Treatment of Industrial Wastewater and Household Waste Using Electrocoagulation Method with Aluminum Electrode

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ABSTRACT

The treatment of industrial wastewater and household waste using the electrocoagulation method with aluminum electrodes aims to determine the optimal time and voltage to reduce iron content, manganese content, and TDS from industrial wastewater and household waste. The method used in this study was the electrocoagulation method with aluminum electrodes. The object of this research was the reduction of iron content, manganese content and TDS of industrial wastewater and household waste. The optimization test of electric voltage and electrocoagulation time was carried out at variations of electric voltage of 5, 10, and 15 volts and time variations of 1, 3, 6, 9, and 12 hours. Then the samples were analyzed using Atomic Absorption Spectroscopy (AAS), pH meter and TDS meter. The results showed that the optimal time and voltage to reduce iron content, manganese content, and TDS of industrial wastewater and household waste was 12 hours and 15 volts. After the electrocoagulation process, the iron content was reduced by 95.37%, the manganese content was reduced by 100%, the TDS value was reduced by 43.66%, and the pH value increased by 26.73%.

Keyword:* *electrocoagulation, aluminum, iron content, manganese content, pH, TDS

1. INTRODUCTION

Wastewater has a terrible impact on the environment because it contains pollutants. Wastewater that is directly disposed into water or the environment without any treatment process will be very dangerous for the health of the environment and human because it contains hazardous, toxic, and pollutant materials that are not able to be digested by microorganisms (Hidayat, 2016). The wastewater comes from industrial or household activities that dispose their wastewater without prior treatment (Yudo & Hernaningsih, 2018). Household wastewater is waste water that is wasted after carrying out daily household activities such as washing clothes, cooking, as well as home industrial processes (Isyanto et al., 2015). The increase in waste water disposal is not matched by increasing wastewater treatment so that the water flow is increasingly polluted and makes it unfit for clean water supplies.

Based on these problems, wastewater treatment needs to be improved in order to not pollute the environment and the availability of clean water still meets the requirements. In this study, the parameters that will be tested as a determinant of improving the quality of industrial wastewater and household waste are iron metal content (Fe), manganese metal content (Mn), pH, and dissolved solids (TDS). If Fe metal is in the environment in an amount that exceeds the limit, it can cause turbidity, corrosion, and if it is absorbed into the body in large quantities, it will cause cancer (Karim et al., 2017). Meanwhile, if the amount of Mn exceeds the limit, it can cause a fishy metallic taste and smell in the water, leaving a brownish color on white clothes and causing liver function disorders (Tampubolon, 2017). Tests for Fe and Mn metal levels were carried out using the Atomic Absorption Spectrophotometry (AAS) method because this method is very selective and sensitive and relatively simple for metal analysis (Ernawati et al., 2019).

There are various ways to treat and separate heavy metals such as iron and manganese in industrial wastewater and household waste, including oxidation, filtration, adsorption, coagulation both conventionally and electrocoagulation, and others (Febrina & Astrid, 2014). There is also the treatment of industrial wastewater and household waste using a chemical process with chemicals. However, wastewater treatment using this chemical process has drawbacks, including the chemicals used can be harmful to health, require a lot of money, and take a long time. In this study, the method used for the treatment of industrial wastewater and household waste is the electrocoagulation method. Electrocoagulation is a process of coagulation or collection with electricity through an electrolysis process to reduce metal ions and particles in the water (Wiyanto et al., 2014). Electrocoagulation technique has the advantages of simple equipment, easy to operate, short reaction time, does not require additional chemicals, and is more economical (Hanum et al., 2015).

The electrocoagulation method is one way of treating water by utilizing metal plates commonly called electrodes in the form of iron, aluminum, or stainless steel which are electrified and immersed in water (Radityani et al., 2020). In the treatment of industrial wastewater and household waste using this electrocoagulation method, aluminum electrodes are used. Aluminum is a light metal that has good corrosion resistance and electrical conductivity (Fasya et al., 2015). In addition, aluminum can also act as a coagulant, the material is non-toxic, and easy to obtain (Hanum et al, 2015). Radityani et al. (2020) proved that the use of aluminum electrodes in sewage treatment can reduce the TSS parameter of wastewater more optimally than other electrodes. The formation of air bubbles in the wastewater accompanied by the release of Al^{3+} from the electrode plate will be followed by the formation of Al(OH)n flocs which are able to bind suspended particles in the water (Radityani et al., 2020).

The effectiveness of the electrocoagulation process in treating wastewater is influenced by several factors including temperature, contact time, electric current, voltage, and pH (Novianti & Tuhu, 2014). In this study, variations in the electric voltage and time variations of the electrocoagulation process will be carried out, in order to obtain effective results in the treatment of industrial wastewater and household waste. The use of the electrocoagulation method is generally used for specific industrial wastewater treatment such as palm oil industrial wastewater, batik industrial wastewater, or laundry wastewater. However, the use of the electrocoagulation method for the treatment of industrial wastewater and household waste as a whole has not been widely carried out, it is necessary to do research on the treatment of industrial wastewater and household waste using the electrocoagulation method with aluminum electrodes.

2. RESEARCH METHOD

The method used was the electrocoagulation method with aluminum electrodes. After the electrocoagulation device was assembled as shown in Figure 1, the wastewater sample was put into the reservoir, then turn on the DC power supply at a voltage of 5 volts, after the process has been running for 1 hour, the DC source was turned off. Then the wastewater sample was measured pH value with a pH meter, TDS value with a TDS meter, iron (Fe) and manganese (Mn) levels using AAS. Then, repeat the same treatment with a voltage of 10 and 15 volts and with the process for 3, 6, 9, and 12 hours. This process was carried out to find the optimal voltage and time for the electrocoagulation process.

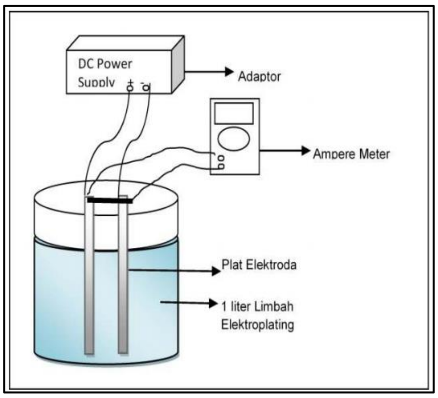

Figure 1. Schematic of the electrocoagulation device circuit (Nofitasari et al., 2012).

After getting the optimal voltage and time for the electrocoagulation process. Then a further electrocoagulation process was carried out for 30 days where the process was carried out for 12 hours per day on samples of industrial wastewater and household waste. After that, the parameters of pH, TDS, iron content, and manganese content were tested.

3. RESULTS AND DISCUSSION

Calibration Curve

The standard solution serves to calibrate so that a plot between absorbance and concentration was obtained whose slope and intercept values can be used for data analysis on samples using AAS. Based on the results of the AAS test, the calibration curve of the Fe and Mn standard solutions shown in Figures 2 and 3.

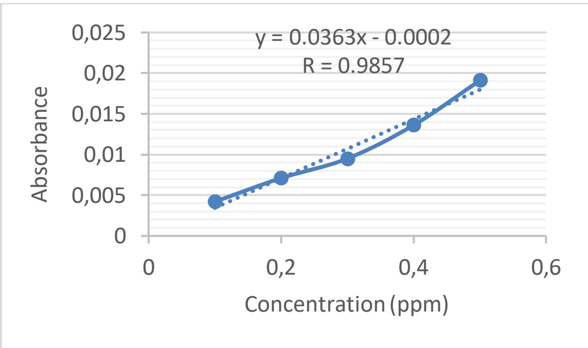

Figure 2. Fe calibration curve

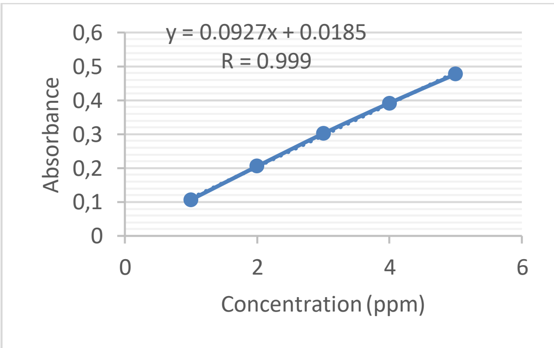

Figure 3. Mn calibration curve

The concentration and absorbance in Figure 2 and 3 are directly proportional and in accordance with the Lambert-Beer law, namely the amount of light absorbed is directly proportional to the content of the substance. The value of the correlation coefficient (R) is close to 1, so the results of this test can be said to be good.

Optimization Test

The variation of the electric voltage used in the optimization test were 5, 10, and 15 volts while the variation of time used were 1, 3, 6, 9, and 12 hours. From this study, data were obtained showing that at a voltage of 5 volts with five variations of time, the decrease in TDS levels, Fe levels, and Mn levels was slow. At 12 hours, the decrease in TDS levels can only reach 128 ppm. Fe and Mn levels have not completely disappeared. The pH value of the water was 8.30. At a voltage of 10 volts with five variations of the same time, the decrease in TDS levels, Fe levels, and Mn levels was faster than 5 volts. At 12 hours, the decrease in TDS levels can reach 95 ppm and the pH value become 8.38. Fe and Mn levels have reached 0.00 ppm at 9 hours and 6 hours. At a voltage of 15 volts with the same time variation, the decrease in TDS levels, Fe levels, and Mn levels very quickly exceeds the decrease at 10 volts. At 12 hours, the decrease in TDS levels can reach 76 ppm and the pH value was 8.46. Fe and Mn levels were no longer in the water at 6 hours. From these data, it can be seen that the optimal voltage and time were 15 volts and 12 hours, respectively. The optimization results were used to electrocoagulate industrial wastewater and household waste for 30 days.

Iron (Fe) Level Test

The results of the iron level test after the electrocoagulation process for 30 days with a voltage of 15 volts and electrocoagulation time per day for 12 hours shown in Figure 4.

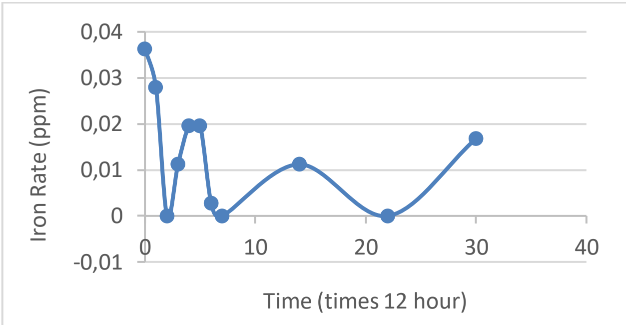

Figure 4. Relationship between Processing Time of Electrocoagulation and Iron Content in Wastewater

From these data it can be seen that the levels of ferrous metal in industrial wastewater and household waste after going through the electrocoagulation process do not show regular results, but the levels of ferrous metals in water are relatively decreased. The decrease in ferrous metal was caused by the $Al(OH)_3$ floc which binds ferrous metal in the wastewater sample. The floc is formed from the oxidation reaction at the anode (Setianingrum et al., 2016). The binding of ferrous metal by floc $Al(OH)_3$ occurs due to the following reaction:

$$Al(OH)_3 + Fe^{2+} \rightarrow Al(OH)_3Fe$$

This binding causes the Fe content in the wastewater to decrease. Irregularity in the levels of ferrous metal in wastewater is caused because the surface of the aluminum electrode is coated with iron metal, then the iron dissolves along with the anode porous.

Manganese (Mn) Level Test

The results of the manganese level test in wastewater after an electrocoagulation process for 30 days with a voltage of 15 volts and an electrocoagulation time per day for 12 hours shown in Figure 5.

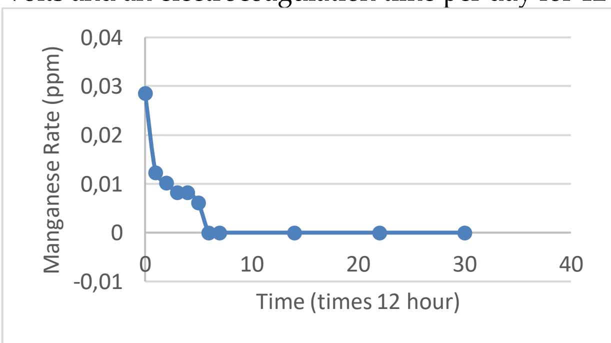

Figure 5. Relationship between Processing Time of Electrocoagulation and Manganese Content in Wastewater

From these data, it can be seen that manganese levels in samples of industrial wastewater and household waste decreased from the first day to day 30. The decrease in manganese metal was caused by the $Al(OH)_3$ floc which binds manganese metal in the wastewater sample. The floc is formed from the oxidation reaction at the anode (Setianingrum et al., 2016). The binding of manganese metal by floc $Al(OH)_3$ occurs due to the following reaction:

$$Al(OH)_3 + Mn^{2+} \rightarrow Al(OH)_3Mn$$

This binding causes the level of Mn in wastewater to decrease so this study proves that the electrocoagulation process can reduce manganese levels in wastewater samples.

TDS Level Test

The results of the TDS level test in wastewater after an electrocoagulation process for 30 days with a voltage of 15 volts and an electrocoagulation time per day for 12 hours are shown in Figure 6.

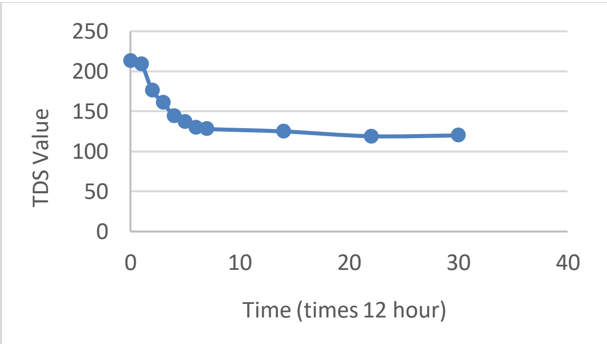

Figure 6. Relationship between Time of Electrocoagulation Process and TDS Levels

The data shows that the TDS of industrial wastewater and household waste which was originally 213 ppm was reduced to 120 ppm on the 30th day. The decrease in TDS was caused by the $Al(OH)_3$ floc which binds to the particles in the wastewater sample. Particles dissolved in wastewater are destabilized by $Al(OH)_3$. Then, the particles will be adsorbed and joined in the $Al(OH)_3$ floc. The $Al(OH)_3$ floc is formed from the oxidation reaction at the anode. The $Al(OH)_3$ floc will settle above and at the bottom of the reservoir and after the filtering process, clean and safe water will be obtained to flow into the environment (Setianingrum et al., 2016). This proves that the electrocoagulation process can reduce TDS levels in wastewater samples.

pH Value Test

The results of the pH value test in wastewater after the electrocoagulation process for 30 days with a voltage of 15 volts and electrocoagulation time per day for 12 hours shown in Figure 7.

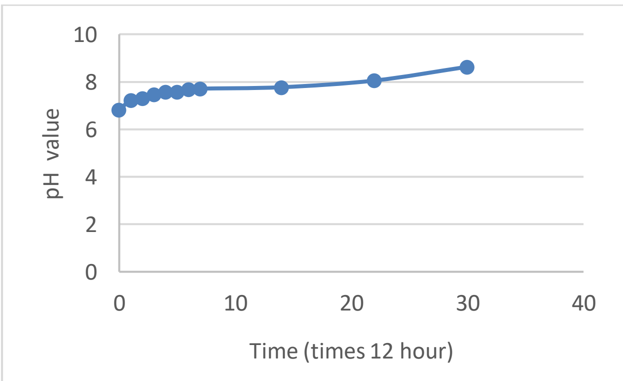

Figure 7. Graph of the Relationship between Time of Electrocoagulation Process and Wastewater pH Value

Based on Figure 7, it can be seen that the pH value of industrial wastewater and household waste which was initially 6.81 (neutral slightly acidic) increased to 8.36 (alkaline) on day 30. This was due to the reaction at the cathode which produced hydroxide ions as follow.

Reaction: $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

When the electrocoagulation process takes place, there is an electrolysis of water that produces hydrogen gas and hydroxide ions, the longer the contact time used, the faster the formation of hydrogen gas and hydroxide ions, if more hydroxide ions are produced it will raise the pH in the solution (Novianti & Tuhu, 2014). The wastewater used in this study initially had a neutral pH value of 6.81, but after the electrocoagulation process the pH value rose to alkaline, namely 8.63. The pH of alkaline water is not good for the environment so it is necessary to do some handling to reduce the increase in the pH value of wastewater, including:

1. Reduce the contact time of aluminum electrodes with sample water or wastewater.
2. Replacing used aluminum electrodes with new aluminum electrodes.
3. When the DC power supply is turned off or the electrocoagulation process stops, the aluminum electrodes are removed from the wastewater and then dried in order to reduce corrosion which causes an increase in pH.

This study proves that the electrocoagulation process using aluminum electrodes can increase the pH of wastewater so that it is suitable for treating wastewater that has a low pH value or is acidic.

4. CONCLUSION

Based on the research that has been done, it can be concluded that:

1. The most optimal time and voltage for reducing iron (Fe), manganese (Mn) levels, and dissolved solids (TDS) of industrial wastewater and household waste in the electrocoagulation process is 12 hours and 15 volts.
2. After the electrocoagulation process with aluminum electrodes was carried out, industrial wastewater and household waste did not have a strong odor and the color of the water changed to colorless. The iron metal content in the wastewater was reduced by 95.37%, while the manganese metal content was reduced by 100%. TDS or dissolved solids in wastewater also decreased by 43.66% and pH value increased by 26.73%

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