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The effect of aluminum electrode distance in electrocoagulation as a reductor of heavy metal lead (Pb) in water: An environmental health study

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***Abstract*---**Electrocoagulation uses an aluminum electrode toreduce lead in water through a chemical reaction. The previous study employed a voltage of 20 volts, a current of 10 amperes, and a contact time of 60 minutes to reduce lead. This follow-up study is still being conducted on a laboratory scale in order to determine the ideal electrode distance. The study's goal was to examine the influence of electrode spacing of 15 cm, 17.5 cm, and 20 cm on the decrease in lead in water at a voltage of 20 volts and a contact period of 60 minutes. The study had a true experimental design with a post-test only control group. Data gathered from 6 replications of 4 treatments, with the factors pH and current strength taken into consideration. The results revealed a difference in lead decrease. The difference occurred at 15 cm electrode distance with a drop of 0.018 mg/liter and 20 cm electrode distance with a decrease of 0.024 mg/liter. pH and current strength did not affect the decrease in lead in variations

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in the distance of the reactor electrode. The best lead reduction occurred at the Aluminum electrode with a distance of 20 cm.

***Keywords*---**electrode distance, lead (Pb), voltage, current

Introduction

The results of the census of the Central Bureau of Statistics of Indonesia in 2015 show that the number of micro and small industries that focus on handling base metals is 31,122 micro-enterprises and 461 small-scale enterprises in 33 provinces in Indonesia. Wastewater generated from metal processing activities is toxic and dangerous, such as heavy metal lead (Pb) (BPS Indonesia, 2015). East Java Province, reported the number of Non-Agriculture Industries as many as 142,626 industries consisting of Industries: a) metals, machinery, metal, machinery, and transportation equipment as many as 61,167, b) chemicals, textiles, and chemical, textile and miscellaneous as many as 61,352, and c) electronics and electronics and telematics as many as 20,108, among these industries wastewater contains lead (BPS Jatim, 2019).

Lead has a high toxicity when in contact with human skin, it must be treated before being released into the environment, where it might harm the ecosystem. According to the (Wahab, 2021), published on Indonesian Institute of Sciences's official website on January 5, 2021, it demonstrates that the increasing damage to coastal ecosystems is incorrect. The cause is heavy metal pollution, such as Cd (Cadmium), Pb (Lead), Hg (Mercury), As (Arsenic), Zn (zinc), Cu (Copper), Ni (Nickel), and Cr (Chrome). Lead is one of the heavy metal pollutants that can damage ecosystems.

According to the findings of Eka & Mukono (2017), acute lead poisoning impacts blood pressure whereas chronic poisoning induces hypertension and reduced renal function in adults. Lead levels in employees as a control group who were not exposed to lead exhibited blood lead levels ≤ 10 µg/d. The findings of this study are consistent with the findings of Cahyani *et al.* (2016), who discovered that lead can damage the neurological system, renal system, reproductive system, endocrine system, and heart.

The electrocoagulation method is a liquid waste treatment method that utilizes a chemical reaction caused by an electric current at the electrode which is thought to be a solution to the problem of handling liquid waste in lead-containing industries. Aluminum (Al) is one of substance that may be used as an electrode in the electrocoagulation process, as well as a reducing agent. Previous research by Kriswandana (2020) employed a spacing of 20 cm between the electrodes and a distance of 10 cm between the electrodes and the media base. As a result, aluminum electrodes in the electrocoagulation process can minimize lead. The greatest reduction occurred at a voltage of 20 volts, a current of 10 amps, and a contact duration of 60 minutes. The drop in lead levels is 85.21% (lead levels from 3 ppm to < 1 ppm) and still has to be improved in order to avoid becoming a burden on environmental contamination, as recommended by the study's findings.

Previous research findings are worth following up on in order to obtain even better specifications based on one of the recommendations, namely paying attention to the most effective variations of the spacing between the electrodes. In the previous research, the electrodes were spaced 20 cm apart, with each electrode 10 cm from the left and right edge walls and the base floor. This follow-up research aims to establish specifications for the most efficient variation of the distance between the electrodes. This is a continuation of the study entitled "Electrocoagulation as a reductant for heavy metals lead (Pb) and mercury (Hg) in water."

This research was conducted by taking into consideration the research roadmap of the *Poltekkes Kemenkes Surabaya* from 2019 to 2024, in accordance with the Vision and Mission of *Poltekkes Kemenkes Surabaya*, with one of the goals: "to produce superior products resulting from research and appropriate technology in the health sector." The research roadmap of *Poltekkes Kemenkes Surabaya* contains a research roadmap of environmental health for the next four years (2020 to 2023), including five study groups, namely waste management, vector control, air pollution, water supply, and food sanitation drink.

The results of this study support the achievement of the target: "The Strategic Plan of *Poltekkes Kemenkes Surabaya* in 2020 to 2024" (pages 113 – 114) in goal 2 is written: "Producing basic, applied and development research in the health sector which is a reference at the national and international levels. international", with target 1 written: "Increasing the quality of research in accordance with the development of science and technology in vocational and professional education", with an indicator of the number of research activities carried out by lecturers in one year and the target "in 2020 is written: 78 titles, 2021: 78 titles, 2022: 81 titles, 2023: 82 titles, and 2024 as many as 83 titles".

Method

The research design was a true experimental that carried out in a laboratory with a post test only control group design, which is a research design consisting of a control group (R) and an experimental group of 3 treatments (R1, R2 and R3). R1 is the electrode distance of 15 cm, R2 is the electrode distance of 17.5 cm, and R3 is the electrode distance of 20 cm. All treatments used a voltage of 20 volts, a current of 10 amperes with a contact time of 60 minutes. Sampling for examination of lead levels was carried out before and after treatment and in the control (Figure 1).

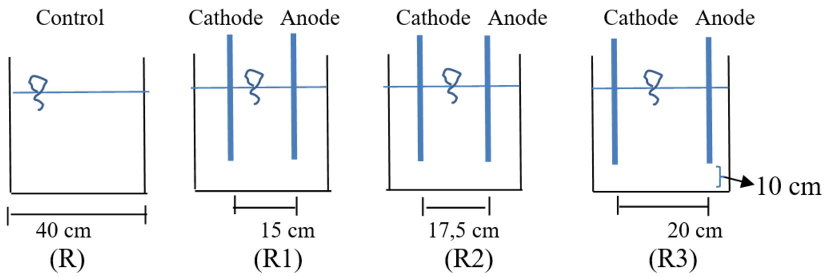

Figure 1. Electrocoagulation reactor design

The sample size was calculated using the Federer replication formula (t-1) x (r-1) > 15, where R is the number of replications depending on treatment and control. R > 6 was obtained in Prihanti (2016). The sample size was calculated by multiplying 6 replications by 4 treatments, yielding 24 data points, and then adding 6 data points before treatment. As a result, there were a total of 30 data points. The acquired data were processed and analyzed using the One-way Anova test, which was preceded by the normality test and followed by the Post-Hoc test which aims to determine the difference in the mean decrease in the test parameters.

Results and Discussion

Table 1 shows electrode distances of 15 cm, 17.5 cm, and 20 cm, as well as controls.

Table 1
Distribution of lead level decrease in the control group, and the electrode group with a distance of 15 cm, 17.5 cm and 20 cm with a voltage of 20 volts and a contact time of 60 minutes

Replication (R)	Lead level decrease (mg/liter)			
	Control	15 cm	17.5 cm	20 cm
1	0.014	0.018	0.020	0.022
2	0.009	0.015	0.017	0.017
3	0.017	0.017	0.023	0.026
4	0.011	0.018	0.025	0.029
5	0.011	0.016	0.018	0.018
6	0.014	0.023	0.026	0.031
Range	0.009-0.014	0.015-0.023	0.017-0.026	0.017-0.031
Average	0.012	0.018	0.022	0.024

Based on table 1, it can be concluded that the average decrease in lead in the control group was 0.012 mg/liter, at the electrode distance of 15 cm it was 0.018 mg/liter, at the electrode distance of 17.5 cm it was 0.022 mg/liter and at the electrode distance of 17.5 cm was 0.022 mg/liter and at the electrode distance of 17.5 cm, 20 cm by 0.024 mg/liter.

The results of statistical tests, which were preceded by normality and homogeneity tests, revealed that the p-value at the electrode variations of 15 cm, 17.5 cm, and 20 cm was normally distributed, with p-value more than 0.05. After the homogeneity test, with p-value of 0.005, all data were homogenous. The One Way ANOVA test yielded a p-value of 0.027, indicating that there was a difference in the average decrease in lead in the electrode reactor at distances of 15 cm, 17.5 cm, and 20 cm. The Post Hoc - LSD test yielded a p-value of 0.028, indicating the difference in lead reduction occurred at electrodes 15 cm by 20 cm.

The decrease in lead levels in the reactor in the control group was caused by the characteristics of lead. Lead is a group 14 element with atomic number 82, has an atomic weight of 207.2, and is more metallic. This feature permits lead to naturally precipitate, resulting in a drop in lead in the control even without the electrocoagulation procedure (Nafilah, 2021).

The reduction in lead at the electrode reactor, which was 15 cm, 17.5 cm, and 20 cm, was higher than the reduction in lead in the control group. This demonstrates that throughout the electrocoagulation process, lead is decreased owing to the presence of a 20-volt electric current for 60 minutes. This drop, according to (Fathan, 2021) was caused by the electrocoagulation process. The basis of electrocoagulation is that two electrode plates, either aluminum or iron, are placed into a vessel filled with water, and then a process of clumping and deposition of fine particles contained in the water is carried out using electrical energy.

The findings of this study support and improve on the research results of Kriswandana, (2020), who discovered that the best lead reduction results occur at a voltage of 20 volts and a contact time of 60 minutes, indicating that the electrocoagulation process with aluminum electrodes can reduce lead in water. The variation in electrode distance is what distinguishes this study. In this research, the optimal electro distance was at a distance of 20 cm and was significantly different from a distance of 15 cm. The percentage of reduction at the electrode distance of 15 cm is 10.4 percent, 7.6 percent at the distance of 17.5 cm, and 44.8 percent at the electrode distance of 20 cm. The highest lead reduction occurred at a distance of 20 cm, which will serve as the foundation for further study in 2022 with the addition of Calcium Hydroxide and activated charcoal to reach specifications with the highest reducing percentage.

According to Said (2010), it is feasible to acquire treated water of the necessary quality by using only one specific procedure, and this must be done by a combination of several processes. According to Aziz *et al.* (2006) the percentage of activated carbon absorption for lead metal using an activator is 51.41% for lead metal. The use of calcium hydroxide $Ca(OH)_2$ will form $Pb(OH)_2$ which precipitates thereby reducing dissolved lead. The findings of electrocoagulation research utilizing aluminum electrodes can be used to reduce water contamination in bodies of water caused by lead-contaminated waste water. According to Aziz, the level of lead in wastewater affects the water load on the receiving water body, such that lower lead levels in water bodies owing to the electrocoagulation process will also reduce lead levels in the food chain.

The presence of pH proved to have no effect on the decrease in lead in the electrocoagulation process using aluminum electrodes at 15 cm, 17.5 cm and 20 cm. The results are shown in table 2. There was no change in pH in the control group despite variances in the decrease in lead concentration. There was a pH change of 1 in the reactor with an electrode distance of 15 cm, except for the fourth replication, where the pH increased from 3 to 5, and at an electrode distance of 17.5 cm and 20 cm, all replications experienced a pH change of 1 from pH 3 to 4, but they were all still in a sour atmosphere. The normality test findings indicated that the variations in the distance between the electrodes of 15 cm, 17.5 cm, and 20 cm were not normally distributed ($p = 0.000$), and the data was not homogenous, therefore the data could not be analyzed for One Way ANOVA.

Table 2.
Distribution of changes in pH and decrease in lead in the control group and the electrode distance group of 15 mm, 17.5 cm and 20 cm at a voltage of 20 volts with a contact time of 60 minutes

Replication (R)	Control		15 cm		17.5 cm		20 cm	
	pH	Pb (mg/l)	pH	Pb (mg/l)	pH	Pb (mg/l)	pH	Pb (mg/l)
1	0	0.014	1	0.018	1	0.020	1	0.022
2	0	0.009	1	0.015	1	0.017	1	0.017
3	0	0.017	1	0.017	1	0.023	1	0.026
4	0	0.011	2	0.018	1	0.025	1	0.029
5	0	0.011	1	0.016	1	0.018	1	0.018
6	0	0.014	1	0.023	1	0.026	1	0.031
Range	0	0.009 – 0.014	1-2	0.015 – 0.023	1	0.017 – 0.026	1	0.017 – 0.031
Average	0	0.012	1.17	0.018	1	0.022	1	0.024

The results showed that the pH in the control group did not change after 60 minutes of contact time. This indicates that the pH does not change during the electrocoagulation process in the control; the pH of the water remains constant. Following the application of 20 Volt DC power for 60 minutes, it was discovered that the pH in all reactors increased from 3 to 4. The electrocoagulation process causes a rise in pH, which resulting in the creation of hydrogen gas and hydroxide ions. This increase in pH is consistent with the findings of Merzouk *et al.* (2009) who discovered that the electrolysis process in this electrocoagulation process produces hydrogen gas and hydroxide ions. The pH tends to rise when there are more hydrogen and hydroxide ions are present.

In this research, the current strength was originally set at 10 amperes for all treatments, and both aluminum electrodes were 15 cm, 17.5 cm, and 20 cm at the start using a DC power source of 20 volts from a switching power supply that was operated for 60 minutes. The current strength decreases at the start of the process due to the load on the solution and increases again at the finish. The loss in current strength at the 15 cm distant electrode runs from 0.15 to 0.40 amperes, with an average of 0.24 amperes, 17.5 cm by 0.197 to 2.12 amperes, with an average drop of 0.17 amperes, and 20 cm by 0.05 – 0.23 amperes, with an average drop of 0.94 amperes.

In the test results of changes in current strength to the decrease in lead in the electrocoagulation process with aluminum electrodes at a distance of 15 cm, 17.5 cm, and 20 cm, it is descriptively seen that the larger the distance of the aluminum electrode is followed by a decrease in the current strength (15 cm = 0.24 amperes, 17.5 cm = 0.17 amperes, and 20 cm = 0.16 amperes). It can be concluded that the average decrease in current strength is followed by the average decrease in lead in water. The distribution of current strength and reduction of lead heavy metal content can be seen in table 3.

Table 3
Distribution of current strength and lead drop in the control group, and electrodes distance of 15 cm, 17.5 cm and 20 cm at a voltage of 20 volts with a contact time of 60 minutes

Replication (R)	15 cm distance		17.5 cm distance		20 cm distance	
	Current strength	Pb (mg/l)	Current strength	Pb (mg/l)	Current strength	Pb (mg/l)
1	0.15	0.018	0.18	0.020	0.05	0.022
2	0.20	0.015	0.30	0.017	0.23	0.017
3	0.40	0.017	0.20	0.023	0.22	0.026
4	0.28	0.018	0.25	0.025	0.17	0.029
5	0.16	0.016	0.17	0.018	0.17	0.018
6	0.23	0.023	0.11	0.026	0.10	0.031
Range	0.15 – 0.40	0.015 – 0.023	0.11 – 0.30	0.017 – 0.026	0.05 - 0.23	0.017 - 0.031
Average	0.24	0.018	0.17	0.022	0.16	0.024

Based on the results of statistical tests that were preceded by testing the distribution of data using the Kolmogorov-Smirnov test, it is known that all data on current strength and lead at various electrodes with a distance of 15 cm, 17.5 cm and 20 cm are normally distributed ($p > 0.05$) and continued with statistical tests to prove the effect current strength against lead drop.

The results of the one way pair test proved that the current had no effect on the decrease in lead ($p > 0.05$). The results of the Post Hoc Least Difference (LSD) test for each pair, namely a distance of 15 cm and 17.5 cm ($p = 0.445$), a distance of 15 cm and 20 cm ($p = 0.093$) and 17.5 cm and 20 cm ($p = 0.329$), it can be concluded that the current strength has no effect on the decrease in lead because the p value is > 0.05.

The results showed that the decrease in current strength at the start of the procedure was caused by the 30 liters of water media in the reactor, and that the decrease in current strength over the 60-minute treatment period decreased again. However, in the electrocoagulation process using aluminum electrodes, the drop in current intensity had no significant effect on the decrease in lead in water.

The reduction in current intensity during the study procedure was consistent with the findings of (Novita, 2017) since the electric current influences floc formation by influencing the quantity of Al^{3+} ions released as a coagulant agent from the anode. The process that occurs in electrocoagulation using aluminum electrodes at 15 cm, 17.5 cm, and 20 cm distances for 60 minutes with a voltage of 20 volts changes the relative current strength in the three reactors, causing changes in lead in the three reactors due to the influence of the aluminum electrode distance.

The efficacy of the reactor in the electrocoagulation process was based on the electrode distance at a voltage of 20 Volts with a contact period of 60 minutes, as shown in table 1. The results presented in table 1 indicate that the best effectiveness in reducing lead in water occurs in reactors with electrodes spaced 20 cm apart with an average lead reduction of 0.024 mg/liter. It was also differed significantly at a distance of 15 cm electrodes of 0.018 mg/liter.

Conclusion

The results revealed that the distance of the aluminum electrode had an influence on the decrease in lead in water via the difference test between the electrodes at 15 cm and 20 cm. The drop in lead in water was unaffected by pH or current intensity, and it happened successfully in reactors with electrodes spaced 20 cm apart. Further study should be conducted utilizing a 20 cm aluminum electrode distance with the inclusion of a further processing system employing extra Ca (OH)2 solution, Activated Charcoal, and a combination of providing Ca (OH)2 and Activated Charcoal solutions.

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