

# Dose Mapping of Maximum Ozone Capacity Using Double Dielectric Barrier Discharge (DDBD) with Mesh-Mesh Electrodes as an Ozone Generator

Azizah<sup>1,4</sup>; Dodi Mariadi<sup>1,4</sup>; Muhammad Fatikha Rizka<sup>4</sup>; William Arthur Leo<sup>1,4</sup>;  
Hanna' Nadiyah<sup>4</sup>; Eko Yulianto<sup>4</sup>; Eva Sasmita<sup>4</sup>; Renni Yuniati<sup>2</sup>;  
Muhammad Nur<sup>3,4\*</sup>

<sup>1</sup>Magister of Physics, Physics Department, Diponegoro University, Tembalang Campus, Semarang, Indonesia, 50275

<sup>2</sup>Department of Dermatology and Venereology, Faculty of Medicine, Diponegoro University, Semarang, Central Java, Indonesia, 50275

<sup>3</sup>Physics Department, Diponegoro University, Tembalang Campus, Semarang, Indonesia, 50275

<sup>4</sup>Center for Plasma Research, Diponegoro University, Integrated laboratory, Tembalang Campus, Semarang Indonesia, 50275

Corresponding Author: Muhammad Nur\*

Publication Date: 2026/05/25

**Abstract:** Ozonated Virgin Coconut Oil (OVCO) has emerged as a promising alternative therapy due to its stable bioactive compounds, such as ozonides and peroxides. However, the lack of standardized production parameters remains a major obstacle to its clinical application. This study aimed to obtain medical-grade ozone as a standard dose for OVCO production by mapping the quantitative relationship between ozone generator parameters, using the highest ozone capacity as a dosage reference, and by validating its antifungal efficacy in vivo. Ozone was generated using a Double Dielectric Barrier Discharge (DDBD) reactor in the form of a dual-cylinder made of borosilicate glass with a thickness of 0.2 cm, equipped with aluminum mesh electrodes measuring 6.2 cm in length, 2 cm in inner diameter, and 4.2 cm in outer diameter. Oxygen gas (O<sub>2</sub>) was used as the feed gas with variations in applied voltage (2.7, 2.9, and 3.1 kV) and oxygen flow rates (0.4, 0.6, and 0.8 L/min). The results indicated that increasing the applied voltage significantly enhanced ozone production, with the highest capacity achieved at 3.1 kV and an oxygen flow rate of 0.6 L/min, yielding an ozone capacity of 0.408 g/min for dissolution into Virgin Coconut Oil (VCO). This maximum capacity was associated with an increase in the peroxide value (PV) and was used as the basis for OVCO dosage mapping. This standardization ensures consistent quality and effectiveness of OVCO as an antifungal therapy.

**Keywords:** Ozonated Virgin Coconut Oil (OVCO), Double Dielectric Barrier Discharge (DDBD), Ozone Capacity, Dosage Mapping.

**How to Cite:** Azizah; Dodi Mariadi; Muhammad Fatikha Rizka; William Arthur Leo; Hanna' Nadiyah; Eko Yulianto; Eva Sasmita; Renni Yuniati; Muhammad Nur (2026) Dose Mapping of Maximum Ozone Capacity Using Double Dielectric Barrier Discharge (DDBD) with Mesh-Mesh Electrodes as an Ozone Generator. *International Journal of Innovative Science and Research Technology*, 11(5), 1481-1486. <https://doi.org/10.38124/ijisrt/26may745>

## I. INTRODUCTION

Ozon (O<sub>3</sub>) is a naturally occurring component of fresh air, formed through reactions between ultraviolet radiation from the sun and the upper layers of the Earth's atmosphere, resulting in the formation of a protective layer that envelops the planet [1]. On a technical scale, ozone is produced through the ionization of oxygen molecules (O<sub>2</sub>) into reactive oxygen atoms (O), which subsequently recombine

with other oxygen molecules with the assistance of a third body (M) that acts as a stabilizing agent [2]. The Double Dielectric Barrier Discharge (DDBD) technology has emerged as an effective solution for generating high-purity ozone. The main advantage of the DDBD reactor lies in the use of two dielectric barrier layers that prevent direct contact between the gas and aluminum electrodes (mesh–mesh configuration), thereby producing stable non-thermal plasma under atmospheric pressure conditions [3].

Ozone is considered a green chemical compound because it is environmentally friendly and does not produce harmful by-products [4]. Ozone gas consists of three oxygen atoms and functions as a disinfectant agent. In this process, olive oil is treated through ozone bubbling or ozonation using ozone gas generated by a Double Dielectric Barrier Discharge (DDBD) plasma reactor [5]. An increase in the applied electrical voltage has been shown to enhance the electric field intensity, thereby increasing the energy of free electrons and accelerating the ionization rate of oxygen gas, which directly leads to an increase in ozone production.

## II. RESEARCH METHODS

This study employed a DDBD reactor with a cylindrical geometry. Double Dielectric Barrier Discharge (DDBD) is a non-thermal plasma generation method that utilizes two dielectric layers to produce ozone in a stable manner [6]. The reactor was constructed from borosilicate (Pyrex) glass with a length of 19 cm and a thickness of 0.2 cm. Inside the reactor, two tubular dielectric barriers were arranged concentrically. The outer tube had an outer diameter of 4 cm, while the inner tube had an inner diameter of 2 cm. The electrodes used were aluminum mesh sheets. The outer electrode was cylindrical in shape, with a length of 15 cm and a width of 15.5 cm, covering the outer surface of the Pyrex tube. The inner electrode, also made of aluminum mesh, had a length of 15 cm and a width of 9 cm; it was cylindrical and placed inside the inner Pyrex tube [7].

The process began with the injection of pure oxygen gas (O<sub>2</sub>) into the reactor, which was equipped with two concentrically arranged electrodes. The inner electrode was connected to a high-voltage alternating current (AC) power supply to generate an intensive electric field within the discharge gap. Meanwhile, the outer electrode functioned as a ground reference electrode, serving to establish an optimal electric field distribution for plasma discharge initiation. The reactor incorporated glass layers as dielectric barriers to ensure stable plasma formation and prevent direct electrical contact between the electrodes [8].

Ozone can be generated through electrical discharge, wherein the discharge (spark discharge) dissociates oxygen molecules into individual oxygen atoms, which subsequently react with other oxygen molecules to form ozone [9]. Within the range of flow rates applied in this study, it was found that ozone concentration increased with increasing flow rate and operating voltage [10]. These findings are consistent with the study conducted by Nur *et al.* (2019), which reported that higher applied voltages result in higher ozone concentrations [11]. In general, ozone concentration increases with increasing applied voltage; however, conversely, ozone concentration may decrease with increasing flow rate [12]. Ozone capacity is influenced by both ozone concentration and flow rate and can be used to determine the appropriate ozone dosage. Previous studies have demonstrated ozone dosing using a double dielectric barrier discharge (DDBD) system with copper plate electrode configurations [13]. Medical-grade ozone can be obtained from a DDBD reactor, as this type of reactor is considered more suitable for medical applications due to the presence of a discharge space between the two dielectric barriers, which enables the generation of high-purity ozone under an applied electric field [14].

The ozone dose produced falls within the dose range specified by the Madrid Declaration for small animals, particularly in the low- and medium-dose categories. In the medical field, ozone is utilized due to its antimicrobial and anti-inflammatory properties, as well as its ability to enhance tissue oxygenation through mechanisms involving Reactive Oxygen Species (ROS). Some of its main applications include:

- Disinfection and Sterilization: Elimination of pathogenic microorganisms (bacteria, viruses, and fungi) on wounds as well as on medical equipment.
- Autohemotherapy: Administration of specific ozone doses in accordance with the standards established in the Madrid Declaration for low- to medium-dose categories.
- Food Safety: Degradation of pesticide residues on fruits and vegetables without generating harmful by-products. Ozone can be generated through several methods, including electrical discharge, ultraviolet (UV) radiation, corona discharge, and Dielectric Barrier Discharge (DBD) ozone formation reactions.

The ozone formation process occurs when high voltage is applied to the reactor, causing oxygen molecules within the discharge gap to become ionized and form cold plasma. The resulting high-energy free electrons subsequently collide with O<sub>2</sub> molecules [15]. The formation of O<sub>3</sub> (ozone) is initiated through dissociation, dissociative attachment, and dissociative ionization processes, as described below.

Dissociative

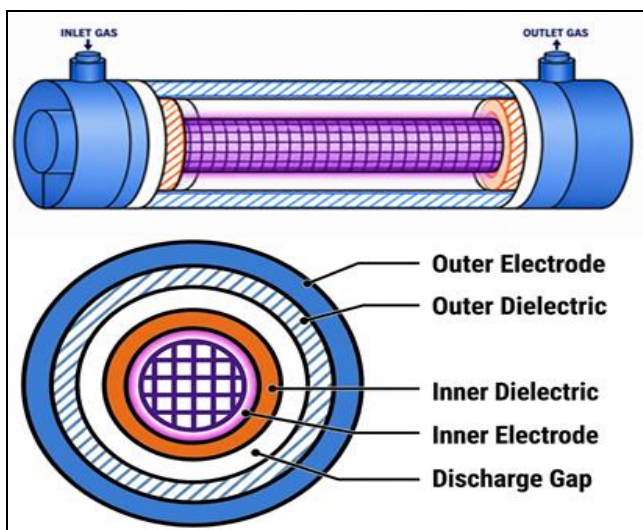
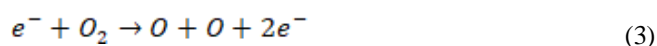


Fig 1 Schematic Diagram of the Double Dielectric Barrier Discharge (DDBD) Reactor

Reaction example:



Dissociative Ionization



to form ozone with the assistance of a neutral molecule acting as a stabilizing catalyst, as described below:



The application of Double Dielectric Barrier Discharge (DDBD) technology enables precise control of ozone output through the adjustment of operational parameters, as illustrated in the following figure:

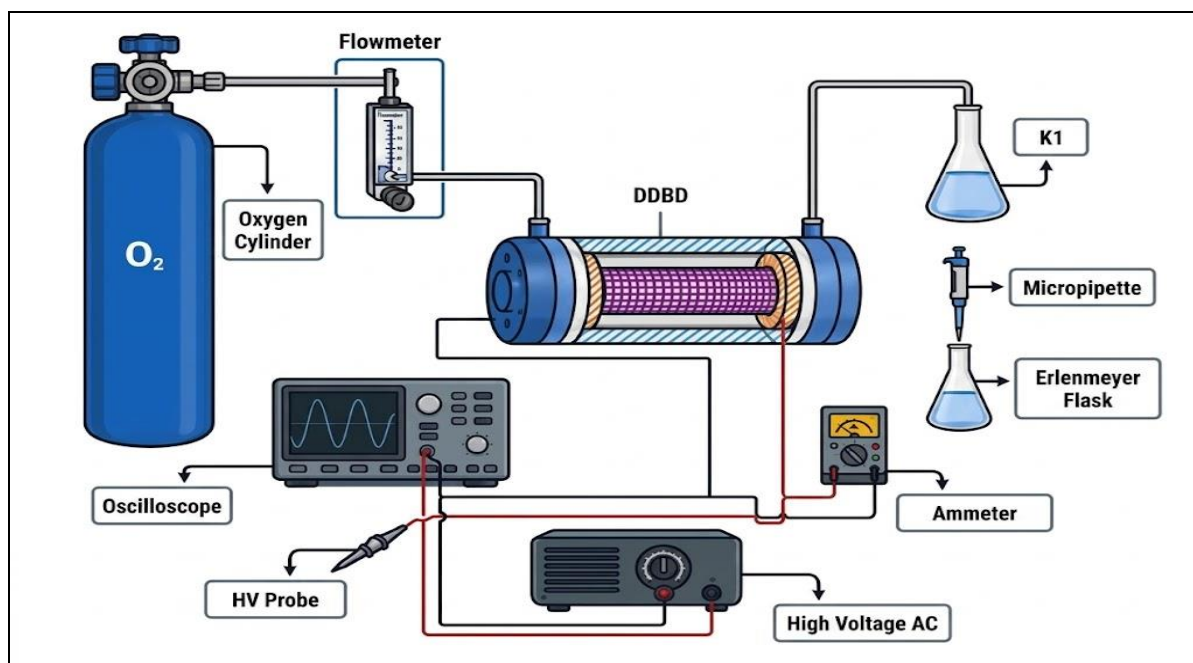


Fig 2 Schematic Diagram of Ozone Dissolution into Virgin Coconut Oil Using a Double Dielectric Barrier Discharge (DDBD) System

However, due to its unstable nature, the application of ozone in gaseous form has inherent limitations. Therefore, ozone production for medical applications requires efficient and reliable methods, one of which is plasma-based technology using Double Dielectric Barrier Discharge (DDBD) with a spiral–spiral electrode configuration. This configuration is considered more suitable as a medical ozone reactor because the space between the two dielectric barriers serves as a dedicated channel for the flow of pure oxygen. This medical ozone generator allows precise control of operational parameters, including applied voltage, exposure time, and the desired ozone dose administered to patients.

### III. RESULT AND DISCUSION

The primary focus of this study is to identify the optimal operating parameters specifically variations in applied voltage and gas flow rate that yield the highest ozone capacity, in order to establish a production protocol that is safe, effective, and clinically reproducible. The

parameters analyzed include applied voltage and gas flow rate.

#### ➤ Effects of Electrical Voltage and Oxygen Flow Rate on Ozone Concentration

Ozone concentration was measured using an ozone monitor under variations of applied voltage and gas flow rate. As the applied voltage increases, the potential difference between the electrodes becomes larger, resulting in a stronger electric field. Consequently, ionization processes and ozone production also increase. A higher potential difference enables more charged particles to acquire sufficient energy to ionize or excite oxygen molecules upon collision. These collisions promote increased ozone formation [16]. Based on the experimental data, the applied voltages were 2.7 V, 2.9 V, and 3.1 V, with gas flow rate variations of 0.4 L/min, 0.6 L/min, and 0.8 L/min. The highest ozone concentration was obtained at an applied voltage of 3.1 V and a flow rate of 0.4 L/min, reaching a concentration of 0.96 g/L.

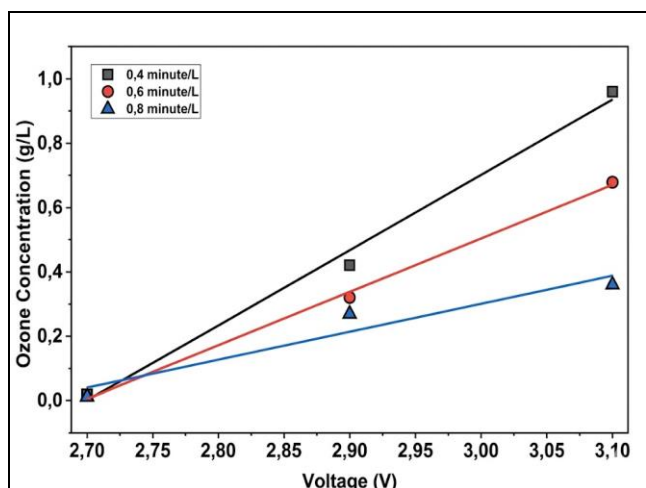


Fig 3 Ozone Concentration as a Function of Applied Voltage Variations

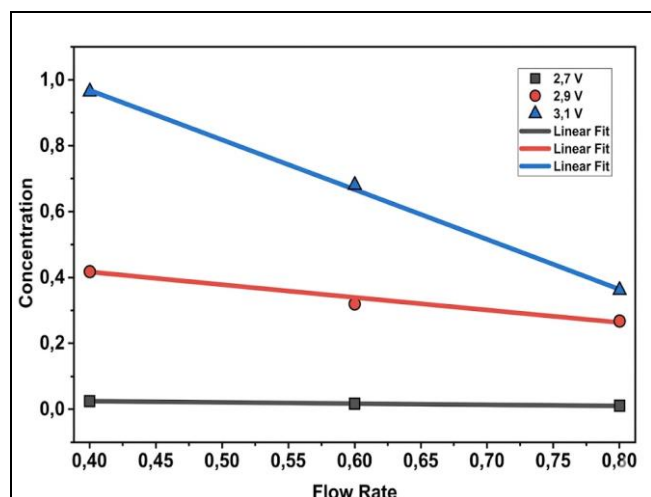


Fig 4 Ozone Concentration as a Function of Oxygen Flow Rate

Ozone formation was observed to initiate at an applied voltage of 3.1 V. The resulting ozone concentration was measured using a titration method, as expressed by the following equation [17].

$$C_{O_3} = \frac{R \times V_t \times N_t}{V_{gas}} \tag{6}$$

$$C_{pO_3} = C_{O_3} \times Q \tag{7}$$

In this equation,  $O_3$  represents the ozone concentration (mg/L), R denotes the molar ratio between the analytical species and the reactant under stoichiometric equilibrium,  $V_t$  is the volume of the thiosulfate solution used (L),  $N_t$  is the normality of the sodium thiosulfate solution (mol/L),  $V_a$  represents the volume of air or gas sample (L), and Q is the oxygen ( $O_2$ ) flow rate (mL/min). The volume of air can be calculated as the product of the gas flow rate and the operating time of the system up to the potassium iodide (KI) reaction endpoint. The titrant volume corresponds to the amount of solution required to titrate the KI solution, which

initially exhibits a yellowish-brown color, until it becomes colorless, indicating the completion of the titration.

➤ *Effect of Voltage and Gas Flow Rate on Ozone Capacity*

The determination of the medical ozone dose is influenced by the ozone capacity. Ozone capacity can be calculated using the following equation [18].

$$C_{pO_3} = C_{O_3} \times flowrate \tag{8}$$

Where  $C_pO_3$  denotes the ozone capacity, expressed in units of grams per hour (g/h) or micrograms per minute ( $\mu\text{g}/\text{min}$ ), and flow rate represents the oxygen ( $O_2$ ) flow rate in liters per hour (L/h) or liters per minute (L/min). Furthermore, the ozone dose can be calculated using Equation (3.4) as follows:

$$Ozone\ Dose\ (O_3) = C_{pO_3} \times t_{expose} \tag{9}$$

Where  $t_{expose}$  represents the ozone exposure duration, expressed in minutes. Variations in the applied voltage (2.7 V, 2.9 V, and 3.1 V) combined with oxygen flow rate variations of 0.4 L/min, 0.6 L/min, and 0.8 L/min resulted in differing ozone capacities.

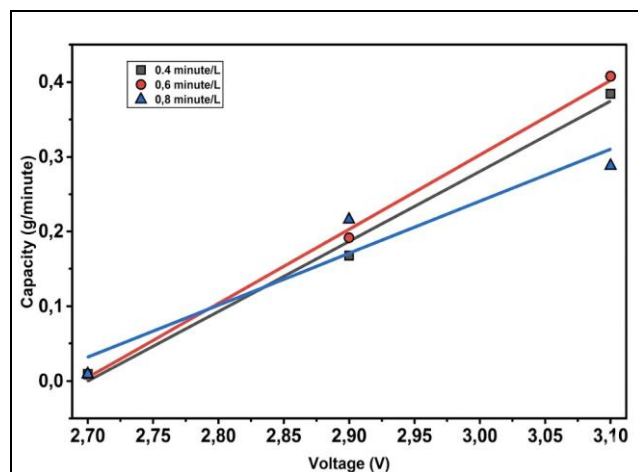


Fig 5 Effect of Applied Voltage Variations on Ozone Capacity

The highest ozone capacity was achieved at an applied voltage of 3.1 V and an oxygen flow rate of 0.6 L/min, yielding a maximum ozone capacity of 0.408 g/min. This result is illustrated in the graph shown below.

$$C_{pO_3} = C_{O_3} \times flowrate \tag{10}$$

Where  $C_pO_3$  represents the ozone capacity, expressed in units of grams per hour (g/h) or micrograms per minute ( $\mu\text{g}/\text{min}$ ), and flow rate denotes the oxygen ( $O_2$ ) flow rate in liters per hour (L/h) or liters per minute (L/min). Furthermore, the ozone dose can be calculated using Equation (2.6) as follows:

$$Ozone\ Dose\ (O_3) = C_{pO_3} \times t_{expose} \tag{11}$$

Where  $t_{\text{expose}}$  denotes the ozone exposure duration, expressed in minutes.

The results indicate that the ozone dose increases with increasing applied voltage and gas flow rate. The findings demonstrate that the DDBD reactor is capable of generating low and stable ozone concentrations. The ozone output can be effectively controlled through variations in applied voltage and frequency, allowing the system to maintain ozone concentrations within a safe range for medical therapy. Furthermore, plasma stability within the DDBD reactor provides significant advantages, including consistent ozone production, good energy efficiency, and operational safety. The use of low ozone doses is critically important to avoid toxic effects, maintain therapeutic effectiveness, and support compliance with established medical ozone standards.

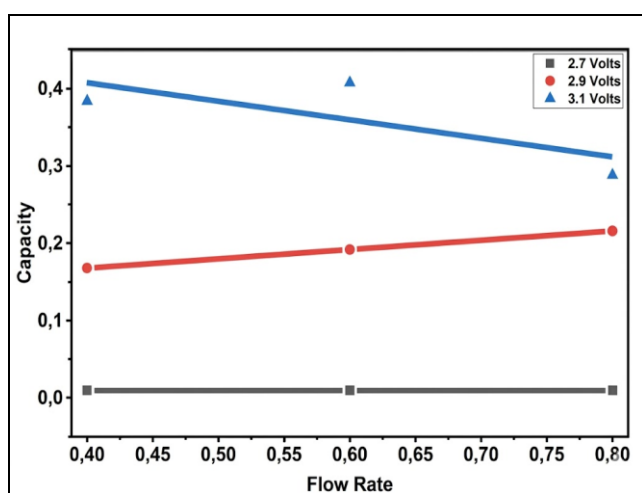


Fig 6 Effect of Gas Flow Rate Variations on Ozone Capacity

The reactor performance was characterized by analyzing the relationships between electrical current and applied voltage, ozone production, gas flow rate effects, and power consumption. These experimental data were integrated to demonstrate the correlation between physical input parameters and chemical output characteristics. Ozone dissolution into virgin coconut oil (VCO) was performed using the maximum ozone capacity of 0.408 g/min, achieved at an applied voltage of 3.1 V and an oxygen flow rate of 0.6 L/min, as this condition provided optimal and stable ozone production.

#### IV. CONCLUSIONS

The results of this study are systematically organized as follows: data structure, parameter mapping, scientific interpretation, and application relevance. The data structure consists of input parameters, including applied voltage (kV), gas flow rate (L/min), and exposure duration (minutes), and output parameters, namely maximum ozone capacity and dose-mapping representation. The dose map was constructed based on multivariable relationships using the Response Surface Methodology (RSM), with primary emphasis on the maximum ozone capacity as the optimal reference point, accompanied by scientific interpretation. The maximum

ozone capacity represents the highest efficiency of ozone generation, the saturation level of the ozonation reaction, and the optimal conditions for the formation of bioactive compounds. This value serves as a production standard, a reference for therapeutic ozone dosage, and a baseline for *in vivo* testing. The proposed framework is structured, reproducible, and aligned with international publication standards.

#### ACKNOWLEDGMENT

Appreciation is also extended to all parties involved in experimental data processing, particularly those who contributed to the development of the ozone dose map based on maximum ozone capacity. Part of this research received equipment assistance from the World Class Research University Scheme No: 222-747/UN7.D2/PP/IV/2025, from the Institute for Research and Community Service, Diponegoro University.

#### REFERENCES

- [1]. Bocci, V. (2005). *Ozone: A New Medical Drug*. The Netherlands: Springer, pp. 9–21.
- [2]. Adam Gilbran, Safina Zahrin Hanif, Risqi Prastianto Setiawan, Arfaza Zettira, Diaz Yanuar Pratama, Sumaryah, Eko Yulianto, Muhammad Nur. (2024). Analysis of Double Dielectric Barrier Discharge (DDBD) Reactor as Ozone Generator: Influence of Pulse Frequency and Duty Cycle. *Tuijin Jishu / Journal of Propulsion Technology*, Vol. 45 No. 4, ISSN: 1001-4055.
- [3]. Ervinawati Elyaswanto, Evita Tiara Maharani, Khairunnisa Syahputra, Eko Yulianto, Siti Susanti, Sumariyah Sumariah, Fadhila Nur Fahada, K. Sofyan Firdaus, Muhammad Nur. (2023). Electrical Study of DDBD Reactor with Mesh-Mesh Electrodes as a Medical Ozone Generator to Produce Standard Doses for Major Autohemotherapy in Small Animals. *International Journal of Innovative Science and Research Technology*, Vol. 8, Issue 11.
- [4]. Agus Sudarmanto, Eko Yulianto, Syukrotus Sa'diati, Syariful Hikam Saryadi, Muhammad Nur. (2024). Development of Ozone Generator Mini with DDBD (Double Dielectric Barrier Discharge) Technology at Atmospheric Air Pressure. *Indonesian Journal of Applied Physics (IJAP)*, Vol. 14 No. 1, page 45. <https://doi.org/10.13057/ijap.v14i1.73360>
- [5]. Puryadi, Muhammad Nur, Sumariyah, Maryam Resti Wijaya, Jhon Bosco Niyomukiza. (2019). Reactor Studi of Double Dielectric Barrier Discharge (DDBD) Plasma for Ozonation Olive Oil. *IJAM/Vol.7.ISSUE 1*. [www.Ijamsr.com](http://www.Ijamsr.com).
- [6]. Muhammad Nur, Ervinawati Elyaswanto, Evita Tiara Maharani, Eko Yulianto, Siti Susanti, Sumariyah Sumariyah, Reni Yuniati, Muhammad Thoar Arifin, Fadilah Nur Fahada, Gunawan Gunawan, Muhhammad Asy'ari. (2024). Medical Ozone Machine by Using DDBD Reactor for Low Dose Standard. *Power System Technology*, Vol. 48, Issue 2, ISSN: 1000-3673. <https://powertechjournal.com>

- [7]. Yulianto, E., Restiwijaya, M., Sasmita, E., Arianto, F., Kinandana, A. W., & Nur, M. (2019). Power Analysis of Ozone Generator for High Capacity Production. *Journal of Physics: Conference Series*, 1170. IOP Publishing.
- [8]. Zhang, H., Kan, L., Chenhua, S., Ziyang, L., Tonghua, S., & Jinping, J. (2014). Enhancement of Styrene Removal Using a Novel Double-Tube Dielectric Barrier Discharge (DDBD) Reactor. *Chemical Engineering Journal*, Vol. 256, pp. 107–118.
- [9]. Yulianto, E., Zahra, I., Zain, A. Z., Sasmita, E., Restiwijaya, M., Kinandana, A. W., Arianto, F., & Nur, M. (2019). Comparison of Ozone Production by DDBD Reactor Difference External Electrodes. *International Conference on Physics and Its Applications (ICOPIA)*. <https://doi.org/10.1088/1742-6596/1153/1/012088>
- [10]. Evita Tiara Maharani, Khairunnisa Syahputra, Ervinawati Elyaswanto, Eko Yulianto, Siti Susanti, Sumariyah Sumariyah, Fadhilah Nur Fahada, K. Sofyan Firdausi, Muhammad Nur. (2023). The Influence of Flow Rate and Voltage in the DDBD Reactor in Producing Medical Ozone for Antihyperglykemia Major Autohemotherapy. *International Journal of Innovative Science and Research Technology*, Vol. 8, Issue 11, ISSN: 2456-2165.
- [11]. Nur, M., Yulianto, E., Andi, W. K., Restiwijaya, M., & Arianto, F. (2019). Development of DDBD and Plasma Jet Reactors for Production Reactive Species Plasma Chemistry. *IOP Conference Series: Materials Science and Engineering*, Vol. 509.
- [12]. Azam, M., Restiwijaya, M., Zaini, A. Z., Sumariyah, S., Setiawati, E., Richandria, V., Hendrini, A. R., Dayana, B., Kinandana, A. W., Arianto, F., Bintang, K. N., Putri, Y., Valas, Y. K., & Nur, M. (2019). DDBD ozone plasma reactor generation: the proper dose for medical applications. *IOP Conference Series: Journal of Physics: Conference Series*, 1217, 012026. <https://doi.org/10.1088/1742-6596/1217/1/012026>
- [13]. Khairunnisa Syahputra, Ervinawati Elyaswanto, Evita Tiara Maharani, Eko Yulianto, Fadhilah Nur Fahada, K. Sofyan Firdausi, Muhammad Nur. (2023). Medical Ozone for Antihyperuricemia Major Autohemotherapy using DDBD Standard Dose Production Analysis. *International Journal of Innovative Science and Research Technology*, Vol. 8, Issue 11, ISSN: 2456-2165.
- [14]. Masfufah, M., Rahardian, A., Maftuhah, S., Yulianto, E., Sumariyah, S., & Nur, M. (2020). Analysis of Ozone Production for Medical with Double Dielectric Barrier Discharge (DDBD) Plasma Technology Against Spiral-Mesh Electrode Combination. *AIP Conference Proceedings*, 2197, 040004. (28)
- [15]. Facta, M., Zainal, S., & Zolkafle, B. (2014). Double Dielectric Barrier Discharge Chamber for Ozone Generation. *1st International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE)*, 978-1-4799-6432-1/14.
- [16]. M. Nur. (2011). *Fisika Plasma dan Aplikasinya*, Semarang: Universitas Diponegoro Press, pp. 8-12.
- [17]. Rahardian, A., Masfufah, M., Maftuhah, S., Yulianto, E., Sumariyah, S., & Nur, M. (2020). Effective Medical Ozone Production Using Mesh Electrode in Double Dielectric Barrier Type Plasma Generators. *AIP Conference Proceedings*, 2197, 040002.
- [18]. Maftuhah, S., Rahardian, A., Masfufah, M., Yulianto, E., Sumariyah, S., & Nur, M. (2020). Experimental Study on Medical Ozone Generation in Double Dielectric Barrier Discharge (DDBD) with Spiral-Spiral Electrodes. *AIP Conference Proceedings*, 2197, 040003.