Analysis of Textile Dyes Wastewater Treatment Using Plasma Corona Discharge with Needles-Planes Reactor

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Abstract. Environmental pollution caused by the textile industry that disposes of wastewater carelessly becomes a severe problem. The colored wastewater comes from dye residue in textile wastewater. In response to that problem, the proper treatment is necessary, namely by using plasma corona discharge. Methylene Blue and Remazol RB Red were used as synthetic wastewater for removal experiments. The research shows that in Methylene Blue under acidic conditions a decrease in concentration occurs until it has a final concentration with a removal percentage reaching 74.64%. In Remazol RB Red dye in alkaline conditions, a decrease in concentration occurs until it has a final concentration with a percentage decrease of 29.83%. An increasing number of H^+ ions in the solution causes a decrease in pH. The TDS value decreased only under acidic conditions. In Methylene Blue dye, there was a decrease of 374 ppm using oxygen. While in Remazol RB Red, the decreased until 372 ppm with the use of oxygen. The EC value decreased under acidic conditions. In Methylene Blue dye, there was a decrease to 396 µS/cm using oxygen. While in Remazol RB Red, the decrease to 432 µS/cm with the use of oxygen.

Keywords: Textile industry, Dyes, Plasma corona discharge, Methylene blue, Remazol RB red

1 Introduction

Water use in Indonesia continues to increase in line with the development of the population and industry. However, the increasing demand for clean water is also accompanied by increasing water pollution in the surrounding environment. Water can be said to be polluted if the parameters contained in the water are inconsistent with the quality standards or regulations set. The impact of polluted water can affect living things health conditions.

Until 2020, several textile industries in rural areas still dump wastewater into rivers [1]. One of the components often found in textile wastewater is dyestuffs, which are of two types, namely

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anionic and cationic dyes. Several methods were performed for treating dye wastewater include coagulation-flocculation, biosorption, biodegradation, and corona discharge plasma. The coagulation method can reduce dyes, pH, and chemical oxygen demand (COD) at a low cost, but it is difficult to determine the appropriate chemical dosage [2]. The biosorption method can reduce COD but requires a long process and can produce other waste [3]. Then the biodegradation method can reduce dyestuffs, total suspended solid (TSS), COD, and biochemical oxygen demand (BOD), but it takes up to 7 days to process dye waste [4]. Meanwhile, the corona discharge plasma method can quickly reduce dyestuffs, pH, COD, and BOD, does not produce other waste and is safe for the environment.

The solution offered in treating dye waste is using the corona discharge plasma method. Such methods can help purification by breaking down chemical chains and decomposing hazardous waste by generating high-voltage impulses to form ozone. Therefore, this study also carried out an analysis of the values of pH, total dissolved solids (TDS), and electrical conductivity (EC) because of the treatment of dye waste using the corona discharge plasma method.

2 Research Methodology

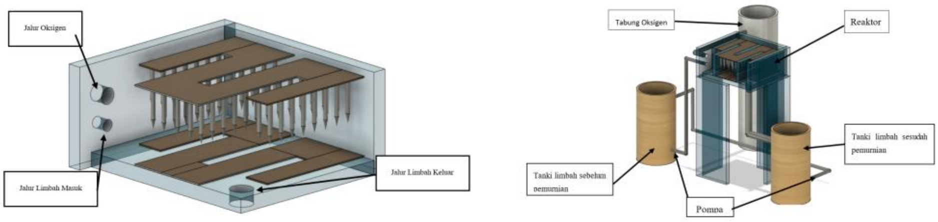
Analysis of the effect of pure oxygen and free air given on the purification reaction will be seen through TDS, pH, dye concentration, and electrical conductivity data. Then another analysis is carried out by varying the degree of acidity in solution so that it can be seen the effect of the degree of acidity on the performance of the reactor in treating dye waste. Then variation was carried out with the multiplicity of cycles at the time of purification to look at the phenomena that occur in the cycle. Finally, dye wastewater treatment was carried out using oxygen and free air to compare ozone formation materials in this study. The reactor on the corona discharge plasma in treating dye wastewater using needles and plane configurations with specifications on the reactor can be seen in Table 1.

Table 1. Equipment Specifications

Specifications	Information
Circulation	6
Switching frequency	50 kHz
Water flowrate	24 L/H
Pump flowrate	240 L/H
Oxygen flowrate	3 L/minute
Free air flowrate	3 L/minute
Output voltage	7,12 kV

In wastewater purification reactors with corona discharge plasma, electrodes in the form of needles and field electrodes with copper base materials were used. So, with a slightly lower voltage, a discharge can form. The electrodes used in the reactor are copper based. The thickness of the plane electrode is 1 mm with dimensions of 9270 mm^2. The needle electrode has a thickness of 3 mm with a needle length of 30 mm, considering the regulation of the air gap of 20 mm.

The corona discharge plasma reactor's design uses acrylic material with a thickness of 10 mm. Three holes in the reactor have functioned as a waste entrance, waste exit route, and air entry route. In the reactor, there is a barrier between electrodes. That functions as a separator and arrangement of the purification path in the reactor. The electrode limiter uses acrylic material that has a thickness of 10 mm, a length of 87 mm, and a height of 50 mm. The following is a look at the overall design of the wastewater purification system with corona discharge plasma (**Figure 1**).



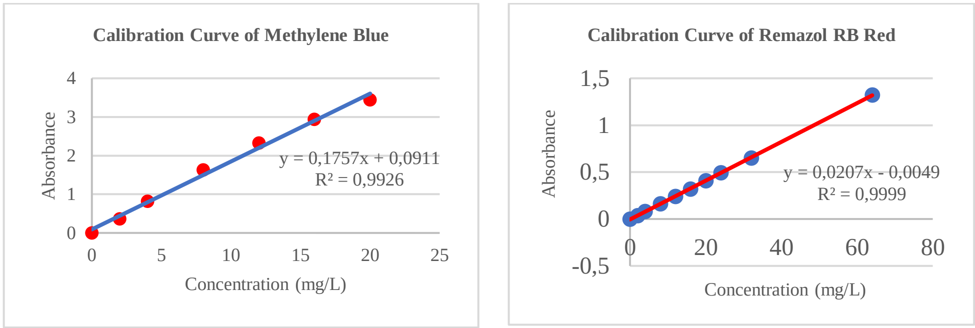
(a) (b)

Fig 1. Design of Purification System (a) Plasma Reactor Design; (b) Overall Design

3 Results and Discussion

3.1 Analysis of dye, TDS, pH, and EC concentrations in Textile Industry waste before the Purification Process

The textile wastewater used was artificially using the dye Methylene Blue as a sample representing cationic dyes and Remazol RB Red dyestuffs as samples representing anionic dyestuffs. Before the purification process, the dyes calibration curve is needed to determine the concentration of a substance. The calibration curve was carried out by varying the concentration of dyes with a concentration of 2 mg/L to 20 mg/L for Methylene Blue (**Figure 1**), while Remazol RB Red dyestuffs up to 64 mg/L (**Figure 2**). The concentration measurement was using a spectrophotometer at each of maximum wavelength by taking the absorbance value (abs) and converted into concentration of mg/L units.



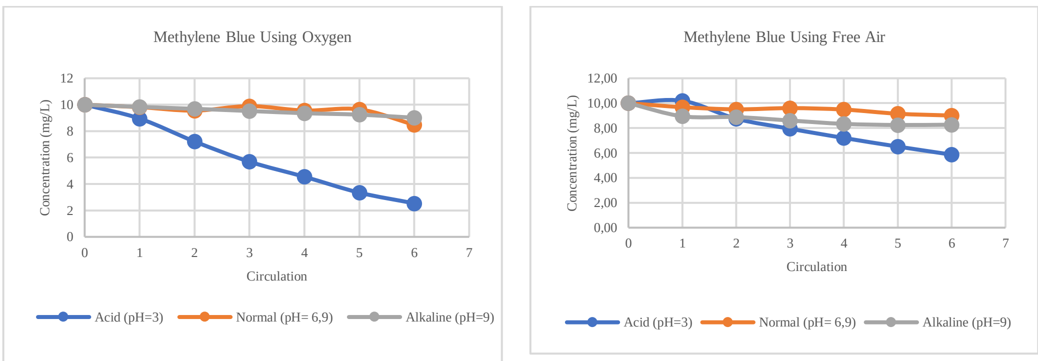
(a) (b)

Fig 2. Calibration Curve of (a) Methylene Blue Dye; (b) Remazol RB Red Dye

It was known that the parameters of Methylene Blue have a pH of 6.9 and the Remazol Red dye's pH of 6.45. Therefore, the solution was varied by mixing HCL 1 M and NaOH 1 M for the experimental sample [5]. So, the acidic condition was carried out at pH 3, and the alkaline condition was conducted at pH 9. Methylene Blue has an initial TDS level of 1 ppm and an EC value of 12 µS/cm. Meanwhile, the Remazol RB Red has an initial TDS level of 41 ppm and an EC value of 52 µS/

3.2 Analysis of the Effect of Variations in Acidity and Circulation Degrees on Decreasing the Concentration of Textile Dyes Solution

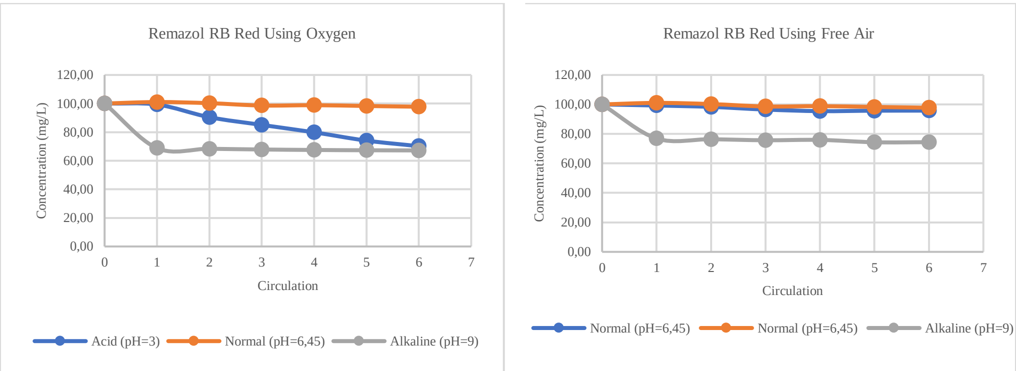
In **Figure 3** can be seen that the concentration of Methylene Blue decreases in acidic condition and slightly decreases for others. This proves that purification using the ozonation method can reduce the concentration of dyes on the solution. The amount of circulation also affects the decrease in concentration. The more circulation carried out, the decreased on the concentration of dye. The most significant decrease in the concentration of dyes occurs in acidic conditions with a decrease of up to 2.53 mg/L in six circulations using oxygen as raw material for ozone formation. Therefore, the decrease in the concentration of Methylene Blue is better than to decrease in acidic conditions by using oxygen or free air. Based on [6], the acidic pH has many ions that react with oxygen radicals.



(a) (b)

Fig 3. Reduction Curve of Methylene Blue Dye Concentration (a) Using Oxygen; (b) Using Free Air

The reduction of Remazol RB Red dye occurred up to 69.69 mg/L in acidic conditions using oxygen as raw material for ozone formation. This value is better than using free air as a raw material for ozone formation. Remazol RB Red experiences a significant decrease in alkaline conditions. However, the decrease in the concentration of dyes that occurs in alkaline conditions was not much different from that in acidic conditions.



(a) (b)

Fig 4. Reduction Curve of Remazol RB Red Dye Concentration (a) Using Oxygen; (b) Using Free Air

3.3 Analysis of the Effect of Variations in Acidity and Circulation on the pH Levels of Textile Dyes Solution

The degree of acidity for each dye, both Methylene Blue and Remazol RB Red, under various conditions have changed. A decrease in the degree of acidity in the dye characterizes such changes. According to the study [7], the decrease was due to the oxidation process in plasma reactors that break the bonds in the solution and make the solution have weak acids. The presence of weak acids in the solution will affect the decrease in acidity. If there are more H^+ ions in the solution, the solution will be more acidic, so that the acidity value will decrease [8]. It can be seen in the curve of change in the degree of acidity in Table 2

Table 2. Effect of Variations in Acidity and Circulation on the pH Level

Condition	Oxygen			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	3	2,96	3	2,58
Normal	6,9	5,73	6,9	5,46
Alkaline	9	6,73	9	7,24
Condition	Free Air			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	3	2,17	3	2,93
Normal	6,45	6,45	6,45	6,43
Alkaline	9	7,31	9	7,17

3.4 Analysis of the Effect of Variations in Acidity and Circulation on TDS Levels of Textile Dyes Solution

The degree of acidity in the solution has no relationship with the value of TDS. It is because the TDS value is influenced by the elements contained in the solution [9]. So, the compounds used as a solution mixture will significantly affect the value of TDS. Ionization energy is required to release an electron from or isolate in the ground state [10].

Table 3. Effect of Variations in Acidity and Circulation on TDS Level

Condition	Oxygen			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	572	Acid	572	Acid
Normal	1	Normal	1	Normal
Alkaline	16	Alkaline	16	Alkaline
Condition	**Free Air**			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	497	Acid	497	Acid
Normal	41	Normal	41	Normal
Alkaline	47	Alkaline	47	Alkaline

From the data obtained on Methylene Blue ($C_{16}H_{18}CIN_3S$), it can be known that for each acidic condition, TDS will decrease, while for normal conditions TDS increased when six circulations carried out. The decrease occurs because, in acidic conditions, the copper element (Cu) cannot carry out a chemical reaction with Oxygen (O_2). According to [11], this is because there is an HCl compound in the solution so that it will have a bond with the element of hydrogen (H^+). The chemical reactions can be seen in the following equations 1 and 2.

$$HCl + Cu \rightarrow \text{No Reaction} \quad (1)$$

$$4HCl + O_2 \rightarrow 2H_2O + 2Cl_2 \quad (2)$$

While under normal conditions Cu will react with O_2, so that the TDS value will increase due to oxidized copper. It can be seen in Equation 3 regarding the chemical reaction between copper and oxygen. In tests using alkaline conditions, there was an increase in the TDS value.

$$2Cu + O_2 \rightarrow 2CuO \quad (3)$$

An increase and decrease in the value of TDS occurs also in the Remazol RB Red. However, in Remazol RB Red, normal and alkaline conditions have a greater value compared to the Methylene Blue, because in the chemical structure of Remazol RB Red ($C_{27}H_{18}CIN_7Na_4O_{15}S_5$)

already has the element sodium (Na) which is the cause of the increase in the TDS value in the solution.

3.5 Analysis of the Effect of Variations in Acidity and Circulation Degrees on EC Levels of Textile Dyes Solution

The large number of ions in the solution indicates the more significant the electrical conductivity of the solution. However, testing the EC value in this study found that the EC value decreased due to the acid condition on solution. Copper could not bond with oxygen because oxygen had bonded with H^+ ions. Generally, the EC value will always be linear with the TDS value in measurements in natural water, which can be seen in Equation 4 below.

$$\mathrm{TDS} = \mathrm{k \; x \; EC} \quad (4)$$

Like TDS, EC value is also not affected by pH. However, the EC value is strongly influenced by the elements in the solution, so the compound was used as a mixture of a solution so that the solution becomes acidic or alkaline, affecting the EC value [9].

Table 4. Effect of Variations in Acidity and Circulation on the EC Level

Condition	Oxygen			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	574	396	656	432
Normal	12	14	52	52
Alkaline	20	16	66	66
Condition	Free Air			
	Methylene Blue		Remazol RB Red	
	Initial Value	Final Value	Initial Value	Final Value
Acid	574	384	656	542
Normal	12	14	52	58
Alkaline	`20	20	66	66

4 Conclusion

Based on the treatment of dye solution with corona discharge plasma. There are several conclusions obtained from this study, including:

1. The purification method with needle-field configuration corona discharge plasma also effectively lowers the concentration of dyes.
2. The influence of variations in the degree of acidity in solution affects the parameters of the concentration of dyes. However, the elements contained in the solution affect the TDS and EC values. TDS values decrease only in acidic conditions. The value of the acidity degree

in the solution will decrease under any conditions due to the oxidation process that occurs in the plasma reactor.

3. The effect of the amount of circulation on the concentration of dyestuffs is that the more circulation is carried out, the more purification processes occur. The addition of circulation will also affect other parameters such as TDS, pH, and EC. The amount of circulation affects decreasing and increase levels of the parameters.

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