Experimental study on medical ozone generation in double dielectric barrier discharge(DDBD) with spiral-spiral electrodes

by Sumariyah Sumariyah

Experimental study on medical ozone generation in double dielectric barrier discharge(DDBD) with spiral-spiral electrodes

Cite as: AIP Conference Proceedings **2197**, 040003 (2020); https://doi.org/10.1063/1.5140908
Published Online: 02 January 2020

S. Maftuhah, A. Rahardian, M. Masfufah, E. Yulianto, S. Sumariyah, and M. Nur

Experimental Study on Medical Ozone Generation in Double Dielectric Barrier Discharge(DDBD) with Spiral-Spiral Electrodes

S. Maftuhah[1, a)], A. Rahardian[1], M. Masfufah[1], E. Yulianto[2], S. Sumariyah[1, 2] and M. Nur[1, 2, b)]

[1]Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
[2]Center for Plasma Research, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia

[a)]Corresponding author: smaftuhah.2018@fisika.fsm.undip.ac.id
[b)] m.nur@undip.ac.id

Abstract. Double Dielectric Barrier Discharge (DDBD) generator is a reactor that is considered more qualified as an ozone reactor for medical applications because there is space between two barriers that function as a place for the flow of pure oxygen. Research on optimization of medical ozone production with Double Dielectric Barrier Discharge (DDBD) technology with spiral-spiral electrode configuration has been carried out. The purpose of this study is to obtain the optimum dose of ozone for applications in the medical field. Variations in the number of coils on electrodes (N), namely 30, 40, 50 and high voltage AC used with voltage variations from 0.5 to 2.3 kV and flowrate variations between 0.2 to 1 L/min with 0.2 intervals. The frequency used is 30 Hz. The results showed that the higher the voltage with a constant flow rate, the higher the current produced so that the ozone concentration obtained was also higher. However, the more the number of turns with a constant voltage, the smaller the resulting concentration. In the configuration of the number of coils, the ozone dosage produced is between 67.2 to 537.6 mg.

INTRODUCTION

Ozone (O_3) is an inorganic molecule that dissolves in water consisting of three oxygen molecules [1]. Ozone is easily broken down by exothermic reactions on pure oxygen, with short survival (40 minutes at 20 °C) [2]. When decomposed, O_3 acts as an oxidant by releasing free radicals [3]. Ozone can be generated using ultraviolet radiation, a photochemical reaction, and Dielectric Barrier Discharge (DBD). DBD is the technique most often used to generate ozone, both on a laboratory and industrial scale [4,5].

Double Dielectric Barrier Discharge (DDBD) reactor is a reactor that is considered more qualified as a medical reactor because there is space between two barriers that function as a place for the flow of pure oxygen [6]. The Double Dielectric Barrier Discharge (DDBD) reactor that configured is more suitable because it isolates the two electrodes from the plasma reaction chamber and to protect the inner electrode from carbon deposits and by-products during chemical reactions [7]. In non-equilibrium DDBD processing chemical species are produced, including radicals, electrons, and ions in the plasma reaction chamber [8].

Medical ozone is a mixture of ozone or oxygen given at low concentrations [9]. Ozone can destroy viruses and bacteria and to disinfect or destroy pathogenic bacteria, sterilize, and destroy malignant cells [10]. Ozone is useful for tissue repair and provides strong antimicrobial effects [2]. The right dose of ozone therapy for medical use is not only useful in a variety of pathological conditions; it can also be a powerful therapeutic resource for the human body without damaging effects [11].

Proceedings of 2nd International Conference on Chemical Process and Product Engineering (ICCPPE) 2019
AIP Conf. Proc. 2197, 040003-1–040003-6; https://doi.org/10.1063/1.5140908
Published by AIP Publishing. 978-0-7354-1948-3/$30.00

Experimental studies of ozone production using DDBD with cylinder-cylinder has already been done to improve the concentration of ozone with voltage variations, gas flow rate variations, dielectric material, and input gas [6,11,12,18]. In this study using DDBD with the spiral-spiral electrode to know its effects on ozone concentrations and get a dose for application in medical ozone therapy with variations of voltage, gas flow rate and the number of coils.

EXPERIMENTAL METHODS

This study uses DDBD reactor with a spiral-spiral electrode configuration (Figure 1). DDBD reactor length is 18 cm, with an outer diameter of 4 cm; inner diameter of 2.3 cm; pyrex thickness 0,275 cm and the distance between pyrex 0,3 cm. Spiral variations include windings 30, 40, and 50.

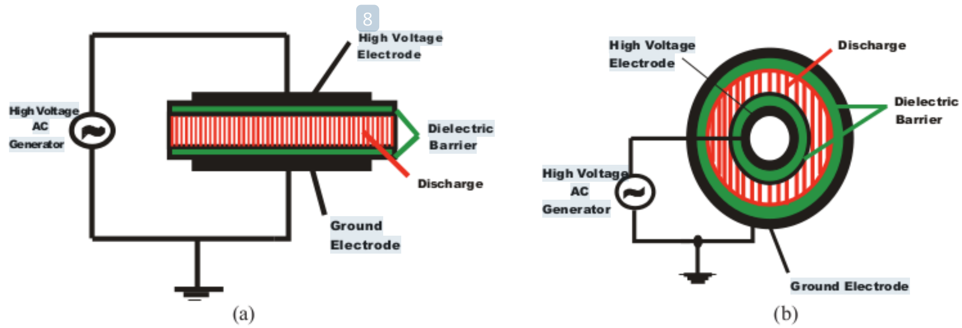

FIGURE 1. Form of the electrode [12] (a) Geometry of the electrode side view (b) Geometry of the electrode front view

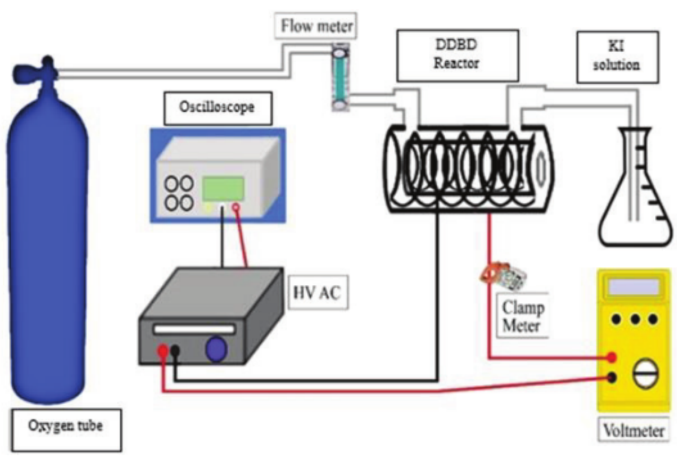

FIGURE 2. Experimental Set-Up

Ozone concentrations can be calculated using the formula [13]:

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

with C_{ozone} is the ozone concentration (ppm), R is the analytic mole ratio of 24,000, Vt is the volume of titrant (L), Nt is the normality of $Na_2S_2O_3$ (mol/L), and V_{gas} is the volume of air (L).
As for the calculation of the dose, namely:

$$\text{Capacity} = C_{ozone}\ (\text{mg/L}) \times \text{oxygen flow rate(L/min)} \tag{2}$$

$$\text{Dosage} = \text{Capacity (mg/min)} \times \text{expose time (min)} \tag{3}$$

RESULT AND DISCUSSION

Current-Voltage Characteristics

This study uses DDBD reactor with a high voltage AC frequency of 30 Hz. The voltage variations used are 0.5 to 2.3 kV. Figure 3 shows that the electric current will increase due to the intensification of the active electrode in the reactor so that when the voltage is increased, the current also generated increases. When the DDBD reactor is at a certain voltage, there is potential energy between the electrodes. A strong electric field will accelerate the movement of particles, ions, and electrons, resulting in collisions between particles. The collision between particles triggers the process of ionization, excitation, deexcitation, and recombination. When oxygen begins to be ionized, free electrons move in the ionization flow region. The electric field accelerates the movement of free electrons and collides with other gas molecules between the two electrodes, resulting in chain ionization and electron multiplication [11,14,15]. Based on Figure 3 also shows that at a constant voltage, for variations in the number of turns that are getting bigger, the resulting current is also getting bigger.

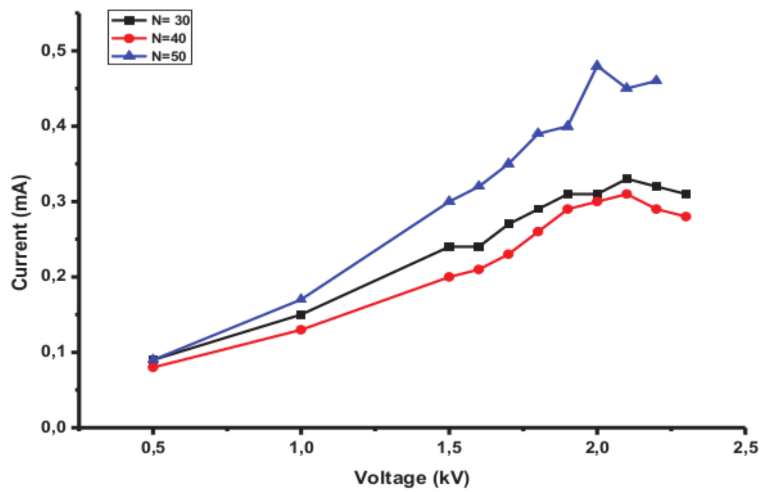

FIGURE 3. Characteristics of currents as a function of the voltage of spiral-spiral DDBD reactors with different number of coils

Effect of the Number of Coils on Ozone Concentration

Figure 4 shows the change in the number of coils given to influence the value of the ozone concentration produced. At constant voltage, the resulting concentration is smaller in the number of coils that are increasing. There related to the electric field distribution and ozone decomposition. In the DDBD reactor, the ozone produced does not interact directly with the electrode so that when the number of coils increases, the electric field between the two electrodes is unable to achieve uniformity resulting in intense and uniform particles, ions or electrons.

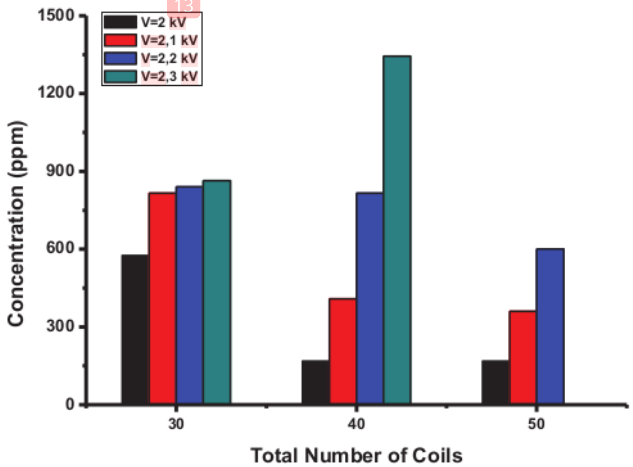

FIGURE 4. Effect of the number of coils on ozone concentration for several voltage values

At the number of coils 50, the resulting concentration only reaches a voltage of 2.2 kV because the more the number of coils, the voltage used to produce ozone is not able to reach the maximum voltage of 2.3 kV. At the number of coils 50, there is an electrical breakdown so that the maximum voltage for ozone formation is only able to reach a voltage of 2.2 kV. Proven by the number of turns 50, the resulting concentration is lower than the number of turns 30 and 40. So that at the number of coils 50, the voltage used to produce ozone begins to experience instability.

Effect of Flow Rate on Ozone Concentration

Figure 5 shows the effect of flow rate variations on ozone concentration values. At greater voltages and lower flow rates, the higher the concentration value. The greater the flow rate will encourage the release of oxygen molecules quickly, so the molecular oxygen residence time in the reactor is shorter, very short molecular state will cause oxygen molecules not to experience a longer collision process and oxygen gas molecules that have ionization, dissociation or recombination less to form ozone, which will produce relatively small ozone [11,12].

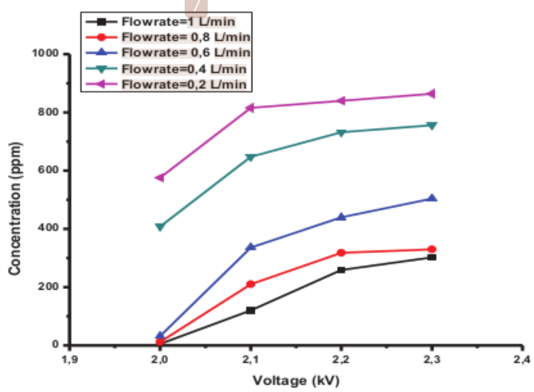

FIGURE 5. Effect of variation of flowrate on ozone concentration for several voltage values

Application for Medical Therapy

Ozone has unique biological abilities for use in the medical field. The use of pure oxygen for medical ozone applications is more recommended than using air, because the original material from the air consists of 78% nitrogen, while nitrogen can be toxic and there is a significant reduction in ozonation efficiency [17]. The ozone used has been validated in pathological conditions such as ischemic syndrome, diabetes, diabetic feet, disc hernias, and other diseases. The effect of ozone on wound healing can be seen from a decrease in bacterial infections, repair of wounds to the ski, or increase in oxygen levels resulting from ozone exposure to wounds [1,2,9]. The following are the results of ozone doses for several voltage values with different coils.

TABLE 1. Ozone dosage values in several voltage values with different coils

Voltage (kV)	Dosage (mg)		
	N = 30	N = 40	N = 50
2	230,4	67,2	67,2
2,1	326,4	163,2	144
2,2	336	326,4	240
2,3	345,6	537,6	-

Medical ozone can be useful because it can dissolve in blood or other body fluids. Although ozone toxicity in the respiratory system is locked in inhalation, it can be recognized as an intermediary useful for oxidative stress-related diseases. The following is a table of dose data that can be applied to several therapies.

TABLE 2. Empirical data from concentrations and ozone dosage for several therapies [16]

Application	Ozone concentration range	Ozone volume	Dosage/ozone amount per treatment
Systemic treatment			
Major autohemtherapy (MAH)	10-30 µg/ml (max. 40 µg/ml)	50 ml	500-1500 µg (max. 2000)
Rectal insufflation	10-25 µg/ml	max. 300 ml	3000-7500 µg
Minor autohemotherapy	10-20 µg/ml	10 ml	100-200 µg
Topical treatment			
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
In combination with local anasthetic	10-20 µg/ml	1-20 ml	10-400 µg

Based on Table 2, it can be found that for the ozone dosage range from 67.2 to 163.2 mg it can be used for injection in pain syndrome or the range 67.2 to 345.6 mg it can be used in combination with a local anesthetic, and for dosage 537.6 mg can be used for major autohemotherapy.

CONCLUSION

The DDBD reactor can be used as a reactor that produces medical ozone where the higher the voltage with a constant flow rate, the higher the current produced so that the ozone concentration obtained is also higher. However, the more the number of coils with a constant voltage, the smaller the resulting concentration. In the configuration of the number of coils, the ozone dosage produced is between 67.2 to 537.6 mg, which can be used for injection in pain syndrome, in combination with a local anesthetic, and major autohemotherapy.

ACKNOWLEDGMENTS

We thanks the Ministry of Technology Research and Higher Education for facilitating the establishment of the Teaching Industry at the Diponegoro University through a contract with the number:865/UN7.P/HK/2018. The realization of this research for utilizing the Teaching Industry facility.

REFERENCE

1. Smith N L, Anthony L W, Jason G, Sohrab V, and Sardar A L. Medical Gas Research 7, pp 212-219, (2017).
2. Neri J S V, Erilma L, Alexandre M K, Silvia R A R, Antonio M T, Marchionni, and Alena R A M. Journal of Oral Diagnosis Vol. 02, pp 1-6, (2017).
3. Breidablik H J, Dag E L, Lene J, Ase S, John R A, and Ole T K. Journal of Hospital Infection 01.026. (2019).
4. Fang Z, Qiu Y, Sun Y, Wang H, and Edmund K. Journal of Electrostatic 66, pp 421-426, (2008).
5. Sung T L, Teii S, Liu C M, Hsiao R C, Chen P C, Wu Y H, Yang C K, Teii K, Ono S and Ebihara K. Vacuum Vol. 90, pp 65-69, (2013).
6. Zhang h, Kan L, Chenhua S, Ziyang L, Tonghua S, and Jinping J.Chemical Engineering Journal 256, pp 107-118, (2014).
7. Kundu S K, Eric M K, Vaibhav V G, Thomas S M, and Bogdan Z D. Chemical Engineering Journal 180, pp 178-189, (2012).
8. Mustafa M F, Xindi F, Yanjun L, Yawar A, Hongtao W, and Wenjing L. Journal of Cleaner Production 174, pp 670-677, (2018).
9. Fernandez O S L, Hansler R V, Gilberto L C, Irainis S E, Yanet H M, Livan D R, Beatriz T S, Gabriel T O, and Juan C P V. European Journal of Pharmacology 789, pp 313-318, (2016).
10. Manoto S L, Makwese J M, and Shirley K M. Saudi Journal of Biological Sciences 25, pp 672-679, (2018).
11. Zain A Z, Restiwijaya M, Hendrini A R, Dayana B, Yulianto E, Kinandana A W, Arianto F, Sasmita E, Azam M, Sumariyah S, Nasrudin N, and Nur M. *IOP Conf. Series, UNNES Physics International Symposium*, 2019, Series 1153 (2019) 012089 pp 1-8.
12. Restiwijaya M, Hendrini A R, Dayana B, Yulianto E, Kinandana A W, Arianto F, Sasmita E, Azam M, and Nur M. *IOP Conf. Series, UNNES Physics International Symposium*, 2019, Series 1170 (2019) 012020 pp 1-6.
13. Chasanah U, Yulianto E, Zain A Z, Sasmita E, Restiwijaya M, Kinandana A W, Arianto F, and Nur M. *IOP Conf. Series, UNNES Physics International Symposium*, 2019, Series 1153 (2019) 012086 pp 1-6.
14. Restiwijaya M, Nur M, and Tri A W. Berkala Fisika 17 ISSN 1410-9662, pp 1-6, (2014).
15. Yulianto E, Restiwijaya M, Sasmita E, Arianto F, Kinandana A W, and Nur M. *IOP Conf. Series, UNNES Physics International Symposium,* 2019, Series 1170 (2019) 012013 pp 1-7.
16. Hansler R V, Olga S L F, and Ziad F. Ozone: Science and Engineering 34, pp 408-424, (2012).
17. Bocci V, Iacopo Z, and Valter T. Atherosclerosis 211, pp 38-39, (2010).
18. Puryadi, Nur M, Sumariyah, Restiwijaya M, and Niyomukiza J B. Int. J. of Allied Med. Sci. and Clin. Research 7(1), pp 127-131, (2019).

Experimental study on medical ozone generation in double dielectric barrier discharge(DDBD) with spiral-spiral electrodes

ORIGINALITY REPORT

24%	13%	22%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	A. Rahardian, M. Masfufah, S. Maftuhah, E. Yulianto, S. Sumariyah, M. Nur. "Effective medical ozone production using mesh electrodes in double dielectric barrier type plasma generators", AIP Publishing, 2020 Publication	9%
2	Muhammad Farooq Mustafa, Xindi Fu, Yanjun Liu, Yawar Abbas, Hongtao Wang, Wenjing Lu. "Volatile organic compounds (VOCs) removal in non-thermal plasma double dielectric barrier discharge reactor", Journal of Hazardous Materials, 2018 Publication	2%
3	www.sciencegate.app Internet Source	2%
4	N I Bogatyrev, S M Morgun, A O Vronskaya. "Increasing the Efficiency of Ozonizing Devices in Agriculture", IOP Conference Series: Earth and Environmental Science, 2021 Publication	2%

5	Nanik Hendrawati, Khalimatus Sa'diyah, Ernia Novika, Agung Ari Wibowo. "The effect of polyvinyl alcohol (PVOH) addition on biodegradable foam production from sago starch", AIP Publishing, 2020 Publication	2%
6	Olga Sonia León Fernández, Renate Viebahn-Hänsler. "Medizinisches Ozon: das Niedrigdosis-Konzept", Zeitschrift für Komplementärmedizin, 2022 Publication	2%
7	Submitted to University of Mauritius Student Paper	1%
8	cpr.undip.ac.id Internet Source	1%
9	Renate Viebahn-Hänsler, Olga Sonia León Fernández, Ziad Fahmy. "Ozone in Medicine: The Low-Dose Ozone Concept—Guidelines and Treatment Strategies", Ozone: Science & Engineering, 2012 Publication	1%
10	doc-pak.undip.ac.id Internet Source	1%
11	patents.justia.com Internet Source	1%
12	Submitted to Ain Shams University Student Paper	

<1%

13 Dong-Hui Zhu. "Collisional Energy Transfer between Highly Vibrationally Excited CsH($X^1\Sigma^+$, v = 15–22) and H_2", Chinese Physics Letters, 09/2011 <1%

Publication

14 aphysrev.ictp.it <1%

Internet Source

15 Muhammad Farooq Mustafa, Xindi Fu, Wenjing Lu, Yanjun Liu, Yawar Abbas, Hongtao Wang, Muhammad Tahir Arslan. "Application of non-thermal plasma technology on fugitive methane destruction: Configuration and optimization of double dielectric barrier discharge reactor", Journal of Cleaner Production, 2018 <1%

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

Experimental study on medical ozone generation in double dielectric barrier discharge(DDBD) with spiral-spiral electrodes

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7