Plasma dielectric barrier discharge for degradation of textile wastewater in a continuous system

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Abstrak. Plasma Dielectric Barrier Discharge (DBD) can be applied to degrade textile wastewater. In this study, a DBD plasma reactor was composed of two electrodes of stainless-steel mesh as the outer electrode and Cu wire as the inner electrode with pyrex glass as the dielectric barrier. The electrodes were connected to an AC voltage of 3.07 kV. As much as 1500 ml of textile wastewater has flowed continuously into the system. Variations time of treatment were 0, 30, 60, 90, and 120 minutes. Physical parameters of textile wastewater such as pH, total dissolved solid (TDS), and absorbance were measured before and after treatment to determine the effect of plasma. As a result, the highest degradation efficiency of 54.29% was obtained after treating the textile wastewater for 120 min.

1. Introduction
The textile industry is a major factor emergence of waste liquid is dangerous. The content of wastewater generally is dye, starch, alkalis, acids, and surfactants as dispersing agents [1]. In the urban industries, the wastewater is carried out directly by flowing into rivers without any recycled. It causes disruption of human health, such as skin diseases, cancer, and eye irritation [2]. The conventional wastewater treatment already well known is filtering, adsorption, and coagulation [3]. However, these methods have not been able to process the chemical content in waste perfectly. Therefore, more effective textile wastewater treatment technology is needed as a complement.

A challenging wastewater treatment method is plasma technology. Plasma is the fourth phase of matter after solid, liquid, and gas [4]. One type of plasma technology is dielectric barrier discharge (DBD) plasma. In the DBD plasma reactor, active species such as OH⁻, H⁺, O₃, and H₂O₂ can be produced [5-7]. In this study, wastewater from the batik industry was treated using the DBD plasma method. The parameters such as color, pH, and total dissolved solids (TDS) were measured before and after treatment to investigate textile wastewater's degradation efficiency.

2. Experimental
2.1. Material
The material used was the textile waste liquid taken from the local batik home industry. It was allowed to stand for 24 hours before treatment. As much as 1500 ml of textile wastewater has flowed continuously during treatment.
2.2. The plasma DBD treatment

Figure 1 shows the DBD plasma reactor consists of a Cu wire and stainless-steel mesh as inner and outer electrodes. Pyrex glass was used as a dielectric material. The electrodes were connected to an AC voltage of 3.07 kV. The treatment time applied was varied as 0, 30, 60, 90, and 120 minutes. Here, the surface of textile wastewater was kept close to the edge of the reactor, as shown in Fig. 1.

![Figure 1. Plasma DBD reactor: 1. Regulator; 2. Vacuum pump; 3. AC Power supply; 4. An acrylic container filled with wastewater; 5. DBD plasma reactor; 6. Water pump; 7. Bucket](image)

2.3. Characterization

Physical parameters of textile wastewater were measured before and after treatment to determine the effect of plasma. Measurement of the pH value in the sample was carried out using a pH-meter, which was calibrated using a buffer solution with a pH of 4 and a pH of 6. The TDS value of the sample was determined using the TDS-meter. The UV-Vis spectrophotometer was used to determine the absorbance value of each sample at wavelengths of 400 - 800 nm. The efficiency of the degradation was obtained by comparing the absorbance value of the sample before to after plasma DBD treatment as expressed in equation (1), where $A_0$ and $A$ are the peak absorbance of the sample before and after treatment, respectively.

$$\text{Efficiency} = \left(\frac{(A_0 - A)}{A_0}\right) \times 100\% \quad (1)$$

3. Results and Discussion

3.1. Plasma DBD

A high voltage difference between the two electrodes produces a non-homogeneous electric field, and giving more energy to electrons results in ionization [8]. Then, a chain of ionization is created due to a collision of high-energy electrons with molecules of gas, resulting in the active species [9]. In this study, we assume that ozone is the most important species to degrade textile wastewater. This ozone can degrade the dyes in textile wastewater [2]. The ozone formation can be shown by reaction (2-3) [10].

$$\bullet e + O_2 \rightarrow O + O + e \quad (2)$$

$$O + O_2 \rightarrow O_3 \quad (3)$$
3.2. The pH
Figure 2 shows the pH of the textile wastewater before (0 minutes) and after treatment for 30, 60, 90, 120 min. In the batik-making processes, sodium carbonate was often used as a dissolved agent of synthetic dye. Therefore the initial pH of wastewater was alkaline. It is known that the abundant components in the air are oxygen (O_2) and nitrogen (N_2). During plasma treatment, their reaction with the wastewater will result in acid, as expressed in equation (4-8) [11]. Therefore, the pH was decreased with increasing treatment time, as shown in Fig. 2.

\[
\begin{align*}
*e + O_2 & \rightarrow O + O + e & (4) \\
*e + N_2 & \rightarrow N + N + e & (5) \\
N + O & \rightarrow NO & (6) \\
O + NO & \rightarrow NO_2 & (7) \\
NO_2 + H_2O & \rightarrow NO_3^- + 2H^+ & (8)
\end{align*}
\]

3.3. The TDS
The TDS measurement was carried out to determine the dissolved substance (solid) with a size of <10^{-6} nm. Figure 3 shows the TDS of wastewater before and after treatment for 30, 60, 90, 120 min. The result shows that the TDS value increases with longer plasma DBD treatment time. The enhancement of TDS might be due to the increment of the dissolved compound as a result of wastewater oxidation.

3.4. The Absorbance
Another parameter that can be used to evaluate the degradation of wastewater is absorbance. Figure 4 shows the absorbance of wastewater before and after treatment for 30, 60, 90, 120 min. The peaks of absorbance were located at 442.5 nm and 470.5 nm.

[Figure 2. The pH of textile wastewater for plasma DBD treatment time of 0, 30, 60, 90, and 120 minute]
[Figure 3. The TDS of textile wastewater for plasma DBD treatment time of 0, 30, 60, 90, and 120 min.]

[Figure 4. Absorbance of textile wastewater for plasma DBD treatment time of 0, 30, 60, 90, and 120 minute]
Figure 4. The absorbance of textile wastewater for plasma DBD treatment time of 0, 30, 60, 90, and 120 min.

Figure 5. The efficiency of degradation for plasma DBD treatment time of 0, 30, 60, 90, and 120 minute

The value of absorbance is related to the concentration of the solution. In Fig. 4, the absorbance decrease for a longer time of treatment. It means that the concentration of pollutants was decreased due to oxidation by active species. Furthermore, the efficiency of degradation calculated by equation (1) was increased for a longer time of treatment, as shown in Fig. 5. The highest degradation of 54.29% was obtained for a treatment time of 120 min.

4. Conclusion
The active species of plasma DBD can be used to degrade the textile waste liquid. The pH of wastewater was decreased due to reactions between active species and molecules of wastewater, resulting in the acid. Moreover, TDS of wastewater was increased because the dissolved substances as products of
degradation were increased. The degradation efficiency of 54.29% was obtained at the treatment time of 120 minutes. It shows that a longer treatment time will result in greater degradation efficiency.

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