly energetic electrons that are then absorbed by electron-accepting substances such as oxygen. These electrons are then transferred to the cathode, where they cause electricity to be produced [22, 23]. The MFC has several applications, while energy generation and wastewater treatment are the most promising [24, 25]. The results and discussion sections of the research also provide an explanation of the mechanism of MFC. At the moment, several efforts are ongoing to address the metal pollution and energy crisis issues through MFC. Despite all of MFC's positive attributes, it faces significant hurdles that prevent MFC's potential from implemented on a commercial scale [26]. Among them, electron generation is a key problem in this technology since MFC is reliant on electron generation, which is directly related to organic substrate material. The organic substrate will offer sufficient power to the microbial community to generate an electron by oxidizing it. Organic substrate stability and long-term ability are challenges [27, 28]. Heavy metal conversion takes a bit longer; thus, a stable organic substrate material is required for MFC to offer valuable metal removal results [29]. Research has shown that rotten rice waste and oil palm trunk sap (OT sap) may make a great combination [30, 31]. According to certain research, both types of biomass waste may provide microbial species with a reliable supply of fuel. Both sorts of materials are abundant in minerals, carbs, and sugars [30, 31]. As a result, rotten rice waste is employed as the primary source of organic substrate in this research. On the other hand, OT sap has been used in order to boost the performance up a notch. The OT sap may further be used to compensate for some of the water lost due to evaporation while the MFC is operating. The present study is limited to Pb, Cd, Cr, and Ni (with 100 mg/L of each metal ion) only.

2. Experimental Details

2.1. List of Used Chemicals and Materials. Lead nitrate, chromium (III) nitrate, cadmium nitrate tetrahydrate, and nickel nitrate hexahydrate are used. These chemicals were received from R&M Chemicals. The commercial graphite rods were received from FUDA 2B Lead, NY, USA. Glucose (D^+) was received from Sigma-Aldrich, and sulphuric acid and sodium hydroxide (Merck) were also used in the present study. The MaTRec research group from Universiti Sains Malaysia provided the OT sap to us.

2.2. Inoculation-Organic Substrate of the Present Work. Following domestic wastewater collection, the wastewater was treated at a concentration of 100 mg/L using a range of various metal ions. The domestic wastewater was collected from Sungai Dua, Pulau Pinang, Malaysia. In this experiment, the metal-added wastewater was figured to be an example of artificial wastewater since it was used as an inoculation source for the MFC that had a single chamber. This was done before the wastewater was put into service. The numerous physicochemical characteristics that are associated with domestic and artificial wastewaters are shown in Table 1. The domestic waste rice was obtained and transported to the laboratory with the aim of satisfying the criteria of the organic substrate. First, we picked out any bones or other contents of food that could have been mixed in with the rice, and then we picked out any grains that had gone bad. This putrid rice is going to be used as the primary

Table 1: The parameters for both artificial and domestic wastewaters used in this investigation.

Parameters	Domestic wastewater	Artificial wastewaters
Colour	Yellowish	Yellowish
pH	6.93	6.40
Odour	Bad	Bad
Pb^{2+}	NO metal concentration	100 mg/L
Cr^{3+}	NO metal concentration	100 mg/L
Cd^{2+}	NO metal concentration	100 mg/L
Ni^{2+}	NO metal concentration	100 mg/L

organic substrate, and it is going to be introduced to the MFC chamber at the very beginning of the operation. OT sap will be provided on a regular basis. According to the supply party, the OT has a very high degree of purity.

2.3. System Setup and Function. In order to accomplish the aims of this research, an MFC with one chamber was used. The MFC had a 15 cm height and had a diameter of 12 cm. In spite of the fact that the total operational capacity of MFC was 1000 mL, only 800 mL of artificial wastewater was used, and moreover, 500 g of rotten rice was inoculated into an MFC chamber. After that, commercial graphite rods with dimensions of 9 cm by 1 cm ($h \times r$) were placed vertically into the MFC for the cathode, and 12 cm by 1 cm ($h \times r$) were inserted for the anode. The anode and cathode were separated by a distance of 13 cm. In order to build the connections between the electrodes, Cu wire was used, and an external resistance of 1000 Ω was connected at various points during the operation. The external resistance was chosen using a process for choosing external resistance, which was based on what was explained in the relevant prior literature [32]. A 5 mL solution of OT sap was provided daily to compensate for the MFC's evaporation-induced water loss. However, an aquarium air pump provided oxygen (the flow rate was very low, such as one air bubble per 30 seconds) to the cathodic water throughout the duration of the experiment. This was done so as to maintain control of the aerobic atmosphere. It took a total of 25 days to complete the MFC experiment, during which time the environment was maintained at room temperature. The MFC model that was used for this specific research endeavor is shown in Figure 1.

2.4. Electrochemical Tests. The voltage that was generated as a consequence of the electrical interactions that took place between the two electrodes was measured using a digital multimeter once every twenty-four hours. The measurements were taken at regular intervals. Ohm's fundamental law was used to get a current value expressed in amperes. The internal resistance (r), power density (PD), and current density (CD) were calculated using equations as described in the literature [26, 27]. The slope of the polarization curve was utilized in combination with a resistive load that ranged in value from 5000 Ω to 100 Ω. This was done so that the MFC's internal resistance could be calculated. In addition, cyclic voltammetry, abbreviated as CV, was used in order to characterize the redox events that took place on the anode surface. It was found that a scanning rate of 10 mV/s and an ideal range of +0.8 V to −0.8 V were the optimum values for the CV measurements. These two parameters were selected. During each of the breaks in the operation, the analysis was carried out. The counter electrode was made out of Pt wire, while the reference electrode was made out of Ag/AgCl. The specific capacitance, or Cp, is calculated by adding the integrations at the anode-cathode throughout the entire set of data. Specific capacitance is quantified in terms of the unit area of the anode and the cathode [33]. It was found that the Cp of the target day's intervals could be computed by using equation (1) from the CV [34, 35].

$$C_P = \frac{A}{2\mathrm{mk}\left(V_2 - V_1\right)}. \quad (1)$$

2.5. Biological Tests. Atomic absorption spectroscopy, often known as AAS, was used for the purpose of analyzing heavy metals in order to determine how effective the system was in removing toxic metals. In a nutshell, about 2 mL of the artificial wastewater from MFC was taken out once every five days and sent for analysis. After doing the AAS analysis, a calculation was made using equation (2) to determine the removal efficiency (RE) of each metal. C1 indicates the metal concentration at the beginning of the method, and C2 indicates the metal concentration at the end of the method. In addition, scanning electron microscopy (SEM) was used in order to analyze the population of bacteria on the biofilm that was located surrounding the electrode surface after the procedure had been completed. An examination using a SEM was performed on the electrode after the operation, both of which were believed to have stable biofilms. In addition, electron dispersive X-ray (EDX) was considered to investigate the elemental geomorphology and composition of the biofilm.

$$\mathrm{RE} = \frac{C_1 - C_2}{C_1} \times 100. \quad (2)$$

3. Result and Critical Discussion

3.1. Electrochemical Tests. During the process of metal removal that was involved in an MFC operation, it turned out that voltage production was switched on, and this phenomenon is indicated in Figure 2. During the course of the procedure, a resistance of 1000 Ω was maintained for a total of twenty-five days. On day 18, it was reported that the voltage range had touched 610 mV, which is the highest level that has ever been recorded. This was the maximum stage that had ever been measured. According to the information that was assembled, the production of voltage began at a rate that could be considered acceptable and progressively grew until it achieved its maximum levels (day 18) after it had first begun. After then, a consistent pattern of the voltage starts to become visible for the first time as a distinct outline. The voltage, however, proceeded to progressively decrease after a short amount of time, hitting its lowest point of 499 mV on day 25, before beginning a steady drop that finally resulted in

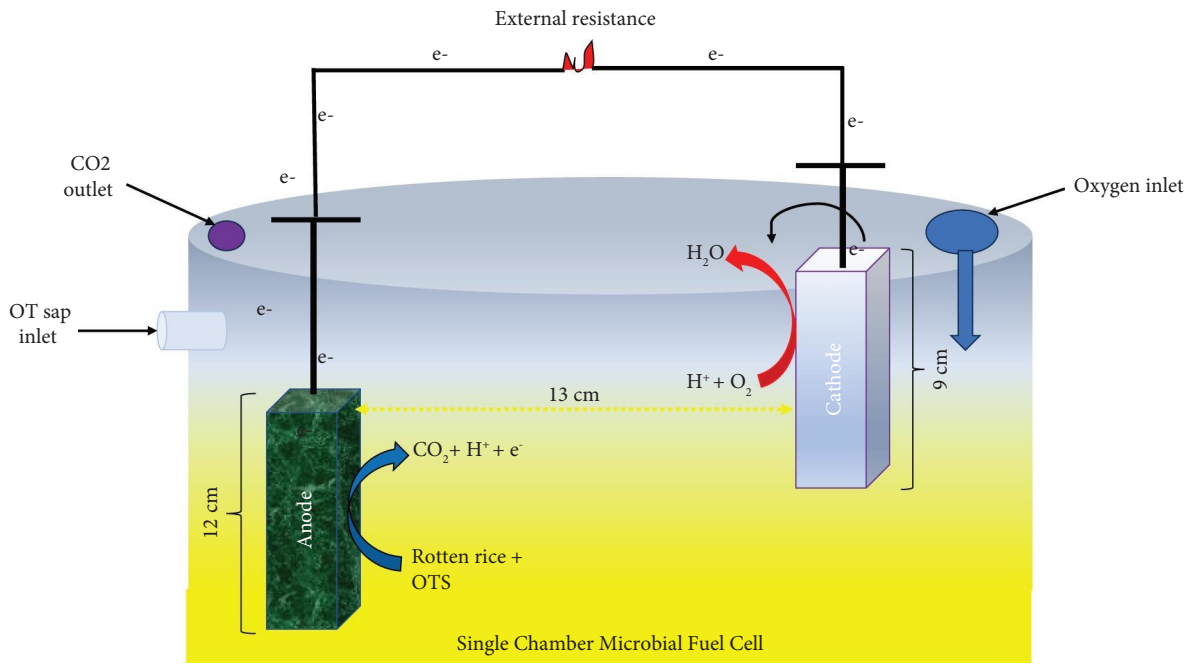

Figure 1: The model of the MFC that was used for this study.

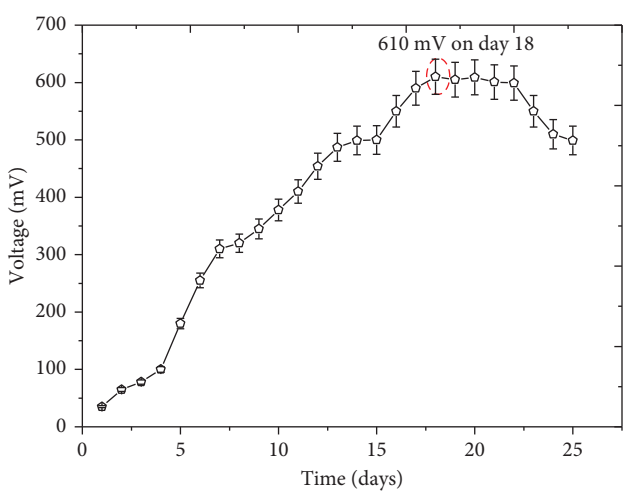

Figure 2: The potential generated during the MFC operation.

it levelling off. The reduction in voltage output is an indication that the lifespans of many distinct kinds of bacteria are drawing closer and closer to an end. After a considerable amount of time spent observing the situation, it became abundantly clear that the predominant tendency continued to be towards a lower voltage. This was the conclusion that could be drawn from the research that was carried out. There is evidence that the exoelectrogens cannot take back control of the activity, which supports the idea that the organic substrate oxidation is coming to an end and will probably be over soon. This is because the exoelectrogens have been unable to take control of the process in the past [36]. The results of this analysis indicate that the voltage reached its highest level on the 18th day of the measurement period. Despite this, a series of scientific studies have proved that the region of a metal that has the highest voltage is also an excellent signal of metal reduction [37–39].

In addition, the value of polarization was studied by examining the relationships between CD, PD, and V, by polarization degree while using a wide range of different external resistances. Figure 3 illustrates the inverse proportional connection that exists between the CD and the V. At a resistance of 1000 Ω, the PD reached its highest value of 3.164 mW/m^2 and the CD touched 77.16 mA/m^2. After doing the research, it was concluded that the PD was 1.31 mW/m^2 and the CD was 22.2 mA/m^2 with an external resistance of 5000 Ω. The 100 Ω resistance led to a PD of 1.16 mW/m^2 and a CD of 148.14 mA/m^2. There is effective movement of electrons; it is essential for both types of resistance, internal and external, to be comparable. This is due to the fact that both forms of resistance are necessary for successful electron transfer. When measured by electron transit, the extreme resistance of the internal conditions exhibits a tendency towards diminishing, and this trend continues as the level drops [35]. Even though the rate at which the potential maintains is lower when the external resistance is low, sufficient electrons continue to be generated and transmitted for the process to be efficient. Despite the fact that the rate at which the potential regulates is considerably slower, this is still the case. Even though the rate of potential stability is slowed down when the external resistance is low, this does not imply that it does not take place at all [34, 35]. The increased electron mobility is to blame for the voltage instability that comes about as a consequence of this. The cathodic response was improved thanks to an oxygen supply that came from the outside, which, in turn, helped to maintain a steady voltage output in spite of the high resistance. The internal resistance equation led to the conclusion that the internal resistance was 520 Ω

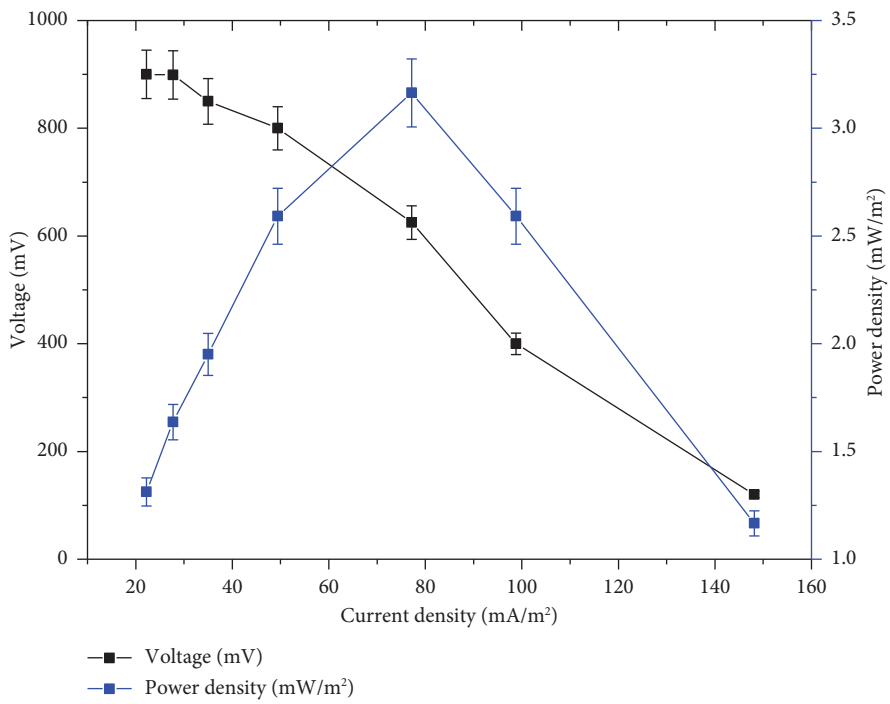

Figure 3: The polarization pattern during the course of this investigation.

in this work. In a number of different investigations, electrochemical performance uses this same pattern to explain its outcomes [35, 40–42].

The evolution of this phenomenon over the course of time is shown in Figure 4, which shows how cell conductivity varies. During the course of the operation, which lasted for a total of 25 days, data on conductivity were collected at a number of different times. From the very first day, when the value was 1550 mS/cm, to the very last day, when the value was 3500 mS/cm, these data have been progressively growing. The rate of increase has been consistent throughout the whole experiment. On day 31, they started a decrease that was not only gradual but also consistent, and it lasted until the very last day of the process. Given that the conductivity was high on day 20, it is reasonable to assume that a great deal of power was produced, and the evidence backs up this idea. After analyzing the pattern of voltage generation, it seems that the experiment reached its peak on day 15–20, with the maximum voltage being produced at that time. After a certain amount of time has passed, the effectiveness of the system starts to begin to diminish as a consequence of a broad range of barriers, as documented in the prior literature [35, 39, 43]. These problems might be the result of a variety of environmental factors. Rojas-Flores et al. [44], who conducted research to clarify the conductivity impact, also presented an analysis that was very comparable.

Conducting CV experiments allowed for an examination of the operation's electrical resistance and redox potential. Throughout the process, the CV was observed many times to provide an understanding of the rate of oxidation-reduction in action [35]. Figure 5 exhibits the rate of scan that is highest in both the forward-backward routes of movement. The varied current levels were found at varied values in both

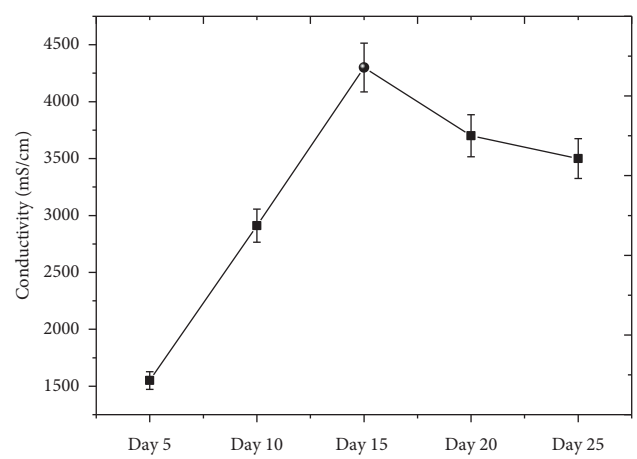

Figure 4: Conductivity trend of the present study at different time intervals.

(forward-reverse) scans. The backward scan achieved its greatest value of −0.00003 mA on day 20, while the forward scan reached its highest value of 0.00023 mA on the same day. The forward and backward scans, respectively, represent the cellular oxidation and reduction processes. The observation showed a steady rise in the rates of the oxidation-reduction activities. As a consequence of this, the highest amount of electron-protons created results from the maximum oxidation rate. Furthermore, the study shows that certain types of bacteria may rapidly oxidize OT sap and rotten rice. Furthermore, the Cp value was calculated in order to examine the time of anode biofilm solidity and formation. The Cp value's constant ascent over time demonstrated the biofilm's gradual growth. The results showed

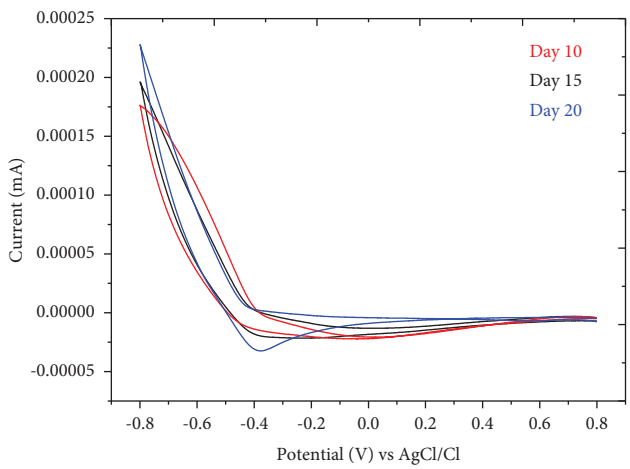

Figure 5: CV curves indicating the oxidation and reduction process of the MFC.

that the various observation days had the greatest value of Cp. For example, day 10 has 0.0000480 F/g, day 15 has 0.0000520 F/g, and day 20 has 0.0000540 F/g. Each time a cycle ended, there would be a little voltage decrease. The biofilm's fragility was ultimately to blame for the size reduction. On days 15 to 20, the biofilm was found to be completely developed. Experts in the field also pursued this line of inquiry to describe the formation and stability of biofilms [39, 43].

3.2. Biological Tests. The conclusions of the study project that investigated the process of removing metal ions are shown in Table 2, which contains a condensed overview of those findings. In particular, in relation to MFC, the use of a bioelectrochemical system as a methodology for the removal of metals is emerging as one of the most cutting-edge and possibly helpful approaches. This is due to the fact that this method can remove metals in an environmentally friendly manner. This approach has the potential to be very successful [34, 45]. The most recent research provides interesting new insights into the process by which metal ions are removed from artificial water. There is a noticeable tendency towards an increase in the degree to which the metal gets destroyed, and this trend may be seen as the process moves closer and closer to its completion. When compared to the findings of past investigations, those presented here are rather interesting and intriguing. During this study endeavor, an efficiency of removal of more than 95% was reached. Based on the facts presented here, it seems that the amount of metal ions present in the artificial wastewater was reduced. Table 3 also includes a comparison profile of the present results with previous literature, and it shows better outcomes.

A wide range of microbial species that have gathered close to and all around the anode electrode are what make up the biofilm. These bacteria work together to build the biofilm. The biofilm is responsible for managing the effect of metals and is also involved in the generation and transmission of energy. During the course of the procedure, the biofilm was produced on its own, not including any support from external sources. Approximately 97% of biofilm is composed of extracellular polymeric substances (EPSs), water, and several types of bacteria [34, 54, 55]. The biofilm's external polymeric component enables bacteria to produce electrons and remove metals. These processes occur simultaneously because the external polymeric component is the prime part of the biofilm [56]. This section of the biofilm holds the majority of the biofilm's water content. The EPS will tell you when the biofilm will develop, and the EPS's efficiency will be subject to how fast the biofilm can attach itself to source of energy. The biofilm's ability to attach itself to organic substrate rapidly will decide how effective the EPS will be. Moreover, EPS components include proteins, lipids, carbohydrates, and compounds besides nucleic acids [57, 58]. The presence of a healthy organic substrate, which boosts the performance of the extracellular matrix (EPS), contributes to an improvement in the biofilm's overall strength. The CV data that were shown before gave the impression that the existing biofilm was quite stable. The SEM image of the biofilm-covered electrode can be shown in Figure 6. The development of the anticipated bacterial species could be seen in SEM photos of an anodic biofilm electrode. Because of their habits and their capacity to survive in harsh environments, bacteria are very useful tools for cleaning up the environment. In addition, an SEM examination was performed on the anode biofilm, and it was discovered to have a surface with a shape that was similar. The anode electrode biofilm may include conductive pili-type bacteria because it possesses rod filaments [34]. According to an extensive study, conductive pili bacteria may be identified by their rod-shaped and filamentous extensions [34, 42]. The reported bacterial genera that have a role in MFC include *Klebsiella pneumoniae, Acinetobacter, Bacillus, E. coli*, and *Lysinibacillus* [55, 59]. Figure 7 demonstrates that after 25 days of operation, the anode that had biofilm had a distinct elemental composition. This was able to be determined by analyzing the EDX spectrum. Based on these findings, it would seem that the surface of the anode is free of any potentially hazardous compounds or ions of metal. Both the EDX data and the SEM photos of the biofilm have evidence of this particular phenomenon. One can see it in both of these types of images. In addition to being adsorbed onto the surfaces of the electrodes, EDX showed that the metal ions were reduced by the bacteria themselves, which was another finding of this technique [59].

3.3. How MFC Works in the Present Study? In the current investigation, numerous bacteria were grown on an organic substrate consisting of rotten rice mixed with OT sap. The rotten rice and OT sap initially consisted of polysaccharides, but over time they were converted into glucose. After that, some species of bacteria will oxidize the glucose, to produce the electron-proton for further processing. During the course of this investigation, oxidation-reduction processes were found to be taking place, which may be summed up as follows [34]:

Table 2: Removal efficiency of the present study.

Organic substrate	Initial concentration of each metal ion	Sample taken on day number	Removal % of Pb^{2+}	Removal % of Cd^{2+}	Removal % of Cr^{2+}	Removal % of Ni^{2+}
Rotten rice + OT sap	100 mg/L	0	0	0		0
		5	10.30	12.26	17.40	25.90
		10	35.11	38.15	36.29	39.50
		15	54.09	50.00	54.00	66.88
		20	68.50	72.46	75.34	82.13
		25	83.67	84.10	84.55	95.99

Table 3: Comparison of the present results with recent literature.

Organic substrate	Target pollutants	The concentration of metal (mg/L)	Removal performance (%)	Source
Sodium acetate	Pb^{2+}	900	44.1	[46]
Potato wastes	Pb^{2+}	50	60.33	[47]
Oil palm trunk sap	Pb^{2+}	100	91.07	[48]
Glucose	Cr^{6+}	20	79	[49]
Sodium acetate	Cr^{6+}	100	82	[50]
—	Cr^{6+}	100	99	[51]
Glucose	Cr^{6+}	—	99	[52]
Sodium acetate	Ni^{2+}	32	95	[50]
Sodium acetate	Cd^{2+}	100	31	[46]
Sweet potato wastes	Cd^{2+}	50	65.51	[47]
Acetate	Cd^{2+}	50	60	[53]

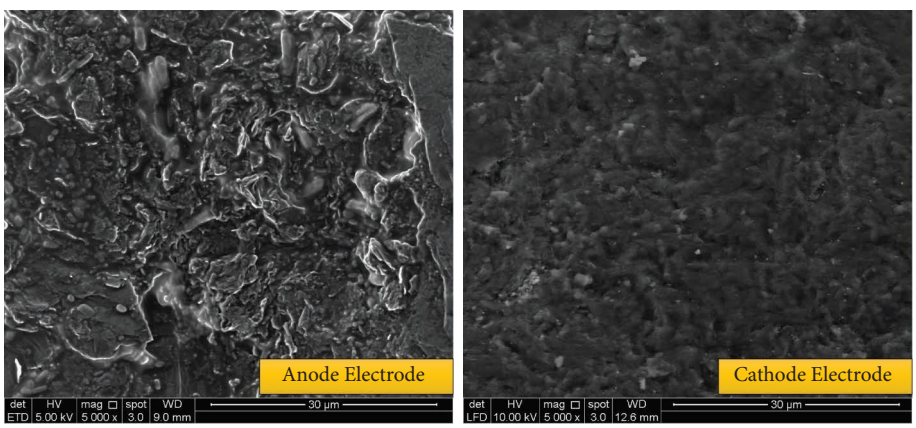

Figure 6: Images taken with SEM of the anode-cathode electrodes on day 25, the last day of MFC operation.

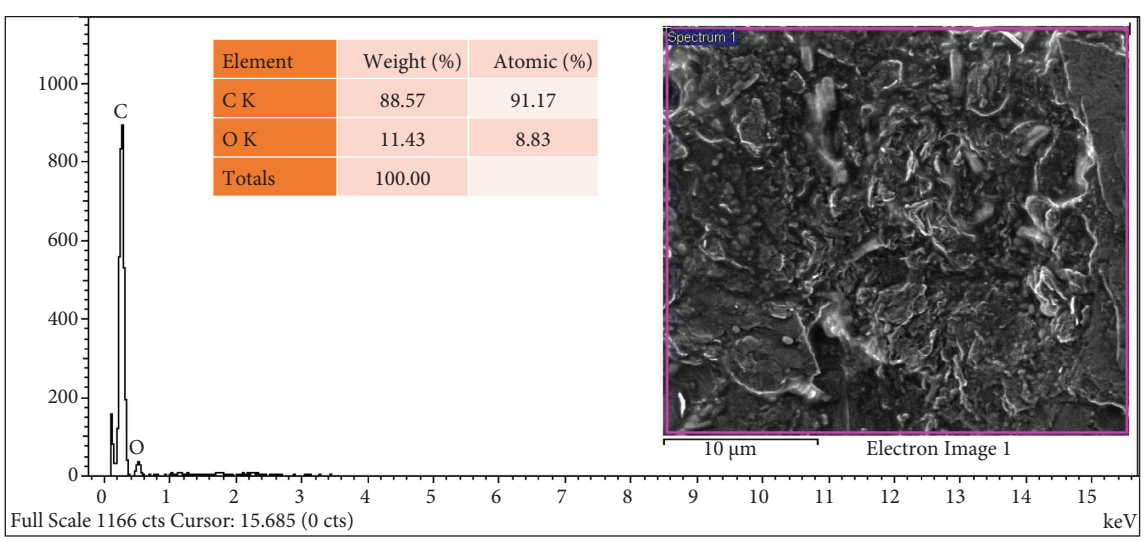

Figure 7: EDX of anode electrode on the last day of MFC operation.

$$\begin{aligned} &\text{Anode: rotten rice + OT } C_6H_{12}O_6 + 6H_2O\ 6CO_2 + 24H^+ + 24e^- \\ &\text{Cathode: } 24H^+ + 24e^- + 6O_2\ 12H_2O \\ &\text{General reaction: } C_6H_{12}O_6 + 6O_2\ 6CO_2 + 6H_2O + \text{Electricity.} \end{aligned} \tag{3}$$

When the process of oxidation is finished, it will have resulted in the generation of electron-protons, both of which will have been transported to the cathode. In an MFC, there was just one chamber located between the anode-cathode; hence, any protons that were travelling between the two could take a straightforward path [60]. The process that has received the most interest from researchers is shown in Figure 8, which is fully discussed in the literature [61]. The idea to draw the mechanism of the MFC is taken from the literature [33].

After going through a redox reaction, metal ions that were previously water-soluble become insoluble. This results in the metal ions losing their solubility [34]. As was indicated previously in the phrase, the condition that was discovered to be insoluble was found to be sludge. This was determined to be the case. The AAS test determined the number of metal ions that were still present in the water. In MFC, the metal removal, which resulted in the ions' subsequent switch into oxides, caused a material to be created that resembled sludge. In MFC, the metal removal, which resulted in the ions' succeeding switch into oxides, caused a material to be produced that resembled sludge. Numerous investigations have shown that the metal ions that have been recovered are changed into their oxide forms, and the waste product that accumulates as a consequence of this process contains the metals in their oxide forms. This conversion of the metal ions into their oxide forms has been proven [30, 62]. The following is a biological explanation for the steps taken during metal reduction:

(i) Pb^{2+} ions:

$$\begin{aligned} &Pb^{2+} + 2e^-\ Pb_{(s)} \\ &2Pb^{2+} + 2H_2O\ 2PbO + 4H^+ \\ &PbO + 2e^- + 2H^+\ Pb_{(s)} + H_2O. \end{aligned} \tag{4}$$

(ii) Cd^{2+} ions:

$$\begin{aligned} &Cd^{2+} + 2e^-\ Cd_{(s)} \\ &2Cd^{2+} + 2H_2O\ 2CdO + 4H^+ \\ &CdO + 2e^- + 2H^+ Cd_{(s)} + H_2O. \end{aligned} \tag{5}$$

(iii) Cr^{3+} ions:

$$\begin{aligned} &Cr^{3+} + 3e^-\ Cr_{(s)} \\ &2Cr^{3+} + 3H_2O\ Cr_2O_3 + 6H^+ \\ &Cr_2O_3 + 6e^- + 6H^+\ 2Cr_{(s)} + 3H_2O. \end{aligned} \tag{6}$$

(iv) Ni^{2+} ions:

$$\begin{aligned} &Ni^{2+} + 2e^-\ Ni_{(s)} \\ &2Ni^{2+} + 2H_2O\ 2NiO + 4H^+ \\ &NiO + 2e^- + 2H^+\ Ni_{(s)} + H_2O. \end{aligned} \tag{7}$$

4. Challenges and Future Suggestions

The ability of MFC technology to convert chemical energy into electrical energy through biological processes is a significant advantage. This enables the technology to biologically adapt to the process of treating a broad diversity of chemical substrates at a variety of concentrations. The electrochemical, biochemical, microbial, and electrode materials are being studied by several research groups. Different parameters, such as the electrode/substrate materials, and other organic molecules are being investigated for their potential effects on these [63]. On the other hand, it is true that technology has never been seen as a serious rival in the field of wastewater treatment, and renewable energy is just now emerging as a problem. Despite being perhaps the only example of a device that can generate energy from the cold oxidation of waste organic matter and, under certain conditions, inorganic carbon, it has not yet found widespread adoption. In terms of the applications, they are capable of being out in the field. The MFC comes with its fair share of advantages as well as disadvantages. The operational issues include high running expenses and limited power output; these issues need to be rectified before the MFC technology can be made available on a commercial scale [64, 65]. There is a possibility that the energy produced by the cell will not be adequate to continually power a detector or transmission. Utilizing microbial fuel cells comes with this major drawback. Since the data can only be sent when there is sufficient energy stored, this challenge may be overcome by increasing the surface area of the electrodes or by using an adequate power management program. This is due to the fact that the data are only sent while there is sufficient energy stored. According to Rahimnejad et al. [66], this takes place whenever an ultra-capacitor is used. Since microbial processes are slower at extreme temperatures, MFC is unable to function at temperatures below room temperature [67]. Over the course of the last two decades, a considerable amount of effort and time has been spent in the research, advancement, and improvement of electrode substances with the intention of enhancing the efficiency of MFCs. In addition to this, it has developed into one of the most critical problems [68, 69]. Considering MFCs are regarded to be a novel

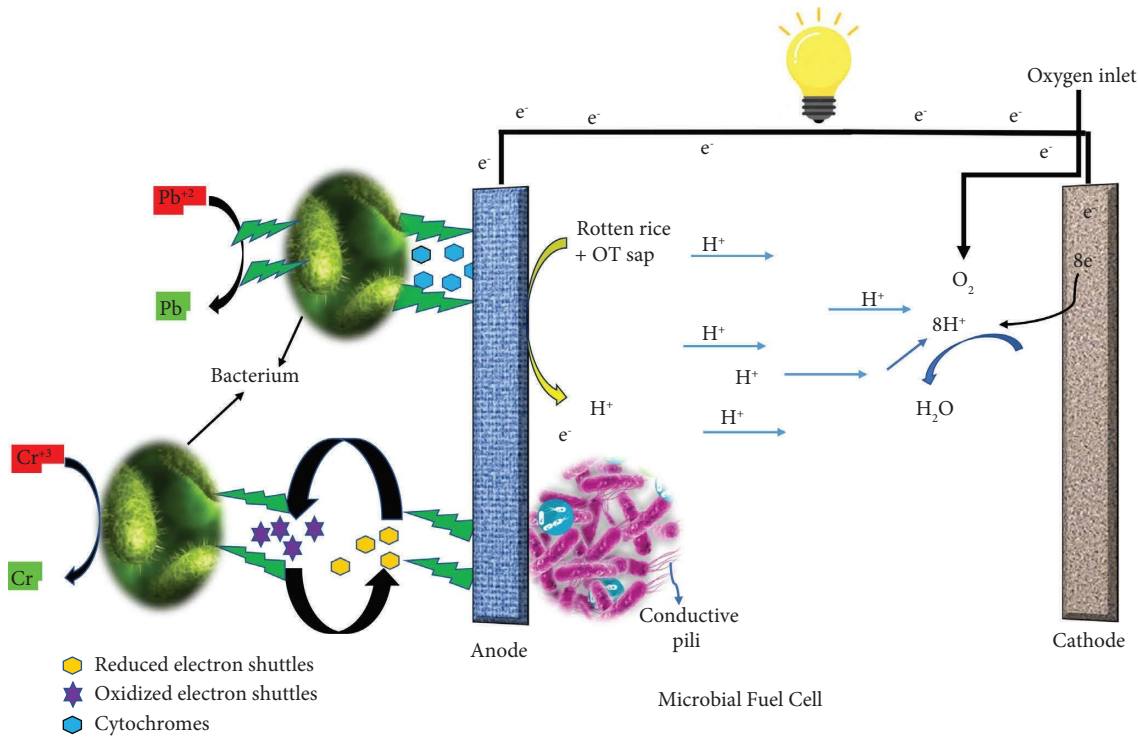

Figure 8: A demonstration of the MFC mechanism.

approach to the treatment of wastewater, it is imperative that future studies concentrate on the following concerns [70]. To begin, there is the issue of metabolic mechanism, which states that in order to have a deeper comprehension of metabolic mechanism, selecting bacteria with high electrochemical activity would contribute to selecting microorganisms with electrochemically active microorganisms. In order to successfully complete this procedure, one will first need to construct a conductively thick biofilm and then adjust the operating conditions. The second factor to consider is that the layout and construction of the reactor for MFCs will directly affect whether or not they are suitable for the treatment of wastewater. Thirdly, the fact that voltage reversal and ionic short circuits are still significant barriers to practical application emphasizes the relevance of MFC stacks. This is because biocatalysts are taking place during the electrode reactions taking place in the MFC. Finally, as the development of a system for power harvesting and use will speed up the process of introducing MFC into the commercial market, further study needs to be done in this area [70].

5. Concluding Statement

The present paper focuses on the utilization of rotting rice and OT sap coupled with MFC as a means to produce energy and remove metal ions from the artificial wastewater. 610 mV was the maximum level of voltage that was capable of being measured. It is an indication that the process of removing the metal has been effective if there are many distinct bacterial species on the anode. It signifies that the rotting rice and OT sap experienced a process of active oxidation, which resulted in electron production. However, modern electrochemical experiments show substantially worse energy efficiency than previous investigations. Despite these contributing factors, energy efficiency has decreased, according to extensive study and analysis. It is possible that with the assistance of specialists in a range of domains, such as material science, bioelectrochemistry, and microbiological science, a number of challenges that are essential to be handled for the MFC to reach the point where it is commercially viable may be addressed.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

Anoud Saud Alshammari, Shehu Sa'ad Abdullahi, and Ghada Mohamed Aleid were responsible for conceptualization, methodology, original draft preparation, visualization, and investigation. Alamri Rahmah Dhahawi Ahmad and Asma D. Alomari were responsible for result interpretation and scientific comments. Rania Edrees Adam Mohammad was responsible for original draft preparation, project administration, supervision, and funding acquisition. Each author has reviewed and approved this article. Each author has made significant contributions to this work. Alamri Rahmah Dhahawi Ahmad and Asma D. Alomari contributed equally to this study.

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