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Application of Electrocoagulation in Soymilk Wastewater Treatment Process with Variation of Time and Voltage

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ABSTRACT

Processing of soymilk liquid waste is carried out using the batch system electrocoagulation method. Variations in processing time are 20, 40, 60, 80, 100, and 120 minutes. The plate used is an aluminum plate measuring 10×5 cm. The electrode distance was 2 cm with an electrical voltage of 10 and 30 volts. The results of this research show that the best electrocoagulation process can reduce COD levels by 64.70%, TSS by 72.90% and increase the pH value to 5.17, however COD, TSS and pH levels are still above standard quality. Initial analysis results of soymilk wastewater with pH 4.06, COD 34408 mg/L, TSS 1550 mg/L, DO 0.30 mg/L, DHL 1090 µS/cm and Al 54.95 mg/L. After carrying out the electrocoagulation process, the pH value was 5.17, COD 12144 mg/L, TSS 420 mg/L, DO 0.37 mg/L, DHL 648 µS/cm and Al 231.33 mg/L at a voltage of 30 V with time. electrocoagulation 120 minutes.

Keywords: Electrocoagulation**,** Wastewater, Soymilk

1. INTRODUCTION

Soy milk is a drink produced using soybeans. The protein content in soy milk is almost the same as cow's milk, namely around 3.5 g/100 g [1]. This soy milk is generally produced by industrial and household scale industries and can produce liquid waste, which causes bad effects on the environment if it is not processed properly.

Wastewater is water that is dirty in general, starting from residential areas, factory environments, water on the ground, households, water on the surface and various other wastes. Currently, waste handling systems in the dairy industry that are widely used include aeration systems, modified activated sludge, irrigation, and ponds [2]. However, the waste processing process using this system is quite complicated, requires chemicals and large areas of land. In this study, the electrocoagulation method was chosen for handling liquid waste because it is simple and efficient.

This electrocoagulation method has the advantage that it does not need to add other chemicals and has a high efficiency value [3]. Electrocoagulation is providing an electric current to waste management techniques using coagulation and flocculation [4]. Applications with this electrocoagulation system have been used to treat various liquid wastes, including in the textile industry, palm oil mills, tofu industry and palm sago liquid waste.

2. METHODS

This research used waste samples, namely soy milk obtained from soymilk sellers in Cibinong Bogor, West Java. This soy milk has expired and is no longer used and is generally thrown away by sellers and most sellers throw it directly into the environment without prior processing so that if this continues to be done it will pollute the environment. So, this research was carried out to be useful as a reference source regarding other simple liquid waste processing alternatives that can be applied to dealing with soymilk liquid waste. The soymilk liquid waste processing process uses the electrocoagulation method, which is a method that uses electric current to agglomerate and settle fine particles in the wastewater. The wastewater is first diluted 1:3 and then the pH is adjusted first. A total of 1000 mL of sample was poured into a 1-liter beaker, and 2 aluminum electrode sheets were also put into the

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beaker. The advantages of this aluminum plate are that aluminum is a good electrical conductor, rust resistant, easy to obtain and can also be used as a coagulant. Analysis is carried out before and after wastewater treatment by measuring earlier parameters, namely COD, TSS, DO, pH, DHL and Al. Processing of soymilk liquid waste is carried out using varying processing times of 20, 40, 60, 80, 100 and 120 minutes. This variation was chosen to determine the optimum electrocoagulation time in reducing COD and TSS and increasing the pH value. According to research by Sinaga, the optimum COD removal at a distance of 2 cm is 76.36%, the optimum TSS removal is 85.16% and increases the pH value from 3.87 to 6.31 in liquid waste from the tofu industry [5]. So, in this study a distance of 2 cm was used the specified electrode distance is 2 cm using an electrical voltage of 10 and 30 volts. Each experiment was repeated 2 times so that there were 24 experiments. The analysis was carried out twice so that not too much laboratory waste was produced. Then the water quality resulting from each electrocoagulation is measured for the same parameters as before the electrocoagulation process, namely the parameters COD, TSS, DO, pH, DHL, and Al.

2.1. Tool

The tools used in this research are a timer, DC Power Supply, cable, crocodile clamp, Whatman filter paper (Grade 934 AH) pore size 1.5 µm, desiccator, oven (memmert), analytical balance (Ohaus), porcelain cup, tongs, vacuum pump, 100 mL volumetric flask, 1000 mL volumetric flask, 2 mL measuring pipette; 5 mL; 10 mL; 20 mL; 30 mL; 40 mL; and 50 mL, 1000 mL beaker; 250 mL beaker; 100 mL beaker, Erlenmeyer, 5 cm diameter watch glass, glass funnel, burette, dropper pipette, DO meter (Lutron DO-5509), pH meter (Hach), conductometer (Mettler Toledo), 10×5 cm aluminum plate, tube container, reflux tube. The instrument used was an atomic absorption spectrophotometer (Agilent 240 FS, series 200 AA (flame)).

2.2. Material

The materials used in this research were liquid soy milk waste samples, distilled water, digestion solution ($K_2Cr_2O_7$) 0.1 N, standard solution of Potassium Hydrogen Phthalate/KHP ($C_8H_5KO_4$) ~ COD 500 mg O_2/L, sulfuric acid reagent solution (concentrated Ag_2SO_4 and H_2SO_4), 0.05 M Ferro Ammonium Sulfate solution, ferroin indicator solution, pH 4, 7 and 10 buffer solution, DHL standard solution namely 0.01 M KCl standard solution, acetylene gas, nitric acid (HNO_3^-), hydrochloric acid and acetic acid.

2.3. Analysis Procedure

2.3.1. Chemical Oxygen Demand (COD) Analysis

COD Analysis Based on SNI 6989.73:2009 is the amount of $Cr_2O_7^{2-}$ oxygen that reacts with the test sample and is expressed as mg O_2 for every 1000 mL of test sample. A 10 mL sample was placed in a tube and then 6 mL of digestion solution with a concentration of 0.1 N and 14 mL of sulfuric acid reagent solution were added. Then the tube was closed and shaken gently until homogeneous, refluxed for 2 hours at a temperature of 150℃. After 2 hours the solution in the tube was cooled to a normal temperature of ± 25℃, the sample was then transferred to an Erlenmeyer flask, 1 drop - 2 drops of ferroin indicator was added and titrated with a 0.05 M FAS standard solution until a clear color change occurred from green-blue to reddish brown [6].

2.3.2. Total Suspended Solid (TSS) Analysis

Suspended solids analysis is based on SNI 06-6989.3-2004. In principle, the homogeneous sample is filtered using filter paper that has been weighed. The residue retained on the filter is heated in the oven for 1 hour until it reaches a constant weight at a temperature of 103℃ to 105℃. Then it is cooled in a desiccator and then weighed [7].

2.3.3. Dissolved Oxygen (DO) Measurement

Before the processing process is carried out, a few liquid soybean milk wastewaters have their dissolved oxygen measured first using a DO meter. First, the DO meter undergoes a calibration process, namely by leaving the probe that has been turned on in the air and waiting until the reading is stable, after that press the CAL/Esc button. Samples of liquid soymilk waste were put into a 100 mL glass cup. The probe is then immediately dipped into the sample where the dissolved oxygen value will be measured, wait until the reading is stable then the digital system number will appear, and the value listed is the DO value contained in the sample.

2.3.4. pH measurement

Based on SNI 06-6989.11-2004, pH measurement uses a pH meter based on the principle of measuring hydrogen ion activity potentiometrically. The tool used was first calibrated at pH 4, 7 and 10. The soymilk wastewater sample was put into a 100 mL glass cup. The electrode is inserted into the sample until the pH meter shows a stable number. The value that appears is the value of the sample pH [8].

2.3.5. Measurement of Electrical Conductivity

Based on SNI 06-6989.1-2004, the measurement of the electrical conductivity of the sample to be measured is carried out using a conductometer electrode and potassium chloride (KCl) as a standard solution. Calibrate the conductometer first using a standard solution of 0.01 M KCl and adjust it until it shows 1413 μmhos/cm. A total of 100 mL of soymilk waste sample is put into a glass cup, then dip the electrode to measure the sample you want to know until the conductometer shows a stable reading. The number that appears is the value of the electrical conductivity of the sample [9].

2.3.6. Determination of Aluminum Content

Aluminum content measurement is based on SNI 6989.34-2009. This test method is used to determine aluminum levels in water and wastewater using atomic absorption spectrophotometry in the range of 5.0 mg/L to 100.0 mg/L at a wavelength of 309.3 nm. Put a 100 mL test sample that has been shaken until homogeneous into a glass cup. Add 2 mL of HCl (1:1) and heat the test sample solution until almost dry. After that, the test sample solution resulting from the work was transferred quantitatively into a 100 mL measuring flask through filter paper. Then the absorption was measured using AAS [10].

3. RESULTS AND DISCUSSION

3.1. First analysis

Initial analysis carried out before waste processing using the electrocoagulation method includes COD, TSS, DO, pH, DHL, and Aluminum content. The initial waste sample is diluted 1:3 (waste sample: water) first. Results can be seen in table 1.

Table 1. Results of Initial Analysis of Soymilk Liquid Waste After Dilution

Parameter	Unit	Quality standards*)	Analysis results
COD	mg/L	300	34408
TSS	mg/L	200	1550
DO	mg/L	-	0,30
pH	-	6-9	5,01
DHL	μS/cm	-	1090
Al content	mg/L	-	54,95

*) Minister of Environment Regulation no. 5 th 2014

Based on the analysis results in table 1, the characteristics of the initial soymilk liquid waste exceed the quality standards based on the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014 concerning Wastewater Quality Standards for soybean processing businesses and/or activities. The high COD value is likely caused by water pollution from organic substances such as carbohydrates and proteins contained in soy milk that has expired and the protein structure has been damaged by microorganisms. The low DO value is probably caused by the high organic material content of liquid soy milk which generally contains a lot of nutrients and when it has expired becomes a good growth medium for bacteria. These bacteria use oxygen to carry out biodegradation so that there is less dissolved oxygen. The emulsion form in soy milk may be one of the causes of high TSS levels. This form of emulsion has the characteristics of low stability in soy milk, is difficult to dissolve and can experience precipitation. So the organic substances in soy milk, namely carbohydrates and proteins which have colloidal properties, cause high TSS. The low pH of wastewater

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is likely caused by wastewater which has high levels of organic materials such as carbohydrates, proteins and amino acids which are then fermented by acidogenic bacteria. The high levels of Al in soy milk are probably caused by the previous addition of the type of soybeans used, because it is known that several types of soybeans contain high levels of Al for plant growth in acidic soil [11].

The characteristics of the initial soymilk liquid waste are that it is concentrated and then several initial conditioning stages are carried out before electrocoagulation is carried out, namely by dilution, pH adjustment and decantation.

3.2. Pattern of Changes in COD Levels in Soymilk Liquid Waste

COD analysis is an analysis that aims to determine the amount of organic material contained in liquid waste. Chemical Oxygen Demand is the amount of oxygen needed for a material in water so that it can be oxidized through chemical reactions and organic waste materials will be oxidized by potassium dichromate which is used as an oxygen source [12]. The results of the analysis of COD levels in soymilk wastewater can be seen in Figure 1.

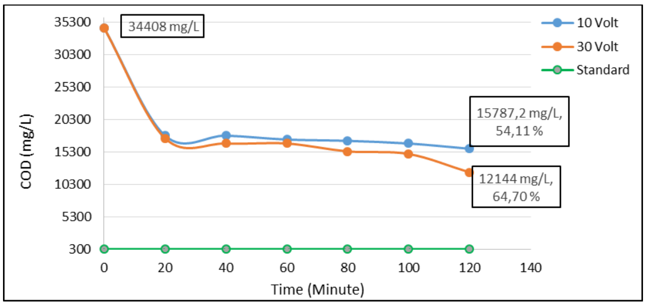

Figure 1. COD levels in soymilk liquid waste

Figure 1 shows the pattern of changes in COD levels in soymilk wastewater with respect to time and voltage used. In the processing of soymilk liquid waste samples after the electrocoagulation process with a voltage of 10 V and 30 V, the reduction graph was not much different. At a voltage of 10 V for 20 minutes, COD levels decreased with an efficiency value of 48.23%. At a voltage of 10 V for 120 minutes, COD levels decreased with an efficiency value of 54.11%. At a voltage of 30 V for 20 minutes, COD levels decreased with an efficiency value of 49.42%. At a voltage of 30 V for 120 minutes, COD levels decreased with an efficiency value of 64.70%. COD levels which are decreasing indicate that more organic materials are being oxidized so that the quality of wastewater is also getting better compared to the initial waste. In this study, the longer the time and the greater the voltage applied during electrocoagulation, the greater the reduction in COD levels. A few contaminants contained in wastewater will be bound by the large number of complex compounds that occur because the formation of H_2 and OH^- during the electrocoagulation process also increases and results in the number of contaminants decreasing. In the electrocoagulation process, COD levels decrease based on the double layer theory, namely innermost circle filled by the coagulant will have a positive charge binds the negative ions located on the outer circle. Payload positive and negative meet then Van der Waals forces (pull) occur interesting) between the two ions so there is a great bond strong and a coagulant is formed this will then form a floc which can degrade compounds organics in waste [13]. This causes COD levels to fall. Apart from that, it is in line with Faraday's law which states that the mass of substances produced at the electrode during the electrolysis process is directly proportional to the amount of current flowing to the electrode. Based on this law, the greater the electric voltage, the stronger the current flowing. From Faraday's law, it was also found that when the electrolysis process is running, using more contact time will cause greater binding of contaminants so that COD levels decrease.

In this study, COD levels experienced the highest decrease, namely at a voltage of 30 V with a contact time of 120 minutes. Where the COD content in the initial waste was 34408 mg/L to 12144 mg/L with an efficiency value of 64.70%. The COD level is still above the quality standard value based on Minister of Environment Regulation No. 5 of 2014, namely wastewater quality standards for soybean businesses and/or processing which should have the highest COD content, namely 300 mg/L, so this research is not optimal. The reduction in COD levels which was not yet maximal was probably caused by the initial waste sample being too concentrated and the number of organic pollutants being too large so that the reaction between the electrode and wastewater became more saturated, causing the electrode to work less than optimally.

3.3. Pattern of Changes in TSS Levels in Soymilk Liquid Waste

TSS pollutants come from organic and inorganic materials, which form suspensions in liquid waste. Apart from that, the source of TSS can also come from mud, clay, and microorganisms. TSS also influences turbidity by limiting the entry of light for photosynthesis in waters [14]. The purpose of measuring TSS levels is to determine insoluble solids in wastewater, usually these solids include clay, certain organic materials, and microorganism cells [15]. The results of TSS analysis in soymilk liquid waste can be seen in Figure 2.

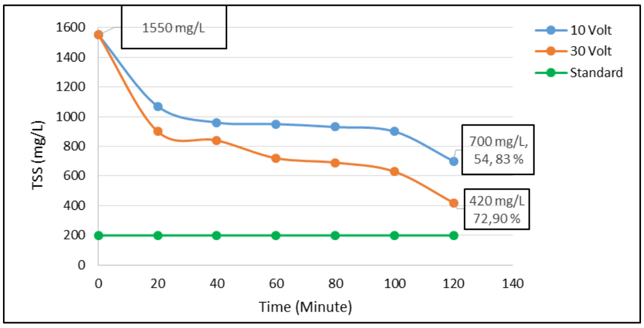

Figure 2. TSS levels in soy milk liquid waste.

Based on Figure 2. TSS levels before the electrocoagulation process were carried out were very high. The dissolved solids in soymilk liquid waste are in the form of suspension solids and colloids originating from a mixture of organic materials. At voltages of 10 V and 30 V based on Figure 2. the drop graph for the two is not much different. At a voltage of 10 V with a contact time of 20 minutes it has an efficiency value of 30.96%. At a voltage of 10 V with a contact time of 120 minutes it has an efficiency value of 54.83%. To reduce TSS levels at a voltage of 30 V for 20 minutes, the efficiency value is 41.93%. And the TSS level at a voltage of 30 V for 120 minutes has an efficiency value of 72.90%. The results of the analysis of TSS levels based on data in Figure 2 show that the large decrease in TSS levels is influenced by the longer contact time and the greater the applied voltage. The cause of this event is because the interaction between the particles and the length of time applied during the electrocoagulation process causes their size to increase and the quality of the wastewater produced will get better [16]. During the electrocoagulation process, pollutants in the wastewater in the form of suspended solids will be coagulated by the $Al(OH)_3$ coagulant, causing a decrease in TSS levels. The formation of floc of a certain size will easily be absorbed into the coagulant or absorbed into air bubbles. The resulting flocs will separate up and down so that the TSS levels in wastewater decrease.

In this study, TSS levels experienced the highest decrease, namely at a voltage of 30 V with a contact time of 120 minutes. The TSS level in the initial waste was 1550 mg/L to 420 mg/L with an efficiency value of 72.90%. However, the TSS level is still above the quality standard value based on Minister of Environment Regulation No. 5 of 2014, namely wastewater quality standards for soybean businesses and/or processing which should have the highest TSS content, namely 200 mg/L, so this research is not optimal. The decrease in TSS levels which has not been maximized is probably caused by the flocs not having settled completely so additional time is needed to settle them so that the suspension and water are separated properly also affecting the electrocoagulation process. Wastewater containing these particles will be stabilized by positive and negative ions produced by the electrode so that a decrease in TSS levels can occur. Based on the graph above, the allowance for TSS levels is influenced by time, the longer the time, the greater the allowance, where during the electrocoagulation process there is an increase in interactions between particles so that the quality of the water produced is better.

3.4. Pattern of Changes in DO Levels in Soymilk Liquid Waste

Dissolved oxygen (DO) level analysis needs to be known to determine the number of pollutants in wastewater, although DO level analysis is not required in wastewater quality standards. If there are more organic pollutants in a water body, the amount of dissolved oxygen will decrease, the cause of this is because microbes will use oxygen to degrade waste

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[17]. The dissolved oxygen content in clear water can be as high as 8 mg/L and this figure depends on the water temperature. The results of the electrocoagulation process can increase dissolved oxygen levels in soymilk wastewater can be seen in Figure 3.

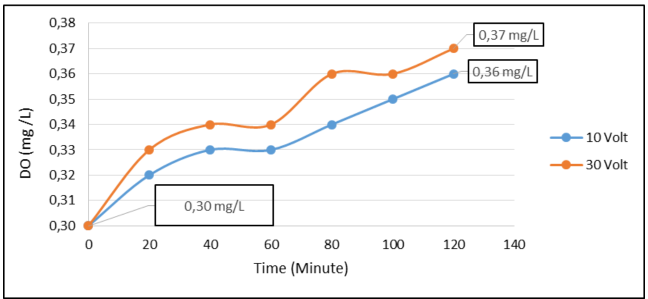

Figure 3. DO levels in soy milk liquid waste.

Figure 3 shows that the DO content in the initial waste of soy milk is 0.30 mg/L. This level is very low because unpolluted public waters have a DO value of >5 mg/L. A low DO value indicates that the water has high levels of pollutants. The results of the DO content analysis based on Figure 3 show that the increase in DO content occurs along with the length of contact time and the amount of voltage applied. The increase in DO levels occurs due to the oxidation reaction of water at the anode due to electrolysis which produces O_2 [18]. After the electrocoagulation process with a voltage of 10 V for 20 minutes, the DO level increased to 0.32 mg/L. At a voltage of 10 V for 120 minutes there was an increase in DO levels of 0.36 mg/L. At a voltage of 30 V for 20 minutes there was an increase in DO levels of 0.33 mg/L. At a voltage of 30 V for 120 minutes there was an increase in DO levels of 0.37 mg/L.

In this study, the highest increase in DO levels was at a voltage of 30 V with a contact time of 120 minutes with a DO level of 0.37 mg/L. However, these levels have not met expectations because the results of treated water after the electrocoagulation process have not been achieved. The slow increase in DO levels is probably due to the decreasing strength of electrolysis as the conductivity value decreases which affects the water oxidation reaction at the anode due to changes in current. The characteristics of the initial waste which has a very high pollutant load with a high TSS value results in turbidity which also affects DO levels. So, this research is not optimal when compared with the research of Sutanto, namely the efficiency and effectiveness as well as the kinetics of electrocoagulation processing of palm sago waste where in this research there was an increase in DO levels [17]. The initial palm sago waste had a DO level of 2.5 mg/L then after electrocoagulation it became 6.8 mg/L. This occurs due to the impact of different initial waste characteristics, causing different efficiency changes in DO levels.

3.5. Pattern of Changes in pH Values in Soymilk Liquid Waste

The increase in pH value occurs because of the presence of OH^- ions produced by the cathode in the electrocoagulation process. The results of pH analysis in soymilk liquid waste can be seen in Figure 4

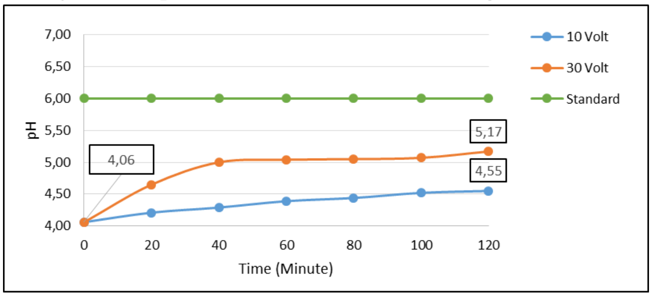

Figure 4. pH value in soymilk liquid waste.

The results of the analysis of the pH value based on the graphic data show that the longer the contact time and the magnitude of the voltage, the increase in the pH value also increases. The initial pH value before the pH adjustment was carried out was 5.01, then the wastewater pH value was adjusted to 4.1. After the pH is adjusted, the soymilk wastewater is allowed to stand so that the water and sediment are separated. The initial pH value before the electrocoagulation process was 4.06. In the processing of soymilk liquid waste samples after the electrocoagulation process with a voltage of 10 V for 20 minutes there was an increase with a pH value of 4.21. At a voltage of 10 V for 120 minutes there was an increase with a pH value of 4.55. In the processing of soymilk liquid waste samples after the electrocoagulation process with a voltage of 30 V for 20 minutes there was an increase with a pH value of 4.65. At a voltage of 30 V for 120 minutes there was an increase with a pH value of 5.17. The formation of water from H^+ and OH^- ions from the reduction

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reaction process on the aluminum electrode cathode will cause an increase in pH in the electrocoagulation process [4]. Based on these data, the largest increase in pH value in soymilk liquid waste samples occurred at voltage. 30 V with contact time.120 minutes i.e. with. pH value of 5.17. However, the pH value is still below the quality standard value based on Minister of Environment Regulation No. 5 of 2014, namely wastewater quality standards for soybean businesses and/or processing which should have a pH value in the range of 6-9, so this research is not optimal. This is likely due to differences in the type of waste, voltage and time applied as well as the use of the type of electrode which will affect the efficiency of increasing the pH. This low pH value is influenced by the high content of organic compounds such as carbohydrates and protein.

3.6. Pattern of Changes in DHL Values in Soymilk Liquid Waste

Electrical Conductivity (DHL) is the ability of water to transmit electrical current which is described numerically. Water can be a conductor of electricity due to the influence of the number of ions or the amount of salt dissolved in the water [19] . The more dissolve salts that can be ionized, the higher the conductivity value [20]. The results of DHL analysis of soymilk liquid waste can be seen in Figure 5.

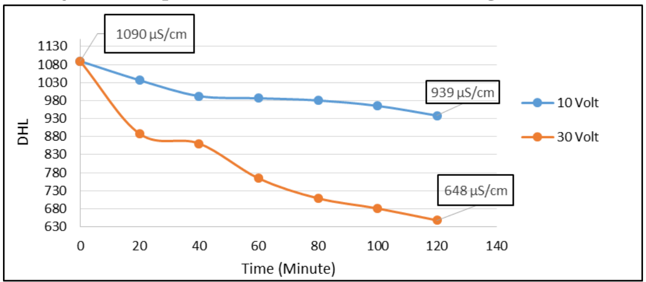

Figure 5. DHL Value in Soymilk Liquid Waste.

The DHL value based on Figure 5 shows that the decrease in the DHL value increases with the length of contact time and the greater the applied voltage. The graph shows that the DHL value in the initial waste is 1090 µS/cm. In the processing of soymilk liquid waste samples after the electrocoagulation process with a voltage of 10 V for 20 minutes there was a decrease with a DHL value of 1037 µS/cm. At a voltage of 10 V for 120 minutes it decreased with a DHL value of 939 µS/cm. At a voltage of 30 V for 20 minutes it decreased with a DHL value of 888 µS/cm. At a voltage of 30 V for 120 minutes it decreased with a DHL value of 648 µS/cm. Based on Figure 5, the largest decrease in the DHL value in the soymilk liquid waste sample occurred at voltage. 30 V with time. contact. 120. minutes, namely with a DHL value of 648 µS/cm. Shallow groundwater generally has a value of 30-2000 µmhos/cm. Pure water conductivity ranges from 0-200 µS/cm. The conductivity value for drinkable water is around 42-500 µmhos/cm. Conductivity values of more than 250 µmhos/cm are not recommended because they can settle and damages kidney stones [21] Based on the data obtained, the DHL value is not dangerous because natural waters have a DHL value of around 20-1500 µS/cm. The continuously decreasing electrical conductivity can be caused by the fact that most of the ions are flocculated so that the electrically conducting ions in the solution are decreasing [17].

3.7. Pattern of Changes in Al Metal Levels in Soymilk Liquid Waste

Based on electrochemical principles, the oxidation reaction (loss of electrons) will occur at the anode while water reduction will occur at the cathode. If an aluminum electrode is used on the anode, oxidation of Al will occur and a coagulant in the form of ions will be formed [17]. The results of the analysis of Al metal content in soymilk liquid waste can be seen in Figure 6.

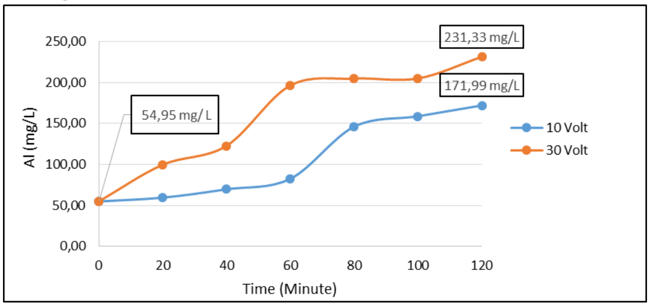

Figure 6. Al Metal Levels in Soymilk Liquid Waste.

The results of the Al metal content analysis based on the graphic data show that the longer the time and the greater the stress, the greater the increase in Al metal content. The graph shows that the Al metal content in the initial waste was 54.95 mg/L. After the electrocoagulation process with a voltage of 10 V for 20 minutes, the Al metal content increased to 59.54 mg/L. At a voltage of 30 V for 120 minutes, the Al metal content increased to 231.33 mg/L. Based on these data, the largest increase in Al metal levels in soymilk liquid waste samples occurred. on. voltage 30 V with time. 120 minutes of contact, namely with an Al metal content of 231.33 mg/L. Al content analysis is not included in the Minister of Environment Regulation No. 5 of 2014, namely wastewater quality standards for soybean businesses and/or processing, but this analysis was carried out to determine the amount of aluminum erosion on the electrodes during the electrocoagulation process. The formation of coagulant in the form of $Al(H_2O)_6^{3+}$ ions or other aluminum species occurs due to oxidation of Al on the anode if the electrode used is aluminum ([17]. If the voltage is greater it will provide a greater potential for breaking down the Al electrode to release Al^{3+} so that the $Al(OH)_3$ floc is also getting bigger [22].

4. CONCLUSION

The conclusion of this research is that the processing of soymilk liquid waste using electrocoagulation does not comply with the quality standards required according to Minister of Environment Regulation No. 5 of 2014. However, the best time and voltage among the others is at 30 volts with a contact time of 120 minutes. COD levels of 34408 mg/L decreased to 12144 mg/L (efficiency 64.70%), TSS levels of 1550 mg/L decreased to TSS 420 mg/L (efficiency 72.90%) and the pH value increased from 4 .06 to 5.17. For the final results after processing, the DO content was 0.37 mg/L, DHL was 648 µS/cm and Al content was 231.33 mg/L.

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