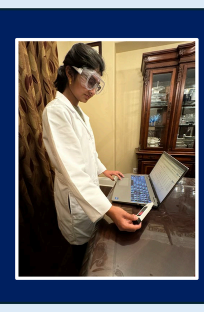
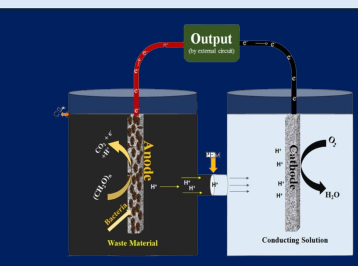




OPTIMIZING MICROBIOLOGICALLY CONTAMINATED WASTEWATER TREATMENT USING MICROBIAL FUEL CELLS

All figures, tables, graphs, and photographs by Jocelyn Mathew unless otherwise stated.

DCMFC diagram courtesy of Int. J. Energy Res. (Wiley)

ABSTRACT

In my experiment, I aimed to enhance the efficiency of a Double Chambered Microbial Fuel Cell (DCMFC) for water purification and electrical output by testing four different anode materials: aluminum, zinc, iron, and nickel. A DCMFC utilizes a Proton Exchange Membrane (PEM) to separate its anode and cathode chambers, employing electrochemically active bacteria to oxidize substrates, thus generating electricity. By measuring the voltage and Total Dissolved Solids (TDS) over five days, I hypothesized that aluminum would be the superior anode due to its high conductivity and corrosion resistance. Surprisingly, zinc outperformed aluminum in increasing voltage and TDS after 120 hours, despite aluminum's initial lead. This unexpected result suggests that aluminum's effectiveness diminishes over time, possibly due to chemical changes under acidic conditions. This study not only underscores the potential for microbial fuel cells in sustainable wastewater treatment but also suggests zinc as a promising anode material for optimizing DCMFC performance.

INTRODUCTION

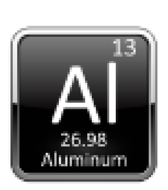
OBJECTIVES

- I aim to optimize the efficiency of DCMFCs for **wastewater purification and electricity generation** by assessing the ability of four anodes: aluminum (Al), zinc (Zn), iron (Fe), and nickel (Ni)
- Based on MFC wastewater treatment studies, "*In an MFC, the anode is a crucial component of the setup...functionally...Poor performance of anode electrode in MFC is still a major setback for its practical applications. Successful anode electrode modification is expected to enhance the MFC...*" [1]
- The goal of my research is to find a solution for water shortage as well as electricity generation using the principle of DCMFCs

KEYWORDS

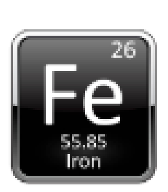
- **DCMFC (Double-Chamber Microbial Fuel Cell)**: a bio-electrochemical system where bacteria in one chamber break down organic matter and generate electricity to a second chamber for extraction
- **PEM (Proton Exchange Membrane)**: a barrier that allows protons (H+) to pass through from one chamber to another while preventing the movement of electrons and bacteria
- **Anode**: Where microbial oxidation of organic matter occurs
- **Cathode**: At the cathode, oxygen combines with protons and electrons to form water

VISUAL COMPARATIVE ANALYSIS OF ANODES

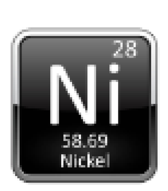


High electrical conductivity + high bacterial adherence

Good electrical conductivity + Good bacterial adherence



Low electrical conductivity + high bacterial adherence



Good electrical conductivity + Good bacterial adherence

Element images courtesy of iStock

HYPOTHESIS

If aluminum is the anode used in a Double Chamber Microbial Fuel Cell (DCMFC), then, it is expected to yield the highest increase in the concentration of the cathodic substrate because it has the highest electrical conductivity, bacterial adherence, and corrosion resistance.

Supporting evidence

According to Flaviana et al., *"The aluminum...was chosen due to its high electrical conductivity, low density (2.68 g cm−3), good corrosion resistance, and very good manufacturability..."* [2]

VARIABLES

Independent Variable: Anode materials (100 mm x 20 mm) - Aluminum, Zinc, Iron, and Nickel

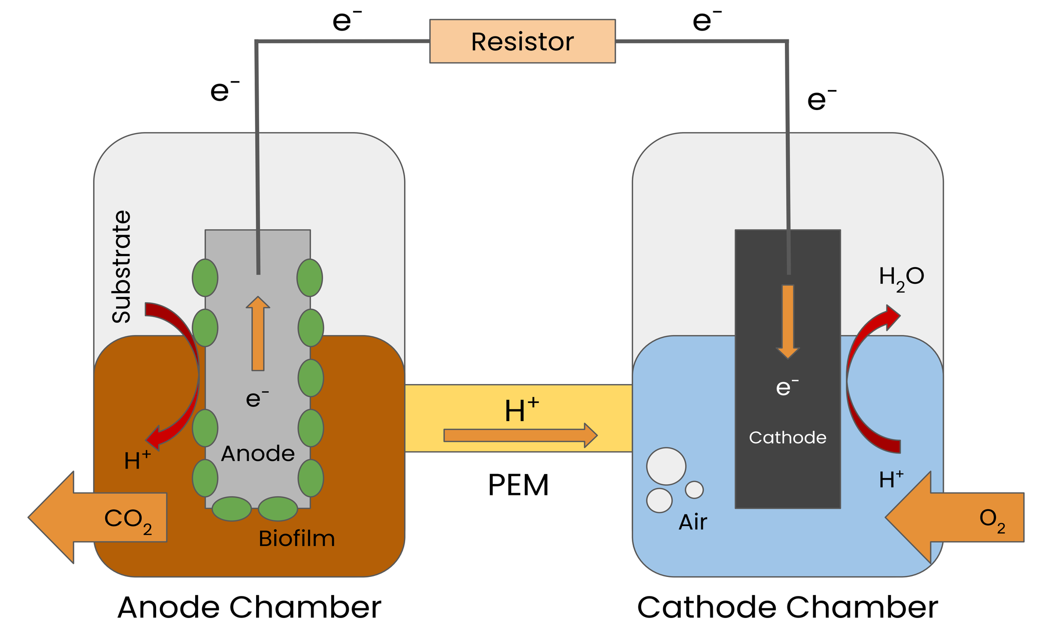
Dependent Variable: Final Total Dissolved Solids (TDS) of cathodic substrate and voltage output

METHODS

1. ***Build*** two Double Chamber Microbial Fuel Cells (DCMFC) using four 1.4-liter containers
2. ***Create*** two Proton Exchange Membranes (PEM) with 1 cup of distilled water, 6 tsp of potassium chloride, 2 tsp of agar, and 2 PVC pipes
3. ***Configure*** the two anodes and cathodes with 1 pair of alligator clips each to a multimeter
4. ***Retrieve*** 2 liters of wastewater from Santa Ana River, Yorba Linda, to put in the two separate 1.4-liter airtight containers and 2 liters of distilled water to put in the last two airtight containers
5. ***Introduce*** the aluminum anode and carbon rod cathode to the DCMFC's respective chambers by clipping each to an alligator clip that connects to the multimeter
6. ***Inoculate*** 1 liter of bacteria-rich wastewater solution into the DCMFC's anodic chamber with the aluminum anode
7. ***Measure*** the voltage output through the multimeter every 12 hours for 5 consecutive days
8. ***Analyze*** the final TDS of the cathodic chamber substrate and average voltage after 120 hours of inoculation in the DCMFC
9. ***Sanitize*** the supplies and area with Isopropanol disinfectant before rearranging DCMFC with the zinc, iron, and nickel anodes
10. ***Repeat*** this process with the rest of the three anodes, each 3 times in 5-day trials

The Total Dissolved Solids (TDS) was measured with a TDS Meter and the electrical output was measured with a multimeter

PROCESS DIAGRAM



MATERIALS

- **2 Double Chamber Microbial Fuel Cells (DCMFC)**
  - 1.4-liter airtight container with lid, 4
  - 4 Anodes (100 mm x 20 mm) - aluminum, zinc, iron, and nickel, 3 of each
  - Carbon cathode rod (100 mm x 7mm), 12
  - 4-inch-long PVC pipe, 2
  - 12 liters of wastewater from Santa Ana River, Yorba Linda
  - 12 liters of distilled water
  - TDS Meter Digital Water Tester, 1
  - Copper alligator clips with wire, 4
  - Multimeter, 1
- **2 Proton Exchange Membranes (PEM)**
  - 1 cup of distilled water
  - 6 tsp of Potassium Chloride
  - 2 tsp of Agar

RESULTS & DATA

DISSOLVED SUBSTANCE (ppm)

Table 1. Dissolved Substance with Anodes Variations (Trial 1, 2, 3 avg. in ppm)

Hour	Zinc	Aluminum	Iron	Nickel
0	2	2	2	2
12	181	183	178	219
24	331	691	284	434
36	698	912	391	548
48	903	986	499	704
60	1051	1047	719	935
72	1399	1276	863	1180
84	1462	1309	909	1282
96	1581	1421	945	1326
108	1694	1568	1003	1384
120	1792	1607	1070	1398

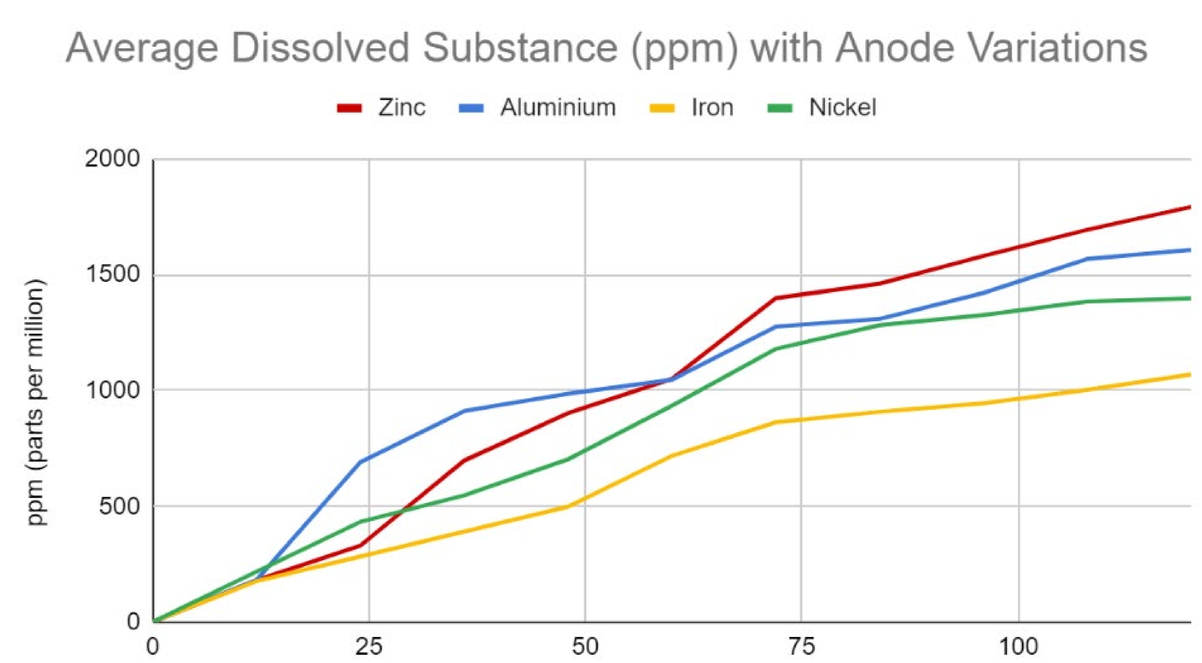


Fig. 1

VOLTAGE (mV)

Table 2. Voltage Measurement with Anodes Variations (Trial 1, 2, 3 avg. in mV)

Hour	Zinc	Aluminum	Iron	Nickel
0	1225	939	770	527
12	1182	1009	738	562
24	1195	1001	807	625
36	1207	1009	752	567
48	1202	1001	811	546
60	1200	1006	780	531
72	1201	1009	798	471
84	1198	1003	777	537
96	1212	1002	754	483
108	1199	1011	789	584
120	1222	1014	751	574

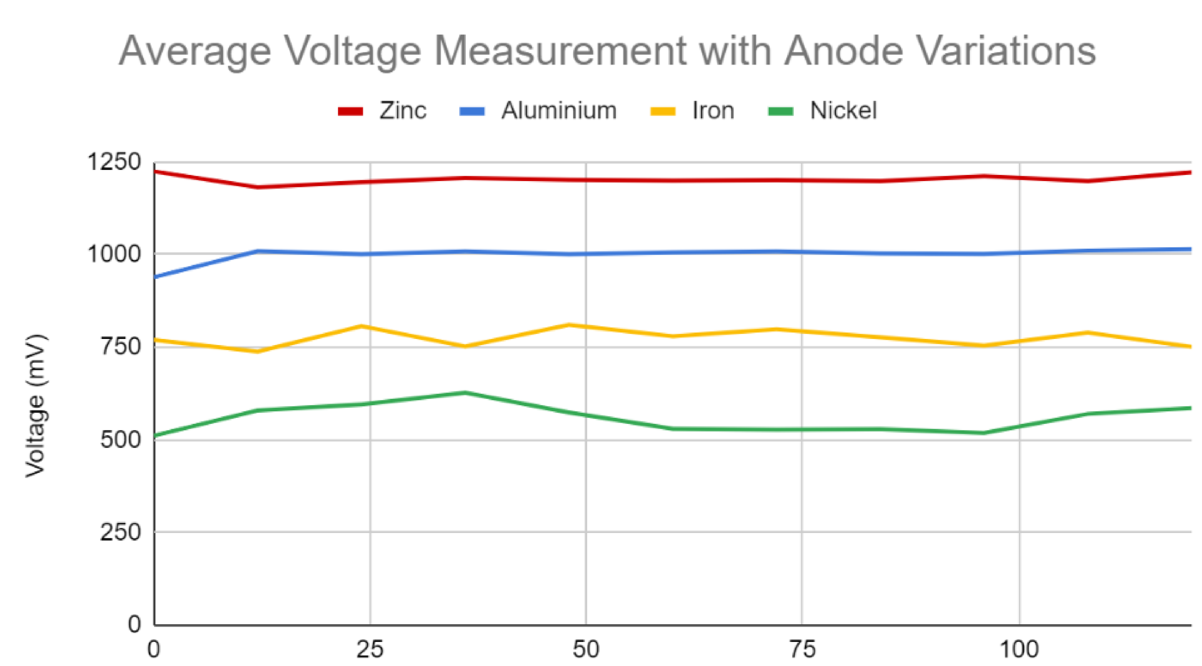


Fig. 2

DATA ANALYSIS

Table 1: Total Dissolved Solids

- Aluminum exhibited a rapid initial increase, reaching 986 ppm by 48 hours, before leveling off to end at 1607 ppm, showing that it may have a faster initial reactivity compared to the other metals.

Figure 1: Total Dissolved Solids

- Illustrated that zinc eventually showing the highest overall increase. Nickel demonstrated the least amount of dissolved substances, indicating the lowest reactivity among the four metals tested over the experimental duration.

Table 2: Average Voltage Produced

- Zinc anodes maintained high and stable voltage levels throughout the 120-hour period, starting at 1225 mV and ending slightly lower at 1222 mV, indicating consistent electrical output.

Figure 2: Average Voltage Produced

- Zinc maintained a high and relatively stable voltage around 1200 mV. Aluminum showed a small decline but remained consistent, averaging just above 1000 mV. Iron's voltage was lower and demonstrated slight variability, stabilizing around 750 mV. Nickel had the lowest voltage, starting around 500 mV and exhibiting a slight increase over time.

DISCUSSION

- In my experiment, the zinc anode provided the highest concentration (ppm) of the cathodic substrate and voltage (mV)
- Final concentration and average voltage produced:
  - **Zinc**: 1792 total ppm, 1204 average mV
  - **Aluminum**: 1607 total ppm, 1000 average mV
  - **Iron**: 1070 total ppm, 775 average mV
  - **Nickel**: 1398 total ppm, 564 average mV
- Graphs show an exponential growth in ppm and stationary graph in voltage
  - Aluminum initially had a higher TDS for the first sixty hours but was eventually surpassed by zinc
- My project did not turn out as I had expected

CONCLUSION/FUTURE WORK

- My hypothesis is partially confirmed. While my hypothesis involved the use of aluminum because of its high bacterial adherence and electrical conductivity, the results showed that zinc performed better in terms of voltage and concentration
- Phenomenon may have occurred due to the decay or chemical alteration of the aluminum anode after being immersed in wastewater (acidic) for over fifty hours
- "The aluminum oxide film thickness is strongly dependent upon the solution pH." [3]
- While aluminum is a highly reactive metal, it is typically protected by a passive layer of aluminum oxide. This layer can be dissolved in acids with a pH below six, which may have been the case with the acidic wastewater

Future Work

If I were to further study this topic, I would research the corrodibility of aluminum anodes. This could lead to innovations of accessible anodes with stronger passive layers, possibly leading to an increase in TDS transfer and voltage. [4]

KEY REFERENCES

1. *Progress and Recent Trends in Microbial Fuel Cells*. (n.d.). ScienceDirect. Retrieved February 27, 2024, from https://www.sciencedirect.com/book/9780444640178/progress-and-recent-trends-in-microbial-fuel-cells#:~:text=The%20poor%20performance%20of%20anodes
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