INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 24, No. 3, p. 9-19, 2024
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Salt enrichment of wastewater increased electricity production with variable impact on wastewater treatment of a microbial fuel cell

Eudora O. Nwanaforo*[1], Onyenonachi C. Ihejirika[1], Chinwe J. Nguma[1], Emilia O. Anyanwu[1], Christopher E. Nwanyanwu[2], Campbell O Akujobi[2]

[1]*Department of Environmental Health Science, School of Health Technology, Federal University of Owerri, Imo State, Nigeria*

[2]*Department of Microbiology, School of Biological Science, Federal University of Owerri, Imo State, Nigeria.*

Article published on March 07, 2024

Key words: Microbial fuel cell, Potassium permanganate, Salt bridge, Double chamber, Power density

Abstract

An H-Type microbial Fuel Cell (MFC) was developed that simultaneously treat Student's hostel effluent and generate electricity. The MFC was designed using a 1.5%/1M NaCl agar salt bridge, copper and carbon electrodes, Potassium permanganate catholyte, and the waste water effluent as anolyte. The effect of addition of the salt enrichment to the anolyte was investigated for its effects on electricity generation and waste treatment. A max average Voltage of 1.10V was obtained which was increased to 1.16V upon enrichment of the anolyte with NaCl. On the other hand, for the COD removal efficiency of the carbon electrode MFC, it was 91.25% and on salt addition 92.29% and for the copper MFC, 86.88% and on salt addition 85.21%. The data for other parameters varies. These demonstrate that while salt enrichment enhances electricity, the effect on treatment varies dependent on type of electrode and the treatment parameter.

***Corresponding Author:** Eudora O Nwanaforo ✉ eudoranwanaforo@gmail.com

Introduction

Developing nations are looking for easily accessible, low-cost waste treatment solutions. In a similar vein, industrialization, which uses fossil fuels, among other things, and unchecked human activity are to blame for the environment's growing pollution (Braide *et al.*, 2016b; Güney, 2019; Palanisamy *et al.*, 2019). Not only are these fuels not environmentally friendly, but they are also difficult to evaluate. Hence, there is an ongoing requirement for alternative energy sources (Braide *et al.*, 2016b; Hansen *et al.*, 2019). A subset of microbial electrochemical cells (MECs), also known as microbial fuel cells (MFCs) or, more recently, microbial electrochemical technologies (METs), are gaining popularity (Di Ilio and Falcucci, 2020; Min *et al.*, 2005; Shafiei and Salim, 2014). Utilizing bacterial redox reactions, this technology purifies wastewater and produces energy (Min *et al.*, 2005; Venkata *et al.*, 2010). Previous studies by Adeleye and Okorondu (2015) have shown that using wastewater from hostel effluents has the potential to generate electricity. This was enhanced by Akaluka *et al.* (2016) and Egbadon *et al.* (2016), who showed that microbial fuel cells can treat piggery and abattoir effluents and produce electricity at the same time. The low power yield of microbial fuel cells is one of their limitations; it is thought that this can be overcome by using a highly oxidised catalyst, such as potassium permanganate or dichromates, and by making the anolyte more conductive.[17]. The anode and cathode's surface areas can both be increased to improve these as well. In this study, we proposed a microbial fuel cell with a strongly oxidised catholyte, increased electrode surface area, and an anolyte enriched in sodium chloride. Next, we looked into the MFC's ability to both generate electricity and treat the wastewater from the Federal University of Technology Owerri's hostel.

Materials and methods

Sample collection

As indicated by a sketched Fig. 1, wastewater was collected from the male hostels at the Federal University of Technology Owerri at four separate mini-dams where waste effluents from Hostels A and B flow through. Using a sterile funnel, composite sampling was carried out at four locations: A, B, C, and D. The sample was collected in a sterile 50-liter gallon. As soon as possible after sample collection, physicochemical and microbiological analyses were carried out to stop the sample's organic carbon content from degrading.

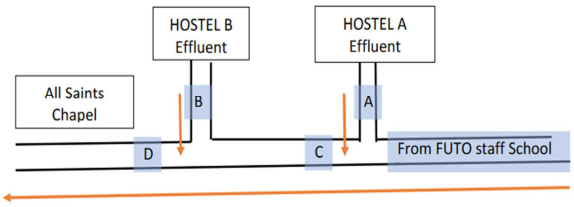

Fig. 1. Different points of collection of wastes (A-D represents waste collection sites and the Orange arrows indicate the direction of flow of the wastewater).

Characterization of wastewater prior to electricity generation

Physicochemical analysis of wastewater

Sample collected was assessed for its physicochemical parameters. This include conductivity, pH, total dissolved solid (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), phosphate, ammonia, total nitrogen and total suspended solid (TSS) according to APHA (1998).

Microbiological analysis of wastewater

Media preparations

After a ten-fold serial dilution, samples were plated using the spread plate technique on Nutrient agar, SS Agar (Salmonella Shigella Agar), Potato Dextrose Agar, Eosin Methylene Blue (EMB) Agar, MacConkey agar, and Cetrimide Agar (Pseudomonas Selective Agar).For 24 to 48 hours, the plates were incubated at 37 °C. Colony Forming Unit per millilitre and the documentation of colonial characteristics were used to calculate the mean viable plate count. The colonies on the plates were subcultured for 24 hours at 37 °C on brand-new, sterile nutrient agar plates. The isolates were then presumedly characterised by means of microscopic, macroscopic, and biochemical analyses.

Constituents and construction of the Microbial fuel cell

Preparing the chambers

Two ten-liter plastic bottles that were purchased from the neighbourhood store functioned as temporary cathode and anode chambers. A 1.5-inch adopter serves as the point of attachment for the salt bridge, which connects the two chambers. After the hole was made, the 1.5-inch adopter was glued together using Abro Sealant. Leaks were avoided by using the proper sealing. Next, a wire-accommodating hole was drilled into the lid of each chamber, and a second hole was made for the cathode chamber to fit the thermometer. Time was allowed for the setup to dry and solidify.

Preparing the electrodes

Copper plates were cut into square electrode shapes, and a hole was made for nuts and bolts to attach the electrodes and provide wire attachments. The copper rod's surface area (20 cm × 2.5 cm × 0.3 cm) was calculated to yield 0.01135 m^2. Conversely, a 20cm x 1.5cm graphite rod was also bought, and its height was changed to produce a 0.00978m^2 total surface area. Based on this, it was determined that the surface area density of the carbon and copper electrodes was 0.000978 and 0.001135 m^2/l, respectively. To improve conductivity, wire attachments were made and these electrodes were ready.

Preparing the catholyte, anolyte and saltbridge

Chemicals were prepared according to methods illustrated by AOAC (2000). Potassium permanganate ($KMnO_4$) was used as preferred catholyte at the molar concentration of 0.1M. The wastewater served as inoculum and organic substrate sources for the Microbial Fuel Cell without any modification such as adjustment of pH or addition of nutrients (Min *et al.*, 2005). NaCl was used to enrich the wastewater at a concentration of 0.01M to increase the conductivity of the MFC. The salt bridge was prepared using 2% Agar-agar and 1MNaCl. A 12cm salt bridge was contained in a PVC 1.5-inch diameter pipe.

Fig. 2. A complete set up of a microbial fuel cell using carbon electrodes.

Coupling and pitching the microbial fuel cell

The salt bridge was made a day before the set-up was coupled. The sample was collected the same day the set-up was to be coupled. The set-up was coupled by joining the two chambers using the salt bridge with the aid of the adopter. The gaps were sealed using Abro sealant. Four MFCs were constructed and labeled with an anode-cathode electrode type label as shown below (Logan and Regan, 2006).

A=Carbon anode-carbon cathode MFC. (C-MFC)
B=Carbon anode-carbon cathode MFC +0.01Msalt. (C+ salt mfc)
C=Copper anode-copper cathode MFC. (Cu-MFC)
D=Copper anode-copper cathode MFC +0.01Msalt (Cu+ salt mfc)

Each microbial fuel cell has four electrodes each in the cathode and the anode chambers. The wastewater was placed into the anode as the anolyte and the multimeter was connected to the cathode and the anode with the aid of the low resistance copper wire before they were inserted into the chambers. The initial reading was taken at time 00hr and allowed to acclimatize for 1h before subsequent readings were taken. The voltage readings were taken on 12 h intervals for 21 days. A complete set up of the microbial fuel cell used in this study is shown in Fig. 2.

Microbiological analysis of raw wastewater after electricity generation

This section's primary goals are to isolate, characterize, and identify the isolates that will be found in the biofilms on the electrodes. Isolation was carried out after the biofilm formed after 21 days of

voltage reading from the MFC. Following this, the MFC was decoupled and a well-labeled, sterile swab was used to scrape the electrodes in order to collect the microbial community in the biofilms. This was then used to prepare a culture medium by suspending the swab in 9 ml of sterile distilled water. The culture medium was diluted, and a preferred dilution (10^7) of the culture was used for growing media inoculation. The medium was aseptically inoculated using the Spread Plate technique in an acetone-alcohol cleaned bench next to a Bunsen flame (Beshir, 1987). The media were then incubated at 30 degrees both aerobically for 24 hours and anaerobically for 72 hours.

Data analysis

Power density

In order to compare the power output of various systems, power is frequently normalized to a reactor characteristic. Since many systems are not designed with power production in mind, the parameter used for normalization depends on the application. Typically, the power output is standardized to the projected surface area of the anode, as this is the site of the biological reaction (Palanisamy *et al.*, 2019). In light of this; the power density (PA^n, W/m^2) was computed using the anode's area (AA^n) (Logan and Regan, 2006) as follows:

$$P_{An} = \frac{E_{cell}^2}{A_{An} R_{ext}}$$

More so, recalling that power is also calculated as the power density can be calculated from the open circuit voltage using the relation

$$P_{An} = \frac{IE_{cell}}{A_{An}}$$

Where I= Current, E= Open circuit voltage, A= Area of the Anode

Waste water treatment efficiency

The ability of the microbial fuel cell to treat waste water was examined. These were obtained in efficiencies (percentages) and calculated as

Efficiency = {(Initial parameter value - Final parameter value)/ (Initial parameter value)} × 100

Parameters examined in this work include are BOD removal efficiency, Nitrate and Nitrate-N removal efficiency, TSS and TDS removal efficiency, Phosphate removal efficiency, Heavy metals removal efficiency, Bicarbonates removal efficiency, and COD and TOC removal efficiency.

Results

Waste water treatment efficiencies

The calculated efficiencies served as a base for the identification of the treatment capacity of the microbial fuel cell. The results revealed that the microbial fuel cell with carbon electrode had the highest value of the efficiency while reducing the TOC by 93.54% while the least efficiency was observed in microbial fuel cell with copper electrode(salt enriched) having an efficiency of -26.90% which is an increase in the copper level instead of a decrease. The individual parameters were shown in Tables 1 and 2.

All efficiencies were recorded in percentage (Table 3). The microbial fuel cell with carbon electrode (salt enriched) recorded the highest COD removal efficiency of 92.29% while microbial fuel cell with copper electrode (salt enriched) recorded the lowest removal efficiency of 85.21%. The microbial fuel cell with carbon electrode and microbial fuel cell with copper electrode (salt enriched) recorded the highest BOD removal efficiencies of 50% while microbial fuel cell with carbon electrode (salt enriched) recorded the lowest removal efficiency of 36.67%. The microbial fuel cell with copper electrode (salt enriched) recorded the highest nitrates removal efficiency of 86.38% while microbial fuel cell with carbon electrode recorded the lowest removal efficiency of 80.87%. The microbial fuel cell with copper electrode (salt enriched) recorded the highest nitrate-n removal efficiency of 86.26% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 82.05%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest total suspended solids (TSS) removal efficiency of 73.15% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 67.17%.

Table 1. Waste water characteristics of the microbial fuel cell before the experiment

Parameter (%)	Microbial fuel cell			
	A	B	C	D
pH	6.8	6.8	6.8	6.8
Conductivity	1649	1649	1649	1649
TDS	167	167	167	167
TSS	112	112	112	112
BOD	13.2	13.2	13.2	13.2
COD	5.9	5.9	5.9	5.9
DO	4.6	4.6	4.6	4.6
Bicarbonate	10.64	10.64	10.64	10.64
Phosphate	860	860	860	860
Nitrate	760	760	760	760
Nitrate-N	1120	1120	1120	1120
TOC	62.82	62.82	62.82	62.82
Copper	0.021	0.021	0.021	0.021
Lead	0.01	0.01	0.01	0.01
Mercury	0.002	0.002	0.002	0.002
Arsenic	0.025	0.025	0.025	0.025
Iron	0.012	0.012	0.012	0.012

Keys: TDS= Total dissolve solid, TSS= Total soluble solid, BOD= Biological oxygen demand, COD= Chemical oxygen demand, DO= Dissolve oxygen, TOC= Total organic carbon.

Table 2. Waste water characteristics of microbial fuel cell after the experiment.

Parameter (%)	Microbial fuel cell			
	A	B	C	D
pH	7. 1	7.3	6.7	6.6
Conductivity	1374.11	1580.24	1635.31	1717.76
TDS	64.23	53.52	66.316	62.09
TSS	32.08	30.07	36.77	36.09
BOD	6.60	8.36	7.48	6.60
COD	0.516	0.46	0.77	0.87
DO	2.62	2.22	2.06	1.75
Bicarbonate	0.66	0.57	0.60	0.59
Phosphate	446.77	368.06	435.59	346.24
Nitrate	110.12	105.49	145.39	103.51
Nitrate-N	155.12	172.26	201.04	153.66
TOC	67.18	76.23	114.4	128.96
Copper	0.02	0.02	0.02	0.03
Lead	0.01	0.01	0.01	0.01
Mercury	0.002	0.002	0.002	0.002
Arsenic	0.02	0.02	0.02	0.02
Iron	0.00	0.001	0.002	0.002

Keys: TDS= Total dissolve solid, TSS= Total soluble solid, BOD= Biological oxygen demand, COD= Chemical oxygen demand, DO= Dissolve oxygen, TOC= Total organic carbon.

The microbial fuel cell with carbon electrode (salt enriched) recorded the highest total dissolved solids (TDS) removal efficiency of 67.95% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 60.26%. The microbial fuel cell with carbon electrode recorded the highest total organic compound (TOC) removal efficiency of 93.54% while microbial fuel cell with copper electrode (salt enriched) recorded the lowest removal efficiency of 87.60%. The microbial fuel cell with copper electrode (salt enriched) recorded the highest phosphates removal efficiency of 59.74% while microbial fuel cell with carbon electrode recorded the lowest removal efficiency of 48.05%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest copper removal efficiency of 0.51%while microbial fuel cell with copper electrode (salt enriched) recorded the lowest removal efficiency of -26.90%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest lead removal efficiency of 9.09% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 4.13%. The microbial fuel cell with carbon electrode recorded the highest iron removal

efficiency of 92.85% while microbial fuel cell with copper electrode (salt enriched) recorded the lowest removal efficiency of 86.28%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest mercury removal efficiency of 22.58% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 6.45%. The microbial fuel cell with copper electrode (salt enriched) recorded the highest dissolved oxygen (DO) removal efficiency of 62.07% while microbial fuel cell with carbon electrode recorded the lowest removal efficiency of 43.10%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest arsenic removal efficiency of 12.77% while microbial fuel cell with copper electrode recorded the lowest removal efficiency of 6.38%. The microbial fuel cell with carbon electrode (salt enriched) recorded the highest bicarbonates removal efficiency of 53.70% while microbial fuel cell with carbon electrode recorded the lowest removal efficiency of 45.99%. The microbial fuel cell with carbon electrode recorded the highest conductivity removal efficiency of 16.67% while microbial fuel cell with copper electrode (salt enriched) recorded the lowest removal efficiency of 4.17%.

Microbial community

The microbial community revealed that the microbial fuel cells consist of gram positives and gram negative organisms. The gram positive organisms include: *Staphylococcus* sp, *Enterococcus* sp, *Bacillus* sp and *Micrococcus* sp, while the gram negative organisms includes, *Escherichia coli, Shigella* sp and *Salmonella* sp. The fungal isolates include *Saccharomyces* sp. Some of the organisms isolated before the experiment were not found in the biofilm after the experiment. These include *Mucor* sp, and *Penicillium* sp. as shown in Table 4.

Table 3. Wastewater treatment efficiency of microbial fuel cell.

Parameters (%)	Microbial fuel cell			
	A	B	C	D
Conductivity	16.67	4.17	0.83	4.17
TDS	61.54	67.95	60.29	62.82
TSS	71.36	73.15	67.17	67.78
BOD	50	36.67	43.33	50.00
COD	91.25	92.29	86.88	85.21
DO	43.10	51.72	55.17	62.07
Bicarbonate	45.99	53.70	50.62	51.36
Phosphate	48.05	57.14	49.35	59.74
Nitrate	85.51	86.12	80.87	86.38
Nitrate-N	86.15	84.62	82.05	86.28
TOC	93.54	92.67	89.00	87.60
Copper	0.00	0.51	-16.75	-26.90
Lead	5.79	9.09	4.13	6.61
Mercury	16.13	22.58	6.45	19.35
Arsenic	8.51	12.77	6.38	10.64
Iron	92.85	91.89	87.83	86.28

Keys: TDS= Total dissolve solid, TSS= Total soluble solid, BOD= Biological Oxygen Demand, COD= Chemical oxygen demand, DO= Dissolve oxygen, TOC= Total organic carbon.

Electricity generation by the MFC

Open circuit voltages

The open circuit voltage and current of the microbial fuel cell over a 21-day period are displayed in Fig. 3A and C. The starting and peak voltages of the carbon electrode microbial fuel cell were 211.38 mV and 1104.31 mV, respectively, while the copper electrode MFC produced voltages of 697 mV and 1050 mV, respectively. This shows that the carbon electrodes performed better than the copper electrodes.

The performance of the two microbial fuel cells improved with the addition of salt, resulting in starting and peak voltages of 254 mV and 1160 mV for the carbon MFC and 913.54 mV and 1053 mV for the copper MFC, respectively.

Current produced by the MFC over 21 days

The current generated by the MFC over a 21-day period is shown in Fig. 3B and D. The voltage generated and the current obtained exhibit the same gradation.

The first day and peak voltage of the carbon electrode microbial fuel cell were measured to be 0.47 A and 3.71 A, respectively, while the starting voltage and peak voltage of the copper electrode MFC were 1.09 A and 2.25 A, respectively. This shows that the carbon electrodes performed better than the copper electrodes. The addition of salt reduced the performance of carbon microbial fuel cells, increasing the current from 1.63 A to 3.71 A for copper MFC and decreasing the starting and peak voltage to 0.57 A and 3.21 A for carbon MFC.

Table 4. Microbial community of microbial fuel cell after treatment

Microbial community		
Gram-positives	Gram-negatives	Yeast
Bacillus sp.	*E. coli*	*Saccharomyces* sp.
Micrococcus sp.	*Salmonella* sp.	
Enterococcus sp.	*Shigella* sp.	
Staphylococcus sp		

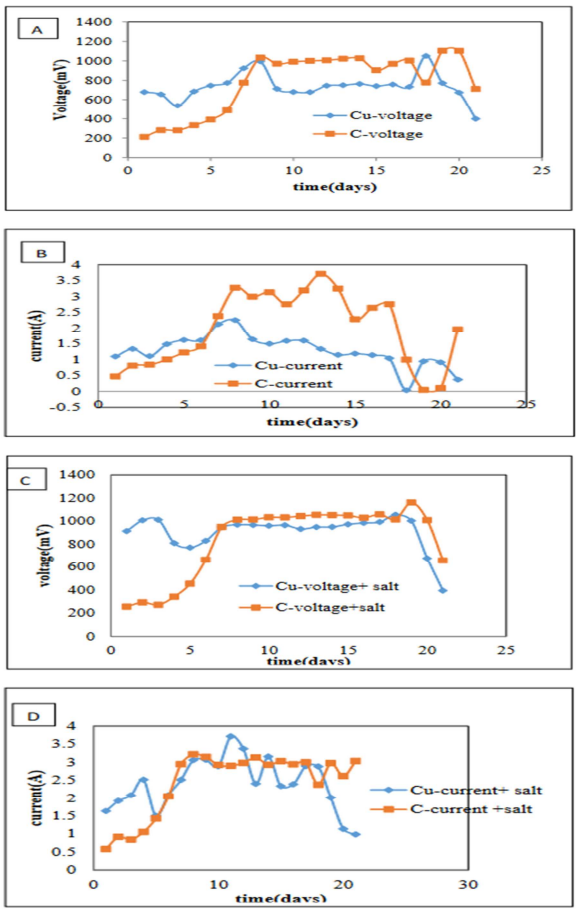

Fig. 3. Effect of electrode type on (A) voltage (B) current produced; and Salt enrichment on (C)voltage and (D) current produced by different electrode type MFCs

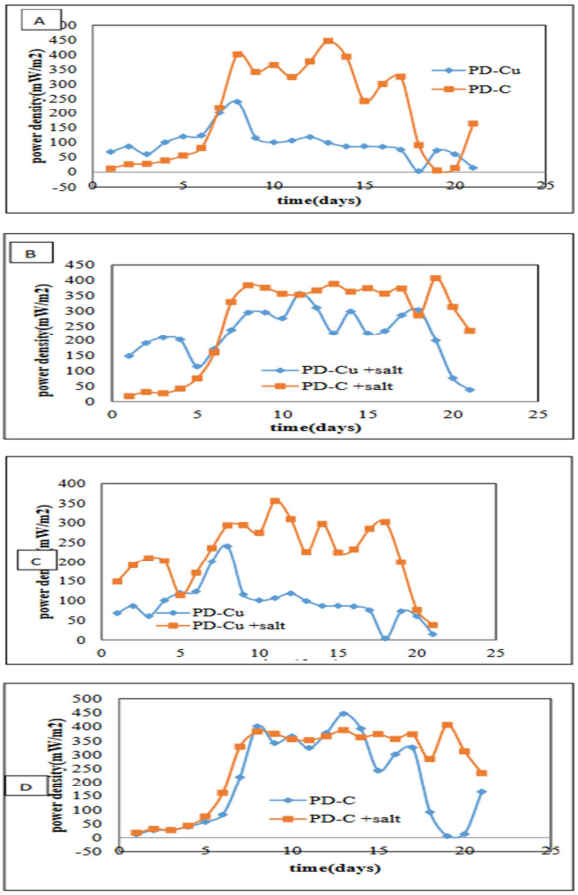

Fig. 4. Effect of (A) electrode type, (B) Salt enrichment (C) Salt enrichment on cupper (D) Salt enrichment on carbon on power densities obtained from the MFCs.

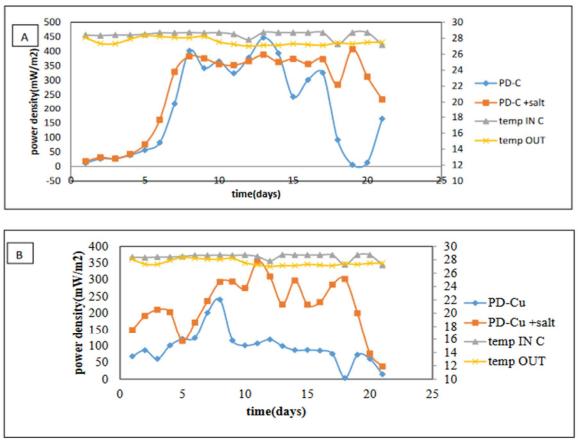

Fig. 5. Temperature measurements during MFC experiments with (A) Carbon and (B) copper electrodes.

Power densities of the microbial fuel cells

Based on electrode type and salt enrichment, the power densities of the microbial fuel cell were

computed and analysed. The power density obtained by the copper electrode microbial fuel cell was 68 mW/m² and 240.73 mW/m², whereas the power density obtained by the carbon electrode microbial fuel cell was 118 mW/m2 and 406.58 mW/m² starting and peak power densities, respectively (Fig. 4A). According to their respective performances, the addition of salt also raised the microbial fuel cells' peak power densities to 446 mW/m² for the carbon and 355.69 mW/m² for the copper microbial fuel cells (Fig. 4B, C and 4D).

Temperature effects on the MFC performance

To observe for potential changes during the experiment, the impact of temperature-both internal and external was also observed. The temperatures of the interior and exterior were both ambient at 28±20C, with no discernible differences between them. The microbial fuel cells' power densities did not exhibit any noteworthy alterations when there was a minor temperature variation ($P<0.05$). Additionally, the experiment's temperature remained relatively constant (Fig. 5A and 5B).

Discussion

Wastewater treatment

The COD removal efficiency of the four microbial fuel cells that were used was found to be 91.25% for carbon and 92.29% for salt addition, and 86.88% and 85.21% for copper MFC. In one study, adding 50 mM of NaCl to the cathode chamber raised the COD removal efficiency from 87 to 90% (Venkata *et al.*, 2010). This finding corroborates the theory that adding NaCl will improve the microbial fuel cell's ability to treat waste water (Shukla *et al.*, 2004). In a different study, the efficacy of COD removal using household wastewater and diary waste water was assessed at wastewater concentrations of 100%, 75%, and 50%. The results were 86.42%, 81.7%, and 75.2%, and 88.4%, 78.6%, and 67.2%, respectively (Shukla *et al.*, 2004). The concentration of the substrate may have also had an impact on this relatively slow removal of COD. When salt was added, the TDS removal efficiency of the carbon electrode MFCs was 61.54% and 67.95%, whereas the copper electrode MFCs showed 60.26% and 62.82% TDS removal efficiency upon salt enrichment of electrolyte.

The efficiency of removing dissolved solids from domestic wastewater at 100%, 75%, and 50% wastewater concentrations was found to be 56.2%, 47.2%, and 38.2% in a prior study. With the same concentration of dairy wastewater, the efficiencies were 5768%, 52.7 %, and 46.5 %, in that order. This further demonstrates how the concentration of the substrate affects the microbial fuel cell's treatment efficiency (Shukla *et al.*, 2004). Additionally, the microbial fuel cells' efficiency rose when salt was added to the medium. The four microbial fuel cells that were used showed the following nitrate removal efficiency: 85.51% for carbon and 86.12% upon salt addition, and 80.87% and 86.38% for copper upon salt enrichment. Since too much nitrogen can eutrophicate a body of water and endanger aquatic life, nitrogen is one of the most important containments in wastewater.

In one study, the removal efficiency of ammonium was found to be above 96% at three different nitrogen loading rates. In contrast, the removal efficiency of nitrate was found to be lower, falling from 91.9±8.1% at 0.07 kg N/m3/day to 67.8 ± 6.1% at 0.21 kg N/m3/day (Chin-Tsan *et al.*, 2010). According to certain research, nitrate may contribute to birth abnormalities, thyroid issues, spontaneous miscarriages, and the emergence of certain adult malignancies.[10] According to the results, the MFC-D had the greatest efficiency value (96.52%) when it came to treating nitrates. Several parameters showed an increase in value, including the anolyte's copper content, which rose by 16.75% and 26.90%, respectively. According to Benetto (1990), the use of copper electrode microbial fuel cells in treatment leads to their dissolution, which raises the concentration of copper in wastewater instead of reducing it. Moreover, the microbial fuel cell outperformed other metals in iron removal, up to 92%. The microbial fuel cells' ability to treat the waste water was significantly improved by the addition of NaCl.

Microbial community composition

Both Gram positive and Gram negative bacteria were isolated from the biofilms that formed on the electrodes. The gram positive bacteria included *Staphylococcus sp*., *Bacillus sp*., *Enterococcus* sp., and *Micrococcus* sp., while the Gram negative organisms included *Escherichia coli, Shigella* sp., and *Salmonella* sp. The fungal isolates included *Saccharomyces* sp. Previous research has identified *Escherichia coli* (Chin-Tsan *et al.*, 2010), *Bacillus* sp.(Lovely, 2006), and *Saccharomyces* cerevisiae (Logan *et al.*, 2005) as being associated with microbial fuel cells. These organisms are typically associated with the formation of biofilms, and they may or may not require a mediator (Logan *et al.*, 2005). Some of the organisms that were isolated prior to the experiment were not found in the biofilm after the experiment. These included *Mucor* sp. and *Penicillium* sp. Due to competitive exclusion, bioelectricity production may be hindered by substrate absence (Chin-Tsan *et al.*, 2010).

Power generation

The 19th day yielded the highest average voltage of 1.10 V for carbon, while the first day produced the lowest average voltage of 0.21 V. The highest average voltage following the addition of salt was 1.16 V on the nineteenth day, and the lowest voltage was 0.25 V on the initial day. When it came to the addition of salt, the highest average voltage was 1.06 V on the 18th day and the lowest voltage was 0.91 V on the 18th day. For copper, the maximum average voltage was 1.05 V on the 18th day, and the lowest voltage was 0.68 V on the 1st day. For roughly ten days, the addition of salt stabilized the voltage generated, signifying the bacterial batch culture's stationary phase (Chin-Tsan *et al.*, 2010). When copper is exposed to salt ions, spurious voltage is produced. The maximum open and closed circuit voltages of 610 mV and 603 mV on the 18 days of the experimental period were recorded by an MFC from wastewater in a prior study (Venkata *et al.*, 2010). Additionally, this concurs with the findings of Shukla *et al.* (2004). Benetto (1990) provided an explanation for the sharp rise in voltage that occurred when salt ions were present.

Because the salt enrichment increases the conductivity of the solution and makes it more electrolytic, the voltage generated and the power densities obtained became more stable. Within seven days, the carbon microbial fuel cell showed improved activity; however, the quick decline suggests that adding salt is preferred. An essential component of power generation is the choice of electrodes and substrate. Because the bacterial activities and potential in mixed bacterial communities differ, it is observed that the voltage produced is decreasing (Logan *et al.*, 2005).

The adopted design

Since the H-type microbial fuel cell is the most suitable design for beginning experimental research, it was used in this work .[18] When NaCl is utilized as the electrolyte, charged particle mass transfer is enhanced, and solution conductivity is raised.[13]

Another constraint on the production of electricity is the availability of protons at the cathode. Because NaCl increased the conductivity of both the anolyte and the catholyte, it may have also improved the power output[16] when added to MFCs to increase the ionic strength. Even though potassium permanganate has a high electrode potential, it has been said to be one of the best catholytes. As a result, the decision was made to use it as a catalyst (Logan *et al.*, 2005). The NaCl-Agar PEM was the only readily available option for material locally, despite reports of its high internal resistance (Logan *et al.*, 2005).

Conclusion

Our environment can be safer and power can be produced with microbial fuel technology, providing a self-sufficient waste treatment solution. It's possible that the microbial fuel cell can be used to treat wastewater in addition to providing electricity. A number of physicochemical and biological factors affect how much electricity is generated in MFCs. The addition of NaCl to the electrolyte enhances charged particle mass transfer and raises solution conductivity. When up scaling, the addition of salt should be taken into account as it greatly improved

the performance of the microbial fuel cell. Since copper dissolves easily, it should only be used for power generation rather than the treatment of wastewater.

Acknowledgements

We would like to express our sincere gratitude to the Department of Environmental Health Science and Department of Microbiology, Federal University of Technology Owerri, for providing enabling environment and helping us to overcome challenges.

References

Adeleye SA, Okorondu SI. 2015. Bioelectricity from students' hostel waste water using microbial fuel cell. International Journal of biological and Chemical Sciences (IJBCS) **9**(2), 1038-1049.

Akaluka CK, Orji JC. Braide W, Egbadon EO, Adeleye SA. 2016. Abattoir wastewater treatment and energy recovery using a Ferricyanide-catholyte Microbial Fuel Cell. International Letters of Natural Sciences **55**, 68-76.

AOAC. 2000. Official Methods of Analysis. International 17th edition; Gaithersburg, MD,USA Association of Analytical communities.

APHA. 1998. Standard Methods of the Examination of Water and Wastewater. 20th Ed. Washington, DC: American Public Health Association.

Beishir L. 1991. Microbiology in Practice: A Self-Instructural Laboratory Course, Fifth Edition, Harper Collins; New York.

Bennetto HP. 1990. Electricity generation by Microorganisms. Biotechnology Education **1**(4), 163-168.

Braide W, Kanu IA, Oranusi US, Adeleye SA. 2016b. Production of bioethanol from agricultural waste. J. Fundam. Appl. Sci. **8**(2), 372-386.

Braide W, Nwachukwu J, Adeleye SA, Egbadon EO. 2016a. Effects of Gas Flaring on the Physicochemical and Microbiological Quality of Water Sources in Egbema, Imo State, Nigeria. International Letters of Natural Sciences **56,** 7-15.

Cheesbrough M. 2000. District Laboratory Practice in Tropical Countries Part 1, Cambridge Second Editions. Published by Press Syndicate of the University of Cambridge, Cambridge chp. 5, 247-258p.

Chin-Tsan W, Wei-Jung Chen B, Ruei-Yao H. 2010. Influence of growth curve phase on electricity performance of microbial fuel cell by *Escherichia coli*. International Journal of Hydrogen Energy **35**, 7217-7223.

Di Ilio G, Falcucci G. 2020. Multiscale methodology for microbial fuel cell performance analysis. International Journal of Hydrogen Energy.

Egbadon EO, Akujobi CO, Nweke CO, Braide W, Akaluka CK, Adeleye SA. 2016. Simultaneous generation of Bioelectricity and Treatment of Swine wastewater in a Microbial Fuel Cell. International Letters of Natural Sciences **54**, 100-107.

Gil GC, Chang IS, Kim BH, Kim M, Jang JY, Park HS. 2003. Operational parameters affecting the performance of a mediatorless microbial fuel cell. BiosensBioelectron 18, 327–334.

Güney T. 2019. Renewable energy, non-renewable energy and sustainable development. International Journal of Sustainable Development & World Ecology **26**(5), 389-397.

Hansen K, Mathiesen BV, Skov IR. 2019. Full energy system transition towards 100% renewable energy in Germany in 2050. Renewable and Sustainable Energy Reviews **102**, 1-13.

Jang JK, Pham TH, Chang IS, Kang KH, Moon H, Cho KS, Kim BH. 2004. Construction and operation of a novel mediator- and membrane-less microbial fuel cell. Process Biochemistry **39**, 1007–1012.

Logan BE, Regan JM. 2006. Microbial fuel cells-challenges and applications. Environmental Science and Technology **40,** 405-408.

Logan BE, Murano C, Scott K, Gray ND, Head IM. 2005. Electricity generation from cysteine in a microbial fuel cell. Water Research **39**, 942-52.

Lovely DR. 2006. Bug juice: harvesting electricity with microorganisms. Nature Review of Microbiology **4**, 497-508.

Lovely DR. 2006. Microbial fuel cells: novel microbial physiologies and engineering approaches. Current Opinion in Biotechnology **17,** 327–32.

Liu H, Ramnarayanan R, Logan BE. 2004. Production of electricity during wastewater treatment using a single chamber microbial fuel cell. Environ. Sci. Technol. **38** (7), 2281-2285

Min B, Cheng S, Logan BE. 2005. Electricity generation using membrane and salt bridge microbial fuel cells. Water research **39**(9), 1675-86.

Mohamed SN, Hiraman PA, Muthukumar K, Jayabalan T. 2020. Bioelectricity production from kitchen wastewater using microbial fuel cell with photosynthetic algal cathode. Bioresource Technology **295**, 122226.

Palanisamy G, Jung HY, Sadhasivam T, Kurkuri MD, Kim SC, Roh SH. 2019. A comprehensive review on microbial fuel cell technologies: Processes, utilization, and advanced developments in electrodes and membranes. Journal of cleaner production **221**, 598-621.

Shafiei S, Salim RA. 2014. Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. Energy Policy **66**, 547-556.

Shah S, Venkatramanan V, Prasad R. 2019. Microbial fuel cell: Sustainable green technology for bioelectricity generation and wastewater treatment. In Sustainable Green Technologies for Environmental Management (pp. 199-218). Springer, Singapore.

Shukla AK, Suresh P, Berchmans S, Rahjendran A. 2004. Biological fuel cells and their applications. Current Science **87**, 455-468.

Venkata, Mohan S, Mohanakrishna G, Sarma PN. 2010. Composite vegetable waste as renewable resource for bioelectricity generation through non-catalyzed open-air cathode microbial fuel cell. Bioresource Technology **101,** 970-976.

Zhang Y, Liu M, Zhou M, Yang H, Liang L, Gu T. 2019. Microbial fuel cell hybrid systems for wastewater treatment and bioenergy production: synergistic effects, mechanisms and challenges. Renewable and Sustainable Energy Reviews **103**, 13-29.