Textile Wastewater Treatment by Using Plasma Corona Discharge in a Continuous Flow System

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Abstract. This study aimed to figure out plasma corona discharge for textile wastewater degradation with continuous flow system. Plasma reactor using AC voltage of 11.5 kV and two stainless steel electrode which set up parallelly 4.0±0.5 mm above wastewater. Continuous flow system means the wastewater flowing continuously with flow rate of 60 ml/min. Characteristics of absorbance, pH, temperature, Total Dissolved Solid (TDS), Total Suspended Solid (TSS) and conductivity were measured before and after plasma treatment. Absorbance, pH and TSS value of wastewater were decrease after plasma treatment, while the TDS, conductivity and the temperature were relatively increase. This result indicate better quality of wastewater.

1. Introduction
Textile industry is one of contributors to high concentrated liquid pollutants. The industry produces waste which consists of complex molecules types of organic compounds which make waste colour, toxic and resistant to conventional treatment [1]. Conventional textile waste processing can be done by physics, chemistry and biology methods. This processing method is effective enough to degrade colours from waste, but there are some disadvantages of these methods. These methods require a lot of costs, chemicals and create secondary wastes like lots of mud [2].

Recently, plasma applications based on oxidation methods for waste degradation begin to be increased because of their flexibility and high oxidative capacity [3]. Wastewater treatment using plasma technology is cheaper and friendlier for environment than biological method because it does not produce secondary waste [3]. Plasma can oxidize waste in water, especially organic compounds. The reaction between ions and electrons in the plasma phase in waste produces UV and shock wave rays. The reaction produces very high energy and break down the water molecule (H₂O) to active species such as OH, O, H, and H₂O₂. The active species which are strong oxidants that can oxidize various kinds of compounds and can also kill bacteria from liquid waste [4].

In the previous study optimization of plasma discharge reactors was carried out with a continuous flow system for methylene blue degradation [5]. Furthermore, this research was carried out by processing textile waste by using plasma corona discharge in a continuous flow system.
2. Experimental
A sample was textile batik printing wastewater with amount of 1 litre. A pair of stainless steel was used as electrodes that each has a diameter of 2 mm with 2.000±0.005 cm apart. It places paralelly 4±0.5 mm above the sample. An AC voltage of 11.5 kV was used to generate plasma. Continuous flow system mean the wastewater was flowing during experiment. The flow rate of sample was 60 ml/min. The optimization of the reactor was evaluated from degradation of wastewater with variation of treatment time with plasma. It was seen from absorbance, pH and temperature, total dissolved solid (TDS), total suspended solid (TSS) and conductivity before and after treatment using the plasma. The absorbance measured with UV-Vis spectrophotometer, while pH and sample temperature were measured using multi-parameter water quality meter. While TDS, TSS and conductivity were measured using TDS and conductivity meter with standard method of preparation.

3. Results and Discussion
Concentration of pollutant in the wastewater is proportional with absorbance. It means the absorbance will high if it contains more pollutant and vice versa. Therefore, measurement the absorbance is one of easy method to point out the concentration of pollutant in the wastewater. Figure 1 shows the comparison between wastewater absorbance without and with plasma treatment for various time. Before plasma treatment (0 minute), highest peak of absorbance is at wavelength of 450 nm. So, the next discussion will be focused at this wavelength. For 60 and 100 minutes of treatment, the absorbance slightly decreases. And then, treatment for 180 minutes result in the more decrease of absorbance.

![Figure 1. Absorbance of wastewater without (0 minute) and with (60,100, 180 minutes) plasma treatment.](image)

For longer of treatment time, the more electrons are produced. Then electron ionizes the air and/or reacts with the wastewater. This simultan reaction resulting species active such as radicals and ions which will degrade the wastewater. Degradation of wastewater means the concentration of pollutants are decrease or in this paper shown by decrease of absorbance. So, longer time of treatment will produce more species active and more degradation will occure. Then, Table 1 shows percentage degradation of wastewater for various treatment times. However, value of degradation in this continuous flow system was smaller compare to the batch system for almost same time. It reasonable because in the continuous flow system, retention time of wastewater with plasma is shorter and it depends on the flow rate [5].
Table 1. Percentage degradation of wastewater with various treatment times.

| Time of treatment (minute) | Percentage (%) |
|----------------------------|----------------|
| 0                          | 0              |
| 60                         | 1.66           |
| 100                        | 3.90           |
| 180                        | 14.87          |

Then, physical characteristic of wastewater such as pH, temperature, Total Dissolved Solid (TDS), Total Suspended Solid (TSS) and conductivity were measured before and after plasma treatment for 2, 3 and 4 hours, as shown in Figure 2.

Figure 2. Physical characteristic of wastewater including (a) pH, (b) temperature, (c) TSS and (d) TDS and conductivity.

Figure 2(a) shows pH of wastewater was increase after 2 hours of plasma treatment. However, the pH was decreased for 3 and 4 hours of treatment. Carbonates dan bicarbonates were contained in Batik wastewater as glue the dyes to textile. Kommineni et al. reported that reaction between active species hydroxyl and carbonates will resulting OH$^-$ as shown in Eq. 1 and 2 [6]. Thus it will makes the wastewater become alkaline and reduce the pH.

\[
\text{OH}^* + \text{CO}_3^{2-} \rightarrow \text{CO}_3^- + \text{OH}^-
\]  

\[
\text{OH}^* + \text{HCO}_3^- \rightarrow \text{HCO}_3^- + \text{OH}^-
\]
In Figure 2(b), temperature of wastewater was increased proportionally with treatment time. In the plasma, species actively collide with each other many times and resulting heat. As consequently, the temperature will increase for longer time of treatment. The high temperature will accelerate the formation of free radicals which play a role to degrade dyes [7].

Total suspended solids (TSS) indicate solids in wastewater that can be trapped by a filter [8-10]. In Figure 2(c) it can be seen that the TSS value is relatively reduced after plasma treatment. With longer treatment time, the more number of active species were produced. This active species plays an important role to degrade organic compounds in waste. Therefore, the more active species were formed, the more effective to remove the organic and inorganic substances in wastewater. Total dissolved solids (TDS) are a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form [8-10]. TDS values increase with increasing treatment time because plasma produces new ionic species. This ionic compound will oxidize the textile waste. Furthermore, another indicator which have a close relationship with TDS is electrical conductivity. It will increase proportionally with TDS value as shown in Figure 2(d).

4. Conclusion
Based on the result, it can be concluded that the plasma corona discharge can be used as promising method to reduce concentration of batik wastewater. The percentage of wastewater degradation increase proportionally with treatment time. Continuous flow system can be used as simple application procedure in the wastewater treatment, even with longer treatment time compare to batch system. Moreover, from measurement of physical characteristics, the quality of wastewater become better after plasma treatment.

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