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Effects of applied voltage and flow rates of ozone generator fed by dry air and O_2 on the coaxial wire-cylinder reactor by varying various electrodes parameters

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Abstract: *Production of ozone is one of the most typical industrial and commercial applications. The ozone generator was designed according to the coaxial wire-cylinder reactor with pure oxygen gas and atmospheric air as feed gases for ozone production. The effect of the flow rate and discharge voltage on the concentration of the ozone were studied, the applied voltage was varied from (1- 9 kV) for two values of the gap space between electrodes D= 2 and 4 mm, and two values of the electrode area* A_e*= 20 and 36* cm^2*. It is found that the concentration of ozone increases with increasing discharge voltage and area of electrode and decrease with increasing flow gas rate and gap space.*

Keywords*: Ozone generation, Non-thermal plasma, coaxial wire-cylinder reactor, Gap space, Electrode area.*

I. Introduction

There are several types of the electrical discharges that have been used for generating nonthermal (cold) plasmas under different experimental techniques. These techniques include the corona discharges, the glow discharges, the dielectric barrier discharge (DBD), the radio frequency (RF) discharges, and the microwave (MW) discharges [1]. All these techniques able to generate localized concentrations of reactive oxygen species, including O-atom [2], O_2 [3], and ozone [4], these species have many technologically applications including treatment of biological media and surface modification of textiles and semiconductors [5]. Ozone production, in particular,

is one of the oldest applications of electrical discharges, dating to 19th century [6].

While dielectric barrier discharges (DBDs) have been a standard means of ozone production for commercial industry, ozone also generated by many other sources, including pulsed streamer corona discharge sources in point-plane [7,8] ,spiral wire-cylinder [9] and wire-cylinder [10] configurations. Recently, ozone has been generated by other cold plasma sources, including microplasma arrays [11–14] and dielectric barrier plasma jet devices [15–19].

Ozone produced by atmospheric pressure plasma is a powerful oxidizer that could destroy microorganisms effectively. Ozone concentration in nature varies between 0.01 ppm to 0.05 ppm, depending on geographic location and season. High voltage discharge ozone generators produce ozone/gas mixture, which contains 1 % to 3 % ozone when using dry air, and from 3 % to 6 % ozone when the feed gas is the high purity oxygen only is used [20]. Ozone is a strong oxidizing agent with a low environmental impact [21]. Therefore, ozone has been used in wide industrial applications such as water treatment, sterilization, bleaching, and decolorizing. The very important reasons for using ozone water treatment are it can destroy organic compounds and can kill bacteria [22,23]. Ozone is a disinfectant that does not leave the rest of the reaction in the water because the ozone will decompose back in to oxygen and also the ability of ozone to dissolve in water thirteen times more easily than oxygen. [24,25]. With more applications and increasing consumption, improvements in ozone production efficiency are required [26].

The paper studies maximization of the ozone yield in a coaxial wire-cylinder reactor by maximising the various parameters that are involved, including the applied discharge voltage, the gas flow rate, the gap spacing between electrodes and the area of the electrode.

II. Experimental Work

The scheme of ozone generating system by using dielectric barrier discharge plasma that was designed can be seen in Figure (1). The ozone cell consists of tube made of Pyrex glass with length of 14 cm and inner diameter of 1.2cm. The cell was connected to the high voltage power supply by two electrodes, the anode was conned through copper rode, concentrated inside the tube, and the cathode was connected by sheet of copper shielded the outside of the tube. The tube have two opened one to entry the gas and other to exit the ozone. The gas passes inside the tube through the gap between the anode and the edge of the glass tube. The high voltage Ac transformer (0 – 15 kV, f=50 Hz) was used to supply ozone chamber with high voltage. The gas flow was monitored by flow meter (Rotameter 1100 GEC-Elliott), and the ozone concentration was measured by ozone monitor (ECO Sensors OS-6 Ozone Swich). To study the effect of the geometry of the ozone chamber, two different electrode areas (A_e= 20, 36 cm^2) and two different gap space between electrodes (D=2, 4 mm) were used.

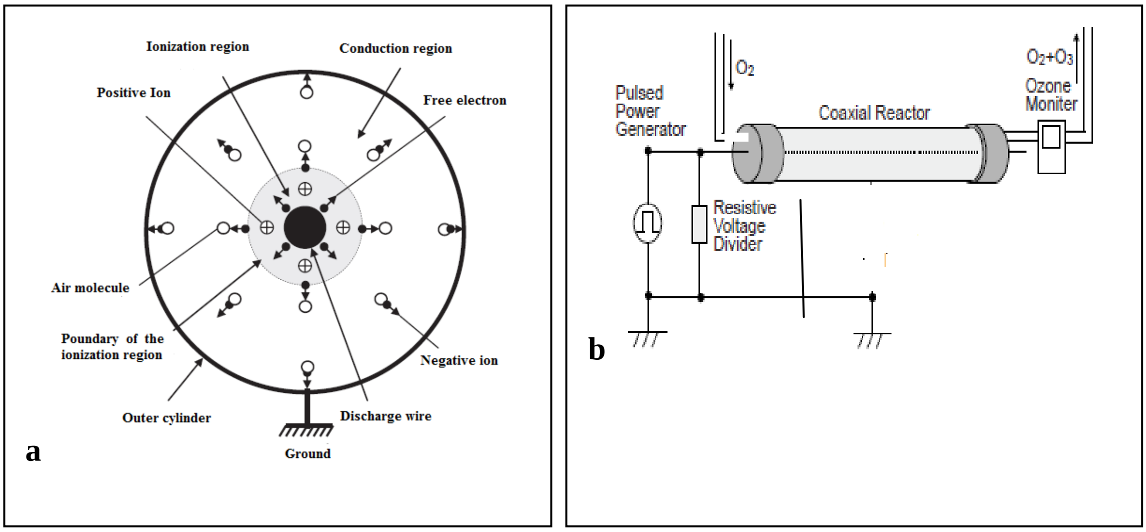

Fig.1. a) Cross section of a coaxial reactor, b) Schematic diagram the ozone production system using a coaxial reactor.

III. Results And Discussions

This paper includes the production of ozone by using two supplied gases:

a. Pure oxygen gas (O_2).

b. Dry air.

a - A pure oxygen O_2 as supplied gas.

3.1 Effect of flow rate on ozone concentration.

To study the effect of the flow rate on the concentration of the ozone produced by an ozone generator, the concentration of ozone has been measured with the flow rate for different discharge voltage (4.5, 5, 6, 7, 8, 9) kV, for two electrodes area (A_e= 20, 36 cm^2), and two gap space (D=2, 4 mm), the results are shown in Fig. 3.

It can be shown that decrease of the concentration of the ozone with increasing of the flow rate. This is because of the residence time of the gas on the ozone chamber inversely related to the gas flow rate, with an increased residence time providing time for a reaction to occur and a correspondingly higher ozone concentration to be produce.

3.2 Effect of discharge voltage on ozone concentration.

From Fig. 2 it can be shown that at a given flow rate the increasing of the ozone concentration with increasing discharge voltage, this can be interpreted as follows:
As the voltage is increased the electrical energy density increase leads to more energy being transferred to the electrons, thereby increasing the possibility of collisions with the oxygen atoms in the chamber.

3.3 Effect of gap space on ozone concentration.

Fig. 3. shows that the effect of reducing gap space from (4 mm to 2 mm) is clearly from the generation of ozone, it is produced a significantly higher at any given gas flow. This is clearly related to the increased energy density as the gap space is decreased, together with increased number

of oxygen molecule/electron collisions and correspondingly increased combination of oxygen atoms with oxygen molecules.

3.4 Effect of electrode area on ozone concentration.

Fig. 4. Shows ozone concentration as a function of discharge voltage for two different electrode area (A_e=20, 36 cm^2). It can be shown that the production of ozone is higher for wider electrode area. This is because of the residence time of the gas on the ozone chamber proportional to the electrode area, therefore, with an increased residence time providing time for reaction to occur and correspondingly higher ozone production occur.

b - The supplied gas is dry air.

To compare the concentration of ozone produced by oxygen as a supplied gas and dry air, the experiment was repeated by using the dry air as supplied gas instead of pure oxygen the results were shown in Fig. 6. It is found the concentration of ozone is also increase with increasing flow rate as the situation when the pure oxygen had been used except the concentration of ozone somewhat lower in second situation, becouse the concentration depends on the number of the oxygen molecules. Fig. 7 shows the difference

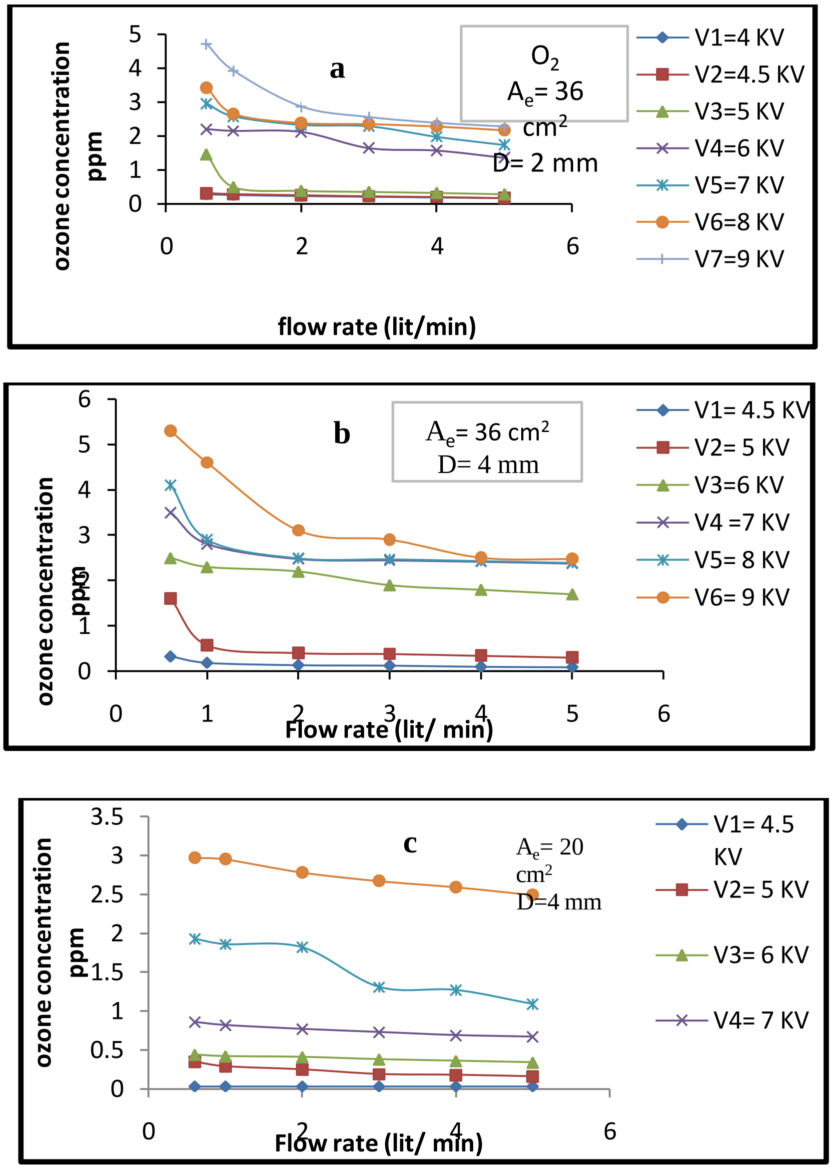

Fig. 2. The ozone concentration as a function of a gas flow rate for different discharge voltage: a) A_e=36 cm^2, D =4 mm, b) A_e=36 cm^2, D=2 mm, c) A_e=20 cm^2, D=4 mm.

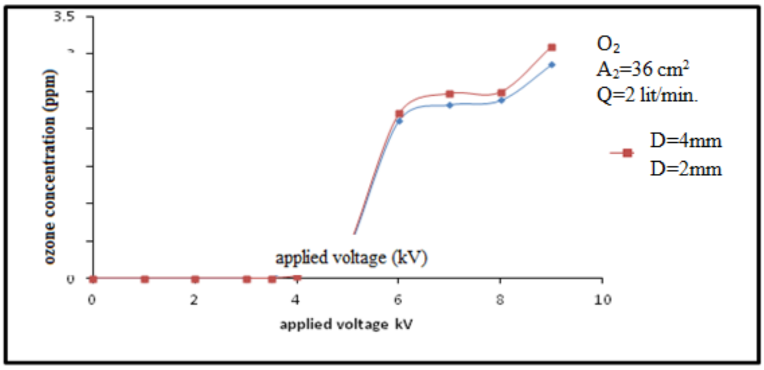

Fig.3. Ozone concentration as a function of applied voltage for two value of gap space (D=2, 4 mm) and given electrode area A_e=36 cm^2 , and gas flow (Q=2 lit./min.).

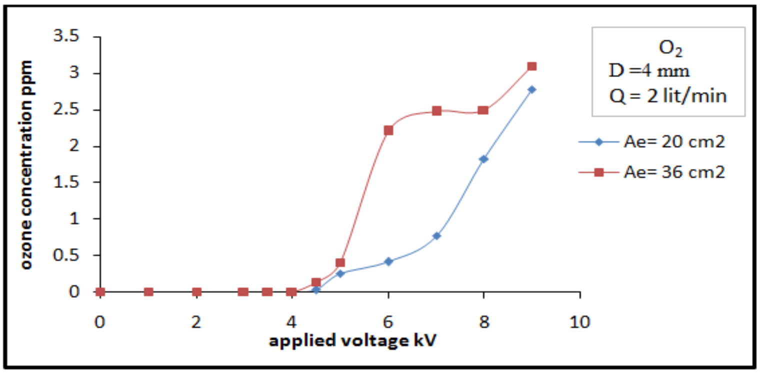

Fig. 4. Ozone concentration as a function of applied voltage for two different electrode area A_e=20, 36 cm^2.

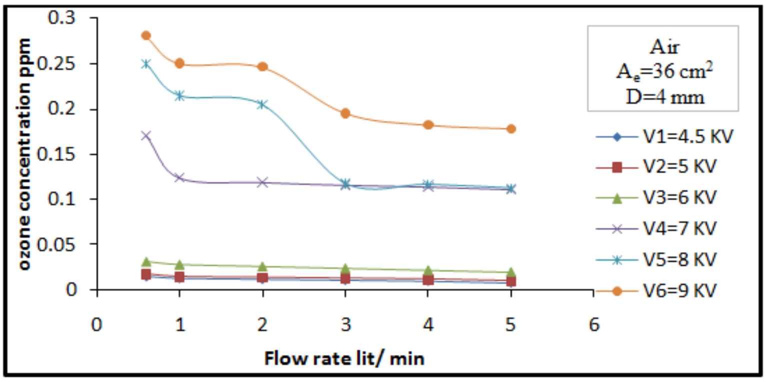

Fig. 5. Ozone concentration as a function of air flow rate for different discharge voltage and given electrode area A_e=36 cm^2 and gap space D=4mm.

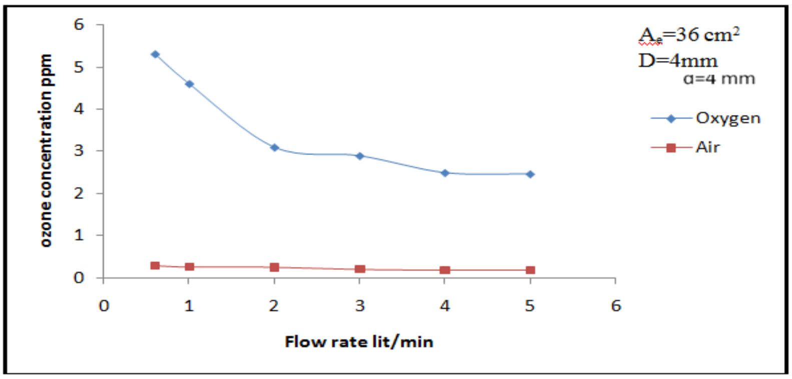

Fig. 6. Ozone concentration as a function of flow rate for Oxygen and air as a feeding gas.

IV. Conclusion

Production of ozone by the coaxial wire-cylinder reactor in pure Oxygen gas and air at atmospheric pressure. with two electrode area A_e=20, 36 cm^2, and two gap space D=2, 4 mm, different flow rates and discharge voltages has been experimentally investigated. It was found that concentration of ozone increase with discharge voltage and electrode area but decrease with and gap space.

The comparison between ozone production using oxygen gas and air as feed gas shows the concentration of ozone somewhat lower in second situation, but the difference between two values can be reduced by using low flow rate, wider electrode area and long discharge time.

These experimental results have provided information which will be useful in the decisions to be made about the commercialization of the plasma jet device for biomedical applications.

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