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Reduction of Turbidity, Color Intensity and COD of Jumputan Wastewater with Electrocoagulation Method

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Abstract

In the production process, the Jumputan industry usually uses synthetic dyes that are harmful to environment. The waste produced contains relatively high chemical oxygen demand (COD), turbidity and color intensity. One of the wastewater treatment technologies that can be applied and is relatively inexpensive is the electrocoagulation method. The purpose of this study was to determine the effectiveness of the electrocoagulation method in reducing turbidity, color concentration and COD levels in Jumputan wastewater treatment. The electrodes used are aluminium plates, both anode and cathode. Variations used in this study were agitation speed and system (batch and intermittent systems). The fixed variable used is a voltage of 3.5 volts, 2 aluminum plates as electrodes, and a volume of 250 ml of Jumputan wastewater. The results showed that the maximum turbidity reduction reached 99.89% for the batch system at a contact time of 150 minutes with an agitation speed of 150 rpm, and 99.97% for the intermittent system at a contact time of 60 minutes with an agitation speed of 150 rpm. The maximum percentage of color removal reached 58.90% for the batch system with a contact time of 90 minutes with a stirring speed of 50 rpm, and 54.74% for the intermittent system with a contact time of 150 minutes with a stirring speed of 150 rpm. The electrocoagulation method could reduce COD by 78.75% for the batch system and 80% for the intermittent system. The intermittent system had a slightly greater effect on turbidity, color and COD reduction than the batch system. Both the batch system and the intermittent system obtain optimal turbidity and discoloration in the first 30 minutes of the electrocoagulation process. The results showed that the electrocoagulation method was effective as an alternative to reduce COD and turbidity in Jumputan wastewater.

Keywords: Aluminium, COD, color, lectrocoagulation, Jumputan wastewater, turbidity

1. Introduction

Wastewater with high turbidity, color intensity, and COD value can affect the ecosystem if it is discharged into the aquatic environment. This is usually caused by the presence of organic or inorganic materials in the form of suspended or dissolved substances such as fine sand and mud. The contaminants generated from textile processing pose a serious risk to the quality of the aquatic environment (Berradi et al., 2019). Jumputan fabric is a woven fabric that uses plain white material to produce certain patterns. Weaving is made of cloth that is tied tightly (tied and dyed), then dipped in various colors and boiled, after which the cloth is untied and dried. The woven fabric industry uses synthetic dyes containing metals such as Pb (lead), Fe (iron), Cd (Cadmium) and Cr (Chrome) (Khan et al., 2015). The types of synthetic dyes used in the dyeing process of Jumputan fabrics are direct dyes, naphthol, and indigosol. Direct dyes are commonly used in the textile industry (Cundari et al., 2019).

One of the wastewater treatment technologies that has the potential to reduce these pollutants is electrocoagulation. The electrocoagulation method is based on a combination of oxidation-reduction reactions or redox reactions, which occur at identical or different electrodes in an electrocoagulation system. The electrocoagulation process produces flocs that contain slightly stable water bonds and are easily filtered (Rusdianasari et al., 2019).

In the electrocoagulation process, electrode plates can be arranged in series and parallel as well as monopolar and bipolar. The arrangement of the electrode plates is determined according to the type of contaminants to be reduced. Pollutant removal efficiency is affected by the arrangement of the electrodes (Ghosh et al., 2008; Khandegar and Anil, 2013). The arrangement of the electrodes has a major influence on the economy in the electrocoagulation process (Khandegar & Anil, 2013). Monopolar electrodes arranged in series have a greater potential difference than monopolar electrodes arranged in parallel. This happens because the electrodes are arranged in parallel, the electrical current will be divided. Monopolar electrodes are more effective than bipolar electrodes, especially when placed in parallel.

The electrocoagulation process can reduce heavy metal cations up to 99% of the liquid waste. Metal electrodes are essentially oxidized to positively charged ions. Water turns into gas as hydrogen and hydroxide ions. According to Jovanovic (2021), there are three types of processes in the mechanism of the electrocoagulation process:

a) Active coagulant is formed from the oxidation reaction that occurs at the anode.
b) The colloidal particles become unstable and the emulsion decomposes when coagulants are formed in the solution.
c) Floc is formed because of unstable colloidal particles that are aggregated.

Referring to the disadvantages of chemical and biological wastewater treatment, the electrocoagulation process is a method that uses simple equipment, low initial installation and maintenance costs, produces small amounts of sludge after treatment with short settling time, and good pollutant removal efficiency (Ebba et al., 2022). The electrocoagulation method is influenced by the amount of direct electric current in the electrodes, the distance between the electrodes and the narrowness of the electrode contact area. Electrocoagulation is not recommended for liquid waste with high electrolyte properties, because it can cause a short circuit among the plates. The electrodes will form a layer that can reduce efficiency. Electrocoagulation is an electrochemical technique used to treat highly polluted sewage in which the anode corrodes to release active coagulant precursors into solution (Ebba et al., 2022; Jing et al., 2020).

Many studies on electrocoagulation have been carried out. Research by Rusdianasari et al. (2019) and Hajar et al. (2021) carried out the electrocoagulation method in songket wastewater treatment, and Rusdianasari et al. (2020) carried out the jumputan wastewater electrocoagulation method. The reduction in TSS levels reached 33.68%, turbidity 99.84%, chromium content 62.5%, color 99.33%, and TDS 66.59% (Rusdianasari et al., 2020). The reduction in COD levels reached 96.37%, TSS 86.18%, and total Cr metal 99.90% (Hajar et al., 2021). The decrease occured by 67.28% for TSS, 54.13% for BOD5, 63.64% for COD, 79.21% for color intensity and 74.93% for phenol content (Rusdianasari et al., 2019).

In this work, electrocoagulation technique is proposed to treat Jumputan wastewater. The purpose of the study was to determine the effectiveness of the electrocoagulation method to reduce turbidity, color, and COD contained in jumputan wastewater. The study was conducted using aluminum electrodes with various agitation speeds and systems (batch and intermittent) used during the electrocoagulation process. The choice of time variation is based on research conducted by Hajar et al. (2021) who showed that the longer the time, the higher the reduction in COD, BOD5, TSS and pH levels.

2. Methodology

2.1. Materials

Jumputan wastewater was obtained from a Tuan Kentang craftsman in Palembang, Indonesia. Aluminum plate 15 cm x 4 cm x 0.1 cm was purchased at the local market. Direct dyes as a parameter model for textile pollution were purchased from Tuan Kentang craftsman, Palembang City, Indonesia. Deionized water was obtained from the Separation and Purification Laboratory, Faculty of Engineering, Universitas Sriwijaya.

2.2. Preparation of Standard Solutions

The initial standard solution was obtained by dissolving 1 g of the dye directly in 200 ml of deionized water. The solution was put in a 1 L volumetric flask. Deionized water was added to the volumetric flask to obtain a direct dye solution with a concentration of 1000 ppm to 1 L. The standard solution was prepared by diluting 1000 ppm stock solution in various concentrations, namely 100, 200, 300, 400, 500 and 600 ppm each of 50 ml. Standard solutions at different concentrations were tested with a spectrophotometer to determine the absorbance at each concentration. Then, these valuees were plotted on a graph to produce a linear equation to determine the initial concentration of Jumputan effluent.

2.3. Batch and Intermittent System Procedures

Wastewater was placed in a beaker glass, a set of tools was connected to a direct current (DC) and the electrodes were arranged in parallel. The schematic of the electrocoagulation device was shown in Figure 1. The electric voltage was adjusted to 3.5 volts, then the samples were stirred with various speeds of 50, 100 and 150 rpm, respectively. The contact time for the electrocoagulation process for both batch and intermittent systems were 30, 60, 90, 120 and 150 minutes.

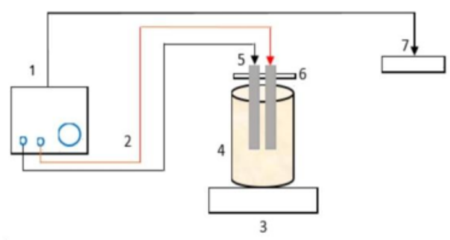

Figure 1. Schematic diagram of an electrocoagulation device. 1 = power supply, 2 = cables and clamps, 3 = hotplate, 4 = Beaker, 5 = Aluminum electrodes, 6 = electrode connector, and 7 = power socket.

In a batch system, the volume of Jumputan wastewater was 50 ml of each sample. In the intermittent system, the volume of Jumputan wastewater was 250 mL, and up to 50 mLof sample was collected for each additional 30 minute contact period. All samples were precipitated for 20 minutes. After the sample settles, it was filtered using filter paper. After the electrocoagulation process, color analysis was carried out with a UV-visible spectrophotometer (Genesys 20 brand) and turbidity analysis was carried out with a turbidity meter. COD was measured with a spectrophotometer at Balai Besar Laboratorium Kesehatan, Palembang, Indonesia.

3. Results and Discussion

The absorbance of the direct dye as a standard solution was tested using a UV-visible spectrophotometer at a wavelength of 493 nm. The absorbance of the standard solution is shown in Figure 2. The linear equation, $y = 0.0033x - 0.1114$ with $R^2 = 0.9995$, is used to determine the initial concentration of the effluent. The initial wastewater absorption from Jumputan was 0.355, resulting in a dye concentration of 141.33 ppm.

In accordance with the Regional Regulation of the City of Palembang No. 2 of 2003 concerning permissible quality standards for textile industry wastewater, the parameter of Jumputan wastewater that exceeds environmental quality standards is COD. Other parameters in the wastewater meet textile industry standards (total chromium content, ammonia content, BOD, oils and fats, and TSS). Test results number 1-7 were obtained from Balai Besar Laboratorium Kesehatan Palembang, and numbers 8-9 were obtained from the Separation and Purification Laboratory.

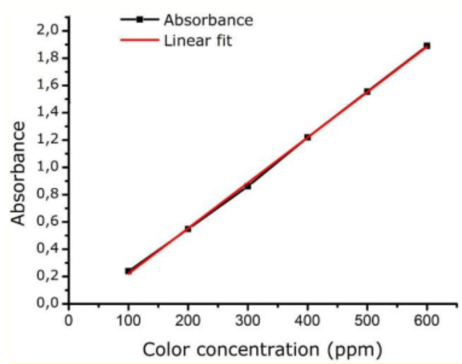

Figure 2. Standard solution calibration graph.

Table 1. Analysis of Jumputan wastewater before treatment

No	Analysis Type	Results	Quality Standard[1]
1.	pH (Unit)	6.24	-
2.	TSS (mg/L)	1.7	50
3.	NH_3-N (mg/L)	5.380	8
4.	Cr-T (mg/L)	<38,509 x 10^{-3}	1
5.	COD (mg/L)	160	150
6.	BOD (mg/L)	47	60
7.	Oils and fats (mg/L)	0.4	3
8.	Turbidity[2] (NTU)	175	25
9.	Color (ppm)	141,333	-

1 = textile industry standard
2 = clean water standard

3.1. Turbidity Removal

The initial turbidity of the wastewater reaches 175 NTU. The data entered is the average result of three test repetitions. Figure 3 shows the effect of agitation speed on turbidity values in a batch system. All variations of agitation showed a rapid decrease in turbidity in the first 30 minutes, then decreased slowly. In the 30 minute process, the stirring speed affected the turbidity decoration, the higher the speed, the higher the turbidity reduction, with the respective numbers of 0.73, 0.77 and 0.23 NTU for 50, 100 and 150 rpm rotation.

Figure 4 shows the details of turbidity after the batch electrocoagulation process occurrs. At

50 rpm, turbidity is expected to drop from 175 NTU to 0.187 NTU. In the first 30 minutes, the turbidity dropped dramatically to 0.73 NTU from the previous. After 30 minutes, degradation becomes slower. These results indicate that the optimal time for the electrocoagulation process is 30 minutes.

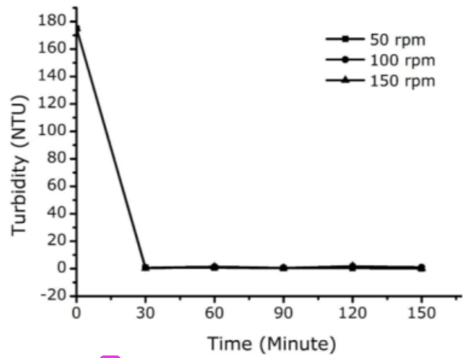

Figure 3. Effect of agitation speed on the turbidity of the batch system

The stirring speed of 100 and 150 rpm showed the same turbidity trend, details are shown in Figure 4. Degradation was fast in the first 30 minutes, then slightly increased to 60 and 120 minutes. Turbidity value fluctuations ranged from 0.23 to 1.88 NTU. The higher agitation speed and contact time causes the turbidity value in the batch system to fluctuate because the resulting flocs breaks, so that the solution becomes unstable.

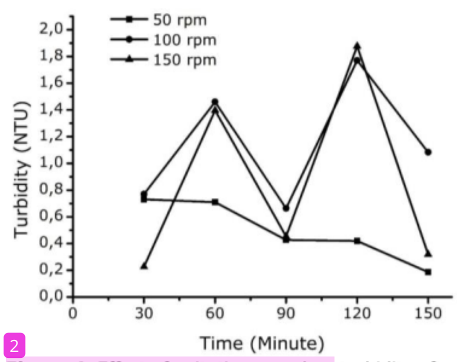

Figure 4. Effect of agitation speed on turbidity after the batch electrocoagulation process (detail Figure 3)

Faraday's first law states the mass of a substance produced by an electrode during the electrolysis process is proportional to the number of moles of electrons (electricity) flowing to the electrode. According to Faraday's first law, the longer the electrolytic contact time, the higher the resulting overall charge. As a result, the electrodes produce a larger mass of substance. The large mass of substances produced causes the largest pollutant to be reduced in wastewater. This means that the optimal turbidity removal point occurs at 30 minutes for all changes in agitation speed.

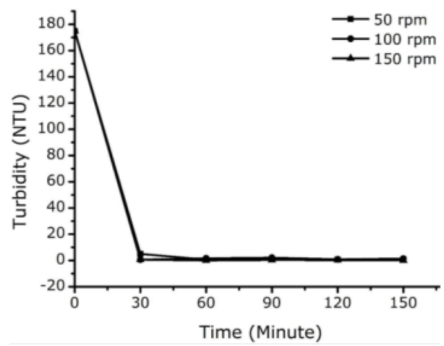

Figure 5. Effect of agitation speed on intermittent system turbidity

Figure 5 shows the effect of agitation speed on the turbidity of Jumputan wastewater using the electrocoagulation method in an intermittent system. Similar to a batch system, rapid reduction occurs over the first 30 minutes and then slowly. Turbidity decreased by 175 NTU to 0.06 NTU. In intermittent system, turbidity data fluctuations do not take place significantly, and the data tends to decrease with contact time.

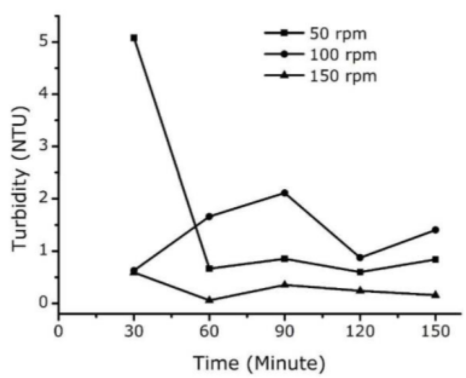

Figure 6. Effect of agitation speed on turbidity after intermittent electrocoagulation process (detail Figure 4)

Based on Figure 6, at a speed of 50 rpm, optimal conditions occur over 60 minutes with a reduction of 0.66 NTU. After 60 minutes, the turbidity value tends to decrease consistently. At a stirring speed of 100 and 150 rpm, the turbidity value tends to fluctuate after 30 minutes of processing, the turbidity ranges from 0.06 to 2.11 NTU. Although the data fluctuated after 30 minutes, the differences were small when the data were compared with each sample after electrocoagulation. Thus, it can be concluded that in the intermittent system, the optimum takes place within 30 minutes. The high agitation rate and long coagulation contact time cause the floc to break so that it is not effective in reducing turbidity.

Figure 7 shows the decrease in the turbidity of Jumputan wastewater treatment using the electrocoagulation method. Batch and intermittent systems, variations in agitation speed and contact time resulted in more than 97% turbidity removal. The turbidity elimination range is 98.92–99.87% for the batch system and 97.10–99.96% for the intermittent system. The difference between agitation speed and contact time is very small. It was concluded that optimum conditions for the Jumputan wastewater treatment electrocoagulation method were 30 minutes, and variations in stirring speed and contact time did not have a significant effect on turbidity removal. All data obtained are aligned with government environmental standards.

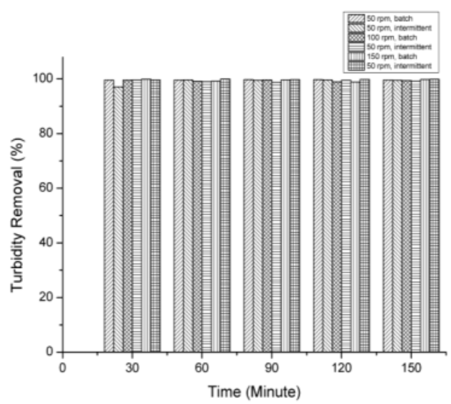

Figure 7. Percentage of turbidity removal from Jumputan wastewater treatment by electrocoagulation.

3.2. Color Removal

The original color concentration of Jumputan wastewater is 141.33 ppm. Based on Figure 8, for a batch system with a stirring speed of 50 rpm, 100 rpm and 150 rpm, the color value is reduced to 58.10-75.98 ppm from the beginning. During the first 30 minutes, the reduction occurrs quickly and slowly thereafter. The optimal electrocoagulation time is 90 minutes at 50 rpm, 120 minutes at 100 rpm and 150 minutes at 150 rpm. The maximum color degradation occurred at a stirring speed of 50 rpm and a contact time of 90 minutes with a color concentration of 58.10 ppm.

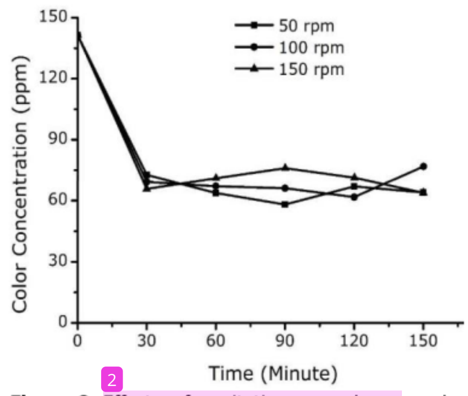

Figure 8. Effect of agitation speed on color concentration in a batch system

According to Figure 9 for the intermittent system, the color reduction during the first 30 minutes was fast and then slowly degraded. It is said that the color approaches the equilibrium state at 30 minutes. This can be seen from the data obtained which did not experience a significant decrease or increase. Maximum color reduction was achieved at an agitation speed 150 rpm and a contact time 150 minutes with a color concentration 63.96 ppm.

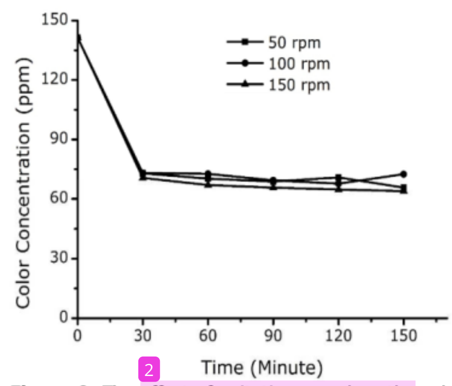

Figure 9. The effect of agitation speed on the color concentration of the intermittent system

The decrease in color concentration occurrs because of the adsorption process. Molecular substances are separated from the wastewater and bound to the coagulant. The electrocoagulation process aims to determine the effect of electric current on dissolved and suspended organic matter in batik waste (Rosariawari et al., 2017).

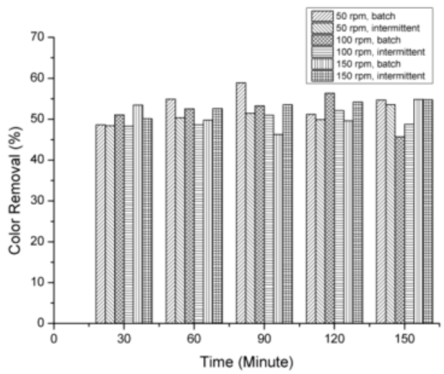

Figure 10. Percentage of color removal in Jumputan wastewater treatment using the electrocoagulation method

Figure 10 shows the removal of color in Jumputan wastewater treatment using the electrocoagulation method. The percentage of color removal varies from 45.67 to 58.90%. Batch and intermittent systems, variations in agitation speed, and contact time had no significant effect on decolorization. The optimal condition for any change is a 30 minute process. These results indicate a similar pattern of turbidity elimination.

3.3. COD Removal

Figure 11 shows the results of the analysis of COD levels in the initial and final samples of jumputan wastewater after the electrocoagulation process using a batch system and an intermittent system. Sample 1 indicated native COD at 160 mg/L. Sample 2 reports the final level of COD using batch electrocoagulation at 50 rpm and 90 minutes. Sample 3 reports the final COD level using an intermittent system that occurs at 50 rpm and 90 min. COD decreased from 160 mg/L to 34 mg/L (78.75% elimination) for the batch system and 32 mg/L (80% elimination) for the intermittent system.

In wastewater treatment, an increase in COD concentration occurs because the organic matter molecules and the electric field in the solution are destabilised by the coagulant during processing. Molecules are adsorbed by the agglomerated and precipitated floc because of the breaking of the physical bonds among organic molecules. Hydrogen and oxygen gases produced from this process produce partially dissolved organic compounds and other dissolved materials float. Flocs settle down after they reach sufficient weight (Cundari et al., 2021).

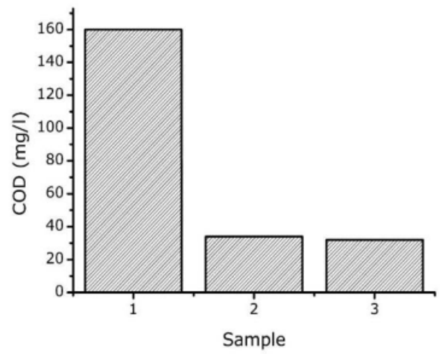

Figure 11. Graph of comparison of reduction in COD levels before and after electrocoagulation treatment.

3.4. Electrocoagulation Performance

In previous studies the application of the electrocoagulation method to wastewater has been applied to textile wastewater, fishery wastewater, cosmetic wastewater, and landfill leachate. Several types of results were obtained based on the parameters of post-treatment wastewater. The electrocoagulation method was found to be effective in the reducing contaminants or pollutants in wastewater. Table 2 shows a comparison of research on wastewater treatment using the electrocoagulation method. Based on research conducted by Mahmad et al. (2016), aluminum electrodes are more effective than stainless steel electrodes. The decolorization and turbidity removal efficiencies of aluminum electrodes were 99.78% and 99.65%, respectively. Meanwhile, the decolorization and turbidity efficiency of stainless steel electrodes were 94.76% and 99.41%, respectively. Stainless steel electrodes are more effective than aluminum electrodes in treating wastewater containing heavy metals other than iron (Nasrullah et al., 2012).

The result of this study show less discolororization compared to Rusdianasari's study (2020). The difference between the two is the number of electrodes, the voltage obtained, the spacing between the electrodes, and the dimension of the electrodes. Rusdianasari (2020) uses four aluminum electrodes with electrode spacing of 1.5 cm, dimensions 11 x 10.5 x 0.15 cm, and a voltage of 20 volts.

Table 2. Comparison of research results

Types of Wastewater	Electrode	Removal Efficiency			Researcher
		COD	Turbidity	Color	
Jumputan wastewater	Aluminium	-	99.84%	99.33%	Rusdianasari (2020)
Printing wastewater	Aluminium	88.9%	-	98.6%	Thuy et al. (2021)
Tofu wastewater	Aluminium	28.57%	-	-	Hajar et al. (2021)
Textile industry wastewater	Aluminium	91.8%	-	84.26%	Sutanto et al. (2021)
Songket wastewater	Aluminium	63.64%	-	79.21%	Rusdianasari et al. (2019)
Jumputan wastewater	Aluminium	-	99.84%	99.33%	Rusdianasari et al. (2020)
Landfill Leachate	- Aluminium - Stainless steel	- -	99.65% 99.41%	99.78% 94.76%	Mahmad et al. (2016)
Jumputan wastewater	Aluminium	80%	99.96%	58.90%	This research

4. Conclusion

Variation of agitation speed and system (batch or intermittent) has no significant effect on turbidity and loss of color. Turbidity removal ranged from 97.10% to 99.96%. The percent color removal is 45.67-58.90%. COD removal is 78.75-80%. Optimal turbidity and discolorization occurred at 30 minutes for all variations.

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