Analysis of ozone production for medical with double dielectric barrier discharge (DDBD) plasma technology against spiral - Mesh electrode combination

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Analysis of Ozone Production for Medical with Double Dielectric Barrier Discharge (DDBD) Plasma Technology Against Spiral - Mesh Electrode Combination

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Abstract. Ozone is a gas that naturally exists in the Earth's atmosphere, has a strong odor, strong oxidizer, and as a disinfecting agent. Determination of the ozone concentration produced by the reactor is very important. Development of a reactor for lower concentrations of ozone needs to be done. The reactor type can use for medical ozone therapy applications. Medical ozone therapy can be produced using multiple DBD plasma reactors with oxygen as a source and voltage variation. The voltage source uses high voltage AC with variations between 0.5-3 kV, a frequency of 40 Hz and measurement of the concentration of titration of ozone production carried out for 2 minutes. The reactor formed by the configuration of copper spiral mesh electrodes with variations in the number of turns 50 and 30 applied to spiral electrodes and the length of the mesh electrodes 13 and 9 cm. Pure oxygen put into the reactor with several variations in the flow rate of 0.2-1 L/min. The titration method is a high-accuracy analytical chemical method that still used. The results showed that the greater the gas flow rate, the lower the ozone concentration produced, the higher the flow rate the dose value was 595.2 mg and 499.2 mg with a voltage of 3 kV, while the low flow rate was 220, 8 mg and 326.4 mg but the number of turns and mesh length also affects the concentration and dosage value, in windings of 50 and the mesh length of 13 cm the concentration are greater than those in coil 30 and mesh length 9 cm.

INTRODUCTION

Ozone formed from oxygen atoms with O_3 chemical symbols. Ozone is a relatively unstable molecule compared to oxygen O2, which is very relatively stable [1]. Ozone naturally can be formed by UV radiation, through the method of sunlight, which can reduce oxygen gas (O2) in the air. The oxygen molecule breaks down into two radical oxygen (O^*) then reacts with oxygen to form ozone [2]. Ozone can also be made using the corona discharge method and the Dielectric Barrier Discharge (DBD) as an experiment conducted by Siemens in 1857 [3,4]. DBD is known as the most effective method of producing ozone. There is because of the dielectric functions as a current limiter prevents spark and distributes the discharge evenly throughout the electrode area [5].

Research on ozone using the Dielectric Barrier Discharge (DBD) was carried out by Nur et al., 2009 using a DBD spiral-cylinder geomtery reactor with AC voltage of 3.8-5 kV to compare ozone production with oxygen and free air gas input. The results showed that oxygen was more optimum in producing ozone [6]. At the same concentration, efficiency for AC voltage is higher than the DC voltage. The ozone concentration decrease with increasing oxygen flow rate and increases with increasing voltage [7,8].

Ozone that can be used for medical applications must be produced from pure oxygen through Dielectric Barrier Discharge (DBD) because the medical ozone generator is different from industrial generators in terms of its ability to produce the purest ozone-oxygen mixture with the right dose. Generators and distribution systems as sources of

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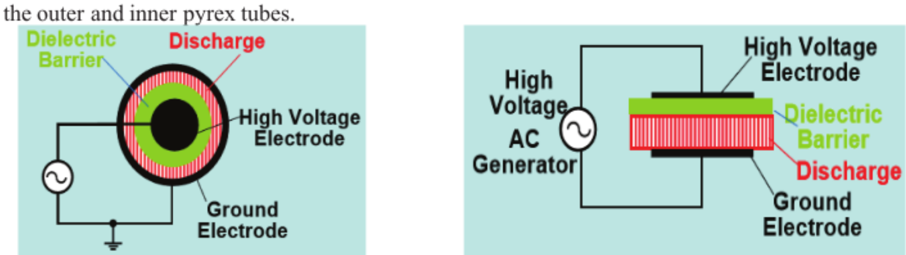
oxygen must have a medical purity level so that they avoid nitrogen and other impurities because nitrogen can be produced NO, which is toxic to the tissue. DDBD qualifies as a medical generator because there is a space between the two barriers as a place for the flow of pure oxygen that is not mixed with nitrogen so that when reacting with an electric field high purity ozone is produced. Based on the description of the background above, in this study, we will observe the optimum oxygen flow rate to produce ozone concentrations that can be applied medically using the DDBD reactor.

EXPERIMENTAL METHOD

In this study, we used a Double Dielectric Barrier Discharge (DDBD) reactor, as shown in Figure 1. The reactor geometry is cylinders and uses a dielectric barrier in the form of a pyrex tube. The electrodes used are copper spirals that cover the outer and inner pyrex tubes.



(a) (b)

FIGURE 1. The DBD double reactor scheme [9] (a) the electrode geometry is seen in front, (b) the geometry of the electrode side of the display

Figure 2. shows the outer electrode as a positive electrode and the inner electrode as a negative electrode. The two electrodes connected to a high-voltage AC source with a frequency of 40 Hz which has been arranged with an ammeters, voltmeter so that it can know the value of the voltage and current used. At 18 cm in length from the end of both sides of the reactor there are two small hoses that function as input and gas output and to connect the gas to the sample and ozone catcher where the reactor outside diameter is 4 cm while the inner diameter is 2.3 cm thick pyrex glass 0.275 cm, in the inner reactor there is a mesh with a length of 13 cm and 9 cm while the outer reactor has a spiral with many turns 50 and 30. The hose used to drain gas is PU hose (Poly Urethane) with a diameter of 0.5 and 0.15 cm thickness. The distance from the oxygen gas cylinder to the flow meter is 150 cm. The distance from the flowmeter to the reactor and the ozone capture solution are 30 cm each. The flow rate given is 0.2 liters/minute to 1 liter/minute at intervals of 0.2 liters/minute.

Ozone concentration measurements started by making a solution of KI (Potassium Iodide) with a concentration of 0.2 M as an ozone catcher and a solution of $Na_2S_2O_3$ (sodium thiosulfate) 0,4 M as a titrant. The ozone from the reactor put into the KI solution in the form of air bubbles, then the KI solution reacts to ozone with a constant time of 2 minutes. Then titrated with sodium thiosulfate solution ($Na_2S_2O_3$). After the ozone is bound in the solution, it will be marked with a yellow color change to clear. The ozone concentration is proportional to the volume of $Na_2S_2O_3$ solution used for titration. The ozone concentration can be calculated using the formula [10]:

$$C_{ozon} = \frac{R \times Vt \times Nt}{Vgas} \quad (1)$$

With R is the analytic mole ratio and reactants of a balanced chemical equation (gram/mol), V_t is the volume of $Na_2S_2O_3$ (ml) droplets, N_t is the sodium thiosulfate $Na_2S_2O_3$ (molar) normality, V_{gas} is oxygen flow rate in liters/minute [11].

Ozone capacity and dosage are calculated using the formula:

$$\text{Capacity } (g/h) = \text{Concentration } (g/L) \times \text{Air flow rate } (L/h) \quad (2)$$

$$\text{Dosage} = \text{Capacity} \times t \quad (3)$$

with t is the time that will use during treatment.

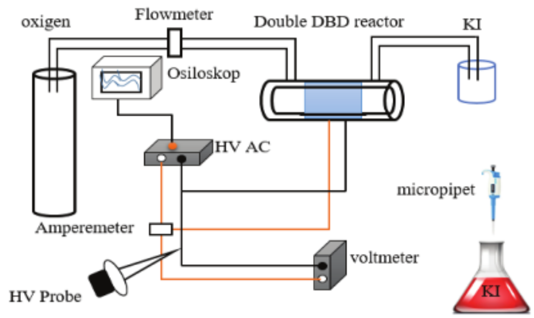


FIGURE 2. Ozone generator scheme

RESULTS AND DISCUSSION

Effect of Voltage on Ozone Concentration

Ozone is produced by the DDBD reactor at a voltage of 0.5 kV to 3 kV at an oxygen flow rate of 1 to 0.2 liters/minute at intervals of 0.2 liters/minute. Ozone form in the space between the two electrodes, which is a narrow gap in the occurrence of plasma. Plasma formed is known as silent plasma discharge because it does not cause hiss due to collisions as in corona plasma. There caused by a dielectric barrier in the form of Pyrex, which inhibits the occurrence of arc discharge. Dielectrics can weaken the electric field between the two electrodes because of the reverse electric field of the molecules contained in the dielectric whose direction is opposite to the electric field of potential difference. The process of ozone formation is when the reactor gave a high voltage, the initial electrons will be accelerated and experience collisions with oxygen atoms in the reactor. The collision results in a doubling of electron folds and produce ions and free radicals. The ions that may was formed are O^+, O_2^+, O^-, O^{2-}, dan O_3^-. While the possible radicals are O* and O^*_2. These ions and radicals are so reactive that they react to each other and produce a new species, ozone. Ozone formation begins with dissociation (4), dissociative binding (5) and dissociative ionization (6) as follows:

Dissociation $$e^- + O_2 \rightarrow 2O + e^- \quad (4)$$
Dissociative engagement $$e^- + O_2 \rightarrow O + O^- \quad (5)$$
Dissociative ionization $$e^- + O_2 \rightarrow O + O + 2\,e^- \quad (6)$$

then the oxygen radical will react with oxygen to produce ozone (8) with the help of neutral molecules as catalysts.

$$O_2 + e \rightarrow 2O + e \quad (7)$$
$$O + O_2 + M \rightarrow O_3 + M \quad (8)$$

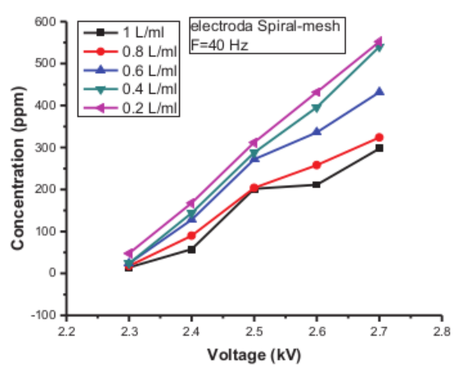


FIGURE 3. Ozone concentration as a function of voltage with a winding of 30 cm and a mesh length of 9 cm at a flow rate of 1 to 0.2 liters/minute at intervals of 0.2

Figure 3. Shows that at constant ozone flow time of 2 minutes into the KI solution, the ozone concentration tends to increase with increasing voltage given both at flow rate 1 to 0.2 liters/minute at intervals of 0.2 liters/minute. The results of this study are by the results of previous studies that ozone concentration increases with higher stress [12]. The increase in ozone concentration due to stress is because when the voltage in the reactor increases, the electric field formed in the reactor becomes higher so that the electrons have higher energy which results in faster electron movements, collisions, and more ionization and dissociation processes. So that more and more free ions and free radicals formed. There results in the ozone produced having a greater concentration. At the same voltage, the reactor flowed with oxygen gas with a lower flow rate has a higher concentration. There is because the flow motion that is getting slower will cause the gas molecule to stay inside the reactor for longer with a small molecular density so that many gas molecules can ionize in the gap between electrodes resulting in more ions and radicals was formed [13].

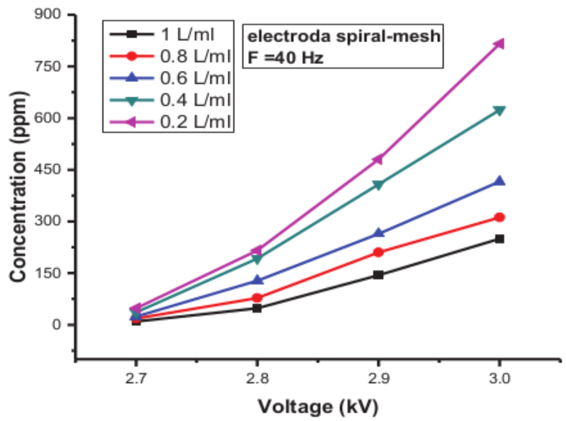


FIGURE 4. Ozone concentration as a function of voltage with a coil of 50 cm and a mesh length of 13 cm at a flow rate of 1, up to 0.2 liters/minute

Ozone starts formed at a voltage of 2.7 kV to 3 kV. Figure 4. Shows that ozone concentration increases with increasing voltage given both at oxygen flow rate 1 to 0.2 liters/minute at intervals of 0.2 liters/minute This relates to the level of voltage saturation. At high flow rates, the voltage experiences saturation or saturation faster than at low flow rates. In other words, at high flow rates breakdown occurs faster than at low flow rates. The optimum ozone concentration is 816 ppm at an oxygen flow rate of 0.2 liters/minute with a voltage of 3 kV.

Effect of Number of Winding and Length of Mesh on Concentration

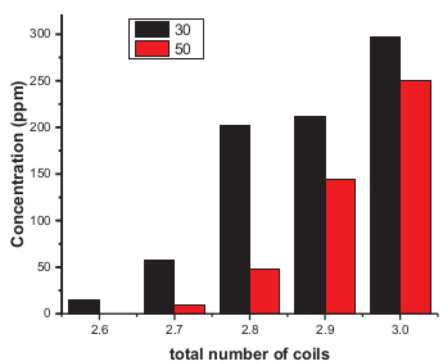


FIGURE 5. The number of turns and length of the mesh to the function of concentration at 1 liter/minute flow rate

Figure 5. Shows that the effect of the number of turns and length of the mesh also affects the results of concentration. The greater the voltage give at a low flow rate, the higher the concentration produced, while at a voltage of 2.6 kV with 50 turns and a mesh length of 13 cm there is still no ozone, ozone begins to form at 2.7 kV. In turn 30, the concentration value of 297.6 ppm obtained while in the 50th coil, the concentration value was 249.6 ppm.

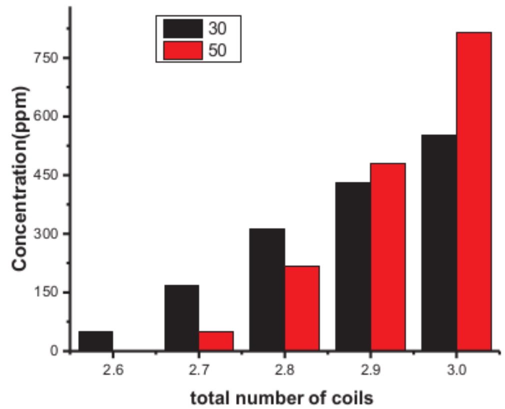


FIGURE 6. The number of turns and length of the mesh to the function of concentration at a 0.2 liter/minute flow rate

In Figure 6. It shows that coil 30 with a voltage of 3 kV obtained a concentration of 552 ppm while in coil 50, a concentration of 816 ppm obtained. The reactor flowed with oxygen gas with a lower flow rate has a higher concentration. There is because the flow motion that is getting slower will cause the gas molecule to stay inside the reactor for longer with a small molecular density so that many gas molecules can ionize in the gap between electrodes resulting in more ions and radicals was formed.

Application for Medical Affairs

The ozone application for the medical association has researched for the past 30 years to get guidance on ozone therapy. Ozone dosage is a very important factor in ozone therapy because ozone deficiency and overdose will result in ineffectiveness or toxic effects. Table. 1 is a guide to ozone application for medical with the right dosage.

Table 1. Ozone concentrations and doses to be applied in the medical field [14].

Application	Ozone Concentration Range	Ozone Volume	Desage/ Ozone Amount Per Treatment
Systemic Treatment			
Major autohemotherapy	10-30 µg/ml (max. 40 µg/ml)	50-100 ml	500-1500 µg (max. 2000)
Rectal insufflation	10-25 µg/ml	Max. 300 ml	3000-7500 µ
Minor autohemotherapy	10-20 µg/ml	10 ml	100-200 µg
Topical Tratment			
Wound cleansing	80-100 µg/ml		
Wound healing	10-25 µg/ml		
Injection in pain syndrome	1-10 µg/ml	1-20 ml	1-200 µg

The right dose can provide a beneficial effect for the medical, for this study the results showed that at a frequency of 40 with 30 turns and a mesh length of 9 cm the optimum ozone dose was 220.8 mg with a concentration of 552 ppm, while at frequency 40 with 50 turns 13 cm mesh length obtained the optimum ozone dose of 326.4 mg with a concentration of 816 ppm. There can be applied to the systematic treatment of major autohemotherapy.

CONCLUSION

DDBD plasma reactors can be used to produce ozone where the concentration values obtained. At high voltage with a low flow rate, the concentration value obtained is greater than the high flow rate. The value of concentration will be greater along with the increase in voltage. The lowest ozone dosage frequency of 40 Hz with many turns 30 and 9 cm mesh length was obtained at a voltage of 2.6 kV while the highest dose obtained at a voltage of 3 kV. But at a frequency of 40 Hz with a lot of turns 50 and a mesh length of 13 cm low dose obtained at a voltage of 2.7 kV while the highest dose obtained at a voltage of 3 kV with a low flow rate.

ACKNOWLEDGMENT

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