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Electrocoagulation Method to Reduce Pollutants in the Wastewater of Jumputan Fabric Industry

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Abstract

Textile industry in Indonesia is not only in the category of large and medium scale industries but also in small scale and even in the home-scale industry. These activities caused water pollution mainly because of the dyeing of textiles. Dye not only used in industrial areas but also used in densely populated settlements. An attempt to treat the waste of the textile industry is needed to solve the environmental pollution. In this research, wastewater processed using the electrocoagulation method, and expected to decrease waste, and to fulfill the required environmental quality standard. Treatment of jumputan wastewater by electrocoagulation method using 4 aluminum electrodes 11x10.5 cm in size with MP-P configuration type (Monopolar-Parallel) for 120 minutes. The parameters measured in this study were chromium heavy metal content, TSS (Total Suspended Solid), TDS (Total Dissolved Solids), as well as changes in pH, color and turbidity values where the applied voltage variations were 10, 13, 15, 17, and 20 volts with variation of electrode distance used 1.5; 2.0; and 2.5 cm. The best condition for each parameter was obtained at a distance of 1.5 cm with a voltage of 20 volts. Effectiveness of method to decrease turbidity value up to 99.84%; color 99.33%, chromium 62.5%; TSS 33.68%; TDS of 66.59% and raised the pH from 5.64 to 8.10, respectively.

Keywords: aluminum electrode, electrocoagulation, wastewater of jumputan

Abstrak (Indonesian)

Industri tekstil di Indonesia tidak hanya berkategori industri skala besar dan menengah, tetapi juga dalam skala kecil dan industri skala rumah tangga (*home industry*). Hal ini menyebabkan polusi yang disebabkan oleh industri tekstil, terutama akibat dari pencelupan zat warna tekstil tidak hanya terjadi di kawasan industri tetapi juga di pemukiman padat penduduk. Untuk mengatasi masalah pencemaran lingkungan yang terjadi diperlukan suatu usaha untuk mengolah limbah hasil industri tekstil. Pada penelitian ini dilakukan pengolahan limbah cair menggunakan metode elektrokoagulasi dan diharapkan dapat menurunkan konsentrasi atau bahaya yang ditimbulkan oleh limbah sehingga memenuhi baku mutu lingkungan. Perlakuan limbah cair dengan metode elektrokoagulasi menggunakan elektroda aluminium berukuran 11x10,5 cm berjumlah 4 buah dengan tipe konfigurasi MP-P (*Monopolar-Parallel*) dalam waktu 120 menit. Parameter yang diukur yaitu kadar kromium, TSS (*Total Suspended Solid*), TDS (*Total Dissolved Solid*), pH, warna dan kekeruhan dimana variasi tegangan 10, 13, 15, 17, dan 20 volt dengan variasi jarak elektroda yang digunakan 1,5; 2,0; dan 2,5 cm. Kondisi terbaik diperoleh pada jarak elektroda 1,5 cm dengan tegangan 20 volt. Efektivitas metode untuk menurunkan nilai kekeruhan hingga 99,84%; warna 99,33%, kadar kromium 62,5%; TSS 33,68%; TDS 66,59% serta menaikan pH dari 5,64 menjadi 8,10.

Kata Kunci: elektroda aluminium, elektrokoagulasi, limbah cair kain jumputan,

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INTRODUCTION

Industrial activity is the process of processing raw material into a half-finished or finished material for the needs of humans and other creatures around it. At the same time, the industry is also inseparable from the side products or waste that can result in environmental pollution. The impact of environmental pollution can be felt directly or indirectly by humans. As a result of the pollution, the environment becomes damaged so that the carrying capacity of nature to human survival is reduced. The purpose of waste treatment is to reduce the volume, concentration or danger posed by waste so that it can meet the required environmental quality standards [1].

One cause of pollution is the amount of wastewater that is discharged without prior treatment or has been treated but has not yet met the water quality standard. This is possible because of the reluctance to treat wastewater. Besides that, the availability of an easy and efficient wastewater treatment technology is not yet available so that it can be applied in industry, both the home industry, small industry, and intermediate industry [2,3].

The wastewater in the Palembang city come from the textile industry (dyestuff), the metal plating industry (electroplating), the laundry industry, domestic liquid waste, landfills (TPA), and others. Textile industry wastewater contains organic and inorganic pollutants, which can be demonstrated with relatively high TSS levels and turbidity [4-8]. The development of the textile industry was also encouraged by the development of the traditional weaving industry at a relatively lower price making it affordable for the wider community. The process of making traditional cloth begins with the process of dyeing yarn/limar for dyeing, in each liquid dyeing waste will be produced around 40-50 liters for one set of limar. Every songket industry dips at least 10 limar every day, so in one day, it can produce around 100,000 liters of wastewater [9,10].

The garment and apparel (GNA) industry is one of Indonesia's highly developed industries. This growth can be seen from the GNA export as a growing asset. Along with the rise in GNA, there are also increases in textile waste, one of which is staining. The textile industry types of dyes exceed approximately 10,000 forms, and annually more than 7 x 105 tons of dyes are made. 10-15% of the textile dyes used were discarded with industrial waste during the coloring process. The coloring agent in waste is around 60-70 mg/L. These dyes can also endanger biodiversity and interfere with health, such as the skin, eye irritation, and cause cancer and mutation and pollute the environment.

Based on the description, an effort is needed to treat industrial waste products so that their impacts on the environment can be minimized. In this study, the object of research is the wastewater of jumputan industry treatment uses the electrocoagulation method to reduce pollutants and it is expected that the results fulfilled the environmental quality standards.

The electrocoagulation method has several important factors i.e. the electric current density, time, electric voltage, type of electrode, and the distance between the electrodes. The previous study shows that voltage affects the reduction in the concentration of chromium metal contained in wastewater. It means there is a relationship between voltage, electric current, and resistance stated in Ohm's law. The resistance is also affected by the distance between the electrodes. The longer the distance, the higher the resistance so that the lower the current flowing [11,12].

Research related to electrodes, both in terms of dimensions and distance shows that the distance between the electrodes affects the reduction of batik waste COD using electrocoagulation while the results of other studies prove that the electrocoagulation process using aluminum plates is better than iron plates to reduce levels of COD, BOD, and TSS in textile liquid waste. The relationship between electrodes also influences electrocoagulation processes such as monopolar-serial (MP-S), monopolar-parallel (MP-P) and biopolar-parallel (BP-P). From these studies, it was found that the MP-P type is the most efficient [13-15]. In addition to the type of electrode, the processing time can affect the effectiveness of electrocoagulation. This study examines more deeply the electrocoagulation method using a monopolar-parallel configuration (MP-P) and the effect of the distance between the electrodes and the electrical voltage in the electrocoagulation method on decreasing the levels of chromium metal (Cr), TSS, TDS, color, turbidity and increasing pH levels textile industry dyeing wastewater using aluminum plates [16].

MATERIALS AND METHODS

Materials

The material used in the electrocoagulation method to reduce levels of pollution in the textile industry waste (in terms of electrode distance and process voltage) is wastewater from the jumputan cloth industry obtained from the Kampung Kain Village Industrial Center, Tuan Kentang Kertapati Village, Palembang, South Sumatra. For the analysis, it is used aquadest for washing, filter paper for TSS and Cr and HNO_3 solution for chromium levels.

Controlled Variable

The controlled variable used in this electrocoagulation method is the number of aluminum electrodes i.e. four pieces with each dimensions of 11x10.5x0.15 cm and processing time of 120 minutes.

Independent Variable

The changing variable is the variation of electrode distance 1.5; 2.0; and 2.5 cm and variations in process voltage (10, 13, 15, 17 and 20 volts).

Characteristics of the Textile Industry Wastewater before Treatment

Initial analysis was carried out on jumputan fabric wastewater. The analysis was carried out before processing by the electrocoagulation method by analyzing the levels of chromium metal, TSS, TDS, turbidity, color, and pH.

Characteristics of the Textile Industry Wastewater after Treatment

This test was conducted to determine the effect of electrode distance with variations and process stresses. The parameter test were chromium metal, TSS, TDS, and turbidity, color and pH values in waste by comparing the results of the final analysis of each treatment with the results of the initial analysis. From the data, it can be determined the most effective conditions that have the highest allowance for pollutants. The electrocoagulator was used to process the wastewater as seen in the Figure 1.

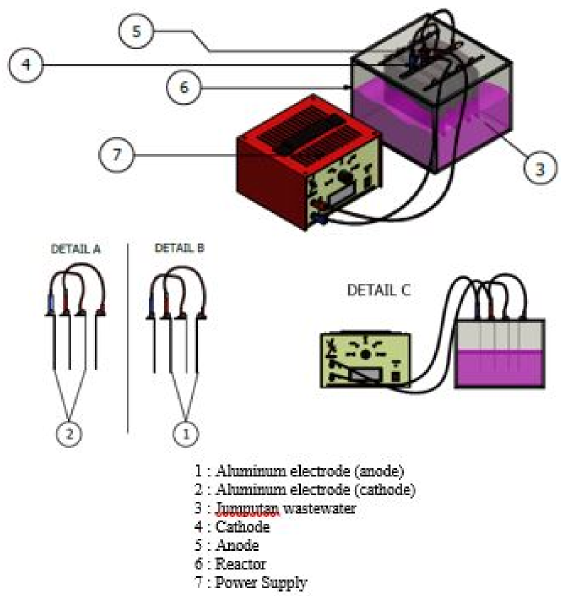

Figure 1. Electrocoagulator

RESULTS AND DISCUSSION

Characteristics of the Textile Industry Wastewater Before Treatment

Textile wastewater samples were taken from the Center Industri Kampung Kain Village, Tuan Kentang Kertapati, Palembang City. South Sumatra. The initial characterization of liquid textile waste is carried out before processing by electrocoagulation method by measuring the pH, humidity, TDS, TSS, color and chromium brat metal content. The results of the initial characteristics of textile wastewater can be seen in Table 1.

Table 1. Analysis of Textile Wastewater Before Treatment

No.	Analysis Type	Quality Standards*	Results
1.	pH	6.0-9.0	5.64
2.	Turbidity (NTU)	-	330
3.	TDS (ppm)	500	969.1
4.	TSS (mg/L)	50	28.2
5.	Color (Pt-Co)	-	3300
6.	Cr Content (mg/L)	1.0	0.08

* Environmental quality standards based on the Governor of South Sumatra No.8 in 2012 [17]

The chromium and TSS values do not exceed quality standards, while TDS, pH, color and turbidity values need treatment. The TDS value obtained is above the textile wastewater quality standard. High TDS can produce water with high hardness, which leaves sediment on household appliances, water pipes and others. This can also be proven in soaps and detergents, which will not produce a lot of foam if the TDS content is too high in the water used. Although TDS itself may be only aesthetic (taste) and technical factors, high levels of solids are also an indicator that dangerous contaminants such as sulfate and arsenic bromide can also be present in the water.

The pH value obtained also needs to be considered because it is still acidic so that treatment is needed so that the pH of the textile wastewater can reach a neutral position. If the pH value is not neutral, it can affect environmental conditions, can disturb the life of organisms in the water and are corrosive to metals. High turbidity and color values also need to be considered because the entry of textile dyes into the aquatic environment creates problems for the ecosystem. It contain toxic materials. Textile dyes that enter the aquatic environment interfere with the penetration of light into the waters. As a result, the process of photosynthesis, which requires light carried out by the manufacturer, is interrupted. This causes a reduction for oxygen in the aquatic environment and other ecosystem imbalances.

The Effect of Applied Voltage on the Decrease in Chromium

Table 2 shows the effect of applied voltage to electrocoagulation process related to the measurement of chromium content by variating the electrodes distance. The results showed that the decrease in the value of chromium metal content at the electrode distance of 1.5; 2.0 and 2.5 <0.003 mg/L while the results of the initial analysis of chromium metal content before processing were 0.08 mg/L.

Table 2. The effect of applied voltage to the measurement of chromium containment

Distance of Electrode	Voltage (Volt)	Current (A)	Cr Content (mg/L)
1.5 cm	10	0.97	<0.003
	13	1.16	<0.003
	15	1.19	<0.003
	17	1.55	<0.003
	20	2.00	<0.003
2.0 cm	10	0.51	<0.003
	13	0.78	<0.003
	15	0.80	<0.003
	17	1.15	<0.003
	20	1.66	<0.003
2.5 cm	10	0.40	<0.003
	13	0.57	<0.003
	15	0.84	<0.003
	17	0.90	<0.003
	20	0.99	<0.003

There is an electric current in the anode that will be an oxidation reaction to the anion (negative ion). The metals such as aluminum will undergo an oxidation reaction to produce Al^{3+} and will bind the ion (OH^-) to form $Al(OH)_3$ floc which can bind chromium ions as well as capture some of the chromium metal that is not deposited on the cathode rod. This condition allows a decrease in chromium content in the waste.

When voltage is applied to the solution continuously, the amount of Al^{3+} from the electrodes increases so that the amount of $Al(OH)_3$ floc also increases. The number of flocs that are too much will cause saturation of the electrodes, so the ability of electrodes to attract chromium ions in the waste will be reduced. The impact of this condition causes a decrease in the magnetic field. The electrocoagulation process will be minimum if there is a saturation of the electrodes and the magnetic field will also be very small which causes the chromium levels in the waste to remain constant. If it act continuously, then the chromium level does not decrease any more. This is because the electrocoagulation process has reached its lowest point.

The Effect of Applied Voltage on TSS

Figure 2 shows the effect of applied voltage to electrocoagulation process related to the measurement of TSS containment by variating the electrodes distance.

The TSS reduction process is very influential where TSS is a pollutant that is suspended. If a wastewater contains high TSS, it can be concluded that the waste is of poor quality and has the potential to damage the aquatic ecosystem specifically. In Figure 2 can be seen the best results in decreasing the value of TSS in the electrocoagulation process using textile waste is at a distance of 1.5 cm electrodes with a process voltage of 20 volts where the initial TSS value of 28.2 mg/L drops to 18.701 mg/L.

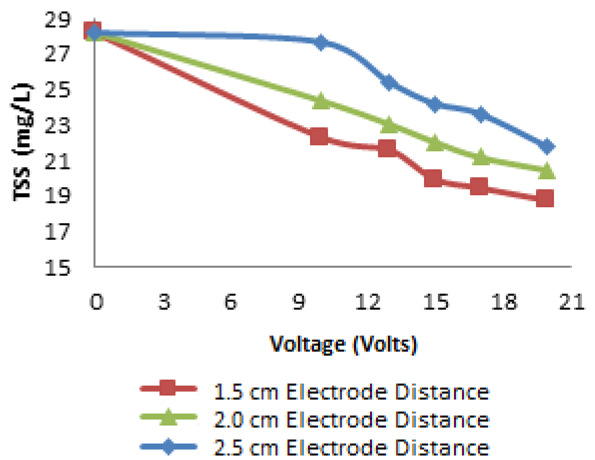

Figure 2. Effect of voltage on the value of TSS on each electrode distance variation

Voltage is directly proportional to current, if the voltage is enlarged, the current flowing will also be even greater. Current is an electron that flows so that if the current is enlarged the number of electrons flowing in the electrocoagulation reactor increases. Increasing the number of electrons increases the amount of OH^- and H_2 gas bubbles, OH^- will join with Al^{3+} (from the anode) to form complex compounds that can bind to pollutants and then form floc. The more amount of OH is formed, the more flock is formed. The increasing number of H_2 gas bubbles formed causes the easier removal of the floc produced to the surface. Flocks that form over time will increase in size and will eventually settle to the bottom of the electrocoagulation reactor.

TSS pollutant sources are organic and inorganic chemicals that form a suspension in liquid waste. Also, TSS sources can also come from metals that form complex compounds either with hydroxide or other anions from these compounds that are suspended in a waste solution due to the nature of the molecular size of the compound or its polarity properties.

The Effect of Applied Voltage on TDS

The results of the TDS analysis after processing using an electro coagulator can be seen in the Figure 3.

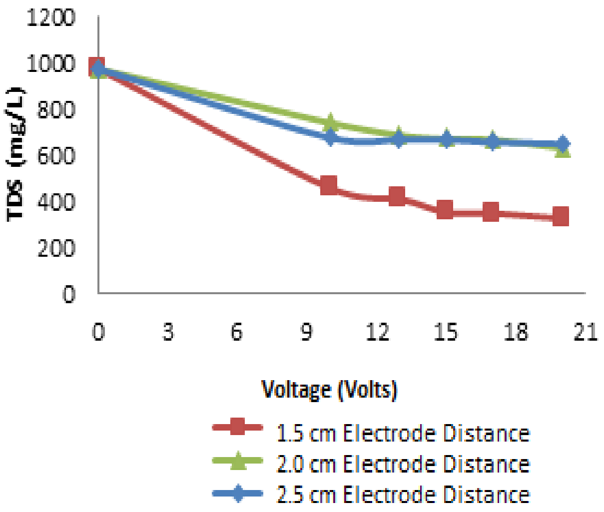

Figure 3. Effect of voltage on the TDS value at each electrode distance variation

Based on the figure, the initial TDS number was 969.1 mg/L and it is categorized as poor according to WHO provisions. The TDS value tends to decrease at higher voltage and at the distance between electrodes 1.5 cm is the best distance for reducing the level of TDS. This phenomenon is caused the electrode distance affects the value of the current flowing. The higher current flowing at a distance of 1.5 cm electrodes causes the electrocoagulation process to occur faster so that the content of dissolved solids in the sample is less. The minimum TDS reduction is at an electrode distance of 1.5 cm with a process voltage of 20 volts where the initial TDS value of 969.1 mg/L is reduced to 323.8 mg/L. Thus it can be said that the electrocoagulation method is able to reduce solids dissolved in wastewater effectively.

The Effect of Applied Voltage on Color Scale Changes

Color is a compound that can be used in the form of a solution so that the color is colored. In the textile industry in the Pottery Fabric Pottery Industrial Village, the color of synthesis is naphthol dyes. The results of the analysis of the value of color absorb after processing using an electro coagulator can be seen in Figure 4.

In Figure 4 seen a decrease of Pt-Co content along with an increasing voltage on the electrocoagulation process. The adsorption process causes color removal the adsorption process serves to set aside aromatic compounds and dissolved compounds. The greater the electrical voltage, the higher the anode solubility so that the number of hydroxyl cationic complexes will increase and cause the existing dyes to form larger lumps.

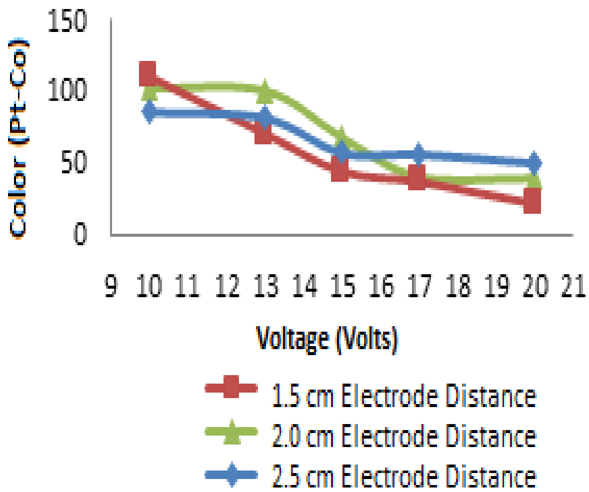

Figure 4. Effect of stress on color values at each electrode distance variation

Along with the formation of a larger floc resulting in the number of sludge produced a lot, so that the dye will form a ligand that binds $Al(OH)_2$ the closer the electrode distance, the faster color elimination because the ionization reaction between the electrodes will be faster so that the color loss occurs faster. In addition, it is showed that a decrease in the maximum color content occurs at a 1.5 cm electrode distance, compared with a distance of 2.0 cm and 2.5 cm at 120 minutes. At the 1.5 cm electrode distance with a voltage of 20 volts, the minimum color absorbance value is 22 Pt-Co with the initial color absorbance value of 3300 Pt-Co textiles.

Effect of Applied Voltage on pH

The results of the analysis of the pH value after being processed using an electro-coagulator can be seen in Figure 5.

The results of the analysis of the pH value of textile wastewater before processing by the electrocoagulation method were 5.64 included in the acid category or still below the textile industry liquid quality standard based on the Governor of South Sumatera Governor No. 8 of 2012. Based on the results of the analysis in Figure 5, it can be seen that the closer the electrode distance and the magnitude of the voltage in the electrocoagulation process, the higher the relative pH increase. This is because in the electrocoagulation process, it produces OH^- ions through the reaction of water at the cathode. The number of ions that affect the amount of pH measured.

The distance between the 1.5 cm electrode has a current that flows on average is greater than the distance between the electrode 2 cm and 2.5 cm. Then the indirect OH-ion generated at the 1.5 cm electrode is relatively greater than the distance of the electrode 2 cm and 2.5 cm so that the pH value at the electrode distance of 1.5 cm is relatively faster. Based on the research, the pH value obtained has increased and the optimum conditions for increasing the pH value are at a distance of 1.5 with a 20 volts process voltage where the pH value obtained is 8, 10 or in a neutral state.

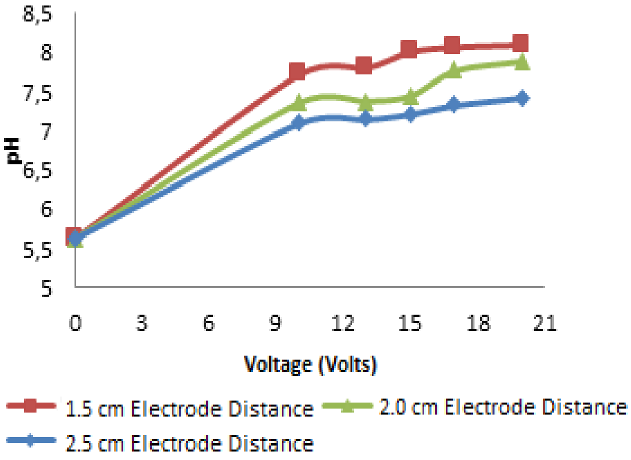

Figure 5. Effect of voltage on the pH value at any variation in electrode spacing

The Effect of Applied Voltage on the turbidity

Turbidity or turbidity of water can be caused by clay, sand, fine organic and inorganic substances, plankton and other microorganisms. Water turbidity standard is set between 5-25 NTU (Nephelometric Turbidity Unit) and if it exceeds the set limits will disrupt the aesthetics and reduce the effectiveness of water disinfection.

The results of the study of turbidity changes from the electrocoagulation process in the textile industry wastewater are shown in Figure 6. Measurement of changes in turbidity of water is carried out using turbidimetry with NTU measurement.

From Figure 6, it can be seen that when the condition of 10-5 volts is seen a significant decrease in turbidity, but under conditions of 15-20 volts, the turbidity of the water becomes more constant even though the process voltage used is higher. When voltage is applied to the solution continuously, the amount of Al^{3+} from the electrodes increases so that the amount of $Al(OH)_3$ floc also increases. The number of flocks that are too much will cause saturation of the electrode plate so that the ability of the electrode to attract solids in the waste will be reduced. The impact of this condition causes a decrease in the magnetic field.

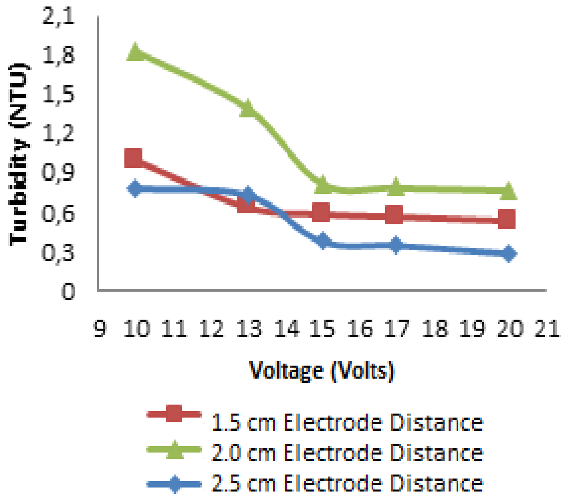

Figure 6. Effect of voltage on the turbidity value at each electrode distance variation

The electrocoagulation process will be minimum if there is saturation on the electrode plate and the magnetic field will be very small which causes the measured turbidity to be constant. In this study, the best electrocoagulation results for turbidity are at a distance of 2.5 cm with a process voltage of 20 volts, where the value drops from 330 to 0.29 NTU. Turbidity in electrocoagulation can occur due to the presence of fine bubbles of hydrogen gas which tends to break away from the electrodes. The gases coming out of this wastewater then bind the colloidal particles that are suspended in the wastewater and then float to the surface as foam waste. The more colloidal particles that remain in the waste, the more foam is formed.

CONCLUSION

Electrocoagulation process to reduce pollutants in jumputan industrial wastewater at a reaction time of 120 minutes with a distance between electrodes of 1.5 cm and a voltage of 20 volts. The effectiveness of the electrocoagulation method in reducing pollutant levels in the textile industry wastewater was obtained for turbidity 99.84%, TDS 66.59%, TSS 33.68%, color 99.33%, and chrome metal content 62.5%.

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