Analysis of Anionic Dyes Wastewater Purification Using Corona Discharge Plasma

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Abstract. One method to treat textile dye wastewater can be used is purification using the ozonation process. Ozonation can be produced by corona discharge plasma generated from the flyback converter method. The output of the flyback converter is connected to the needle-field electrode via the flyback. The needle-field electrode was chosen because it was proven that these two electrodes had the highest level of field non-uniformity. The dye wastewater purifier used in this study was Remazol Red RB. The purification results prove that the ozonation process generated through corona discharge plasma can reduce the concentration of dye and the pH value. As a result, the decrease in dye concentration and pH will be higher, along with the increase in circulation and the amount of oxygen supplied to the test reactor. However, the purification results from TDS and EC increased. It was caused by construction gap corrosion and stress corrosion due to the presence of an electrolyte solution and high voltage applied to the copper. The Remazol Red RBexperienced increased dissolved solids, increasing the dissolved solids content and causing the TDS value to increase.

Keywords: Corona discharge plasma, Electrical conductivity (EC), pH, Remazol red RB, Total dissolved solid (TDS)

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1 Introduction

The environment is all aspects that can affect the survival of living things. Therefore, the environment is an essential aspect of ensuring the quality of human life [1]. So that if there is a sustainable environmental problem, it will reduce the quality of life for humans and other living things. Environmental problems can occur due to various factors, including wastewater. Wastewater is generated from water mixed or suspended with waste materials resulting from the rest of the production. One of the remaining productions that produce wastewater comes from the textile industry. In processing textile materials into a product, the dyeing process can potentially cause water pollution [3]. The process produces non-product output as dye wastewater [4]. Textile dyestuffs have a high Total Dissolved Solid (TSD) value, are colorful, and have a non-neutral pH. Therefore, a textile dye wastewater purification process is needed before being discharged into the environment or reused. Several methods can be used to treat dye wastewater, including corona discharge plasma. Corona discharge plasma will produce a chemical reaction that increases ozone levels around the corona. Ozone can play a role in reducing the concentration of dyestuffs, lower pH levels, and removing solid pollutants contained in dye waste (TDS). The ozone will dissolve in water and react to become hydroxide radicals (OH). (OH) radicals are non-selective, so materials that cannot be treated with ozone will be oxidized by OH radicals.

The ozone produced by this corona discharge plasma can be generated using a DC high-voltage generator. The method that can be used in the generation of high DC voltage is the *flyback converter*. *The flyback converter* works by *switching* MOSFET, which is then connected to a flyback transformer. The output of the *flyback converter* is connected to the positive and negative electrodes of the reactor. At the end of the positive electrode, an avalanche of electrons will be created, which will then increase the electric field that tries to penetrate the air gap between the two electrodes, which is called the *partial discharge* or *corona discharge* which will later form ozone which is used in the dyestuff purification process.

2 Methodology

This research was carried out quantitatively with an experimental approach in the laboratory by designing a dye wastewater purification system using the ozonation method, which was generated using *a flyback converter*.

2.1 Research Design

Anionic dye wastewater is purified using the ozonation method, which is produced from corona discharge plasma. It is designed to create a high-voltage impulse generator. This corona discharge plasma generation system was designed using three Switching Mode Power Supply, which is connected to a controller circuit as a regulator of frequency and duty cycle, which IC TL 494CN signals. The output of the TL494CN IC is connected to the TLP 250, which protects the TL494 CN IC in the event of a backflow on the 494 CN IC. The output of the TLP 250 is connected to the flyback converter, which oversees providing input to the MOSFET. The output of this MOSFET produces an impulse signal which is input to the flyback transformer. The anode on the flyback is connected to the needle electrode in the reactor, while the cathode is

connected to the field electrode in the reactor. **Figure 1** shows the corona discharge generator circuit illustration, and **Figure 2** shows the illustration of the reactor.

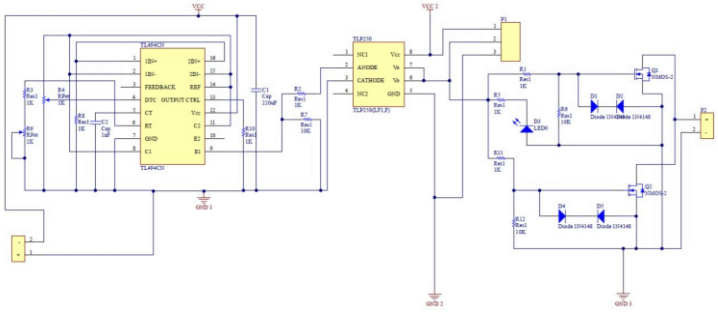

Fig. 1. Corona Discharge Plasma Generation Circuit.

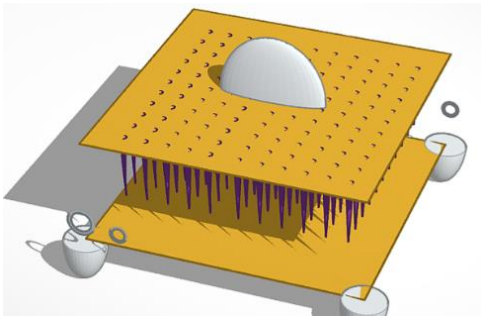

Fig. 2. Field Needle Reactor Ilustration .

2.2 Methods of Data Collection

This study collected data using a literature study and experimental methods related to designing a dye waste purification system using *a flyback converter*. Literature studies are used as a reference in analyzing the data obtained. Several things are considered in collecting anionic dyestuff purification test data on the dyestuff purification system, as shown in Table 1. following.

Table 1. Consideration of Data Collection.

No.	Parameter	Consideration
1	Generation Circiut	Flyback Converter with output voltage 7.12 kV
2	Switching Frequency	50 kHz
3	Duty Cycle	44%
4	Total Purification circulation	6 times
5	Test Paramaters	Dyestuff concentration, pH, TDS, and EC

2.3 Methods and Procedure of Data Analysis

In the purification process, two test conditions will be carried out to analyze the parameters affecting the process, as seen in Table 2 below.

Table 2. Method of Data Analysis

Condition	Parameter Analysis	Test Parameter
1	Effect of circulation on the results of purification of anionic dye	Concentration of dyestuff, TDS, pH, EC
2	Effect of the use of free air and pure oxygen on the results of purification of anionic dye	Concentration of dyestuff, TDS, pH, EC

The experimental of Remazol Red RBremoval was performed by following procedure as follows: 1) Prepare the anionic dye of Remazol Red RBwith a concentration of 100 ppm; 2) Set the frequency value and duty cycle of the waste purification equipment by 50kHz and 44%; 3) The anionic dye waste is put into the reactor as much as 50 mL; 4) Connect the free air pump to the hose on the reactor; Wastewater is purified for 2.5 minutes for each circulation; 5) The purified wastewater was measured for dye concentration, pH, TDS, and EC; 6) Steps 1 – 5 are repeated for the next cycle. In pure oxygen testing, Step 4 is replaced by connecting the reactor to an oxygen cylinder set at a 0.2 liters/minute flow rate.

4 Data and Analysis

4.1 Analysis of Dye Concentration, TDS, pH, and EC in Anionic Dye Wastewater Before Purification Process

Anionic dye samples were used Remazol Red RB. Therefore, a calibration curve is needed for chemical analysis to guarantee the quality of results in testing activities. The dye concentration after treatment was obtained by testing the absorbance using a spectrophotometer at the peak of wavelength (518 nm), which was then converted into units (mg/L). The calibration curve is shown in **Figure 3**. From the calibration curve in **Figure 3**, a correlation coefficient of 0.9999 was obtained, proving a strong relationship between the x and y variables. The linearity equation of the calibration curve is as in equation (1). Anionic dye wastewater of Remazol Red RBhad initial dye concentration values of 100 mg/L, TDS value of 40 ppm, pH of 6.35, and EC value of 48 µS/cm.

$$y = 0{,}0207x - 0{,}0049 \quad (1)$$

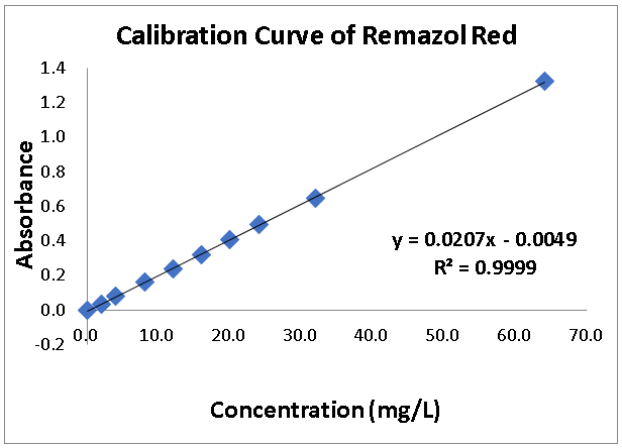

Fig. 3. Calibration Curve of Remazol Red RB133

4.2 Analysis of the Effect of Using Free Air and Pure Oxygen on Dye Removal

The anionic dye Remazol Red RB was removed using the ozonation method under two conditions: injecting free air into the reactor and pure oxygen. After purification, the concentration of dyes decreased. It is because when purification occurs, ozone has reactive properties that allow it to break bonds of certain chemical compounds through ozonolysis events faster. Ozonolysis is a process of separating compound bonds by ozone, which makes the degradation of molecules smaller. It is what causes a decrease in the concentration of dyes. The reduction graph for dye concentration can be seen in Figure 4. Dye removal has a more significant reduction by testing using pure oxygen. The role of oxygen is critical due to the formation of ozone. Ozone is formed from oxygen molecules that break into oxygen atoms that bond to form ozone molecules (O_3). So that the purer oxygen available, the more ozone will be produced during the purification test, which will make the bond breaking of chemical compounds faster.

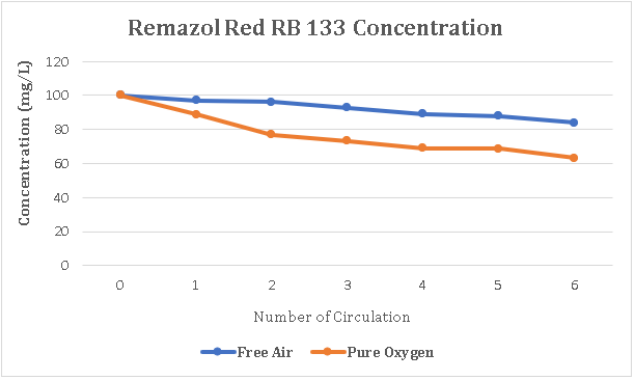

Fig. 4. Dye removal using free air and pure oxygen

4.3 Analysis of the Effect of Testing Using Free Air and Pure Oxygen on the TDS Value

TDS is a parameter that indicates the number of solids dissolved in water. TDS values after the purification process have increased. It was because, during the purification process, corrosion occurs on copper, the material of electrodes in the reactor. The oxidation reaction in these electrodes is crevice corrosion caused by the welding joints added during the reactor manufacture. This type of corrosion occurs in construction cracks. In addition, during the copper purification process, a high voltage of 7.12 kV is applied. It caused stress corrosion due to the presence of an electrolyte solution and the high voltage applied to the copper, so the Remazol Red RB experienced an increase in dissolved solids levels. The graph of the increase in the TDS value can be seen in **Figure 5.** When testing with oxygen, the TDS value was higher than free air. It was due to the oxidation of copper and oxygen to form copper oxide (CuO). The chemical reaction for forming (CuO) is in equation (2). So, when the oxygen content in the reactor is higher, it will increase the oxidation process of the reaction.

$$2Cu + O_2 \rightarrow 2CuO \tag{2}$$

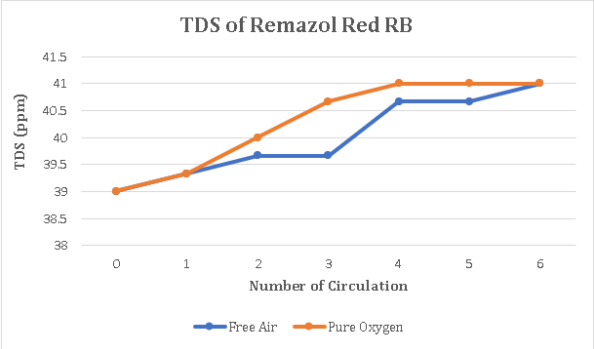

Fig. 5. TDS value with free air and pure oxygen during dye removal process

4.4 Analysis of the Effect of Testing Using Free Air and Pure Oxygen on the pH Value

Another parameter tested in the purification process of Remazol Red RB is pH. The pH decreased both with free air and pure oxygen during the dye removal process. It was due to the increase in the ozone level in the reactor during the purification process because of the corona discharge plasma. The ozonation process produces compounds with more acidic properties compared to those that cause the pH value to decrease, which is explained as a chemical reaction in equation (3).

$$O_3 + H_2O \rightarrow O_2 + H_2O_2 \tag{3}$$

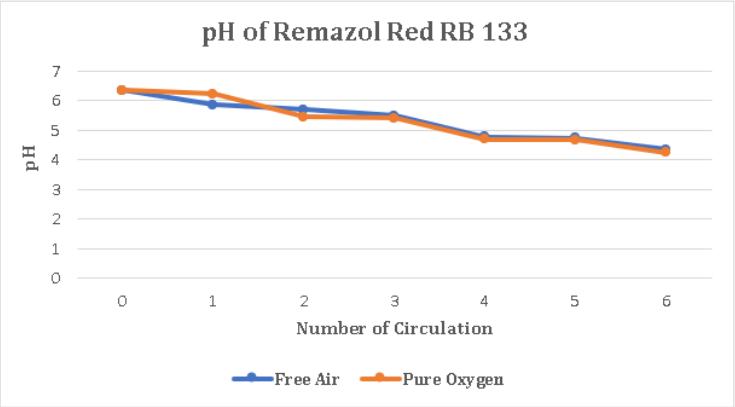

Fig. 6. pH value with free air and pure oxygen during dye removal process

5 Conclusions

Remazol Red RB anionic dye wastewater was purified using ozonation generated from corona discharge plasma using the flyback converter method. The tests proved that the purification system successfully reduced the concentration of dye. A higher concentration decreases in the dye wastewater occurred in the test using pure oxygen, which was 36.91%. The ozonation process became faster due to the injection of pure oxygen into the reactor. The pH value of the dye wastewater also experienced a higher decrease in testing using oxygen. High ozone levels cause this due to the ozonation process increasing the hydroxide ion levels in the wastewater, increasing the acid levels. In contrast, the TDS values increased after purification. While The EC value also increases because the TDS and EC values are linear. The effect of circulation on dye concentration and pH decreased with increasing circulation. It proves that the longer the circulation, the lower the concentration and pH values. While TDS and EC have increased in value along with the increase in circulation, it was because the more prolonged circulation makes the dissolved solids in the wastewater due to crevice corrosion and stress become more and more so that the TDS and EC values increase.

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