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The Influence of Flow Rate and Voltage in the DDBD Reactor in Producing Medical Ozone for Antihiperglikemia Major Authohemotherapy

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Abstract:-The influence of flow rate and voltage in the Double Dielectic Barrier Discharge (DDBD) reactor in producing medical ozone has been carried out. The aim of this study was to obtain medical ozone as a standard dose for Major Autohemotherapy (MAH) in cases of hyperglycemia. DDBD is a double cylinder made of borosilicate glass with a thickness of 0.2 cm and electrodes made of aluminum mesh with a length of 6.2 cm, an inner diameter of 2 cm and an outer diameter of 4.2 cm. The input gas is oxygen (O_2) with flowrates of 0.2 L/minute-0.8 L/minute. At the flowrate limit used, this study found that the ozone concentration increased with increasing flowrate and operating voltage. The standard dose of MAH which is in accordance with the provisions of the Madrid Declaration for cases of diabetes mellitus/hyperglycemia, the specific dose is at the flow rate. of 0.4 L/min and a voltage of 3400 V, concentration of 293.64 µg/ml, capacity of 117.45 µg/second, with a dose obtained for the low dose of 18 µg and the high dose of 33 µg.

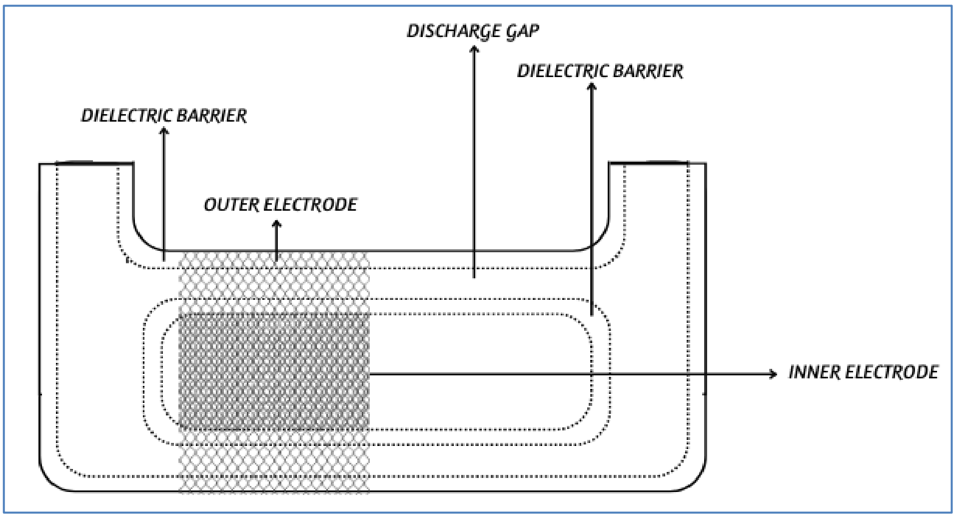
Keywords:- *Medical ozone, double dielectric barrier discharge, major autohemoteraphy (MAH), hiperglikemia.*

I. INTRODUCTION

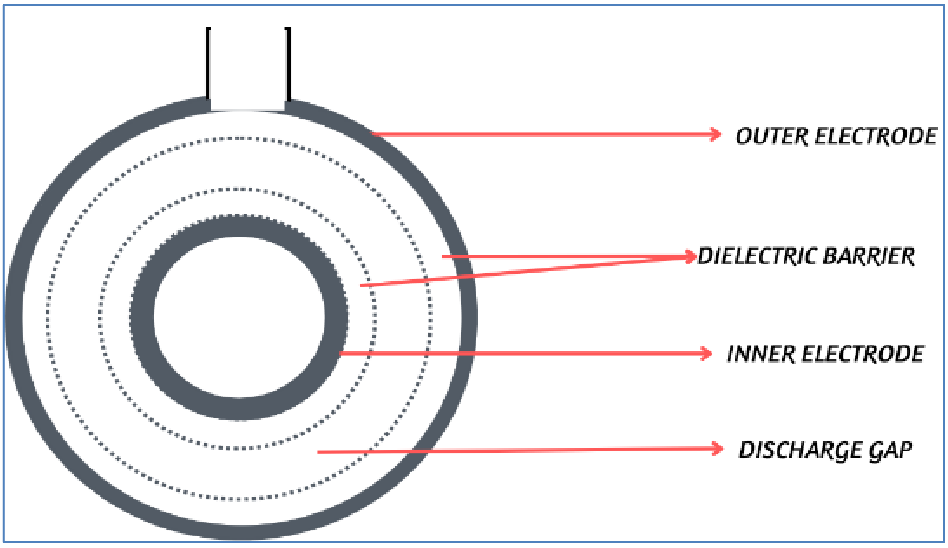
Ozone (O_3) is a natural gas in the earth's atmosphere that has a specific and strong aroma and is a form of allotropic oxygen. O_3 is a strong oxidant and has the potential to be used as a disinfectant to kill pathogenic microorganisms such as bacteria, viruses and fungi. This has led to the application of ozone in various fields such as disinfection of bottled drinking water, wastewater treatment, sterilization of medical equipment, and preservation of raw food ingredients [1]. Ozone also has potential in the health sector because it is believed to have a therapeutic effect. Medical ozone used in ozone therapy is a form of ozone gas used for disinfection and treatment of disease [2]. Ozone therapy is a modern, non-medical treatment method that has been used for more than 100 years. It has been shown to be consistently effective, safe, and with minimal side effects [3]. Russia (1992) reported the successful use of ozone in NaCl baths to treat burns. In 1999-2011, Bocci used the extracorporeal blood oxygenation and ozonized (EBOO) technique. The working procedure of the EBOO technique resembles classic dialysis (dialysis) with the difference that a mixture of oxygen-ozone gas flows through the dialyzer. Benefits of the EBOO technique include: Critically inoperable and critically ischemic limbs (stages III and IV, Leriche Fontaine) when amputation remains the only option, end-stage ischemic myocardiopathy, acute cerebral ischemia, chronic HCV hepatitis in IFN-resistant or intolerant patients IFN, Chronic renal failure which is always accompanied by immunosuppression and chronic oxidative stress continues to worsen metabolic disorders, metastatic cancer, chemo resistance and severe primary or secondary (to treatment with HIVprotease inhibitors) [4]. O3 has been used as a therapeutic agent in treating various diseases, the effects on psychophysiology events are obtained through Reactive Oxygen Species (ROS) [5]. O_3, for applications regarding human medicine, is used to improve several diseases such as abscesses, acne, eczema, psoriasis, human immunodeficiency virus and acquired immune deficiency syndromes, fibromyalgia, arthritis, asthma, cancers, inflammation, cardiac disease, liver disorders, uveitis, cystitis, chronic wounds, dyslipidaemia, osteomyelitis, Raynaud's disease, Parkinson's disease, sepsis, sinusitis, dental caries, infections of the oral cavity, and diabetic foot [6]. Ozone can be produced using the Dielectric Barrier Discharge (DBD) method. DBD is known as the most effective method for ozone production, because of the dielectric which functions as a current limiter so that it can prevent sparks and distribute the discharge evenly throughout the electrode area [7]. Then there was the development of the DBD reactor, namely the Double Dielectric Barrier Discharge (DDBD) reactor. The DDBD reactor is considered to meet the requirements as a medical ozone generator because it has a space between two double barrier layers between the electrodes as a place for pure oxygen to flow so that there is no contact between the input air and the electrodes during the ozone production process to produce ozone concentration so that ozone with relatively high purity is obtained. The ozone produced by the DDBD reactor is pure and suitable for use in medical applications [8.9,10]. For applications in the medical field, the parameters for determining the medical ozone dose produced by the DDBD reactor are based on the Major Autohetherapy (MAH) method [10,11,13]. Major Autohemotherapy (MAH) is a type of treatment that involves mixing the patient's blood with medical ozone (O_2-O_3) which is then returned to the patient's body via intravenous infusion [12]. Based on the basic description above, in this research the optimal oxygen flowrate will be observed to produce ozone concentration using a DDBD reactor with an aluminum mesh electrode configuration. Then it can be applied medically and a dosage suitability test is carried out based on the regulations issued by the Madrid Declaration on Ozone Therapy in 2023 for Major Autohemotherapy (MAH) for conditions of hyperglycemia or diabetes mellitus in small animals.

II. RESEARCH METHODS

This research uses a Double Dielectric Barrier Discharge (DDBD) reactor with a cylindrical reactor geometry. The zone cavity is formed by plasma using a double dielectric barrier in the form of a pyrex tube with a length of 18 cm and a glass thickness of 0.2 cm which can be seen in Figure 1. The outer diameter of the tube is 4.2 cm. and the inner diameter of the tube is 2 cm. This type of DDBD is known to generate high purity ozone, because the barriers keep the electrodes free from corrosion preventing contamination [13].



(a)



(b)

Fig. 1: The DDBD reactor uses mesh electrodes (a) side view; (b) front view.

The electrodes used have an aluminum mesh configuration that covers the outside and inside of the reactor Pyrex tube. Pure oxygen was used as a feed-gas source. The volumetric flow rate of the oxygen gas into the generator was set to be 0.2 L/min, 0.4 L/min, 0.6 L/min and 0.8 L/min, while the voltage discharge applied to the DDBD was 3 kV. The two electrodes are connected to a pulsed AC high voltage source which functions to supply high voltage to the reactor with voltage variations ranging from 0 kV to 10 kV Volts and a frequency of 60 Hz (produced by Dipo Technology, Indonesia) as a source of potential, while the output voltage waveform across the two electrodes of the DDBD plasma was measured using a high voltage probe (AC/DC max voltage 40 kV, EC 1010, EnG1010 Taiwan), respectively, and an oscilloscope (GOS-653 50 MHz). The output current discharge was measured by an analog multimeter (Sanwa YX361TR, China).

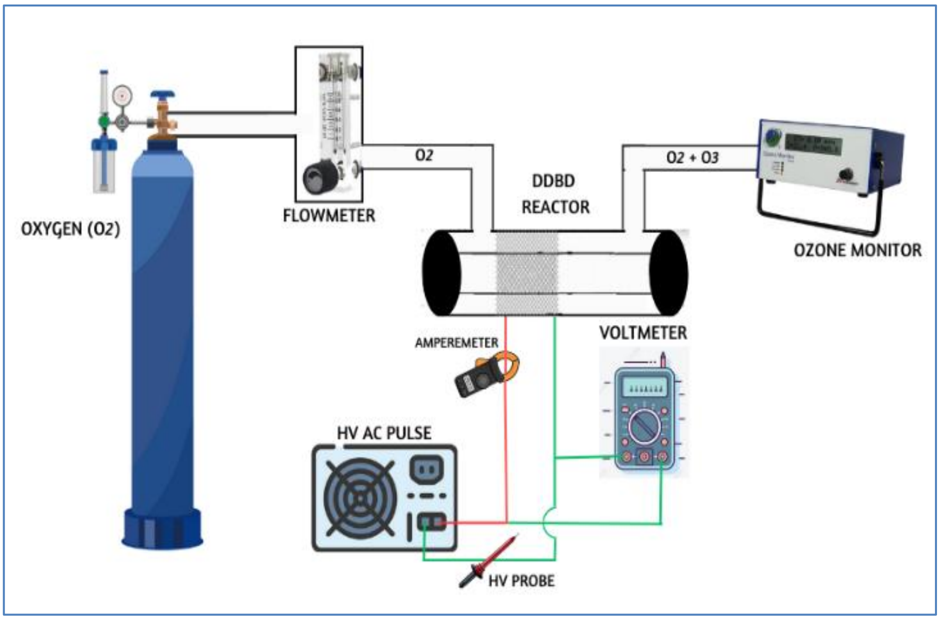


Fig. 2: Ozone generator setup scheme

Ozone produced by the DDBD reactor is measured with an ozone monitor (2B Technologies An InDevR Company 106-M Serial 1182M, China and specifications with specifications for using a maximum flow rate of 1.5 L/Minute and can read ozone concentrations ranging from 0 to 1.000 mg/l).

Concentration is determined by 3 parameters including voltage, distance between two electrodes, oxygen flow rate. According to Yulianto et.al, 2019, ozone concentration (is the amount of ozone that has been successfully released by the ozone generator. Meanwhile, ozone capacity (is the level of ozone that can be transferred into solution with the units used being grams/hour. To calculate the amount of ozone capacity, you can use equation (1) below:

$$Cap_{O_3} = C_{O_3}.flowrate \quad (1)$$

Where is the ozone capacity in mg/min, is the ozone concentration whose units are grams/L and flowrate is the ozone flow rate whose units are L/hour. To calculate the dose parameter (Doz) it can be obtained using equation (2) as follows:

$$Doz = Cap.t \quad (2)$$

Where Doz is the ozone dose in mg units, is the ozone capacity in mg/min units and t is the ozone exposure time in s units [9].

III. RESULT AND DISCUSION

A. Voltage Current Characterization.

Figure 6 shows the variation of the electric current of the average plasma discharge in the DDBD reactor as a function of voltage for several flow rates of oxygen through the reactor. Not much difference in the flow rate produced at 0.2 L/min - 0.8 L/min as a function of voltage. From the barr error we get the variation of current as a function of voltage when the voltage is between 1500V - 3500V.The electric current that occurs in the DDBD reactor is a capacitive current. This occurs due to the ionization process in the gas. Basic mechanisms in plasma. The mechanism of interaction between the electric field and the gas is an ionic collision with neutral gas molecules. Collision of electrons with neutral molecules gives charge accumulation and changes due to changes in time.

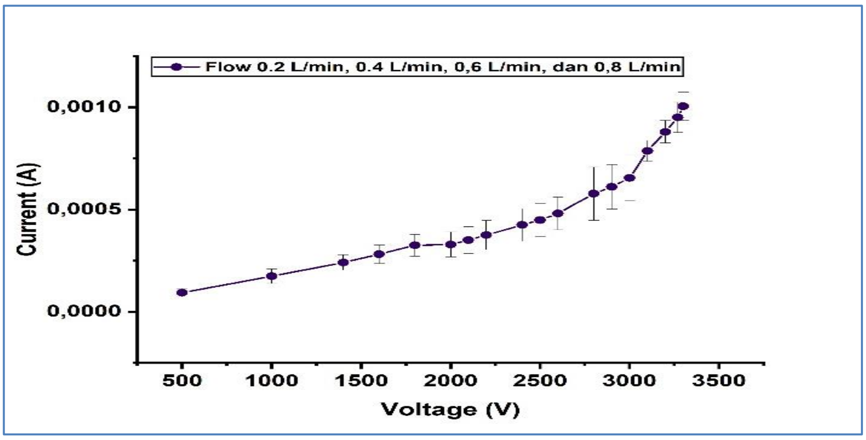


Fig. 3: Trends in current characterization as a function of voltage

B. Effect of voltage on concentration and capacity

Figure 3 below shows the ozone concentration as a function of applied voltage for several flowrate variations, namely 0.2 L/min, 0.4 L/min, 0.6 L/min and 0.8 L/min. In this picture it can be seen that when the voltage is increased there is an increase in the ozone concentration. This is because the amount of energy possessed by the particles is getting bigger. The transfer of energy and momentum allows ionization, the dissociation of oxygen molecules when collisions occur. This collision results in the formation of more ozone. To provide conditions for initial medical ozone production, this reactor can produce it with a voltage of 3270 volts, as can be seen in Figure 4.Figure 4 shows the variation of ozone concentration with the voltage applied to the DDBD reactor. For all flow rates used from 0.2 L/min - 0.8 L/min, the ozone concentration increases linearly with increasing voltage. The trend of linear increase in ozone concentration with increasing voltage was also obtained by Fang *et. al.*[15], Nur *et al.* [13].

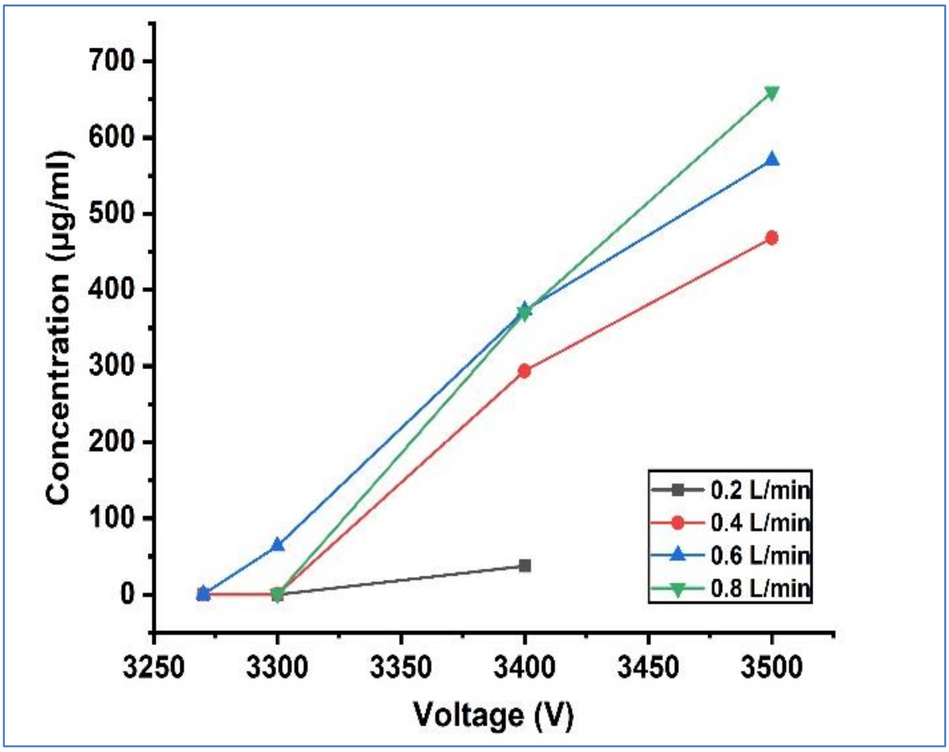


Fig. 4: Effect of voltage on ozone concentration

In the reactor we use, the highest operating voltage before instability and arct is 3500 V. For the same operating voltage, for example 3500 V, the ozone concentration for that voltage depends on the given flowrate.

C. Influence of flowrate for Ozone Concentration

Figure 4 shows that the ozone concentration for the low flowrate used is visible as the gas flow rate increases, but is not so high that it starts to show a decrease. Research conducted by Nur, et al. 2017 [13] with an initial flow rate of 4 L/min appears to continue to decrease and follows a negative exponential. Understandably, this research has not yet reached the threshold limit for particle density in the ionization zone so the average path distance is still large enough so that electrons do not lose energy in collisions. Thus, the greater the number of particles passing through the ionization zone, the smaller the collision energy and the less oxygen dissociation that can occur. In the reactor used in this research is pure oxygen. The process of ozone formation in high electric fields such as in DBD or DBD reactors generally follows several stages. High energy electrons (1-10 eV) collide with O_2 molecules. The effect of oxygen flow rate on the ozone concentration produced is shown in Figure 4. Ozone concentration increases as the oxygen flow rate increases in the reactor. The flow rate used in this research was between 0.2 L/min - 0.8 L/min. This can be categorized as a low flowrate for an ozone generator. Medical ozone often uses low flowrates. The resulting increase in ozone concentration is in accordance with that obtained by Siriprom et.al. [16], also the same thing was reported by Cuong et al. [7] who reported that ozone generators produce low ozone yields at low flow rates. Nur et. al. [13] found that in the DBD type reactor with a spiral-spiral electrode configuration, the flow rate provided the optimum value. Initially, a low flow rate produces ozone concentration which increases with increasing flow rate, after passing this value the ozone concentration actually decreases with increasing flow rate [13]. In this study (DDBD Reactor) the tendency to exceed the optimum ozone concentration point was seen at a flow rate of 0.6 L/min, at operating voltages of 3400 V and 3300 V.

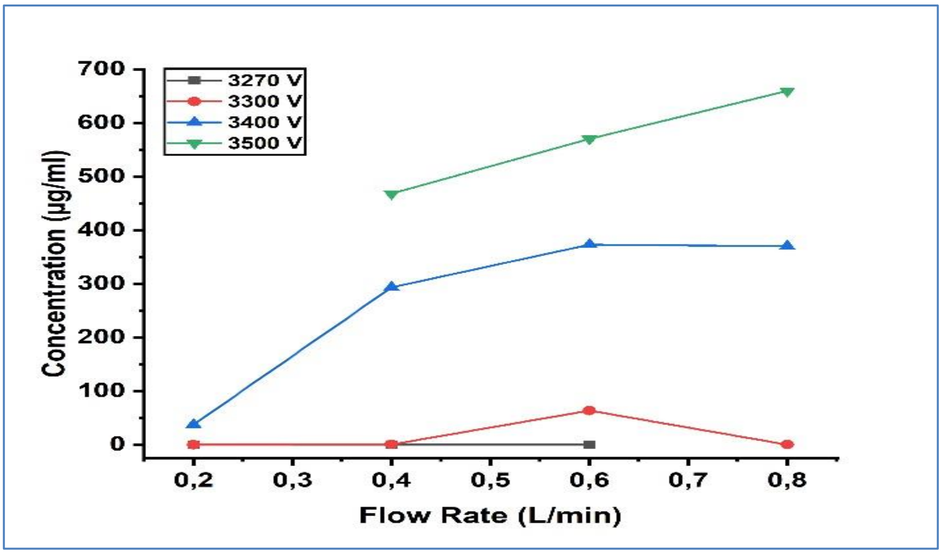


Fig. 4: Influence of gas flowrate for ozone concentration production

Then the oxygen molecules will be dissociated into oxygen atoms. Oxygen atoms may combine with oxygen molecules to form O_3.The formation of ozone can be explained by the reaction below:

e + O_2 ---> O* + O* + e
O* + O_2+ M ---> O_3 + M

where, *M* is another molecule that functions to absorb part of energy in the process of formation of O_3. This molecule is not involved in chemical reactions. Therefore, the generation of ozone is based on silent discharge phenomena, electrolytic, opto-chemical reaction. The ozone gas is generated from oxygen or air by the electron bombardment of molecules in glass-barrier based discharge. Figure 10 addressed average of ozone concentration as function of air flow rate.

D. Medical Ozone Dosage

The dosage of medical ozone depends on the disease being treated. From the dosed ozone generator, a harmonious combination can be achieved between the ozone reactor configuration, operating voltage, high voltage pulse frequency, and oxygen gas flowrate. The gas source for generating ozone by a medical ozone generator must exclusively reach medical oxygen standards, at least 99.5% pure medical grade oxygen, originating from medical grade with certified containers. The use of oxygen concentrates is limited to exceptional situations.

Based on research that has been carried out, the ozone concentration obtained produces a standard dose of MAH which is in accordance with the provisions of the 2023 Madrid Declaration [12] for cases of diabetes mellitus/hyperglycemia conditions in the low dose and high dose range categories (shown in table 1). The specific dose obtained for low and high doses is at a flow rate of 0.4 lpm and a voltage of 3400 V, concentration 293.64 µg/ml, capacity 117.45 µg/second, with the dose obtained for the low dose being 18 µg with time exposure for 10 seconds, meanwhile for the high dose it is 33 µg with an exposure time of 17 seconds which can be seen in the figure 5.

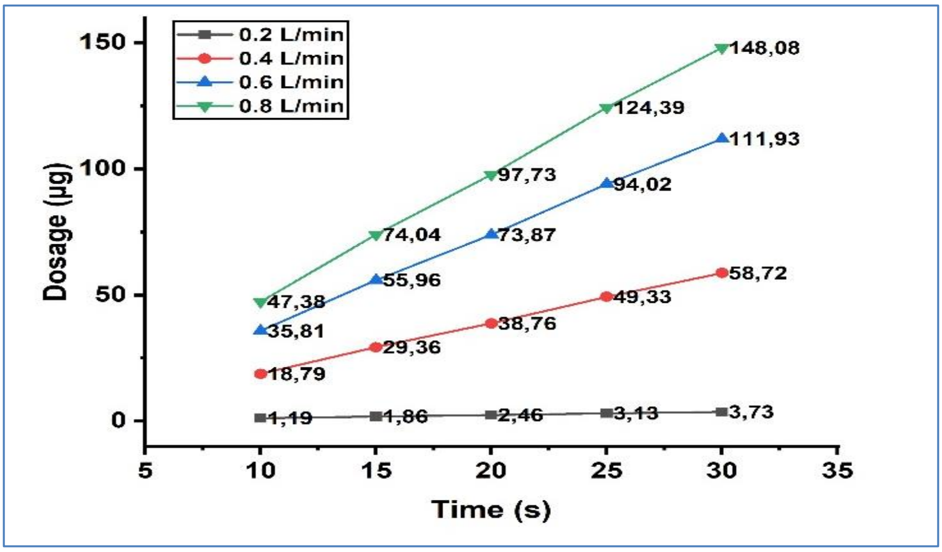


Fig. 5: Characterization of ozone dose as a function of time for a voltage of 3400 Volts

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Based on studies conducted by [14] and also discussed guidelines for the concept of low dose ozone [14], the ozone concentration range for systemic application in the form of MAH should not exceed 10–40 µg/mL. Above 50 µg/mL, the toxic effects of ozone must be taken into account, and 80 µg ozone per mL of blood should not be used. The ozone dose per treatment will cover a range between 500 and 4000 µg. See

Table 1 below can be discussed that MAH for hyperglycemia/diabetes mellitus according to the 2023 Madrid Declaration [12]:

µg of ozone per mL of ozone/oxygen mixture delivered by the ozone generator. When such medical ozone is produced from a generator. Dosage also means that µg of ozone per mL of blood, orthe total amount of ozone in µg per total amount of blood, or total countozone in µg per treatment. In medicine, the ozone concentration is usually used in units of 1 µg/mL.

Table 1: Dosage range for Major Autohemotherapy for hyperglycemia/diabetes mellitus according to the 2023 Madrid Declaration [12]

Ozone (O_3)	**Dose Administration Rate**			**explanation**
	Low	**Medium**	**High**	
				Sample Volume 1,5 mL/kg (blood)
V. (mL/kg)	1 – 1,5 mL/kg (blood)			
Dosis. (µg/kg)	10 -20	20 - 30	30 - 35	

IV. CONCLUSIONS

The Double Dielectic Barrier Discharge (DDBD) reactor can be used to produce medical ozone and the concentration obtained meets the standard dose for Major Autohemotherapy (MAH) in cases of hyperglycemia.For all flowrates used in this research between 0.2 L/min - 0.8 L/min, the ozone concentration produced increases linearly with increasing operating voltage. In this study (DDBD Reactor) the tendency to exceed the optimum ozone concentration point was seen at a flow rate of 0.6 L/min, at operating voltages of 3400 V and 3300 V.

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