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Study of Voltage and Electric Current Generated from Cu-Zn Electrodes in a Medium of Sawdust and Coal Stockpile Wastewater

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Abstract

Industrialization has positive effects on the economy, but on the other hand, it also adversely impacts the environment and energy needs. This phenomenon needs to be solved in an integrated way, including using wastewater from coal stocks and sawdust as electrolyte media to generate electrical energy. This study aims to analyze the voltage and electric current generated by electrode pairs consisting of copper (Cu) and zinc (Zn) immersed in different sawdust media denoted as M1 (2 grams), M2 (4 grams), M3 (6 grams), and M4 (8 grams), dissolved in 100 milliliters of coal stockpile wastewater. Additionally, the study explores the effects of varying the distance between the Cu-Zn electrodes at 1, 2, and 3 cm. The results showed that the highest voltage generated from the combination of coal stockpile wastewater and sawdust was highest in M3 (6 grams of sawdust + 100 ml of coal stockpile wastewater at a distance of 1 cm at 0.736 volts. The highest electrical current generated by the Cu-Zn electrode in the M3 media combination was 0.221 mA. It is due to coal stockpile wastewater in M3 sawdust powder, which contains ions that enhance electron conduction compared to M4.

Introduction

Nowadays, industrialization has been growing. This development can be attributed to science and technological advances. This industrial progress has ambivalent effects; on the one hand, it positively impacts economic growth; on the other hand, it harms the form of waste by-products. The wastes were produced by mining activity, including temporary storage or stockpiles [1] and the wood processing industry. The produced waste is in the form of sawdust. As a fossil-based energy resource, coal is used for 36% of the world's energy needs. Achieving the coal needs, including soil, air, and water, impacts the environment. Coal stockpile wastewater contains a lot of ions, both positive ions/cations and negative ions/anions [2], which disrupt aquatic ecosystems and harm people when they enter the marine environment.

The research has been carried out to minimize the stockpile wastewater effect, including biological, physical, chemical, and even combined methods. One of the methods was electrolysis [3, 4]. Other ways to minimize the adverse effects were conducted chemically and physically but inexpensively, utilizing stockpile wastewater as electrolyte media by which the electrode was soaked. Setiawan et al. found that stockpile wastewater contains dissolved ions, one of them being heavy metals. Heavy metals can harm life when they get into the environment. The community has long used efforts to minimize sawdust waste as biomass energy in the form of briquettes [5], waste adsorbing material [6, 7], planting media [8], and battery media [9].

The metal with a small standard reduction potential will undergo oxidation/anode (--pole), while the other metal will experience reduction/cathode (+-pole). The advantage of this method is to produce electrical energy that is renewable, cheap, and environmentally friendly. These metals include Cu and Zn, which can be used as electrodes. Schmidt-Rohr suggested that Cu and Zn electrodes produce an electric current when inserted into an electrolyte medium containing positive ions (cations) and negative ions (anions). Other researchers who used coated and uncoated Cu and Zn electrodes with Ag metal in seawater media showed that these electrodes could illuminate a 12-volt 3-watt LED lamp [10]. Other researchers used Zn-Cu and Al-Cu electrode pairs in seawater media, indicating that the Zn and Cu electrode pairs produced the highest voltage and electric current, 839 mV and 1.75 mA, respectively [11]. Golberg et al., using Zn-Cu electrodes in potato fruit media, found that the electricity produced was cheaper than batteries in general. The researchers used these two electrodes because the two materials are easy to obtain, and the cost is relatively inexpensive. The electrodes used are Zn metal as the anode electrode and Cu metal as the cathode electrode. Setiawan et al. used Cu-Zn electrodes in various fruit extract waste media consisting of pineapple, tomato, orange, and banana, showing that tomatoes produced the highest voltage and electric current, which were 0.99 V and 1.41 mA, respectively [12].

The endeavor to generate electricity from eco-friendly sources using agricultural waste as an electrolyte medium indirectly aids in mitigating environmental pollution. Pulungan et al. studied eco-friendly electricity generation by recycling discarded batteries. The electrolyte within the used batteries was replaced with a paste made from banana peels and supplemented with salt electrolyte. [13]. Salafa et al. team researched bio-batteries by utilizing an electrolyte medium derived from squeezed orange juice, which was added to the wood powder. This medium's measured voltage and electric current were recorded at 0.81 volts and 0.049 mA, respectively [14].

Combining electrolyte media consisting of ions from coal stockpile wastewater with sawdust media is interesting to study to determine how much electrical energy can be generated. The ions in the stockpile waste as electrolyte media can be used as a medium for conducting electricity. With this electrolyte medium, if two different metals are inserted, an electric current can be used as a battery, known as a voltaic or galvanic cell.

This research is essential to find renewable energy resources [15] that are environmentally friendly and low-cost [16] [17][18]. Therefore, this research aims to analyze the electric voltage and current generated by diverse sawdust variations in coal stockpile wastewater, employing varying sizes of Cu-Zn electrodes.

Experimental Method

This research was conducted experimentally. The coal stockpile was taken from the coal stockpile at Keramasan Kertapai, while the sawdust was taken from the wood frame artisans. The experiment was carried out in the Integrated Chemistry Laboratory of the Palembang PGRI University.

The tools used are digital balances, volume pipettes, glass beakers, digital multitesters, balances and containers, cables, alligator clamps, and electrode clamps. The materials used are Cu, Zn electrode sheets, coal stockpile wastewater, sawdust waste, and alcohol. The electrodes were made from Cu and Zn sheets of 5 x 5 cm. The electrode sheet is cut using scissors. The electrodes are cleaned of stains using alcohol and dried. The stockpile water waste was first cleaned of impurity particles by filtering it, while the sawdust waste was taken to be cleaned of wood pieces.

This research is an experiment using a 2-factor experimental design. Factor 1 was the amount of media (M) of sawdust (SD) used 2, 4, 6, and 8, where each sawdust was added with 100 ml of coal stockpile wastewater (SWW). Factor 2 is the distance (D) of the electrode used. The combination experiments are shown in Table 1; each experimental unit was repeated three times.

Table 1. Combination Experimental Design

Media SD + SWW (100 ml)	**Notation**	**Elektroda Distance (1 cm)**	**(2 cm)**	**(3 cm)**
SD (2 gram)	M1	M1 - D1	M1 – D2	M1 – D3
SD (4 gram)	M2	M2 - D1	M2 – D2	M2 – D3
SD (6 gram)	M3	M3 - D1	M3 – D2	M3 – D3
SD (8 gram)	M4	M2 - D1	M2 – D2	M2 – D3

Sawdust is weighed 2, 4, 6, and 8 10 grams and placed into a square plastic container. 100 ml of stockpile wastewater was added and poured into the container. Cu and Zn electrodes were inserted into the container, and the distance between the electrodes was set at 1 cm. The Cu electrode (reduction/positive pole) was connected to a red clamped wire, while the Zn electrode (oxidation/negative pole) was connected to a black clamped wire. The electrode clamp cable was held with paperclip clamps so that the electrode position did not change (Figure 1)

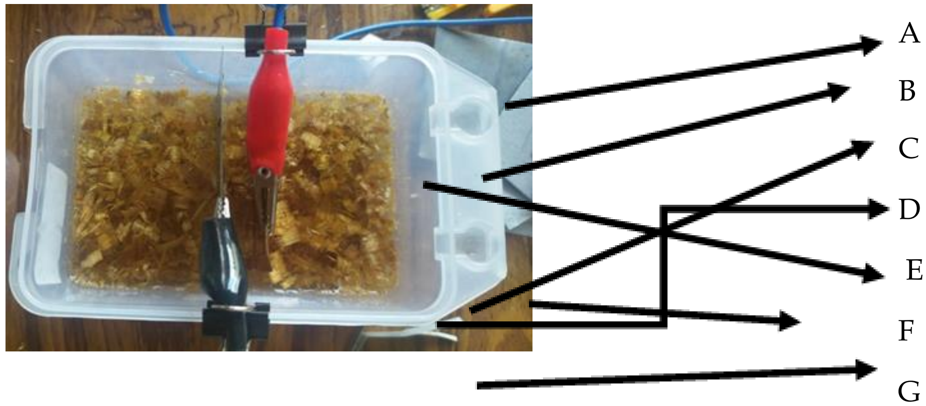

Figure 1 Electrode positions with A = Paperclip, B = Electrode clamp (+), C = Cu Electrode/ Cathode, D = Electrode clamp (), E = Zn Electrode /Anode, F = Sawdust + stockpile wastewater, G= Paperclip

The above steps were repeated for electrode spacings of 2 and 3 cm. The voltage and current were measured. The research stages were repeated three times.

The variables used were Variable 1 type of media M1 (2 g of sawdust + 100 ml of coal stockpile wastewater), M2 (4 g of sawdust + 100 ml of coal stockpile wastewater), M3 (6 g of sawdust + 100 ml of stockpile wastewater coal), and M4 (8 g sawdust + 100 ml coal stockpile wastewater). Variable 2 electrode distance 1, 2, and 3 cm. Parameters observed include voltage (V) and electric current (I).

The observed data includes voltages and electric currents generated due to variations in media types and electrode spacing. The data obtained was then analyzed descriptively how the resulting voltage and electric current resulted from media type variations and electrode spacing variations. The data obtained was also analyzed by variance F test 2 factors (factor 1 type of media and factor 2 electrode distance) to see how these variations affect the voltage and electric current generated. Calculate the F value > F Table 5% or sig. Value <5%, meaning the research treatment significantly reduced heavy metal content. Data analysis was continued with the Least Significant Difference (LSD) analysis to see the level of difference between treatments.

Result and Discussion

The research has been carried out using Cu and Zn metal electrodes with electrode spacing variations of 1, 2, and 3 cm and in coal stockpie wastewater media combined with sawdust. Sawdust media varied M1 (2 g sawdust + 100 ml coal stockpile wastewater), M2 (4 g sawdust + 100 ml coal stockpile wastewater), M3 (6 g sawdust + 100 ml coal stockpile wastewater), and M4 (8 g of sawdust + 100 ml of coal stockpile wastewater).

The mechanism of electric current occurs when the Cu and Zn electrodes are immersed in an electrolyte medium derived from coal stockpile wastewater. The Zn electrode, serving as the anode (negative pole), undergoes oxidation, releasing electrons. These released electrons move through the electrolyte medium and are then captured by the Cu electrode (positive pole), acting as the cathode, resulting in the flow of electric current. The utilization of sawdust as a battery medium has also been employed by other researchers [9].

The mechanism of electric current associated with chemical reactions is known as electrochemistry[19]. When chemical reactions originate from electrodes within an electrolyte medium, it is termed a voltaic cell. A voltaic cell comprises two electrodes (anode and cathode) containing an electrolyte. An electrode with a small standard reduction potential compared to the other electrode will undergo oxidation (negative pole). In contrast, the one with a more significant potential will experience reduction (positive pole). The use of Zn electrodes has drawn attention from researchers in electrochemistry due to their low cost and high safety levels[20].

The standard reduction potentials of Cu and Zn metals [15] are shown in reaction equations 1 and 2.

$$Zn^{2+} + 2e^{-} \longrightarrow Zn \qquad -0.76\ V \ldots\ldots\ldots\ldots\ldots 1$$
$$Cu^{2+} + 2e^{-} \longrightarrow Cu \qquad +0{,}34\ V \ldots\ldots\ldots\ldots\ldots 2$$

The reduction potential of Zn metal is -0.76 V < Cu +0.34 V, so that Zn metal is the anode/--electrode (undergoes oxidation) Cu metal acts as the cathode/+-pole (undergoes reduction), so that the redox reactions that occur are:

$$Zn \longrightarrow Zn^{2+} + 2e^{-} \qquad +0.76\ V$$
$$Cu^{2+} + 2e^{-} \longrightarrow Cu \qquad +0{,}34\ V$$

$$Zn + Cu^{2+} \longrightarrow Cu + Zn^{2+} \qquad +1{,}20\ V \ldots\ldots\ldots\ldots\ldots 4.3$$

The measurement data of the electric voltage and current resulting from variations in media and electrode distances are shown in Figures 2 and 3.

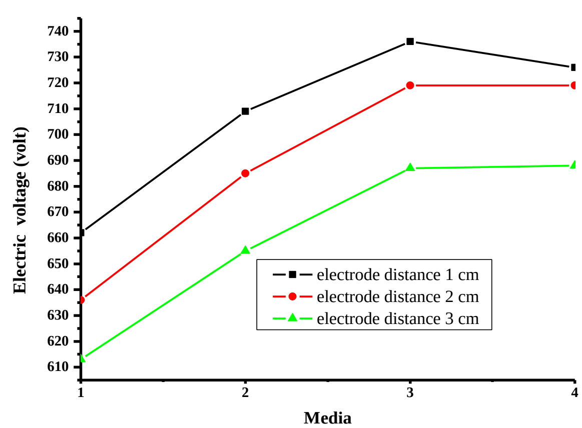

Figure 2. Variations in media composition and electrode distance affect the resulting electric voltage

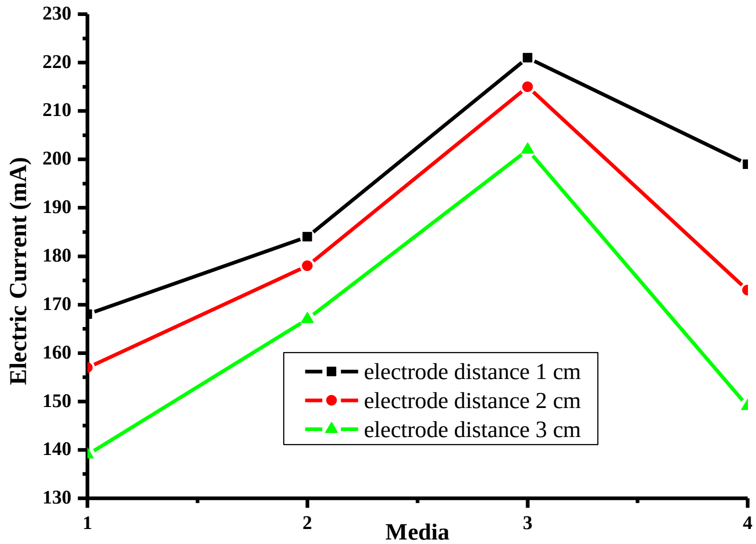

Figure 3. Variation of media composition and electrode distance to the resulting electric current

Figures 2 and 3 show that the electrode spacing of 1 cm in various media compositions shows the voltage and current value is relatively more significant than the distance of 2 and 3 cm. This is due to the closer distance between the electrodes. The voltage and current produced were more excellent than the electrodes farther apart. The research aligns with [21], which researched bio-batteries with Cu and Zn electrodes in fruit and vegetable waste media at various distances. The results show that the closest electrode distance produces the most significant relative voltage. Pawarangan et al. studied bio-batteries using a paste made from coffee powder and Cu-Zn electrodes. The different electrode spacings of 2, 4, and 6 cm, observed for over 4 hours, revealed that the electric voltage at a 2 cm distance was relatively more significant than at 4 and 6 cm[22].

Figures 2 and 3 also show that the composition of the media M1 (2 g of sawdust + 100 ml of coal stockpile wastewater) to M3 (6 g of sawdust + 100 ml of coal stockpile wastewater) results in an increase in voltage. In contrast, in composition, M4 does not show enhancement. This is because the composition of M1 to M3 sawdust can still be submerged by coal stockpile wastewater, which contains ions so that the ions can carry the electrons released by the Zn metal (oxidation) in the medium. The electrons emitted are captured by Cu metal (reduction). The composition of M4 (8 g sawdust + 100 ml of coal stockpile wastewater), where the sawdust is not submerged in the coal stockpile wastewater media so that the flow of electrons released by Zn metal (oxidation) is relatively slower so that the measured voltage and current is relatively not that big. Since it contains many dissolved ions, Stockpile wastewater can conduct electricity [2]. So, to show the electricity [21], the F test of variance was carried out to see the effect of electrode distance and media composition in generating electric voltage.

Analysis of variance F test 2 factors (factor 1 electrode distance and factor 2 media composition on electrical voltage), produced data in Tables 2, 3 and 4

Table 2. The amount of media data and distance between Between-Subjects Factors

		N
media	1	9
	2	9
	3	9
	4	9
distance	1	12
	2	12
	3	12

Table 2 shows that the amount of data on the media composition each amounted to 9 data (3 distances between electrodes x 3 replicates). The distance between 1, 2, and 3 cm electrodes was 12 data (4 media compositions x 3 replicates).

An F-test analysis was carried out to see the effect of the media and the distance between the electrodes on the resulting voltage (Table 3).

Table 3. F test analysis as of media composition and electrode distance to the generated voltage

Tests of Between-Subjects Effects

Dependent Variable: volt

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5,160[a]	11	,469	17041,636	,000
Intercept	12,827	1	12,827	465970,859	,000
media	2,684	3	,895	32504,598	,000
distance	1,036	2	,518	18812,428	,000
media * distance	1,440	6	,240	8719,891	,000
Error	,001	24	2,753E-5		
Total	17,988	36			
Corrected Total	5,161	35			

a. R Squared = 1,000 (Adjusted R Squared = 1,000)

Table 3 shows that the calculated F values for the treatment of media composition, the distance between electrodes, and the interaction of media composition with respective distances are 32,504, 18,812, and 8,719. Significant sign value (sig.) for distance, media composition, and interaction between media 0.000 <5%. The result means that the treatment of the composition of the media, the distance between the electrodes, and the interaction between the distance between the electrodes and the composition of the media shows a significant effect on the generated electric voltage.

Table 4 Analysis of Significant Differences (BNT) between media treatments for the generated electrical voltage

Multiple Comparisons

Dependent Variable: volt
LSD

(I) media	(J) media	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-,45600*	,002473	,000	-,46110	-,45090
	3	-,58256*	,002473	,000	-,58766	-,57745
	4	-,73000*	,002473	,000	-,73510	-,72490
2	1	,45600*	,002473	,000	,45090	,46110
	3	-,12656*	,002473	,000	-,13166	-,12145
	4	-,27400*	,002473	,000	-,27910	-,26890
3	1	,58256*	,002473	,000	,57745	,58766
	2	,12656*	,002473	,000	,12145	,13166
	4	-,14744*	,002473	,000	-,15255	-,14234
4	1	,73000*	,002473	,000	,72490	,73510
	2	,27400*	,002473	,000	,26890	,27910
	3	,14744*	,002473	,000	,14234	,15255

Based on observed means.
The error term is Mean Square(Error) = 2,753E-5.
*. The mean difference is significant at the ,05 level.

Table 4 shows that the treatment of the composition of M1 media compared to M2, M3, and M4 media shows a significant (significant) difference in generating electric voltage. It is marked with an *, while the comparison of horseradish treatments between electrodes can be seen in Table 5.

Table 5 Analysis of Least Significant Difference (LSD) between electrode distance treatments against the generated electrical voltage

Multiple Comparisons

Dependent Variable: volt
LSD

(I) jarak	(J) jarak	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-,38617*	,002142	,000	-,39059	-,38175
	3	-,32583*	,002142	,000	-,33025	-,32141
2	1	,38617*	,002142	,000	,38175	,39059
	3	,06033*	,002142	,000	,05591	,06475
3	1	,32583*	,002142	,000	,32141	,33025
	2	-,06033*	,002142	,000	-,06475	-,05591

Based on observed means.
The error term is Mean Square(Error) = 2,753E-5.
*. The mean difference is significant at the ,05 level.

One can see in Table 5 that the treatment of the distance between the electrodes also shows a significant difference in generating electric voltage. It is indicated by an *.

An analysis of variance was performed on the F test of two components (factor 1, media composition, and factor 2) needed to determine the effect of media composition and electrode distance on the resulting electric current,. Tables 6 and 7 show the electrode distance.

Table 6. The amount of data that was inserted against the generated electric current

Between-Subjects Factors

		N
media	1	9
	2	9
	3	9
	4	9
distance	1	12
	2	12
	3	12

Table 6 shows that the amount of data input for the composition of media M1, M2, M3, and M4 each has 9 data. There are 12 data for each electrode distance that is input. To see the effect of treatment on the resulting electric current, we analyzed the F test, and the data is obtained in Table 7.

Table 7. Analysis of a variety of media compositions and electrode distance to the generated electric current

Tests of Between-Subjects Effects

Dependent Variable: current

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	,022[a]	11	,002	115,658	,000
Intercept	1,158	1	1,158	67552,571	,000
media	,016	3	,005	306,044	,000
distance	,005	2	,003	146,703	,000
media * distance	,001	6	,000	10,116	,000
Error	,000	24	1,714E-5		
Total	1,180	36			
Corrected Total	,022	35			

a. R Squared = ,981 (Adjusted R Squared = ,973)

Table 7 shows that the calculated F values for media composition, distance, and interaction of media composition with distance to the resulting electric current are 306,044, 146,703, and 10,115 with significant values (sig.), respectively 0.000<5%. It means that the treatment composition of the media and the distance between the electrodes significantly affect the electric current produced. To see the differences between the treatments, an analysis of the Least Significant Difference (LSD) was carried out. Data are obtained from Tables 8 and 9.

Table 8 Analysis of Least Significant Difference (LSD) between media treatments of the generated electric current

Multiple Comparisons

Dependent Variable: current
LSD

(I) media	(J) media	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-,02167*	,001952	,000	-,02569	-,01764
	3	-,05778*	,001952	,000	-,06181	-,05375
	4	-,01878*	,001952	,000	-,02281	-,01475
2	1	,02167*	,001952	,000	,01764	,02569
	3	-,03611*	,001952	,000	-,04014	-,03208
	4	,00289	,001952	,152	-,00114	,00692
3	1	,05778*	,001952	,000	,05375	,06181
	2	,03611*	,001952	,000	,03208	,04014
	4	,03900*	,001952	,000	,03497	,04303
4	1	,01878*	,001952	,000	,01475	,02281
	2	-,00289	,001952	,152	-,00692	,00114
	3	-,03900*	,001952	,000	-,04303	-,03497

Based on observed means.
The error term is Mean Square(Error) = 1,714E-5.
*. The mean difference is significant at the ,05 level.

Table 9. Analysis of the Least Significant Difference (LSD) between treatments of electrode distance to the generated electric current

Multiple Comparisons

Dependent Variable: current
LSD

(I) distance	(J) distance	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	,01217*	,001690	,000	,00868	,01565
	3	,02883*	,001690	,000	,02535	,03232
2	1	-,01217*	,001690	,000	-,01565	-,00868
	3	,01667*	,001690	,000	,01318	,02015
3	1	-,02883*	,001690	,000	-,03232	-,02535
	2	-,01667*	,001690	,000	-,02015	-,01318

Based on observed means.
The error term is Mean Square(Error) = 1,714E-5.
*. The mean difference is significant at the ,05 level.

Table 8 shows a significant difference in the treatment of media composition 1 compared to media composition 2, 3, 4, and 5. It is marked with an *, while the distance treatment can be seen in Table 9. Table 9 shows that all treatments 1 (1 cm) electrode distance compared to 2 and 3 cm electrode distance or treatment 2 (2 cm) electrode distance compared to 1 cm and 3 or treatment 3 (3 cm) electrode distance compared to 1 cm and 2 cm distance show a significant difference in generating electricity. it is marked with an *.

Conclusion

The highest voltage generated from Cu-Zn electrodes in the combination of coal stockpile waste with sawdust is highest in M3 media (6 grams of sawdust + 100 ml of coal stockpile wastewater) with a distance of 1 cm at 0.736 volts. as well as size. The highest electric current generated from the Cu-Zn electrode in the M3 media combination was 0.221 milliamperes. The mechanism for electrical flow occurs when the electrode is in an electrolyte medium, where the Zn electrode (- pole) experiences oxidation (release of electrons), while the Cu electrode (+ pole) experiences reduction, resulting in an electric flow.

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