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The Effect of Immersion Depth and the Distance Between Copper and Zinc Electrodes on the Potential Difference Generated in an Experiment Using a Saltwater Electrolyte Battery

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Abstract

The demand for energy continues to rise alongside today's technological advancements, particularly the need for electricity generated from environmentally friendly sources. Saltwater can serve as an alternative energy source—a medium used to generate electricity that is relatively inexpensive, readily available, and non-hazardous. Saltwater commonly encountered in daily life is NaCl, or what is commonly known as table salt. By constructing a simple voltaic cell, an experiment was conducted to determine the extent to which variations in immersion depth and the distance between the two electrodes in the saltwater electrolyte affect the reaction with the electrodes in generating an electric potential difference. This experiment used two different electrodes: copper (Cu) as the cathode and zinc (Zn) as the anode. The saltwater electrolyte used also varied in salt concentration. It is hoped that the results of this study can be utilized by the public to help provide an alternative source of electrical energy and reduce monthly electricity bills.

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Keywords: Saltwater, Alternative Energy, Voltaic Cell, Electric Potential Difference, Electrode

1. INTRODUCTION

In light of current global issues, namely climate change, the effects of global warming, and the future of fossil fuels *(non-renewable energy)* in relation to the sustainability of human life on Earth.

This is in accordance with Indonesian Law No. 16 of 2016 on the ratification of the Paris Agreement to the *United Nations Framework Convention on Climate Change*. This is also in line with the results of the International Energy Agency (IEA) Convention on *the Roadmap for the Global Energy Sector*, as outlined in *"Net Zero by 2050*"—specifically, the roadmap for reducing global carbon emissions by 2050. It is also related to Presidential Regulation No. 5 of 2006 on National Energy Policy, which addresses the development and utilization of new and renewable energy sources.

Therefore, it is important to study renewable energy sources. Moreover, efforts to find green energy sources that can replace conventional energy sources—in order to save the Earth from the negative impacts of global warming and climate change—must continue to be encouraged, and their development must be strengthened.

Saltwater can serve as an alternative energy source for generating electricity. Furthermore, saltwater is still rarely utilized for this purpose.

In the Philippines, 600 households from several coastal tribes have already been using saltwater as a source of electrical energy (Usman, Hasbi, & Sudia, 2017). This was one of the reasons the research team was interested in utilizing saltwater as a medium in their study, given its easy availability, low cost, and safety. However, numerous studies have already been conducted on the use of saltwater as a medium. The study conducted by Muh. Ali Usman et al. also utilized

saltwater with the objective of determining the effect of the cross-sectional area of copper and zinc on the power generated by saltwater.

A study conducted by Munawar Alfansury Siregar et al. also used a saltwater medium, testing various distances between the cathode and anode. The results of the hydrogen gas pressure tests showed differences in pressure for each electrode: the closer the distance between the electrodes, the higher the resulting gas pressure.

A similar study was also conducted by Siti Zaenab et al., focusing on the analysis of an electric power generator using saltwater as an electrolyte solution, through experiments involving three different electrodes: Fe (iron), Al (aluminum), and Zn (zinc). The experiments aimed to determine the effects of electrode type and salt concentration in the water solution on the generation of electric current and voltage. (Haq, Kurniawan, & Ramdhani, 2018).

The difference between this study and previous studies that also used a saltwater medium lies in the variations in the treatments applied and the results observed. The treatments applied involved altering the distance and immersion depth of the two electrodes, as well as varying the salt concentration, and the results observed were the resulting potential differences; thus, this study serves as a complement to previous research.

2. METHODS

2.1. Data Description

a. Definition of Saltwater

Salt is a strategic commodity; in addition to being a consumer necessity, it also serves as a raw material for the chemical industry, such as caustic soda, sodium sulfate, and others. Without salt, human life would be impossible, as salt regulates the flow of nutrients in the body, as well as the contraction of the heart and other bodily tissues.

b. Electrical Potential Difference

Electrical potential difference is the difference in the number of electrons in an electric current. On one side of the current source, electrons are concentrated, while on the other side, there are fewer electrons. This occurs due to a magnetic force acting on the material. In other words, the source becomes electrically charged. If the circuit is touched by a material that conducts electricity, the flow of electrons will pass through whatever is touching it. If a person touches the object, an electric current will flow through their body. The magnitude of this electric current depends on the magnitude of the difference in the number of electrons accumulated in a material (Wikipedia & Sumartono). Two objects with a potential difference can cause an electric current to flow, provided that the two objects are connected by a conductor. The magnitude of the potential difference is expressed in Ohm's Law as V = IR Ω; potential difference is directly proportional to current and resistance. The instrument used to measure potential difference (electrical voltage) is a voltmeter.

c. Battery

A battery, also known as a voltaic cell, is an electrochemical cell in which highly efficient, reversible electrochemical processes take place. A reversible electrochemical process means that within the battery, chemical energy can be converted into electrical energy (discharge), and conversely, electrical energy can be converted back into chemical energy. Recharging is achieved by regenerating the used electrodes, specifically by passing an electric current in the opposite direction (polarity) within the cell. (Mochamad Idris, 1991, Accumulator: Use and Maintenance).

This voltaic cell uses the reaction between zinc (Zn) and Cu^{2+}ions to generate electricity. The standard reduction potentials of each electrode can be determined by comparing them to a standard electrode, namely the standard hydrogen electrode (SHE). The standard conditions referred to are when the pressure $_{of\ H_2}$ gas is 1 atm, the concentration ^{of} $^{H^+}$ ions in the solution is 1 mol, and the measurement is taken at a temperature of 25°C. The SHE has a standard reduction potential of zero (E°red SHE = 0).

SHE can be used to determine the standard reduction potential (E°red) of other electrodes. Thus, we can compile a list containing the E°red values of the electrodes in order from the smallest (most negative) to the largest (most positive). This sequence of electrodes is known as the Voltaic Series (metal reactivity series).

Li – K – Ba – Sr – Ca – Na – Mg – Al – Mn – Zn – Cr – Fe – Cd – Co – Ni – Sn – Pb – H^+ – Cu – Ag – Hg – Pt – Au

Metals located to the left of H^+have negative E°red values. The further to the left, the smaller (more negative) the E°red value. Metals located to the right of H^+have positive

E°red values. The further to the right, the larger (more positive) the E°red value.

By convention, the cell potential (E°cell) is the combination of the cathode's E°red and the anode's E°red, as shown by the following equation:

$$E°cell = E° \text{ cathode} – E° \text{ anode}$$

The standard reduction potentials (E°red) for each electrode are shown in Table 1.

Table 1. Electrode Potentials (Utami, B, et al., 2009)

Electrode	Reaction	E° (V)
Li^+/Li	$Li^+ + e^- \rightarrow Li$	-3.045
K^+/K	$K^+ + e^- \rightarrow K$	-2.925
Ca^{2+}/Ca	$Ca^{2+} + 2e^- \rightarrow Ca$	-2.870
Na^+/Na	$Na^+ + e^- \rightarrow Na$	-2.714
Mg^{2+}/Mg	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.370
Al^{3+}/Al	$Al^{3+} + 3e^- \rightarrow Al$	-1.660
Zn^{2+}/Zn	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
Cr^{3+}/Cr	$Cr^{3+} + 3e^- \rightarrow Cr$	-0.740
Fe^{2+}/Fe	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.440
Ni^{2+}/Ni	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
Sn^{2+}/Sn	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.140
Pb^{2+}/Pb	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
H^+/H_2	$2H^+ + 2e^- \rightarrow H_2$	0.000
Cu^{2+}/Cu	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.337
Ag^+/Ag	$Ag^+ + e^- \rightarrow Ag$	+0.799
Pt^{2+}/Pt	$Pt^{2+} + 2e^- \rightarrow Pt$	+1.200
Au^{3+}/Au	$Au^{3+} + 3e^- \rightarrow Au$	+1.500

2.2. Study Period

This research was conducted over a period of 1 (one) semester, from June 2023 to October 2023.

2.3. Research Location

The design and construction of the equipment, as well as data collection, were carried out at the Electrical Engineering Laboratory and the Electronics Laboratory at the Jakarta Maritime Academy (STIP).

2.4. Research Method

The research approach used in this study was the experimental research method, which is used to determine the effects of a given treatment on a subject under study. Experimental research is conducted to determine the effects of a treatment on the research subject.

2.5. Data Collection Techniques

Data collection involved observing the experiments conducted. Consequently, the data obtained and used in this study are primary data. Data were collected from observations of the applied treatments by recording the potential differences generated using solutions with varying salt concentrations, varying immersion depths of the copper (Cu) and zinc (Zn) electrode rods, and varying distances between the Cu and Zn electrode rods.

2.6. Data Analysis Techniques

The data analysis techniques used in this study were qualitative, involving the interpretation of observational data, and quantitative, using statistical tests to determine whether depth and electrode distance influenced the generated potential difference.

3. RESULTS AND DISCUSSION

3.1. Research/Experimental Stages

a. Constructing Experimental Equipment/Devices

1) Design an experimental setup (experiment kit) consisting of a 1.2-liter plastic container filled with a saltwater solution.

A pair of electrode clamps is then placed on top of the container; the distance (D) between the two electrodes can be adjusted, and the position of the electrode rods can be raised or lowered to vary the immersion depth (h).

2) Prepare saltwater solutions with varying salt concentrations: 1%, 3%, 5%, 7%, and 10%.

3) Place the copper (Cu) and zinc (Zn) electrodes in the clamps, adjusting the distance between them to the following values: 1 cm, 3 cm, 5 cm, 7 cm, and 9 cm.

5) Adjust the immersion depth of both electrodes in the electrolyte to the following variations: 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 6 cm, 7 cm, 8 cm, 9 cm, 10 cm, and 11 cm.

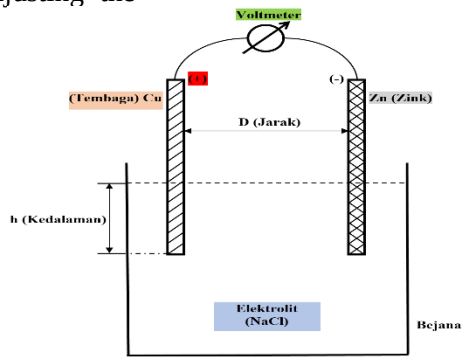


Figure 1. Experimental Voltaic Cell Design

b. Experimental Observation Results

1) Observe and measure the potential difference on a digital voltmeter for each variation in salt concentration, electrode spacing, and immersion depth.

2) For each reading, wait at least 5 minutes before recording the measurement data.

3) Record the observed potential difference readings from the voltmeter on the provided data sheet.

3.2. Observation Data

a. Observation Data from the Experiment on 1% Saltwater Sample

Table 2. Potential Differences from the Saltwater Battery Experiment Using Copper and Zinc Electrodes (Volts)

h (cm)	D=1cm	D=3cm	D=5cm	D=7cm	D=9cm
1	0.882	0.873	0.877	0.868	0.866
2	0.888	0.882	0.879	0.874	0.870
3	0.893	0.886	0.882	0.879	0.875
4	0.897	0.890	0.888	0.883	0.879
5	0.901	0.894	0.891	0.888	0.883
6	0.905	0.897	0.894	0.891	0.887
7	0.908	0.901	0.897	0.894	0.891
8	0.911	0.905	0.901	0.897	0.894
9	0.914	0.908	0.905	0.901	0.897
10	0.917	0.911	0.908	0.905	0.901
11	0.920	0.914	0.911	0.908	0.905

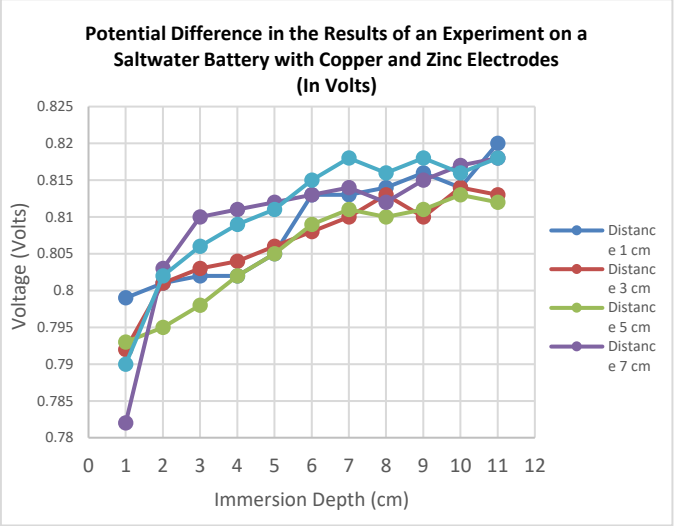


Figure 3. Graph of Potential Differences from the Saltwater Battery Experiment with a 1% Salt Concentration

b. Observation Data from the 3% Salt Solution Experiment

Table 3. Potential Difference from the Saltwater Battery Experiment Using Copper and Zinc Electrodes (Volts)

h (cm)	D=1cm	D=3cm	D=5cm	D=7cm	D=9cm
1	0.912	0.903	0.897	0.893	0.888
2	0.920	0.912	0.905	0.900	0.895
3	0.926	0.918	0.912	0.906	0.901
4	0.931	0.923	0.917	0.912	0.907
5	0.935	0.928	0.922	0.917	0.912
6	0.939	0.932	0.926	0.921	0.917
7	0.943	0.936	0.930	0.925	0.921
8	0.946	0.939	0.934	0.929	0.925
9	0.949	0.943	0.937	0.933	0.929
10	0.952	0.946	0.940	0.936	0.932
11	0.955	0.949	0.943	0.939	0.935

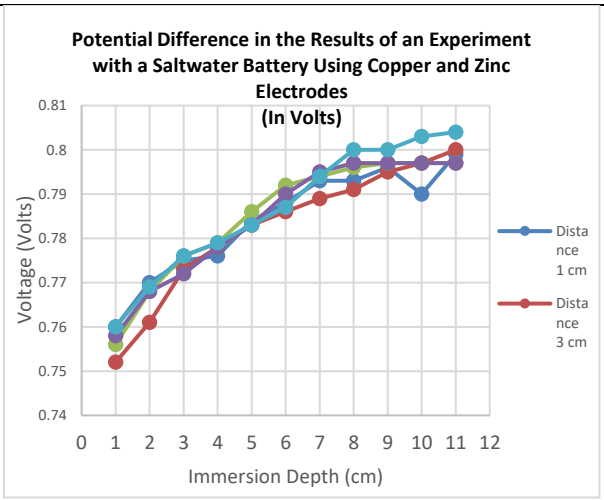


Figure 4. Graph of Potential Difference from the Saltwater Battery Experiment with a 3% Salt Concentration

c. Observation Data from the Experiment on a 5% Salt Solution Sample

Table 4. Potential Difference from the Saltwater Battery Experiment Using Copper and Zinc Electrodes (Volts)

h (cm)	D=1cm	D=3cm	D=5cm	D=7cm	D=9cm
1	0.932	0.924	0.917	0.912	0.906
2	0.940	0.932	0.925	0.920	0.914
3	0.946	0.938	0.932	0.926	0.921
4	0.951	0.943	0.937	0.932	0.927
5	0.955	0.948	0.942	0.937	0.932
6	0.959	0.952	0.946	0.941	0.937
7	0.963	0.956	0.950	0.945	0.941
8	0.966	0.959	0.954	0.949	0.945
9	0.969	0.963	0.957	0.953	0.949
10	0.972	0.966	0.960	0.956	0.952
11	0.975	0.969	0.963	0.959	0.955

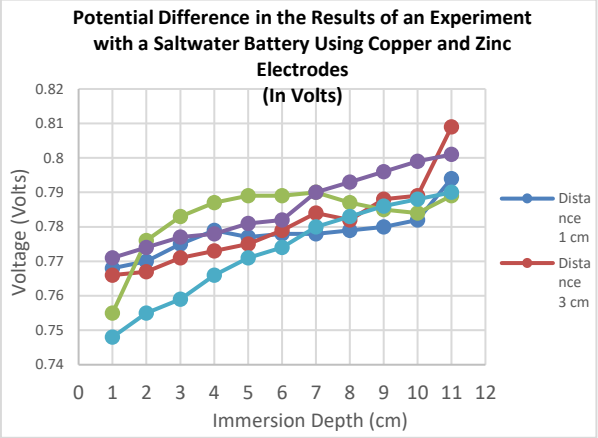


Figure 5. Graph of Potential Difference from the Saltwater Battery Experiment with a 5% Salt Concentration

d. Observation Data from the Experiment on a 7% Salt Solution Sample

Table 5. Potential Difference from the Saltwater Battery Experiment Using Copper and Zinc Electrodes (Volts)

h (cm)	D=1cm	D=3cm	D=5cm	D=7cm	D=9cm
1	0.946	0.938	0.931	0.926	0.920
2	0.954	0.946	0.939	0.934	0.928
3	0.960	0.952	0.946	0.940	0.935
4	0.965	0.957	0.951	0.946	0.941
5	0.969	0.962	0.956	0.951	0.946
6	0.973	0.966	0.960	0.955	0.951
7	0.977	0.970	0.964	0.959	0.955
8	0.980	0.973	0.968	0.963	0.959
9	0.983	0.977	0.971	0.967	0.963
10	0.986	0.980	0.974	0.970	0.966
11	0.989	0.983	0.977	0.973	0.969

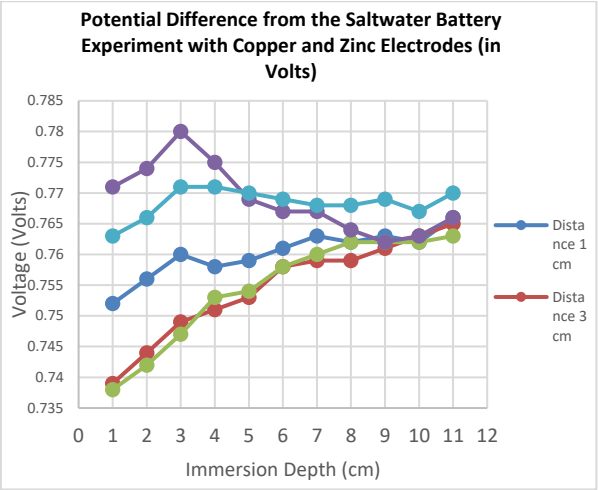


Figure 6. Graph of Potential Difference from the Saltwater Battery Experiment with a 7% Salt Concentration

e. Observation Data from the Experiment on a 10% Salt Solution Sample

Table 6. Potential Difference from the Saltwater Battery Experiment with Copper and Zinc Electrodes (Volts)

h (cm)	D=1cm	D=3cm	D=5cm	D=7cm	D=9cm
1	0.963	0.955	0.948	0.943	0.937
2	0.971	0.963	0.956	0.951	0.945
3	0.977	0.969	0.963	0.957	0.952
4	0.982	0.974	0.968	0.963	0.958
5	0.986	0.979	0.973	0.968	0.963
6	0.990	0.983	0.977	0.972	0.968
7	0.994	0.987	0.981	0.976	0.972
8	0.997	0.990	0.985	0.980	0.976
9	1.000	0.994	0.988	0.984	0.980
10	1.003	0.997	0.991	0.987	0.983
11	1.006	1.000	0.994	0.990	0.986

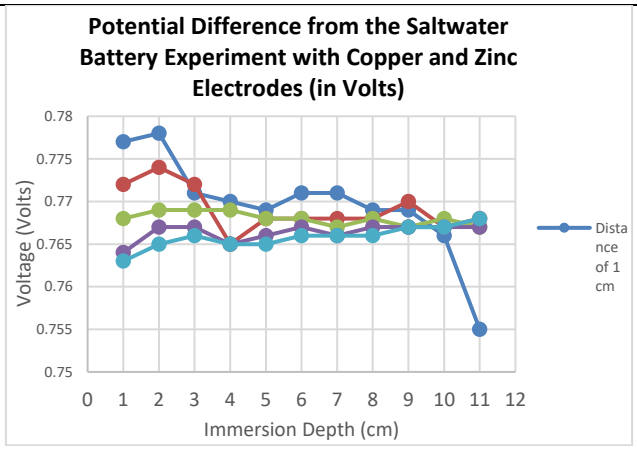


Figure 7. Graph of Potential Difference from the Saltwater Battery Experiment with a 10% Salt Concentration

3.3. Statistical Analysis

To obtain more conclusive results, statistical tests were conducted as follows:

Disclaimer 1: The immersion depth of the electrode rods was treated as a factor, and the data were grouped based on distance. The analysis did not examine whether distance itself was a significant variable.

The purpose of this analysis is to determine whether there is an effect of the 11 electrode immersion depth treatments on the potential difference generated, with the distance between the two electrodes serving as the grouping factor.

Disclaimer 2: The distance between the electrodes is the independent variable, and the data are grouped based on immersion depth. This analysis does not examine whether immersion depth influences the potential difference as a variable.

The purpose of this analysis is to determine whether there is an effect of the 5 treatments of the distance between the copper and zinc electrodes on the potential difference generated, with electrode immersion depth as the grouping factor.

3.4. Analysis Results

1) Hypothesis

   $H_0: \tau_1 = \tau_2 = \cdots = \tau_{11} = 0$

2) Immersion depth does not affect the potential difference generated

   $H_1: Minimal\ terdapat\ salah\ satu\ \tau_i = 0$

   (there is an immersion depth that affects the generated potential difference)

3) Significance Level

   α = 5% = 0.05

4) Test Statistic

   ANOVA Test for a Randomized Block Design

5) Test Criteria

   Reject H0 if the $_{calculated}$F-value is greater than $_{the\ table}$F$_{-value}$; accept H0 otherwise.

6) Test Results

K	35.93661389
JKP	0.002883709
JKK	0.000219564
JKT	0.003470109
JKG	0.000366836

Decision	
Treatment	H0 Rejected
Group	H0 Rejected

Source of Variation	Db	JK	KT	F. Hits	F. Table
Treatment (Depth)	10	0.002884	0.000288371	31.44409	2.077248
Block (Electrode Spacing)	4	0.00022	5.48909E-05	5.985329	2.605975
Error	40	0.000367	9.17091E-06		
Total	54	0.00347			

From the calculations, the $_{calculated}$ F-value $_{for}$the treatment was 31.44009 and $_{the\ calculated}$F$_{-value\ for}$the group was 5.985329.

Meanwhile, from the F-table, the F_{table}value for the treatment—with α = 0.05, 1 degree of freedom (treatment) = 10, and 40 degrees of freedom for *error* = 40—is 2.077248. For the F_{table}value for groups, with α = 0.05, degrees of freedom for group = 4, and degrees of freedom for *error* = 40, the F_{table}value is 2.605975.

Conclusion:
For both the treatment (immersion depth) and the group (electrode distance), all reject H_0 / all are significant. This means that at a salt concentration of 1%, with a 5% significance level, it can be concluded that there is at least one electrode immersion depth that affects the generated potential difference and at least one group of electrode distances that affects the generated potential difference.

4. CONCLUSION

Based on the results of the observations and analysis, the following conclusions can be drawn:

1) The results of the observations in the tables and graphs indicate that the treatments applied to the copper (Cu) and zinc (Zn) electrode rods had an effect.
2) The results of the ANOVA statistical analysis indicate that H0 is rejected and H1 is accepted; there is an effect of electrode depth and distance on the generated potential difference.

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