PROCEEDING MICTOPH 3 (3) 2024
MICTOPH: MULAWARMAN INTERNATIONAL CONFERENCE ON TROPICAL PUBLIC HEALTH
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Effect of Voltage and Electrode Pair Variation on Acid Mine Drainage Effluent Using Electrocoagulation Method

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Abstrak

Kegiatan penambangan batubara dapat menghasilkan air asam tambang (AAT) dari kegiatan penambangan terbuka dan akan berdampak pada kualitas tanah dan air tanah. Salah satu metode penanganan AAT adalah elektrokoagulasi yang dinilai lebih ramah lingkungan. Penelitian ini dilakukan dalam skala laboratorium dengan menganalisis pengaruh variasi tegangan 20, 22, dan 24 V serta jenis pasangan elektroda pada metode elektrokoagulasi dengan plat Al—Al dan Al—C untuk mengetahui efektivitasnya dalam memurnikan AAT. Hasil yang diperoleh adalah semua variasi pengujian menunjukkan efisiensi yang baik, dimana untuk parameter TSS, Fe, dan Mn berkisar 89-99%, seiring dengan peningkatan pH dari kondisi asam menjadi netral. Penelitian ini juga menunjukkan bahwa penggunaan Al pada katoda cenderung menunjukkan hasil yang kurang optimal jika dibandingkan dengan jenis plat yang menggunakan C sebagai katoda-nya. Pengaruh tegangan dari metode elektrokoagulasi untuk menentukan seberapa cepat atau lambatnya terbentuknya flok, semakin besar tegangan yang dihasilkan maka hasil pengolahan akan semakin cepat terbentuk, begitu pula sebaliknya.

Kata Kunci: Air Asam Tambang (AAT), Elektrokoagulasi, Plat Elektroda, Tegangan

Abstract

Coal mining activities can produce acid mine drainage (AMD) from open pit mining activities and will impact soil and groundwater quality. One method for treating AMD is electrocoagulation, which is considered more environmentally friendly. This research was conducted on a laboratory scale by analyzing the effect of voltage variations of 20, 22, and 24 V and the type of electrode pair on the electrocoagulation method with Al—Al and Al—C plates to determine its effectiveness in purifying AMD. The results obtained are all test variations show good efficiency, where TSS, Fe, and Mn are around 89-99%, along with the increase of pH from acidic to neutral conditions. The study also shows that Al on the cathode tends to show less optimal results when compared to the kind of plate that uses C on the cathode. The effect of voltage from the electrocoagulation method to determine how fast or slow a floc will form, the greater the voltage produced, the faster the processing results will be formed, and vice versa.

Keywords: *Acid Mine Drainage (AMD), Electrocoagulation, Electrode Plate, Voltage*

INTRODUCTION

Coal mining activities can produce acid mine drainage (AMD) both in open mining (Fachlevi, 2015) and mining in coal processing units as well as piles of rocks, soil, or waste ecosystems (overburden) (Kamarullah, 2022; Kusdarini, 2024). The potential for the formation of acid mine drainage continues to occur both during mining and post-mining. Acid mine waste can dissolve metals, cause corrosion, make water toxic, and potentially be fatal (Fatmawati, 2017; Mahyuni, 2023). This potential must be known before mining activities begin operating so that environmental problems can be overcome with preventive efforts and do not become problems in the future (Nurdandi, 2017).

Mining activities using the open pit method can produce acid mine water due to sulfur elements originating from sulfide rocks that are oxidized by oxygen and then dissolved in water (Hirfan, 2016; Tandiarrang, 2016; Wahyudin, 2018; Saptawartono, 2024). In addition to active pits, acid mine water is formed from the reclamation and disposal areas. Overburden material that is moved to the disposal area or the reclamation area has the potential to contain iron sulfide (FeS) as pyrite material, and if this material is exposed to air, it will oxidize and form acid mine water which is then dissolved by rainwater that occurs in the area (Hirfan, 2016).

Acid mine drainage will impact both soil and groundwater quality because the pH in the area decreases very sharply (Wahyudin, 2018). The impacts resulting from this AAT include mining companies experiencing the impact of accelerated corrosive processes on equipment made of iron or steel so that equipment damage becomes faster which of course affects the company's finances. In biodiversity, the impact of this AAT is damaging the fauna and flora life systems that occur in mining areas, along with other impacts caused by AAT are the difficulty of increasing reclamation on ex-mining land because the quality of the soil and water is too acidic for plants to continue to grow and develop (Ashari, 2016; Rahmatullah, 2023).

The method commonly used to treat acid mine drainage in reducing heavy metals and turbidity is by using the coagulation method. An interesting coagulation method to be applied sustainably is electrocoagulation (Nurdandi, 2017). Electrocoagulation is an electrochemical water treatment method where active coagulants are released in the form of metal ions into the solution at the anode (Joning, 2022). At the cathode, an electrolysis reaction occurs in the form of the release of hydrogen gas (H_2) (Putri, 2023). Electrolysis is the process of decomposing an electrolyte by an electric current in an electrolysis cell that occurs, namely electrical energy is converted into chemical energy by flowing an electric current into a solution or electrolyte melt (Joning, 2022). Electrocoagulation can precipitate particles dissolved in water using electrical energy with a direct current (Wiyanto, 2014; Joning, 2022; Putri, 2023).

The removal of pollutants by the electrocoagulation process has several factors that influence it, namely the density

E-ISSN: xxx-xxx
Universitas Mulawarman, Samarinda, November 22, 2024

of the electric current, the contact time of the water with the electrode plate, voltage, pH, plate thickness, and the distance between electrodes (Nuradi, 2017; Fauzi, 2019; Putri, 2022; Anugrah, 2024; Waryati, 2024). According to Rasman (2018), a voltage of 20 V can reduce the most optimum iron (Fe) levels, which is 99.74%. According to Rasman (2018), a voltage of 20 V with a distance of 2 cm can reduce TSS levels with an efficiency of 99.64% and pH levels with results reaching 9.8. The contact time used in this study was 45 minutes, this was determined based on research by Fitriah (2022), that heavy metals can be effectively reduced at a contact time of 45 minutes. In electrochemical processing through domestic wastewater, carbon electrodes are used to reduce COD and TSS. The reduction using carbon electrodes on COD and TSS was 55.0% and 44.0%, respectively (Hamid, 2014).

Metals that have a high reduction potential will more easily release electrons in the electrolysis process. The release of more electrons will increase the number of metal ions produced. More metal ions will produce more flocs (Pauzi, 2018). According to Rahman (2021), carbon is used as a cathode. After all, carbon is an inert electrode that does not react to electrolysis because inert carbon does not react with organic waste and electrolytes so what will experience reduction at the cathode is the water. Research on the use of carbon electrodes in the electrocoagulation process in the processing of acid mine water waste has never been done.

Therefore, this study aims to determine the effect of variations in the type of electrode pairs and voltage variations on the pH, TSS, Fe, and Mn values contained in acid mine water and to determine the effect of voltage variations using electrocoagulation on the pH, TSS, Fe, and Mn values contained in acid mining water.

METHOD

This study was carried out based on the research design which functions as a general guide to carry out the experiments from start to finish. As for the research design, it can be seen in Figure 1.

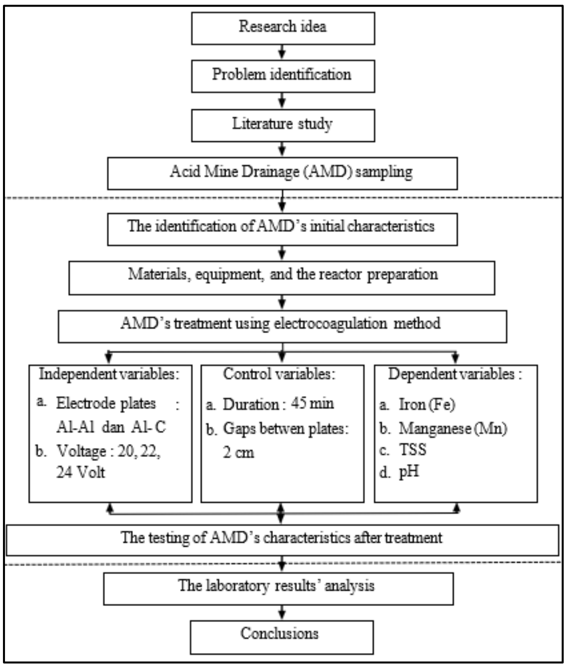

Figure 1. The Research Design of This Study

This research was conducted for 4 months from May – August 2024 in several locations, which are PT. X as the AMD's sampling location at Gerbang Dayaku Bakungan St., Loa Janan, Kutai Kartanegara. Sample research and testing of acidity levels (pH) and Total Suspended Solids (TSS) were conducted at the Environmental Technology Laboratory of the Faculty of Engineering, Mulawarman University. As for the testing of Iron (Fe) and Manganese (Mn) metals, it was conducted at the Bestari Nature Laboratory, Samarinda, East Kalimantan.

The research variables consist of independent, dependent, and control variables. The independent variables are the electrode plates (Al-Al and Al-C) and the voltage from the DC power supply (20, 22, and 24 V). For the dependent variables, there are pH, TSS, iron (Fe), and manganese (Mn). As for the control variables, there are the gap between plates (about 2 cm) and the duration of the electrocoagulation process (45 min). Based on the independent variables, there are 6 different reactors used in this experiment. For the details of the experiment, it can be seen in Table 1.

Table 1. The Research Variables in AMD's Treatment using Electrocoagulation Method

Dimension (cm)	Gap between plates (cm)	Plate(s)	Voltage (V)	Reactor
10 x 2	2	Al-Al	20	A
			22	B
			24	C
		Al-C	20	D
			22	E
			24	F

Sampling was done using the grab sampling method, used when sampling is taken directly from the inlet being monitored. This sample is used in the electrocoagulation method process and for sample testing to describe the characteristics of parameters in the acid mine water contents so that the amount of water sample taken is 5000 mL (5 L). Water sampling using research jerrycans. Water sampling should use a container treated with prior treatment so that the container is free from the influence of contaminants that are not physically visible.

After all the materials and equipment needed were gathered, the next step was to construct the electrocoagulation reactor by assembling some of the materials and equipment, along with connecting the electrode plates with the DC power supply. The illustrations of the reactor can be seen in Figure 2.

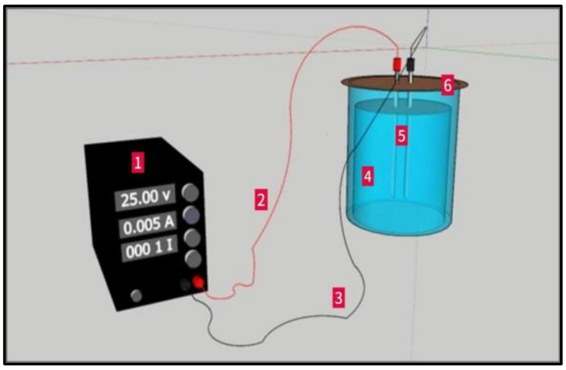

Figure 2. The Electrocoagulation Reactor for AMD's Treatment

After all the experiments were done, the treated water was put into the sample bottle for testing the water's characteristics based on the dependent variables which were determined in the previous paragraphs. The measurement of pH from the sample water was carried out electrometrically using a pH meter based on SNI-06-6989.11:2004. Measurement of TSS of sample water was carried out using the gravimetric method based on SNI 6989.3:2019. Testing of Iron (Fe) and Manganese (Mn) metal levels contained in acid mine water using Atomic Absorption Spectrometry (AAS) spectrophotometer based on SNI 6989.3:2019. Then, the data from laboratory experiments was collected for further analysis to determine the effectiveness of the electrocoagulation method by comparing the water quality before and after the treatment. The analysis was also carried out to compare the water quality after the treatment with the East Kalimantan Regional Regulation Number 02 of 2011 concerning Water Quality Management and Water Pollution Control, wastewater quality standards for coal mining activities.

RESULT AND DISCUSSION

In this study, the wastewater used was acid mine drainage from PT. X. The mining location of PT. X is located on Jalan Gerbang Dayaku Bakungan, Loa Janan, Kutai Kartanegara Regency. Acid mine drainage formed at mining locations generally has a low pH (<6) which is affected by the opening of the potential acidity of the rocks. The quality parameters of acid mine drainage measured include pH, Total Suspended Solid (TSS), Iron (Fe), and Manganese (Mn). The results of the initial parameter tests of acid mine drainage are in Table 2 below.

Table 2. The Research Variables in AMD’s Treatment using Electrocoagulation Method

No	Parameter	Unit	Value	Standard Quality
1.	pH	-	6,1	6-9
2.	TSS	mg/L	616	300
3.	Iron (Fe)	mg/L	1,45	7
4.	Manganese (Mn)	mg/L	0,03	4

Based on Table 2, the results of the initial characteristic test show that the results of the acid mine water samples on some parameters are based on East Kalimantan Regional Regulation Number 02 of 2011 concerning Water Quality Management and Water Pollution Control, wastewater quality standards for coal mining activities. The dissolved metal content in acid mine water makes the physical condition of the water cloudy. The brownish color of acid mine water is a physical indication of water that the low pH content can dissolve the heavy metals. The acid mine water used comes from the sump which is then pumped to the settling pond. This can be seen in Figure 3 and 4.

Figure 3. The Initial Condition of AMD from PT. X

Figure 4. Sampling of AMD from PT. X

Based on the research that aims to analyze the effect of voltage variations and types of electrode pairs with aluminum (Al) and carbon (C) plates on the electrocoagulation method, the research conducted can determine the results of efficiency in processing acid mine water waste. This research was conducted on a laboratory scale using acid mine water samples processed using the electrocoagulation method as much as 600 ml for 6 samples with variations of carbon and aluminum electrodes and voltage variations of 20, 22, and 24 volts. The electrodes used in this method are aluminum (Al)-aluminum (Al) and aluminum (Al)-carbon (C) plates with dimensions of 10 x 2 cm. Testing of iron (Fe) and manganese (Mn) parameters after processing was carried out at PT Laboratorindo Alam Bestari. For pH and total suspended solid (TSS) parameters, independent testing was carried out at the Environmental Technology Laboratory, Faculty of Engineering, Mulawarman University.

The first parameter to be analyzed is pH value. Based on the results of the analysis of the pH concentration value after the processing of acid mine water, the level of effectiveness of the processing applied to the electrocoagulation method can be known. The measurement results can be seen in Table 3.

Table 3. The Results of the pH Value Testing

Treatment			Voltage	pH Value	
Time (min)	Gap (cm)	Electrode Plate		Before	After
45	2	Al-Al	20	6,1	6,5
			22		6,7
			24		6,9
		Al-C	20		6,9
			22		7
			24		7,1

From the laboratory test results in Table 3, a graph was made to see the changes in pH values produced in acid mine water after processing using the electrocoagulation method, which can be seen in Figure 5 and 6.

Post-processing tests were carried out on the pH of the acid mine water samples, which were carried out at the Environmental Technology Laboratory, Mulawarman University. This test was carried out to determine the acidity level of the sample. The pH value before processing was obtained at 6.1 and the pH value after processing was obtained at a range of 6-7.1. Measurement of pH values using acid mine water with the electrocoagulation method in each variation using a pH meter with a test method based on SNI 6989:1 in 2019. The pH measurement using this pH meter aims to compare the pH values before and after processing with the electrocoagulation method. From the results after electrocoagulation treatment, a pH value test was carried out using an Al-Al plate with consecutive voltages of 20, 22, and 24 volts. The results obtained from a voltage of 20 V were 6.5, a voltage of 22 V was 6.7, and a voltage of 24 V was 6.9. In the processing of acid mine water using the electrocoagulation method for pH value testing using Al-C plates, the voltage used in this method is respectively 20, 22, and 24 volts. The results of the pH value test at a voltage of 20 V are 6.9, at a voltage of 22 V is 7, and at a voltage of 24 V is 7.1.

The reason for increasing pH value in electrocoagulation treatment is because the higher the voltage, the more OH^- ions are produced. Ions that can affect the acidity and alkalinity of air are OH^- ions and H^+ ions (Zusagka, 2014). OH^- ions that are not bound to Al^{3+} ions can cause the air pH to become alkaline. Therefore, the higher the voltage, the more alkaline the air pH will become.

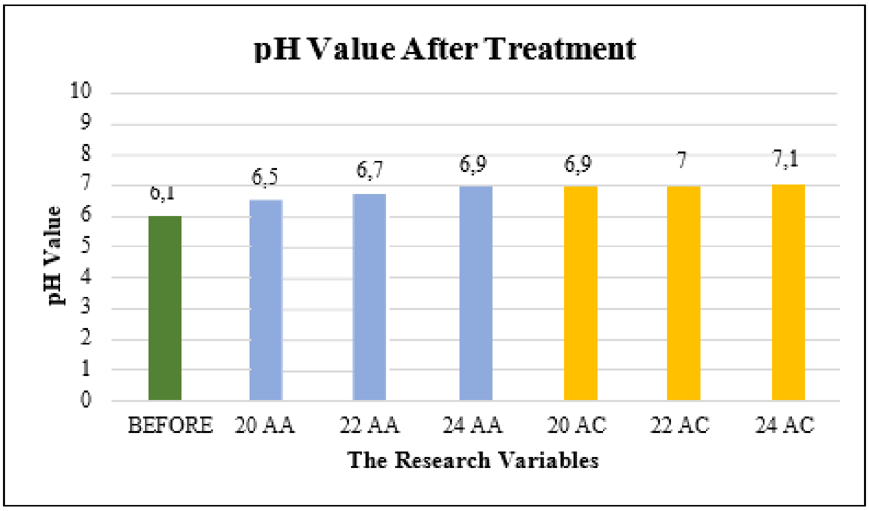

Figure 5. Comparisons of pH Value Before and After Treatment

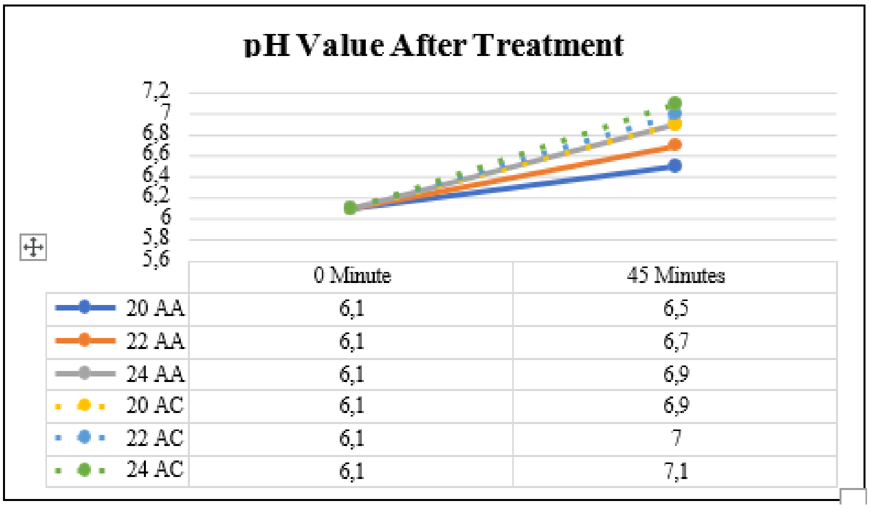

Figure 6. The Trendline of pH Value based on Experiment Time

The next parameter is the Total Suspended Solid (TSS). Based on the results of the analysis of TSS concentration values after the processing of acid mine water, the level of effectiveness of the processing applied to the electrocoagulation method can be seen. The measurement results can be seen in Table 4

Table 4. The Results of the TSS Testing

Treatment			Voltage	TSS Concentration (mg/L)		
Time (min)	**Gap (cm)**	**Electrode Plate**		**Before (mg/L)**	**After (mg/L)**	**Removal Efficiency (%)**
45	2	Al-Al	20	616,67	64	89,63
			22		55	91,08
			24		46	92,54
		Al-C	20		41	93,35
			22		29,5	95,22
			24		19,5	96,84

Based on the analysis of laboratory test results in Table 4, a graph was made to see the changes in TSS values produced in acid mine water after processing using the electrocoagulation method, which can be seen in Figure 7.

Same as before, the post-processing testing was carried out on TSS on acid mine water samples at the Environmental Technology Laboratory, Mulawarman University, with the purpose to see changes in suspended materials that cause water turbidity from the sample. The TSS value before processing was obtained at 616.67 mg/L and the TSS value after processing was obtained at a range of 19.5 - 64 mg/L. Measurement of TSS values using acid mine water with the electrocoagulation method in each variation using the gravimetric method with a test method based on SNI 6989.3 in 2019. TSS measurements based on this SNI aim to compare TSS concentrations before and after processing with the electrocoagulation method as the main component of water quality degradation that causes physical, chemical, and biological changes (Rinawati, 2016). Based on the processing results, a TSS concentration test was carried out using an Al-Al plate with consecutive voltages of 20 V, 22 V, and 24 V. The results obtained from a voltage of 20 V were 64 mg/L, a voltage of 22 V was 55 mg/L, and at a voltage of 24 V was 46 mg/L. The TSS concentration obtained from the solution tended to decrease with each increase in voltage used. In the processing of acid mine water using the electrocoagulation method for the TSS concentration test using an Al-C plate, the voltages used in this method were respectively 20, 22, and 24. The results of the TSS concentration test at a voltage of 20 V were 41 mg/L, at a voltage of 22 V was 29.5 mg/L, at a voltage of 24 V was 19.5 mg/L. Changes in TSS concentration were caused by a decrease in solids, both organic and inorganic. According to Sihombing (2022), this is because the higher the current strength indicates the greater amount of electricity flowing into the acid mine water waste, which means that the number of substances produced at both electrodes is greater. The dissolution of the Al electrode at the anode into Al^{3+} and the decomposition of water at the cathode into hydroxide ions (OH^-) which are increasingly larger will form $Al(OH)_3$, which will form a larger coagulant, and the number of pollutants deposited will also increase in reducing the Total Suspended Solid (TSS) levels.

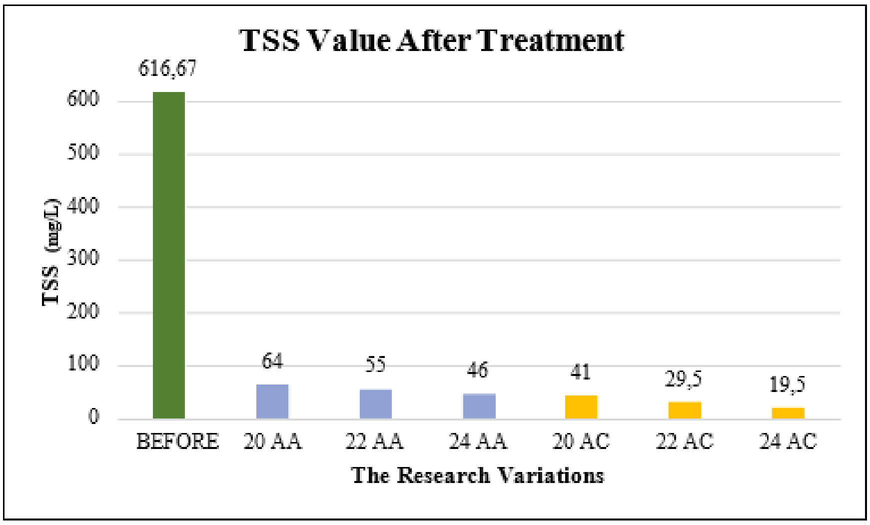

Figure 7. Comparisons of TSS Concentration Before and After Treatment

In this study, the TSS concentration test of acid mine water using the electrocoagulation method for TSS parameters resulted in significant removal after the processing process. The TSS content after the processing process obtained the lowest efficiency value of 89.63% on the Al-Al plate with a voltage of 20 V while the highest efficiency value was 96.84% on the Al-C plate with a voltage of 24 V. Based on the TSS efficiency obtained after processing, the results obtained have met the quality standards of the East Kalimantan Provincial Regulation No. 02

of 2011. The graph for the comparison of removal efficiency between research variables can be seen in Figure 8.

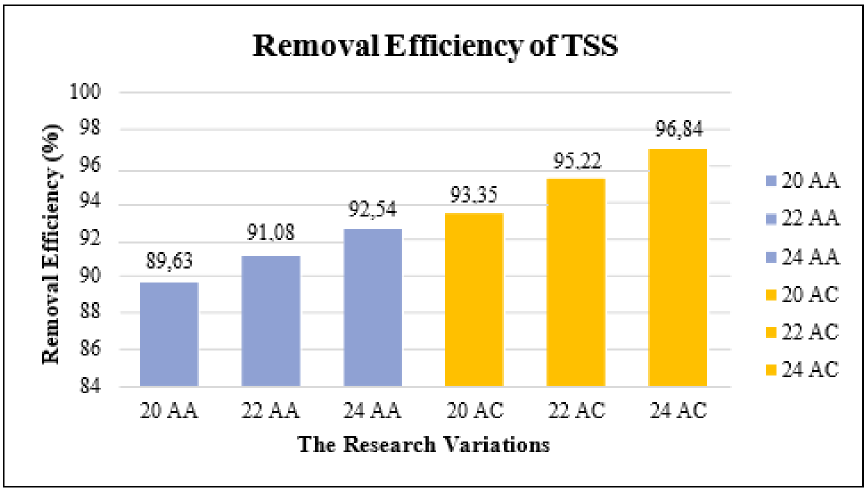

Figure 8. The Removal Efficiency of TSS Concentration based on the Research Variables

Now, we are entering the other parameter, which is the presence of Fe in the water. Based on the results of the analysis of the Fe concentration value after the processing of acid mine water, the level of effectiveness of the processing applied to the electrocoagulation method can be known. The measurement results can be seen in Table 5.

Table 5. The Results of the Fe Testing

Treatment			Voltage	Fe Concentration (mg/L)		
Time (min)	Gap (cm)	Electrode Plate		Before (mg/L)	After (mg/L)	Removal Efficiency (%)
45	2	Al-Al	20	1,45	< 0,09	99,87%
			22		< 0,09	99,87%
			24		< 0,09	99,87%
		Al-C	20		< 0,09	99,87%
			22		< 0,09	99,87%
			24		< 0,09	99,87%

Based on the analysis of laboratory test results in Table 5, a graph was made to see the changes in Fe values produced in acid mine water after processing using the electrocoagulation method, which can be seen in Figure 9.

From the laboratory tests, post-treatment testing was carried out on Fe on acid mine water samples at the Environmental Technology Laboratory, Mulawarman University. This test was carried out to see changes in the metal content of the water from the sample. The

Fe value before processing was 1.45 mg/L and the Fe value after processing was <0.09 mg/L. Measurement of the Fe value in acid mine water used the Atomic Absorption Spectrometry (AAS) method based on SNI 6989.3 in 2019. The measurement of Fe based on this SNI aims to compare the concentration of Fe before and after processing using the electrocoagulation method. Then, based on the processing results, Fe concentration tests were carried out using Al-Al plates and Al-C plates with voltages of 20, 22, and 24 respectively. The results obtained from a voltage of 20 V were <0.09 mg/L, a voltage of 22 V was <0.09 mg/L, and at a voltage of 24 V was <0.09 mg/L. The concentration of Fe obtained from the solution reached the lowest level at each increase in the applied voltage. This is because the addition of coagulants to the electrocoagulation process can disrupt the stability of metal ions that cannot precipitate on their own. The stability of metal ions is disrupted by the addition of coagulant materials (Ningsih, 2022). Coagulants form small flocs that combine into larger flocs through the flocculation process. The coagulants formed bind to metal ions causing instability so that the particle charge becomes neutral. When the resulting floc increases, its mass increases and settles at the bottom (Afdal, 2020).

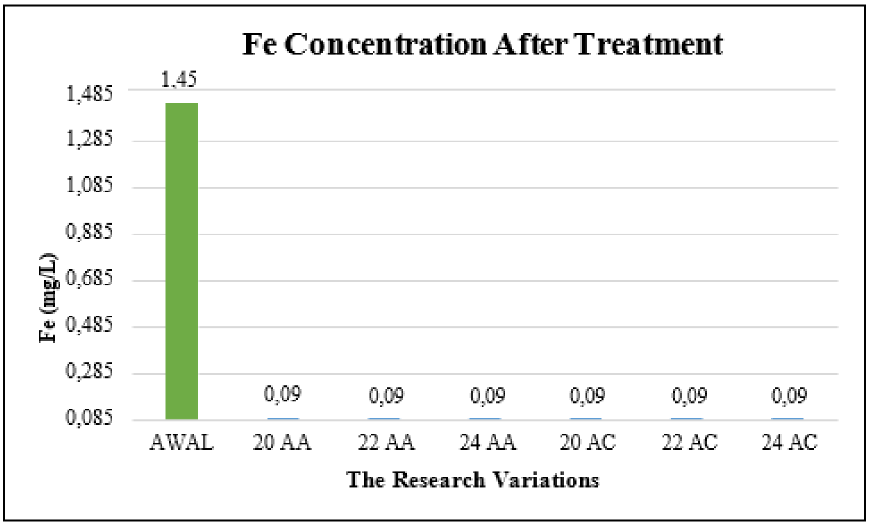

Figure 9. Comparisons of Fe Concentration Before and After Treatment

In this study, testing the Fe concentration of acid mine water using the electrocoagulation method for the Fe parameter, there was a significant removal after the processing process. The Fe content after the processing process obtained the highest efficiency value of 99.87% on the Al-Al plate and Al-C plate with a voltage of 20, 22, and 24 volts. Based on the Fe efficiency obtained after processing, the results obtained have met the quality standards of the East Kalimantan Provincial Regulation No. 02 of 2011. The graph for the comparison of removal efficiency between research variables can be seen in Figure 10.

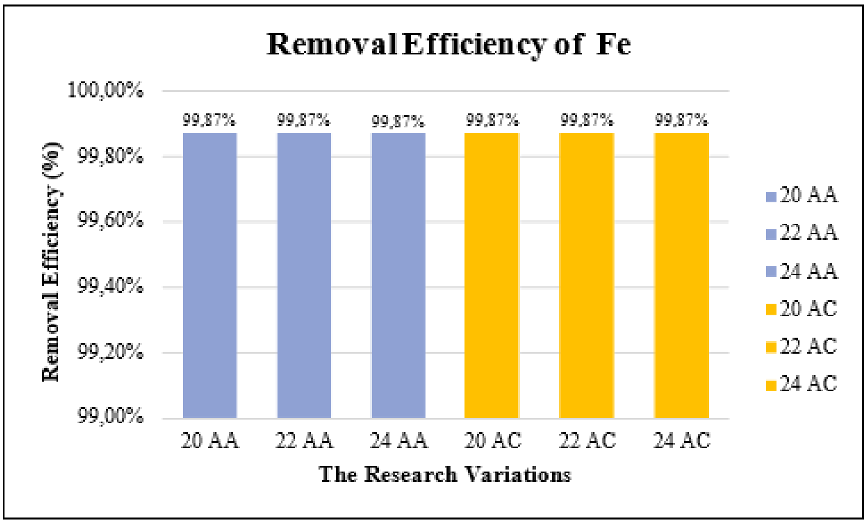

Figure 10. The Removal Efficiency of Fe Concentration based on the Research Variables

Based on the final test results obtained, the Fe value at a voltage of 20, 22, and 24 volts on the aluminum-carbon and aluminum-aluminum electrodes, the same high efficiency results were obtained, which can be seen in Table 5. The difference in efficiency between the use of aluminum-aluminum and aluminum carbon is not clearly visible, this is because the initial characteristics of the Fe content in acid mine water are below the quality standard, so that the removal efficiency obtained is 99.87% at each voltage used. The final concentration value reading reached the lowest value, so that the calculated value obtained from the formula used was <0.09 mg/L from the initial characteristic value of 1.45 mg/L.

The last one is the Mn parameter. Based on the results of the analysis of Mn concentration values after the processing of acid mine water, the level of effectiveness of the processing applied to the electrocoagulation method can be known. The measurement results can be seen in Table 6.

Table 6. The Results of the Mn Testing

Treatment			**Voltage**	**Mn Concentration (mg/L)**		
Time (min)	**Gap (cm)**	**Electrode Plate**		**Before (mg/L)**	**After (mg/L)**	**Removal Efficiency (%)**
45	2	Al-Al	20	0,03	< 0,03	99,99%
			22		< 0,03	99,99%
			24		< 0,03	99,99%
		Al-C	20		< 0,03	99,99%
			22		< 0,03	99,99%
			24		< 0,03	99,99%

Based on the analysis of laboratory test results in Table 6, a graph was made to see the changes in Mn values produced in acid mine water after processing using the electrocoagulation method, which can be seen in Figure 11.

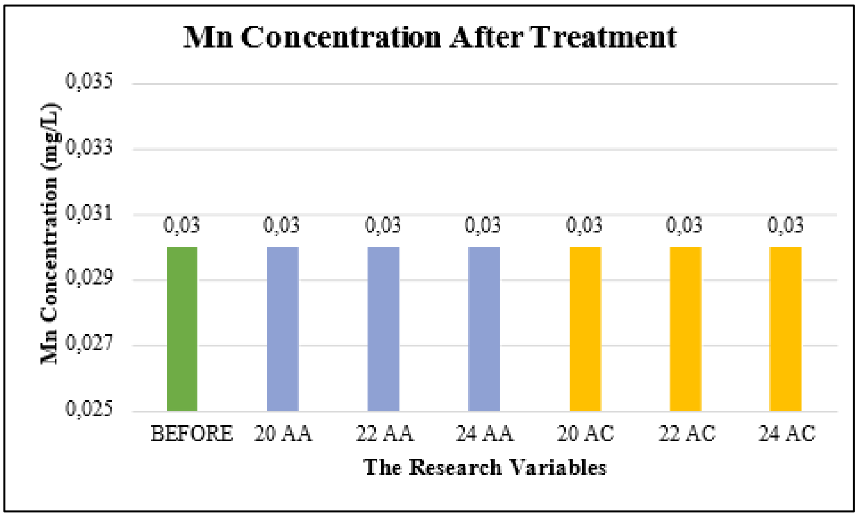

Figure 11. Comparisons of Mn Concentration Before and After Treatment

From the laboratory tests, post-processing testing was carried out on Mn on acid mine water samples at the Environmental Technology Laboratory, Mulawarman University. This test was carried out to see changes in the metal content of the water from the sample. The Mn value before processing was obtained at 0.03 mg/L and the Mn value after processing was obtained at <0.03 mg/L. Measurement of the Mn value in acid mine water used the Atomic Absorption Spectrometry (AAS) method based on SNI 6989.3 in 2019. The purpose of measuring Mn based on this SNI is to compare the Mn concentration before and after processing using the electrocoagulation method. Based on the processing results, an Mn concentration test was carried out using Al-Al plates and Al-C plates with voltages of 20, 22, and 24 volts respectively. The results obtained from a voltage of 20 V were <0.03 mg/L, a voltage of 22 V was <0.03 mg/L, and a voltage of 24 V was <0.03 mg/L. The concentration of Mn obtained from the solution reached the lowest level at each increase in applied voltage. As for the reason why the Mn concentration can be reduced, it is the same reason as the Fe concentration, which is the addition of coagulants to the electrocoagulation process can disrupt the stability of metal ions that cannot precipitate on their own. Although, there is a possibility that it is because the acid mine water comes into contact with air so the amount of dissolved oxygen in the acid mine water increases. Sufficient oxygen content can oxidize Mn (II) ions in the acid mine (Li, 2019).

In this study, the concentration of Mn in acid mine water using the electrocoagulation method for the Mn parameter, there was a significant removal after the processing process. The Mn content after the processing process obtained the highest efficiency value of 99.99% on the Al-Al plate and Al-C plate with a voltage of 20,22, and 24. Based on the Mn efficiency obtained after processing, the results obtained have met the quality standards of the East Kalimantan Provincial Regulation No. 02 of 2011. The graph for the comparison of removal efficiency between research variables can be seen in Figure 12.

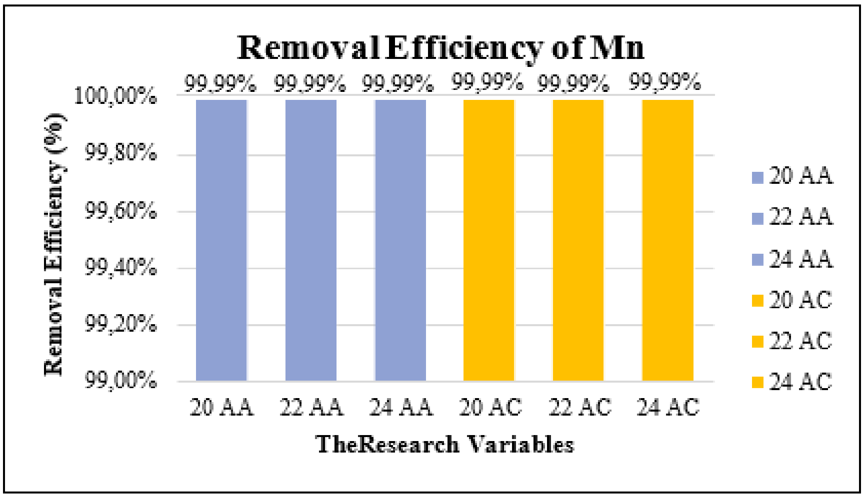

Figure 12. The Removal Efficiency of Mn Concentration based on the Research Variables

Based on the final test results obtained, the Mn values at 20, 22, and 24 volts on the aluminum-carbon and aluminum-aluminum electrodes, the same high efficiency results were obtained, which can be seen in Table 6. The difference in efficiency between the use of aluminum-aluminum and aluminum carbon is not clearly visible, this is because the initial characteristics of the Mn content in acid mine water are below the quality standard, so that the removal efficiency obtained is 99.99% at each voltage used. The final concentration value reading reached the lowest value, so that the calculated value obtained from the formula used was <0.03 mg/L from the initial characteristic value of 0.03 mg/L.

CONCLUSION

Based on the research using the electrocoagulation method, the following conclusions can be drawn are: **a.)** The type of plate that uses aluminum on the cathode tends to show less optimal results when compared to the type of plate that uses carbon on the cathode. Based on the processing carried out, the physical conditions obtained were that processing with aluminum tended to look cloudier, and **b.)** The effect of voltage from the electrocoagulation method as a determinant of how fast or slow a floc will form, the greater the voltage produced, the faster the processing results formed, conversely, the smaller the voltage produced, the slower the processing results formed.

It is better for further research to reduce the contact time used, because in this study the water looks quite clear before reaching the specified contact time. It is better for further research to consider a larger distance variable so that it is more efficient in terms of cost. In further research, it is also better to take more representative sampling so that the analysis results can be accounted for.

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