Comparison of Anionic and Cationic Dyes Wastewater Treatment by Utilizing Corona Discharge Method

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Abstract. The most dangerous water pollution comes from industrial waste, including in the textile industry. Two synthetic dyes can be found in the environment: cationic dyes, represented by Methylene Blue, and anionic dyes, represented by Remazol Red RB 133. The corona discharge plasma method was chosen because it does not add chemicals or produce new waste. Wastewater treatment with corona discharge plasma and the influence of contact time can reduce the concentration value of Methylene Blue dyestuffs but does not apply to Remazol Red RB 133. Methylene Blue and Remazol Red RB 133 tend to be acidic with a pH range of 5.0 – 6.0. Meanwhile, the number of coils affects the performance of decreasing the concentration of dyes, pH, TDS, and EC due to the corona strength in 11 coils being more significant than the number of other coils.

Keywords: Anionic dyes, Cationic dyes, Corona discharge, Ozonization, Textile waste

1 Introduction

Clean water is essential for living things and will be harmful when polluted. Water pollution can come from various things; industrial wastewater is the most hazardous. One type of industrial wastewater that causes water pollution is textile wastewater.

Several methods have been used to treat textile wastewater, such as adsorption, biodegradation with fungi Polyporus sp., coagulation–flocculation, photodegradation, and corona discharge plasma [1]–[5]. However, some of these methods have drawbacks, generating new waste and new chemical reactions that need to be re-examined before being thrown away. Therefore, this test's selected method for processing textile wastewater is corona discharge plasma. The corona discharge plasma method does not add chemicals or generate new waste [6]-[7]. Besides, The process is environmentally friendly and does not require large land broad [8].

The plasma reactor is a device that utilizes high-voltage impulse generation and pure oxygen to produce plasma corona discharge [9]. Impulse high voltage generation is used to produce plasma

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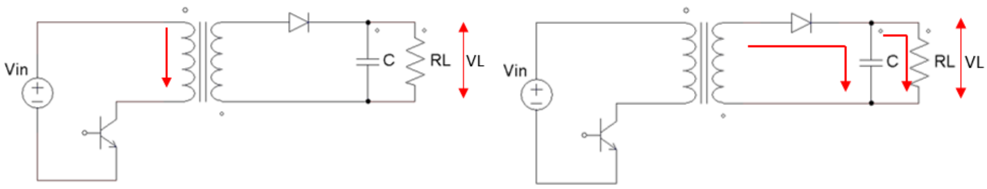
using the flyback converter method. Corona discharge plasma will appear when a high voltage impulse from the flyback converter encounters pure oxygen. Pure oxygen and wastewater are fed into a plasma reactor, to processing are carried out. Then, the results of water treatment, the waste goes out to a landfill. Then, the waste in the shelter at the end will be moved back to the initial shelter for reprocessing.

2 Literature Review

2.1 Flyback Converter

The flyback converter is a DC–DC converter with the basic topology of a buck–boost converter. It has a large voltage gain due to the turns ratio on both sides of the transformer compared to the buck and boosts converter. The flyback converter has two conditions: switching ON and OFF [10]. **Figure 1** shows when the condition is switched ON and OFF.



(a) (b)

Fig. 1. Flyback Converter: (a) Switching ON; (b) Switching OFF

2.2 Plasma Reactor

Plasma can be defined as an ionized gas due to a mixture of electrons, positive ions, and negative ions. Corona discharge occurs due to the meeting of gas media with high voltage originating from the electrode geometry configuration, causing the gas particles to be ionized [10]. The characteristics of corona discharge include the appearance of a purplish-blue light, the emergence of a hissing sound, and the smell of ozone [11].

Dielectric barrier discharge (DBD) is a silent corona discharge plasma with a closed system [12]. Corona discharge plasma is generated from the gap between the inner electrode (active electrode) and the outer electrode (passive electrode). When the two electrodes are applied, a voltage will produce an inhomogeneous electric field [13].

2.3 Textile Industry Wastewater

Textile industry dye wastewater can be seen from the change in the color of the water to blue, red, yellow, and so on from synthetic dyes. The dyes used in this research were Methylene Blue (cationic dye) and Remazol Red RB 133 (anionic dye). When discharged into the environment without any processing, these dyes will harm the environment. The quality standard of textile industry wastewater in Indonesia for pH is 6-9 [14]. While for hygiene sanitation, the maximum limit of total dissolved value (TDS) is 100 mg/L [15].

3. Research Methodology

The plasma reactor for textile wastewater treatment used wire and spiral electrodes. **Figure 2** shows the corona discharge generator circuit illustration, Figure **3** shows the plasma reactor designs, and Table 1 shows the reactor specifications. The working system of this tool was to enter wastewater and oxygen into the reactor. In addition, it provided a high-voltage connection to the electrodes. The wire electrode (threaded iron) was connected to the anode, and the spiral copper wire electrode was connected to the cathode. Combining oxygen and high voltage would produce a corona discharge plasma, producing ozone gas. *Ozone gas* is a substance that treats wastewater so that the wastewater can be discharged into the environment or reused. Before the wastewater treatment results can be discharged into the environment or reused, it is necessary to check the dye concentration, pH, TDS, and EC. Then, the wastewater was processed for 5 minutes per travel time with a total travel time of 6 times.

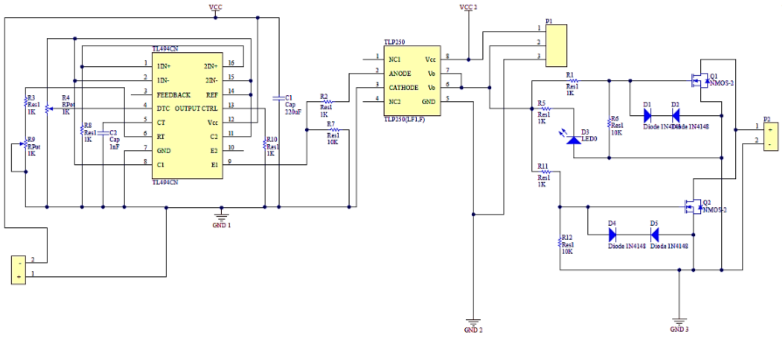


Fig. 2. Corona Discharge Generation Circuit

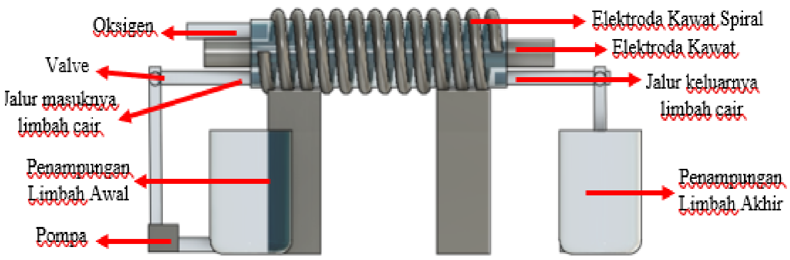


Fig 3. Plasma Reactor Design

Table 1. Parameter and Specification of the Reactor

Parameter	Design
Variations of textile dye waste	Cationic (*Methylene Blue)*, Anionic (*Remazol Red RB 133*)
Plasma reactor electrode	Threaded iron electrode and spiral copper wire electrode
Number of turns of electrode	3 variations
Time	5 minutes per times (6 times)
Test parameter	Dye concentration, pH, TDS, and EC
Switching frequency	150 kHz
Output voltage	8,65 kV
Current	0,7 µA
Pompa	240 L/H

Wastewater flow rate	250 ml/mins
Oxygen flow rate	7 L/mins

4. Results

4.1 Analysis of the Characteristics of the Characteristics Syntethic Dye Wastewater

A calibration curve is used to determine the value of the dye waste concentration. Before making a calibration curve, it is necessary to know the maximum wavelength of a substance to determine absorbance using a spectrophotometer. Based on the spectrum measurement results, the absorbance peaks of Methylene Blue and Remazol Red RB 133 are at wavelengths of 664 nm and 518 nm, respectively. These wavelengths then be used to analyze the absorbance of residual sample after treatment. The calibration curve is shown in **Figure 4**. The equation results obtained from the calibration curve in **Figure 4** are used to determine the concentration of the solution. The correlation coefficients obtained on the Methylene Blue and Remazol Red RB 133 calibration curves are namely 0.9926 and 0.9999.

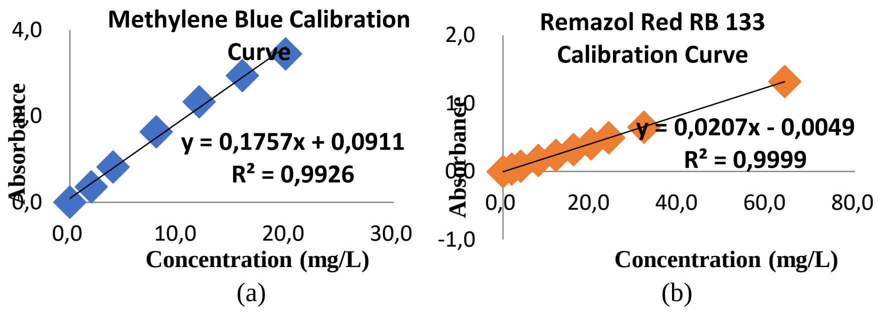
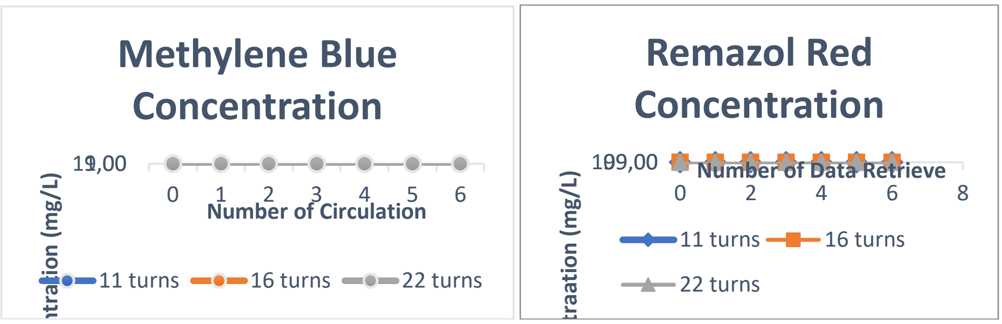


Fig. 4. Calibration Curve: (a) Methylene Blue; (b) Remazol Red RB 133

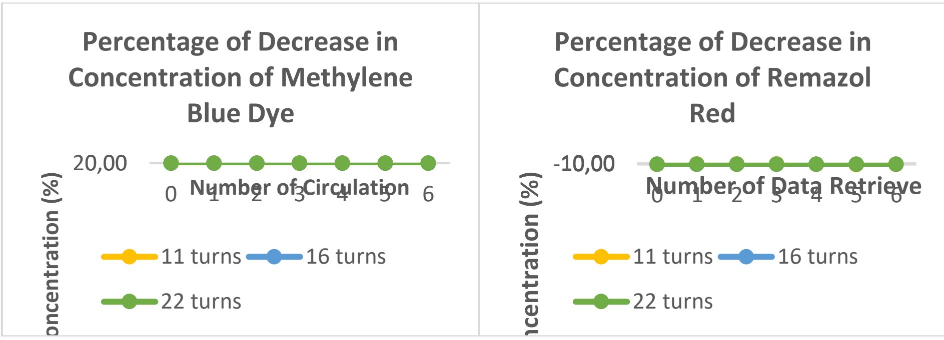
4.2 Analysis of the Effect of the Number of Turns on Spiral Electrodes and Travel Time on the Concentration of Dyes

Dye wastewater treatment using corona discharge plasma is carried out by varying the number of turns and the number of circulations. The first parameter to be analyzed for the effect of the two variations is the decrease in the dye concentration. Data and graphs of the decrease in dye concentration can be seen in **Figure 5** and **Figure 6**. Based on **Figure 5**, it can be seen that the concentration of Methylene Blue dye decreased after the wastewater was processed. The decrease in dye concentration can occur due to the indirect reaction of ozone which produces OH radicals as a decomposition process [16], [17].



(a) (b)

Fig. 5. Concentration Curve of: (a) Methylene Blue; (b) Remazol Red



(a) (b)

Fig. 6. Percentage of Decrease in Concentration of: (a) Methylene Blue; (b) Remazol Red

The percentage decrease in the concentration of the resulting dye increased (Figure 5). Therefore, it can be proven that the variation of travel time for synthetic wastewater treatment with corona discharge plasma causes the dye concentration value to decrease. However, the number of turns affects the performance of the dye concentration and the percentage of dye reduction. The effect of the number of turns that produces the most significant percentage of dye reduction was the number of turns, as many as 11, with a percentage of 14.43%. This is because the corona strength in 11 turns exceeded the number of other turns. Meanwhile, the power of the corona in the 22 coils is smaller (faint), so less ozone is produced, and the decrease in the concentration of the dye produced is prolonged.

Based on Figure 4.4, the Remazol Red RB 133 dye concentration increased, so the percentage decrease in concentration (Figure 8) decreased (concentrated). Remazol Red RB 133 is an azo group dye or double bond (-N=N-), which is difficult to decompose. According to research from Fathul Jannah (2017), the ozonation method using a dielectric barrier discharge (DBD) reactor on an artificial red azo group type dye resulted in a lower concentration produced but became constant. The percentage decrease in absorbance was only 4%, or the ozonation method did not form a suspension. [32]. Based on the data obtained and Fathul Jannah's research (2017), it can be concluded that the dielectric barrier discharge (DBD) reactor with screw iron rod configuration with spiral copper wire was not able to reduce the concentration of azo group dyes, if possible the processing takes a long time and the corona intensity. This happens because the DHF reactor used was only in the form of sound or hiss. Several methods can decompose dyes from azo groups (Remazol Red RB 133), namely electrocoagulation, electrolysis, photocatalysis, photo electrocatalysis, Fenton methods, and treatment using FeSO4 and ozone [18], [19].

4.3 Analysis of the Effect of the Number of Turns on Spiral Electrodes and Travel Time on the Degree of Acidity (pH)

According to the government quality standards, the standard pH value of textile industry wastewater is 6.0 – 9.0. However, the pH value of Methylene Blue obtained after processing based on Figure 9 tends to be unstable. As a result, the pH value obtained after processing tends to be acidic (pH range 5.0 – 6.0) and is not following the quality standard. It also applies to Remazol Red RB 133. The pH value decreases due to an ozonation reaction that makes compounds from dyestuffs ionize and releases hydrogen ions. The more hydrogen ions are dissolved in water, and the pH value will decrease. Therefore, it is under equation (1).

$$3Fe + 4H_2O \rightarrow 4H_2 + Fe_3O_4 \quad (1)$$

In addition, according to research from Isyuniarto, the ability of ozone to reduce wastewater levels only works at high pH [20]. Therefore, the obtained pH tends towards an acidic pH.

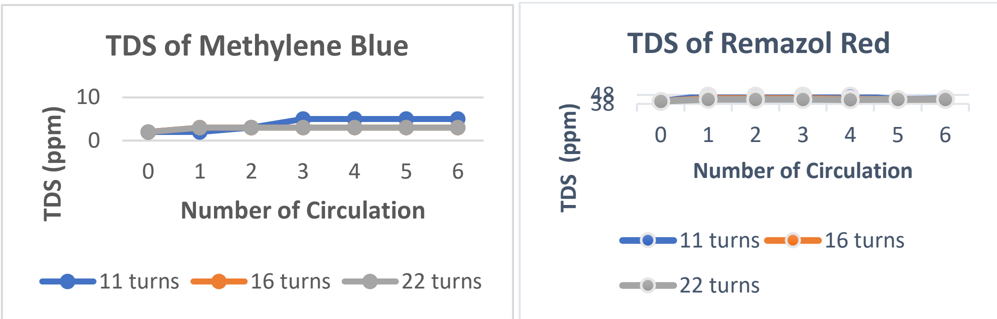
(a) (b)

Fig. 7. pH of: (a) Methylene Blue; (b) Remazol Red

4.4 Analysis of the Effect of Number of Turns on Spiral Electrodes and Travel Time on Total Dissolved Solids (TDS)

Based on **Figure 10**, it can be seen that the resulting TDS value tends to increase. In addition, the more the number of turns, the TDS value will tend to decrease. The increase in TDS value occurs due to an oxidation reaction at one of the electrodes (screw iron), which meets oxygen. The oxidation reaction causes the screw iron to dissolve into the wastewater. The oxidation reaction on screwed iron can be written as equation (2). The greater the TDS value, the more iron will be dissolved into the water.

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e \quad (2)$$

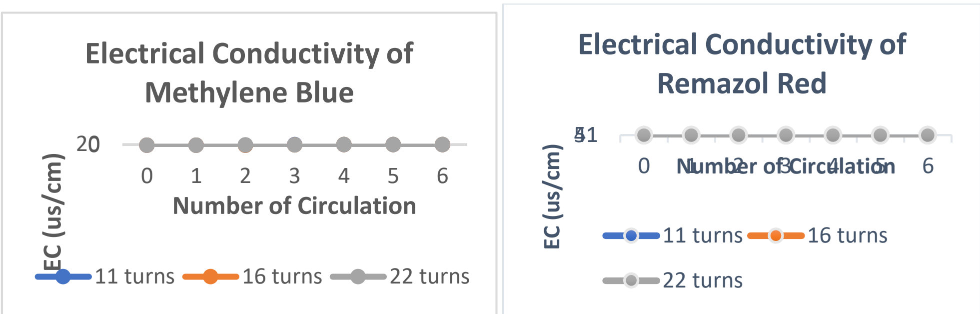


(a) (b)

Fig. 8. TDS of: (a) Methylene Blue; (b) Remazol Red

4.5 Analysis of the Effect of Number of Turns on Spiral Electrodes and Travel Time on Electrical Conductivity (EC)

Based on **Figure 9**, it can be seen that the more circulation, the higher the EC value resulted. The higher the EC value, the higher the TDS value. So the ability of water to conduct electric current and the TDS value will be higher. It follows the results of the oxidation reaction in equation (2). It also follows Das et al. (2005) research that the TDS and EC values have a linear relationship [21].



(a) (b)

Fig. 9. Electrical Conductivity of: (a) Methylene Blue; (b) Remazol Red

Conclusion

Using corona discharge plasma (ozonization method) can reduce the concentration of Methylene Blue dye but did not apply to Remazol Red RB 133. Then, the pH values of Methylene Blue and Remazol Red RB 133 were unstable and tended to be acidic (pH range 5.0 – 6.0). The TDS and EC values of Methylene Blue and Remazol Red RB 133 increased due to the oxidation reaction. Similiar result has also shown by the effect of the long travel time which reduced the concentration of Methylene Blue dye but did not for Remazol Red RB 133. Meanwhile, the number of turns affects reducing dye concentration, pH, TDS, and EC performance. Good results in the processing are in the number of coils of 11. It was due to the strength of the corona in the 11 coils being more significant than the other coil numbers.

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