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# Water Treatment Using Plasma Discharge with Variation of Electrode Materials

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**Abstract**. This research studied water treatment using plasma discharge. Plasma generated in this study produced active species that played a role in organic compound decomposition. The plasma reactor consisted of two needle electrodes made from stainless steel, tungsten, aluminium and grafit. It placed approximately 2 mm above the solution and connected with high-AC voltage. A solution of methylene blue used as an organic solution model. Plasma treatment times were 2, 4, 6, 8 and 10 min. The absorbance, temperature and pH of the solution were measured before and after treatment using various electrodes. The best electrode used in plasma discharging for methylene blue absorbance reduction was the graphite electrode, which provided the highest degradation efficiency of 98% at 6 min of treatment time.

## 1. Introduction

Water is the most important source of life in an ecological system. The problems related to water resources has been increasing due to industry, agriculture, and rising population [1]. Therefore, it is necessary to perform water purification so that water-soluble pollutants can be separated, improving water quality.

Plasma is the fourth state of matter, beside gas, liquid and solid material [2]. Plasma is defined as an ionized gas. A gas will turn into plasma if the temperature is raised, causing the atoms to release some oral of their electrons. During this process, the remaining atom is positively charged, while the negative electrons move freely. Plasma technology has now begun to be used for water purification. Plasma can be generated in gas and water, forming some radicals, ions, ozone, or namely active species, which have high potential oxidation rates, break down organic compounds and kill microorganisms by decomposing pollutants without leaving secondary pollutants [3].

There are several plasma technologies that are commonly used for water purification, such as ozone, electron beam and electrical discharge. In this study, we used the electrical discharge method due its simplicity. The plasma discharge generates ions and electrons with very high energy as active species, causing water to decompose. The active species also kill the bacteria and further oxidize the compounds contained in water [4].

Due to their physical and chemical properties, the material used for the electrodes affects the chemical process of plasma in water, necessitating a study of variation in electrode material in plasma discharge applied in organic solution removal. The electrode materials used in this study were stainless steel, tungsten, aluminium and grafit. The effect of electrode material variation on plasma discharging

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before and after treatment was studied not only by absorbance reduction but also in the changes of pH solution and temperature.

## 2. Experimental

The initial solution was prepared by dissolving 6 mg of methylene blue powder in 1 litre of distilled water. Before treatment, the temperature and pH of untreated solution was measured as a control sample. The absorbance of untreated solution was also analysed by using a UV-Vis spectrometer with a scanning method at a wavelength range of 400-800 nm.

The plasma reactor used two parallel electrodes installed 2 cm apart. An AC power supply with a voltage of 46.3 kV was connected to the electrodes to start the discharge. The electrodes were made from grafit, stainless steel, tungsten or aluminium. A sample of 30 ml methylene blue solution placed in a beaker was treated under the electrodes while it was stirred at 6 rpm. The distance between electrode and sample was set at 2 mm. Plasma discharging was applied for 2, 4, 6, 8 and 10 min. The pH, temperature and absorbance after treatment were measured and compared with pH, temperature and absorbance results in the untreated sample before treatment.

## 3. Results and Discussion

Figure 1 shows the absorbance of methylene blue after treatment from 0 to 10 minutes for (a) aluminium, (b) grafit, (c) stainless steel and (d) tungsten electrode, respectively, compare to the absorbance of control sample. It can be seen that the methylene blue absorbance more decreased with longer time of plasma treatment. Reaction between active species of plasma will decompose the methylene blue [5]. The longer treatment time will resulting much more decomposition and reduce more absorbance.

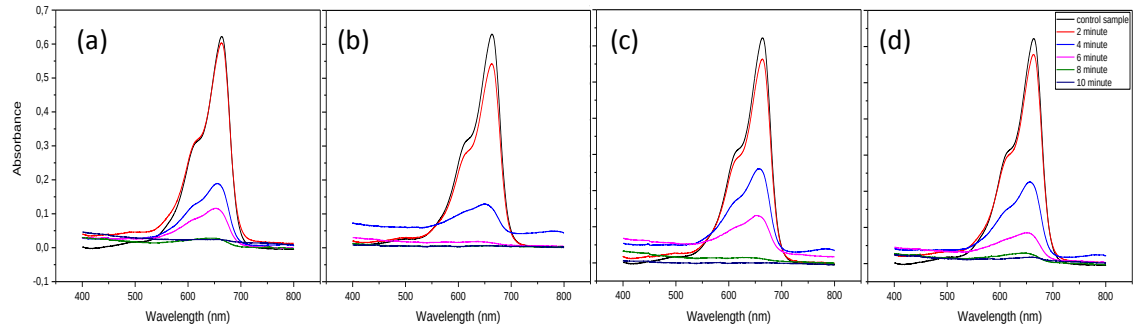



**Figure 1.** The absorbance of methylene blue for control sample and (a) aluminium, (b) grafit, (c) stainless steel and (d) tungsten elctrode at treatment time of 2, 4, 6, 8 and 10 minutes.

Moreover, Fig. 2 resume percentage degradation of methylene blue after plasma treatment for a given time compare to control sample. At treatment time of 2 to 4 min, plasma treatment using grafit electrode show the highest degradation. During plasma generation with high voltage, grafit which is consist of C-C bond might be broken and react to decompose the methylene blue [6]. Furthemore, for all electrode materials, after conducting the plasma treatment for 8 min, the absorbance reduction reached 99%. This indicates that the methylene blue was no longer present in the sample. It also indicated in the colour differences at each time as shown in Figure 3.

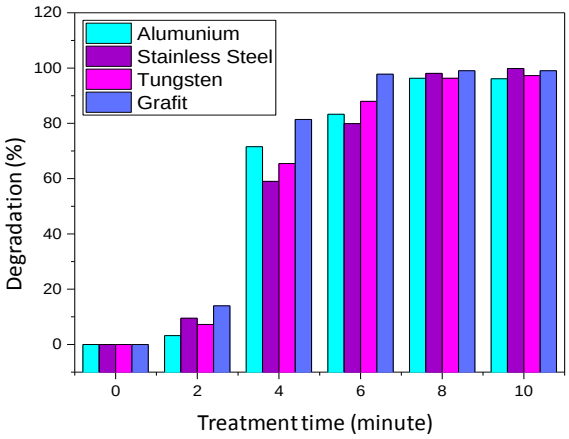



**Figure 2.** Degradation of methylene blue after plasma treatment for a given treatment time.

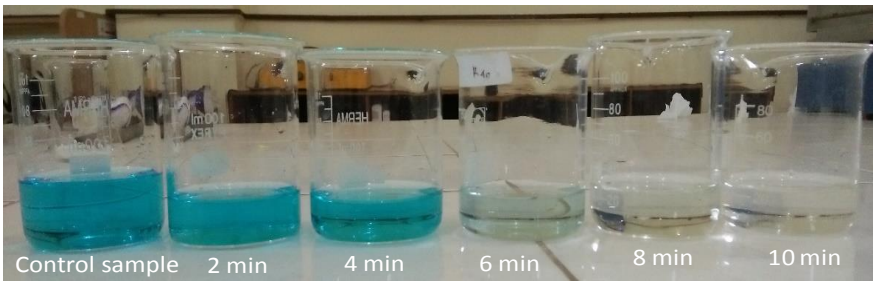



**Figure 3**. The colour difference of methylene blue after plasma treatment for a given treatment time.

Figure 4(a) shows the relationship between temperature and treatment time. Longer treatment times resulted in higher solution temperature. It is due to the electric discharges generated have a high velocity that causes strong collisions between water molecules, increasing heat. Along with increased treatment time, the collisions lead to the increasing of solution temperature. Figure 4(b) shows the relationship between pH and treatment time where the pH decrease with increasing treatment time. It occurs because the oxidation process in the plasma reactor breaks the complex bonds in the methylene blue solution into mild acids [7]. Longer treatment times mean that more mild acids form and make the solution becomes more acidic. The formation of mild acids during the process decreases the solution's pH with the addition of treatment time [8].

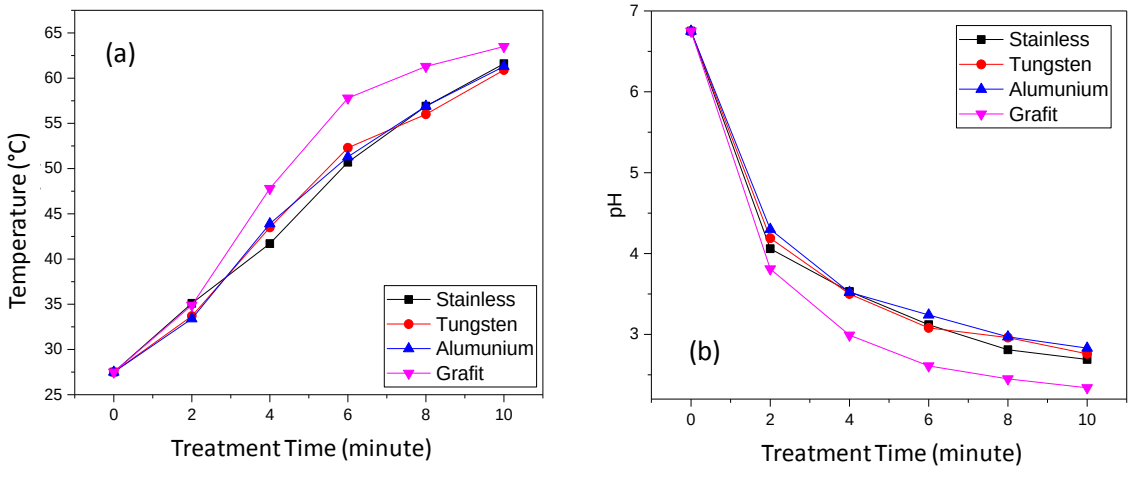



**Figure 4**. The relationship of (a) temperature and (b) pH with plasma treatment time

## 4. Conclusion

The study of variation of electrode materials used in plasma discharging for water treatment with methylene blue as solution model provided different degradation efficiencies. Grafit showed the best results in plasma treatment because it provided higher absorbance reduction efficiency in a shorter time compared to the other materials.

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