Evaluation of Titration Method on Determination of Ozone Concentration produced by Dielectric Barrier Discharge Plasma (DBDP) Technology

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Abstract. Determination of the ozone concentration produced by a reactor is very important. The titration method is an analytical chemical method with high accuracy still in use. Research on titration for measurement of ozone concentration generated by a generator at a given flow rate has been done. Ozone is produced by a dielectric barrier discharge plasma reactor. The reactor is formed with a cylindrical-cylindrical electrode configuration made of stainless steel wire mesh. Evaluation of ozone concentration of titration method was done by varying air flow rate between 4-15 liter/min. The titration time is varied between 3 -12 minutes. Voltage source was used a high-voltage AC with variation between 6 - 11 kV. The greater the air flow rate the resulting ozone concentration will decrease. The concentration of ozone obtained is smaller with a large tear time at the same voltage and flow rate. From the results of this study, the time of titration in determining the concentration of ozone is not required larger, at 3 minutes has given the best results. The long of titration time probably the ozone dissolve and saturated in the titrant (KI) and released into the air again.

1. Introduction
Currently and in the future, the ozone utilization continues to be in demand because of its role as an environmentally friendly non-chemical disinfectant [1,2]. Ozone has been widely used in various sectors. Ozone is used for water treatment both for consumption purposes and for aquariums. Ozone can also be used as infected in liquid waste treatment [3]. In industrial processes, ozone is used for sterilization in the packing process [4]. In the field of food, ozone is capable of killing microorganisms, bacteria, spores so as to prolong the shelf life of fish, rice, chili [5,6,7,8,9,10]. Therefore, it is important to conduct an analysis related to the measurement of ozone concentration and ozone capacity produced by ozone generators.

Quantitative analysis methods that have been commonly used to determine the concentration of ozone is volumetric. The volumetric method for measuring ozone concentration is by iodometric titration method. This method is quite easy and simple but requires a bit of a process. Tjahyanto et al. [4], have compared methods of measuring ozone concentrations between volumetric methods with spectrophotometric, and better volumetric methods. The ozone concentration generated by the DBDP reactor is generally affected by stress, flow rate, reactor length, electrode configuration and gas input source [11,12]. In this paper, we studied the measurement of ozone concentrations and capacities generated using DBDP reactor configuration of cylinders with an air-gas source. The parameters we studied are the effect of stress, gas flow rate, ozone exposure time.
2. Experimental Method

The ozone reactor used involves plasma dielectric barrier discharge (DBDP) technology. The electrode configured cylinders - cylinders with pyrex glass barrier. The inner diameter of the pyrex glass is 27 mm and the outer diameter is 31 mm, while the length is 230 mm. The active electrode and ground electrode are made of stainless steel wire mesh with length 200 x 160 mm². The ozone generator power supply uses high-voltage AC and varies by 6.2, 7, 8, 9, 10, 10.55 kV. The air flow rate is varied with flowmeter of 4, 7, 10, 13 and 15 Liter/min. Measurement of electric current using amperemeter / current monitor. High voltage measurements using a voltmeter / HV monitor equipped with an HV probe. The research scheme is shown in the following figure:

![Figure 1. Set up eksperiment](image1)

![Figure 2. Titration process](image2)

Ozone production uses free air feedstock. Ozone production is calculated concentration by titration method. Ozone is bound by KI solution by exposing it. While for the titration process use Sodium Thiosulfate. Ozone has flowed into an Erlenmeyer containing 50 ml of 0.2 M KI solution with exposure time varied from 3, 6, 9, 12 min. The KI solution will change color from clear to brownish yellow. This color comes from I₂ formed by the oxidation reaction.

\[
\text{O}_3 + 2\text{I}^- + \text{H}_2\text{O} \rightarrow \text{I}_2 + 2\text{OH}^- + \text{O}_2
\]

(1)

The equation of the above indicates that the O₃ mole will be proportional to the number of moles of I₂. So that the number of moles of I₂ can be used in calculating the measurement of ozone concentration. Determination of the number of moles of I₂ is done by titrating the solution using sodium thiosulfate. Titrations are carried out until the amount of I₂ is proportional to sodium thiosulfate, which is characterized by a change of color from brownish yellow to clear.

\[
\text{I}_2 + 2\text{Na}_2\text{S}_2\text{O}_3 \rightarrow 2\text{NaI} + \text{Na}_2\text{S}_4\text{O}_6
\]

(2)

From the equation of the above reaction equation, the number of moles of ozone is equal to half the number of moles of sodium thiosulfate. So the calculation of ozone concentration can use the equation [13,14]:

\[
C_{\text{ozone}} = \frac{R \times V_t \times N_t}{V_{\text{gas}}}
\]

(3)

\(C_{\text{ozone}}\) is the concentration of ozone (gram / L), \(R\) is the ratio of the analytical mol and the reactant of a balanced chemical equation, \(N_t\) is the normality of sodium thiosulfate (mol / L), \(V_t\) is the volume of titrant (L) and \(V_{\text{gas}}\) is the air volume (L).
3. Results and Discussion

3.1 Characteristics of current as a function of voltage

The ozone-generated DBDP plasma reactor used is associated with a high-voltage AC source ranging from 6.2 - 10.55 kV. The current characteristic as a voltage function is shown in Fig. 3. The curve in Fig. 3a is a voltage-current characteristic obtained at a 4 L/min flow rate with varying ozone exposure time. The increasing stress contributes greatly to the change in charge of each unit of time, which increases. From this curve shows that the time of exposure to ozone does not affect the current.

Figure 3.

(a) Characteristics of current as a function of voltage, (a) at flow rate of 4 L/min, (b) at ozone time exposure of 3 minutes

Figure 3b shows the current-voltage characteristics with the time exposure of 2 minutes with different flow rates. It appears that the flow rate has an effect on the measured electrical current. Airflow rate shows the amount of oxygen molecular particle supply that is passed in the reactor. Flow rate variations cause the number of dissociated oxygen molecules to be different, so the charge changes in time units are also different. Generally, the current characteristic as a function of voltage for all air flow rates shows the same trend.

3.2 Effect of pressure on ozone concentration

Figure 3 shows the effect of stress on ozone production. The voltage causes the formation of an electric field. The ever greater stress contributes to the increasingly powerful electric field. Strong electric field, enabling electrons to have higher energy that can be used to produce more ionization processes. The movement of electrons accelerates and the probability of collisions becomes higher, causing higher ozone concentrations [12].

Figure 3a shows that ozone exposure time influences measurement of ozone concentration. Voltages ranging from 6.2 to 10 kV, the higher ozone production formed for all ozone exposure time treatments on ozone concentration measurements. Time of exposure to ozone 3 minutes obtained results of measurements of high ozone concentrations for all voltage variations. While at ozone exposure 6, 9, 12 minutes and at a voltage above 10 kV, the measurement of ozone concentrations appears to decrease as a result of saturation of the KI solution in ozone binding. Figure 3b is a characteristic ozone concentration as a function of the voltage at 3 ozone exposure time with flow rate variation. The voltage increase shows the same trend for all flow rates.
Figure 4. The effect of voltage to ozone concentration, (a) at flow rate of 4 L/min, (b) at ozone exposure time of 2 minutes

3.3 Effect of flow rate on ozone concentration and ozone capacity
The effect of flow rate on ozone formation is shown in figure 5a. Low flow rate results in high concentrations. The concentration of ozone with a flow rate of 4 L / min and the exposure time of ozone 3 minutes at a voltage of 10 kV, with a concentration of 168 ppm ozone. This depends on the residence time of the air molecules in the reactor, the greater flow rate will push out the molecules of the air quickly, so that the residence time of the air molecules within the reactor is shorter, the state of these very short molecules will cause air molecules have not undergone a longer collision process and air gaseous molecules have less ionisation, dissociation or recombination to form ozone, resulting in a relatively small ozone [12].

Figure 5. The effect of flow rate, (a) to ozone concentration, (b) to ozone capacity

Ozone capacity is the amount of ozone in units of time produced successfully. The ozone capacity can be calculated from the multiplication of ozone concentration (grams/hour) with flow rate (L / min) [15]. Figure 5b shows the effect of flow rate on ozone capacity with the variation in ozone exposure time. The large airflow rate produces a large ozone capacity, this is because the supply of ozone feedstock through the reactor is abundant.

3.4 Effect of exposure time to the measurement of ozone concentration
Figure 6 shows that ozone exposure time greatly influences the measurement of ozone concentration. The longer ozone exposure time actually results in a decrease in the measurement of ozone concentration using titration method. Long ozone exposure time causes KI solution to have saturation. This saturation condition causes the KI solution no longer able to bind ozone, so the measured ozone
concentration becomes small. This is confirmed by curves 6a and 6b, at all voltages and flow rates, the longer the ozone exposure, the measured ozone concentration is decreasing.

![Figure 6](image)

**Figure 6.** The effect of ozone exposure time to ozone concentration, (a) at flow rate of 4 L/min, (b) at voltage of 10.55 kV

4. **Conclusion**

DBDP reactor cylinder wire mesh configuration - stainless steel cylinder capable of producing ozone with a capacity of 69 grams/hour. The highest ozone concentration was 192 ppm at a voltage of 10.55 kV and a flow rate of 4 L/min with free air as the source. Measurement of ozone concentration is strongly influenced by the time of exposure of ozone to the KI solution. The 3-minute ozone exposure time in this study is the best measurement of ozone concentration.

5. **References**

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