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RESEARCH ARTICLE

The Effectiveness of Reduction of Weight Metal Contents of Pb, and Hg in Water Electro-coagulation Method

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Abstract

Background and Aim: Heavy metals in certain levels can reduce the quality of air, water, and soil. Furthermore, causing health problems for plants, animals and humans, when there is accumulation as a result of industrial activity. Until now, the reduction of heavy metal content in liquid waste has been carried out physically, chemically and biologically. Therefore it is deemed necessary to reduce levels of heavy metals in liquid waste by electrocoagulation. The purpose of this study is to study the performance of electrocoaglation as a reducing agent in reducing Pb and Hg levels in water, so that it can provide references and input for the electroplating industry, batik industry, and others. Method and Materials: This research is a true experimental research with a post test only control group design, which is a research design consisting of a control group and an experimental group. The research sample will be examined in the laboratory. The sample used in this study is a preparation that has been made by dissolving Pb and Hg so that it is like waste from the batik industry or electroplating waste or battery factory waste. The variations in this study were the current / voltage (16, 20, and 24) volts and the detention time (30, 40, 50, and 60) minutes. The independent variable is electrocoagulation which is equipped with cathode and anode. This variable will affect changes in the dependent variable. The dependent variable in this study is the quality of the waste after electrocoagulation by observing the parameters of Pb and Hg. Statistical Analysis: Data analysis using the One-way Anova test or One-way Anova. Results: The results of this study indicate that electrocoagulation as a reducing agent at 16 Volts, 20 Volts, and 24 Volts with a contact time of 30 minutes, 40 minutes, 50 minutes and 60 minutes has a significant effect on Pb and Hg reduction with $\alpha = 0.05$. The most significant reduction in average Pb occurs in processing with a 20 volt electricity voltage and 60 minutes contact time. Meanwhile, the most significant decrease in Hg levels occurs in processing with a 24 volt electricity voltage and contact time for 30 minutes. Discussion and Conclusion: The reduction in Pb and Hg levels using the electrocoagulation method with aluminum electrodes comes from a redox reaction process where the anode (in acidic pH) will form the Al(s) → Al3+ (aq)¬ + 3e and the cathode will form 3H+ (aq) + 3e- → 1,5H2 (g)¬. After the anode and cathode react, there will be a floc formation which functions as a coagulant that will bind Pb. The conclusion of this study is that the most significant decrease in the average Pb level occurs in processing with a power supply of 20 volts and a contact time of 60 minutes. Meanwhile, the most significant decrease in Hg levels occurred in the treatment with 24 volt electricity and the contact time was 30 minutes.

Keywords: *Electro-coagulation, Voltage, Contact time, Heavy metals.*

Introduction

Heavy metals can be defined based on density, whereas in physics, the distinguishing criterion is the atomic number. Minutes require several heavy metals, which are necessary for certain biological processes. Heavy metals, on the other hand, can cause more serious toxic effects, including cancer, brain damage or death, and not just the harm they can cause to the skin, lungs, stomach, kidneys, liver, or heart. Heavy metals are often considered highly toxic or damaging to the environment, while some are toxic if and only if they are consumed in excess or encountered in certain forms. Environmental heavy metals (chromium, arsenic, cadmium, mercury) and lead have the greatest potential to cause damage due to their wide use, the toxicity of some of their compounds or elements, and their wide distribution in the environment. Hexavalent chromium, for example, is as poisonous as mercury vapor and many mercury compounds. These five elements have a strong affinity for sulfur; in the human body they are normally bound to enzymes, via a thiol group (-SH), which is responsible for controlling the rate of metabolic reactions. The resulting sulfur-metal bonds inhibit the function of the enzymes involved; worsening human health, sometimes with fatal consequences. Chromium (in its hexavalent form) and arsenic are carcinogens; cadmium causes degenerative bone disease; and mercury and lead damage the central nervous system.

The results showed that marine waters in various regions in Indonesia (Madura, Ancol Jakarta) were contaminated by heavy metals [1, 2]. The Pb concentration in the Madura Strait water was still below the quality standard, while in the sediment it had far exceeded the Pb quality standard of 62.06 mg / kg).

The concentration of Pb in A. nodifera was 60.10 mg / kg, M. lyrata was 51.48 mg / kg, and S. lamarckii was 45.29 mg / kg. These results indicate that the concentrations of the three types of shellfish have exceeded the maximum limit of heavy metal contamination in food (Pb of 1.5 mg / kg) [2]. Other studies have shown that Mercury (Hg) and Lead (Pb) have entered public waters so that they accumulate in aquatic plants and animals which can eventually enter the human body through the food chain [3].

Until recently, the reduction of heavy metal levels in liquid waste was mostly done physically, chemically and biologically, therefore it was deemed necessary to reduce the levels of heavy metals in liquid waste by electrocoagulation. This research will use the electrocoagulation method as a reducing agent for heavy metals Pb and Hg in water.

Purpose

The purpose of this study was to study the performance of electrocoaglation as a reducing agent in reducing Pb and Hg levels in water.

Materials and Method

This type of research is a true experimental design with a post test only control group design, namely a research design consisting of a control group and an experimental group. The research sample will be examined in the laboratory. The sample used in this study is preparations that have been made by dissolving Pb and Hg so that they are like waste from the batik industry or electroplating waste or battery factory waste. The variations in this study are the current / voltage (16, 20, and 24).Volts and detention times (30, 40, 50, and 60) minutes.

The sampling technique is determined by means of replication; the sample size is determined by the formula. Federer [4].The size of the study sample was obtained from the number of replications multiplied by the number of treatments (12) plus control (1), the total replication was 13 × 3 = 39 samples. The independent variable is electrocoagulation which is equipped with cathode and anode. This variable will affect changes in the dependent variable. The dependent variable in this study is the quality of the waste after electrocoagulation by observing the parameters of Pb and Hg. The collected data were processed descriptively and analytically. The data analysis used is One-way Anova.

Results

Results of Measurement of Pb Levels in Water before and After Processing Using the Electrocoagulation Method

Table 1: Results of Measurement of Pb Levels in Water before and After Processing Using the Electro coagulation Method

Parameter	Information	Time Testing	Measurement results Replication (1,2,3) (ppm)			Average Decrease (ppm)	Percentage of Decrease (%)
Pb	Control	30’	3.386	3.371	3.350	3.369	
		40’	3.327	3.287	3.331	3.315	
		50’	3.248	3.224	3.256	3.242	
		60’	3.229	3.188	3.210	3.209	
	Pretest	30’	3.461	3.434	3.390	3.428	
		40’	3.310	3.331	3.342	3.327	

Parameter	Information	Time Testing	Measurement results Replication (1,2,3) (ppm)			Average Decrease (ppm)	Percentage of Decrease (%)
		50'	3.317	3.394	3.349	3.353	
		60'	3.326	3.303	3.314	3.314	
	16V	30'	2.641	2.459	2.890	2.663	22.31
		40'	2.457	2.098	1.948	2.167	34.86
		50'	1.755	1.477	1.659	1.630	51.38
		60'	1.227	1.091	.944	1.087	67.19
	20V	30'	0.984	0.899	0.832	0.905	73.59
		40'	0.822	0.735	0.966	0.841	74.72
		50'	0.710	0.688	0.881	0.759	77.36
		60'	0.520	0.455	0.497	0.490	85.21
	24V	30'	1.134	0.931	1.078	1.047	69.45
		40'	1.289	0.873	0.956	1.039	68.77
		50'	.980	1.098	1.259	1.112	66.83
		60'	1.003	1.537	1.690	1.410	57.45

Table 1, the results of measuring pb levels in water before and after processing using the electrocoagulation method show that there is a decrease in Pb levels in the water sample after processing using the electrocoagulation method with variable voltage variables varying respectively 16 volts, 20 volts, and 24 volts and a variable time. The contact was varied for 30 minutes, 40 minutes, 50 minutes, and 60 minutes. The smallest average reduction in Pb levels occurred in treatments using 16 volts of electric voltage with a contact time of 30 minutes, namely 22.31% (2.663 ppm). While the largest percentage reduction in average Pb levels occurred in the processing of liquid waste samples using 20 volts of electric voltage and 60 minutes of contact time, which was 85.21% (0.490 ppm).

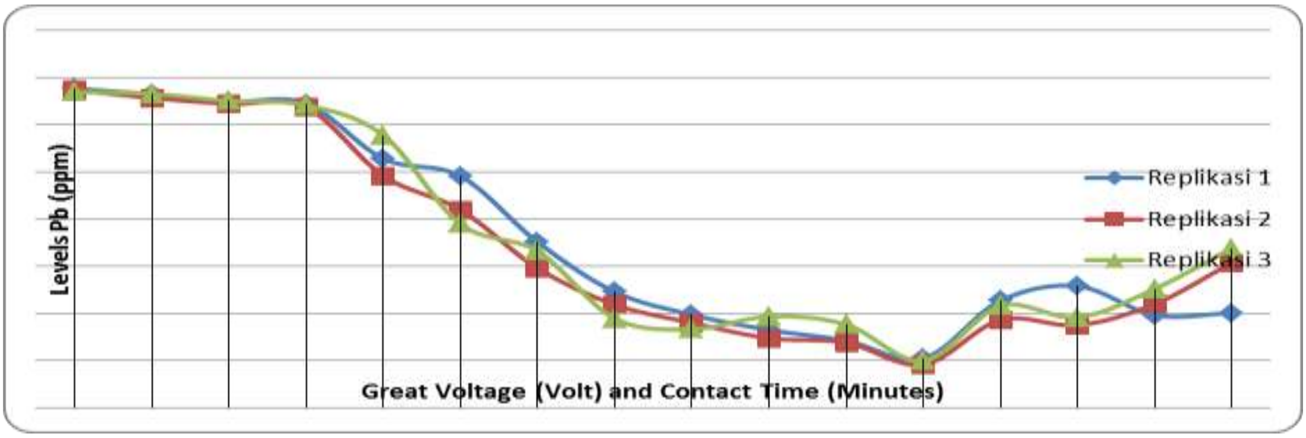

Figure 1: Graph of Decrease in Pb Levels in Water after Processing by Electrocoagulation Method

Figure 1 shows that the optimum voltage and time to reduce Pb metal in liquid waste by electrocoagulation method occurs in the treatment with an electric voltage of 20 volts with a contact time of 60 minutes. Meanwhile, processing with a voltage of 24 volts and contact time of 30 minutes, 40 minutes, 50 minutes, and 60 minutes showed a decrease in removal efficiency in each observed time period. It is possible that saturation occurs in the electrocoagulation process at a voltage of 24 volts. Due to the saturation of the process, the reduction in Pb levels is not optimal and tends to be stagnant. For more details, here is a graph of the reduction in Pb levels in wastewater after processing using the electrocoagulation method.

Measurement Results of Hg Levels After the Electrocoagulation Process

Table 2: Results of Measurement of Hg Levels in Water before and After Processing Using the Electro-coagulation Method

Parameter	Information	Time Testing	Measurement results Replication (1,2,3) (ppm)			Average Decrease (ppm)	Percentage of Decrease (%)
Hg	Control	30'	2.955	2.918	2.811	2.894	
		40'	2.832	2.807	2.814	2.817	
		50'	2.820	2.786	2.800	2.802	
		60'	2.741	2.758	2.760	2.753	
	Pretest	30'	2.982	2.977	2.903	2.954	
		40'	2.983	2.958	2.921	2.980	
		50'	2.836	2.821	2.819	2.825	
		60'	2.806	2.812	2.874	2.830	
	16V	30'	2.209	2.140	2.331	2.226	24.64
		40'	1.876	1.650	1.835	1.787	40.03
		50'	1.653	1.339	1.567	1.519	46.23
		60'	1.198	1.209	1.198	1.201	57.56
	20V	30'	0.902	0.977	0.975	0.951	67.80
		40'	0.893	0.807	0.821	0.840	71.81
		50'	0.714	0.726	0.664	0.701	75.18
		60'	0.520	0.505	0.556	0.527	81.37
	24V	30'	0.456	0.491	0.510	0.485	83.58
		40'	0.876	1.193	0.897	0.988	66.84
		50'	1.008	1.198	1.259	1.155	59.11
		60'	1.003	1.335	1.235	1.191	57.91

Based on Table 2, it is known that there is a decrease in Hg levels in the water sample after processing using the electrocoagulation method with a variable voltage with a voltage variation of 16 volts, 20 volts, and 24 volts and a variable contact time with time variations for 30 minutes, 40, minutes, 50 minutes, and 60 minutes. The smallest average decrease in Hg levels occurred in the treatment using 16 volts of electrical voltage with a contact time of 30 minutes, namely 24.64% (2.226 ppm). Meanwhile, the largest percentage decrease in Hg levels on average occurred in the processing of liquid waste samples using 24 volts and 30 minutes of contact time, which was 83.58% (0.485 ppm).

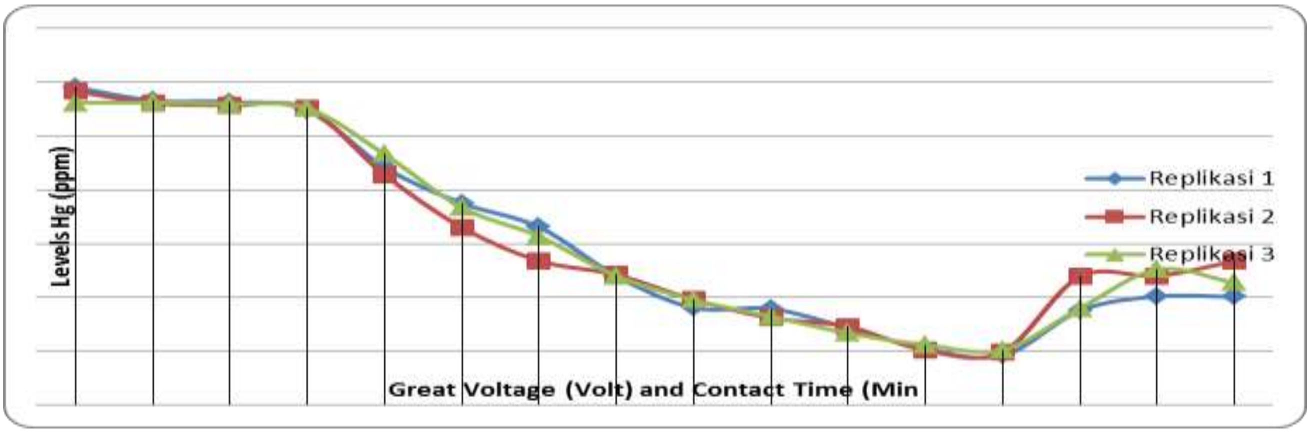

Figure 2: Graph of Decrease in Hg Content in water After Processing by Electrocoagulation Method

From the graphic data above (figure 2), it can also be seen that the optimum voltage and time to reduce Hg metal in water by the electrocoagulation method occurs in processing with an electric voltage of 24 volts with a contact time of 30 minutes. This is due to saturation during processing with a voltage of 24 volts and contact time of 40 minutes, 50 minutes, and 60 minutes. Due to the saturation of the process, the decrease in Hg levels is not optimal and tends to be stagnant. For more details, here is a graph of the reduction in Hg levels in wastewater after processing using the electrocoagulation method.

Statistical analysis of Pb and Hg levels in Industrial Wastewater after being treated with the Electro-coagulation Method

Table 3: Data Normality Test Results of Pb and Hg Levels in Water at a detention time of 30 minutes, 40 minutes, 50 minutes, and 60 minutes after processing with the electrocoagulation method

Great Voltage		*Kolmogorov-Smirnov*		
		Statistics	**Df**	**Sig. (ρ-value)**
Pb levels	Kontrol (0 Volt)	0.161	12	0.200
	6 Volt	0.148	12	0.200
	9 Volt	0.156	12	0.200
	12 Volt	0.196	12	0.200
Hg levels	Kontrol (0 Volt)	0.238	12	0.059
	6 Volt	0.137	12	0.200
	9 Volt	0.131	12	0.200
	12 Volt	1.170	12	0.200
Contact Time		*Kolmogorov-Smirnov*		
		Statistics	**Statistics**	**Statistics**
Pb levels	30'	0.283	12	0.009
	40'	0.215	12	0.131
	50'	0.223	12	0.103
	60'	0.202	12	0.192
Hg levels	30'	0.244	12	0.046
	40'	0.222	12	0.105
	50'	0.197	12	0.200
	60'	0.285	12	0.008

The results of the data normality test of Pb and Hg levels in water after processing using the electrocoagulation method with variations of 3 different electrical voltages, namely 16 volts, 20 volts, 24 volts and contact time for 30 minutes, 40 minutes, 50 minutes, and 60 minutes. The results of the data normality test of Pb and Hg levels in water at a detention time of 30 minutes, 40 minutes, 50 minutes, and 60 minutes after processing with the electrocoagulation method are shown in Table 3.

Table 4: Kruskal-Wallis Test Results, Pb and Hg Levels in Water after Processing by Electro-coagulation Method

Parameter	Variable	df	Asymp. Sig. (ρ-value)
Pb levels	**Contact Time**	2	0.040
	Great Voltage	2	0.000
Hg levels	**Contact Time**	1	0.027
	Great Voltage	1	0.000

Table 4. The results of testing the average difference in Pb and Hg levels in water after processing using the electrocoagulation method with 3 different electrical voltages, namely 16 volts, 20 volts, 24 volts and contact time for 30 minutes, 40 minutes, 50 minutes, and 60 minutes.

The results of the kruskal-wallis statistical test for the Asymp. Sig. (ρ) or the probability value of a hypothesis <0.05, which means that H0 is rejected. So it can be stated that there is an average difference between the Pb and Hg levels of industrial wastewater in the control sample with the levels of Pb and Hg after processing with the electrocoagulation method.

Discussion

Table 1, the results of measuring pb levels in water before and after processing using the electrocoagulation method show that there is a decrease in Pb levels in the water sample after processing using the electrocoagulation method with variable voltage variables varying respectively 16 volts, 20 volts, and 24 volts and a variable time. the contact was varied for 30 minutes, 40 minutes, 50 minutes, and 60 minutes.

The smallest average reduction in Pb levels occurred in treatments using 16 volts of electric voltage with a contact time of 30 minutes, namely 22.31% (2.663 ppm). While the largest percentage reduction in average Pb levels occurred in the processing of liquid waste samples using 20 volts of electric voltage and 60 minutes of contact time, which was 85.21% (0.490 ppm). Another study using the electrocoagulation method was proven to reduce COD concentrations to 99.18% at 60 minutes, a voltage of 10 volts with a distance of 3 cm between electrodes. While the average efficiency of decreasing COD concentration by electrocoagulation method reached 71.2695%.

The decrease in COD concentration in electrocoagulation was due to the oxidation and reduction processes in the electrocoagulation reactor. On the electrodes, oxygen and hydrogen gases are formed which will affect the reduction of COD [5]. Research with the same method also states, the most effective conditions in reducing ferrous and manganese concentrations with electric current of ± 2.5 A in 90 minutes. Effectivity in ferrous and manganese metal reduction was 98.7% and 99.6%, respectively. The final concentration of ferrous and manganese metal was 0.08 mg/L and 0.01 mg/L respectively. Optimum concentration of TSS reduction was 83.7% with the final concentration of 72 mg/L. The wastewater pH value became 7, 1.

Finally, the results demonstrated that the electrocoagulation process using aluminum electrode is a reliable technique for removal of pollutants from coal stockpile wastewater [6]. Electrocoagulation-flotation is an alternative method to classic chemical coagulation for many reasons. ECF is capable of reducing the need for chemicals due to the fact that the electrodes provide the coagulant.

However, many individuals still use chemical coagulants to attempt to enhance treatment [7]. Based on the results of this study and other studies, it can be concluded that the optimum voltage and time to reduce Pb metal in liquid waste by electrocoagulation method occurs in processing with an electric voltage of 20 volts with a contact time of 60 minutes.

Meanwhile, processing with a voltage of 24 volts and contact time of 30 minutes, 40 minutes, 50 minutes, and 60 minutes showed a decrease in removal efficiency in each observed time period. It is possible that saturation occurs in the electrocoagulation process at a voltage of 24 volts. Due to the saturation of the process, the decrease in Pb levels is not optimal and tends to be stagnant. For more details, here is a graph of the reduction in Pb levels in wastewater after processing using the electro-coagulation method [5, 6, 7].Based on Table 2, it is known that there is a decrease in Hg levels in the water sample after processing using the electrocoagulation method with a variable voltage with a voltage variation of 16 volts, 20 volts, and 24 volts and a variable contact time with time variations for 30 minutes, 40, minutes, 50 minutes, and 60 minutes.

The smallest average decrease in Hg levels occurred in the treatment using 16 volts of electrical voltage with a contact time of 30 minutes, namely 24.64% (2.226 ppm). Meanwhile, the largest percentage decrease in Hg levels on average occurred in the processing of liquid waste samples using 24 volts and 30 minutes of contact time, which was 83.58% (0.485 ppm). The reduction in Pb and Hg levels using the electrocoagulation method with aluminum electrodes comes from a redox reaction process where the anode (in acidic pH) will form the $Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e$ and the cathode will form $3H^{+}_{(aq)} + 3e^{-} \rightarrow 1{,}5H_{2\,(g)}$ after the anode and cathode react, a floc formation will occur which functions as a coagulant material that will bind Pb [8, 9, 10].

The decrease in Pb levels in wastewater treated using the electrocoagulation method is influenced by several factors, including: voltage and process contact time. According to [7, 10, 11], the quantity of reduction in heavy metal content in treated waste is influenced by the contact time where the longer the contact time, the more the decrease in metal content.

However, there is saturation of contact time where when the optimum condition has been reached; the decrease in the treated metal content will be stagnant. This is confirmed by the results of this study where the optimum contact time for reducing the Pb level is 60 minutes with a voltage of 24 V in an acidic pH state [12, 13].

Further studies are needed to determine whether after 60 minutes the electrocoagulation process is still optimal for reducing Pb levels in water [14]. The reduction in Hg levels in liquid waste that has been treated by the electrocoagulation method is in principle the same as the reduction in the levels of Pb pollutants. Namely through the process of forming a coagulant agent by the anode and cathode. According to [15] electro-coagulation with aluminum electrodes is effective in reducing Hg levels in drinking water. The levels of Hg will be removed by coagulant agents from the aluminum oxidation reduction process.

However, there are disadvantages from using similar electrodes, namely the formation of acidic chlorides and sulfates which will reduce the ability of coagulants to form over the length of time of contact, due to the influence of sulfates and chlorides that are formed [15, 16]. This is thought to have happened in this process when the contact time was given longer; there was no significant decrease in Hg levels. This is evidenced by the test results which state that the most effective treatment to reduce Hg levels in water is 30 minutes with a voltage of 24V.

Conclusion

The reduction of heavy metal levels in liquid waste is mostly done physically, chemically and biologically. This study conducted a test for the reduction of heavy metal content using the electrocoagulation method. The research used voltage parameters (16 Volt, 20 Volt, and 24 Volt) and contact time (30 minutes, 40 minutes, 50 minutes, and 60 minutes) and the type of electrode used was aluminum. It can be concluded that the electrocoagulation method with voltage (16 Volt, 20 Volt, and 24 Volt) and contact time (30 minutes, 40 minutes, 50 minutes, and 60 minutes) and the type of aluminum electrode, is very effective in reducing Pb and Hg in water.

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