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Study of DBD Argon Plasma Jet on Electrical Characteristics, Spectroscopic Emissions due to the Influence of Gas Flow Rate

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Abstract:- Research on the analysis of DBD argon plasma jet as a producer of dissolved reactive oxygen spicies (ROS) in distilled water as plasma actived medium (PAM) has been carried out. Characterization of the Ar plasma jet was carried out regarding its electrical properties, emission spectrum for three different flow rates (2 L/min, 6 L/min, and 10 L/min). The Ar plasma jet that comes out of the reactor is directed towards the distilled water at varying distances (5 cm and 10 cm). It was found that the maximum concentration of dissolved reactive oxygen compounds in distilled water was obtained at a distance of 10 cm from the jet tip to distilled water and a treatment time of 40 seconds. The I-V categorization obtained a curve following a quadratic polynomial. The emission spectrum of Ar jet plasma yields almost all wavelengths for Ar plasma. The emission intensity is directly proportional to the flow rate.

Keywords:- *Plasma Jet Argon, ROS,Dissolved Ozone,Spectrum Emission, Electrical Behavior, Plasma Actived Medium.*

I. INTRODUCTION

Atmospheric pressure plasma jets have been used in several fields including industry, biomedicine, beauty and medicine [1,2,3]. Plasma Jet is the result of ionized gas flow from the plasma discharge column [1,2]. Plasma jets are generally produced at atmospheric pressure, and are cold plasma whose temperature is slightly above room temperature. This type of plasma is classified as a plasma that has local thermodynamic equilibrium [3]. Cold plasma jets are also widely applied in materials processing and biomedical applications such as disinfection and decontamination [4]. In the field of medicine, plasma jets are combined with other media such as distilled water, olive oil, virgin coconut oil (VCO) as plasma active media (PAM), by shooting the tip of the jet at a certain distance from the medium [2,5,6]. Medical plasma is applied as a health therapy to living creatures. Medical plasma is an application of cold plasma, with plasma jets frequently used and generally at atmospheric pressure. Plasma jets have medical applications such as wound healing, disinfection and decontamination. Some applications of low temperature or non-thermal plasma (cold plasma) include: sterilization, plasma dentistry, cancer treatment or plasma oncology, plasma pharmacology, cosmetics, and wound healing. The progress of the wound healing process in the intervention group with cold plasma always increased every day, where there was an increase in the percentage value of wound healing getting better [7]. The addition of ozone in therapy also provides a pleasant sensation and reduces treatment pain in ozone bagging ajuvant therapy [8]. The chemical species produced by cold plasma can kill bacteria quickly at room temperature without increasing chemical residues. Fungal cells are damaged and killed by cold plasma [9,10]. Cold Argon Plasma beams are capable of treating biological surfaces [11]. Plasma is defined as quazintral of electrons, radicals, positive and negative ions. Plasma is a very significant area for electron collision reactions to occur. Plasma occurs when the temperature or energy of a gas is increased so that it allows the gas atoms to be ionized, causing the gas to release its electrons which normally surround the nucleus. The low-temperature plasma jet interacts with helium and is driven by high voltage. Plasma jets have a wide range of dimensions, ranging from micrometer scales suitable for local and accurate treatment, to large scales suitable for large-scale sample treatment [10]. Plasma Jet is the result of ionized gas flow from the plasma discharge column. Plasma Dielectric Barrier Discharge (DBD) is characterized by an insulator layer between two electrodes, planes or cylinders connected to an alternating voltage source. Dielectric barrier discharge is a convenient way to produce non-thermal or non-equilibrium plasma at atmospheric pressure [12]. Noble gases are gases that are non-reactive and very difficult to react with other chemicals. Among the noble gases, Argon (Ar) is the most abundant in the air with levels of 0.93% in dry air. Argon has almost the same solubility in water as oxygen, and is 2.5 times more soluble in water than nitrogen. ROS (Reactive Oxygen Compounds) is a very reactive compound. ROS are able to damage tissue by modifying lipids and proteins in living bodies. The most reactive ROS groups are superoxide radicals and hydroxyl radicals. This reactivity is caused by the presence of unpaired electrons. Oxidative stress can be reduced or inhibited by administering antioxidants that have scavenger properties against existing free radicals [6, 8, 13,14]. Low ROS levels function to activate and modulate signal transduction pathways, modulate the activity of redox

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sensitive transcription factors and regulate cell defense. ROS originate from the reduction of oxygen, producing a group of highly reactive ions, molecules and radicals [6,14,15,16]. This research will observe the length of the plasma jet as a function of flowrate with an average voltage of 9.3 kV. This research also aims to determine the characteristics of a plasma jet using a discharge column with a dielectric barrier. Apart from that, this research will also observe the concentration of dissolved ozone in distilled water that has been given plasma jet treatment by varying the distance between the tip of the plasma jet to the distilled water, time and flow rate. So it can confirm that distilled water that has been treated with plasma jet can help in the wound healing process.

II. RESEARCH METHODS

This research uses a DBD reactor, with a plasma jet generator set up and treatment with distilled water shown in Figure 1. A Pyrex tube with a plasma jet reactor tube length of 8.35 cm. Argon gas is flowed into the plasma jet reactor. The plasma jet generator Pyrex tube has an inner diameter of 15 mm and an outer diameter of 29 mm. The plasma jet reactor is equipped with 2 electrodes attached to the outside of the tube which are 0.5 cm long and the distance between the electrodes is 3.9 cm. The plasma jet exits through the end of the tube. The end of the plasma jet drops distilled water at a certain distance. Optical emission spectroscopy (OES) was used to detect argon plasma emissions, with varying flow rates (2 L/min, 6 L/min, 10 L/min). Spectroquant is used to analyze the compounds contained in the liquid. Dissolved ozone concentration in distilled water as a function of flow rate (2L/Min, 6L/Min, 10L/Min), treatment distance (5cm and 10cm) between the jet tip and distilled water, and treatment exposure time given (20s, 40s, 60s, and 120s). This concentration is measured using a Spectroquant tool. The length of the jet produced as a function of flowrate (2L/Min, 6L/Min, 10L/Min), is measured with a micrometer. This research was carried out by starting to provide a flowrate of argon gas through a plasma reactor tube to create a plasma jet so that it could provide treatment to the prepared distilled water.

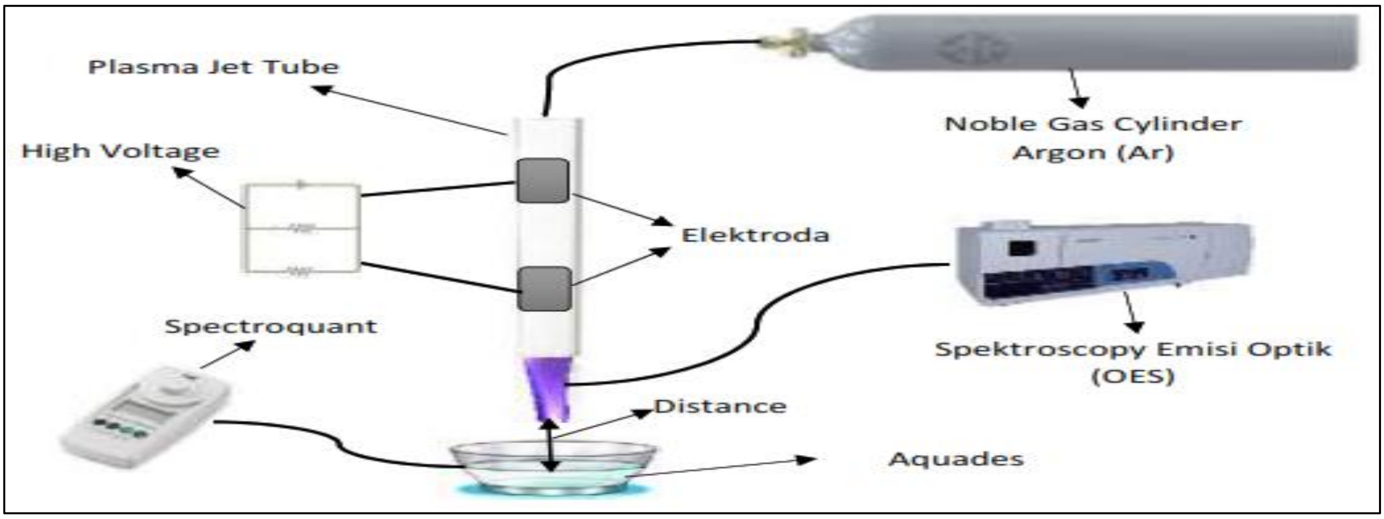

Fig 1: Experimental Set Up Plasma Jet and Disolved ROS in the Aquades

III. RESULT AND DISCUSION

A. Characteristic and Length of Plasma Jet

The current-voltage characteristics of the DBD argon plasma jet are shown in Figure 2. The results of current measurements in the DBD plasma jet reactor to obtain I-V characteristics were carried out at operating voltages between 3.0 kV – 9.3 kV. The graph in Figure 2 shows that the greater the voltage applied, the greater the current produced.

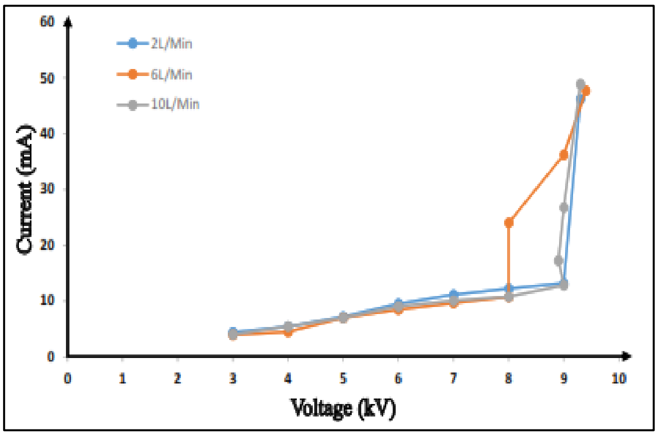

Fig 2: Current as a Function of Voltage for Several Flow Rates in a Plasma Jet

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The phenomenon in the graph can be understood that the AC voltage applied to the DBD Plasma Jet reactor increases the amount of electric charge caused by the ionization of Ar atoms through the process of electron collisions. Plasma is formed, the capacitive current is measured by changes in charge due to changes in time. The capacitive current produced according to equation ($I = C\frac{dV}{dt}$) will be greater. From this graph it can also be seen that the current follows a second order polynomial equation in accordance with the trend formulation from modified Robinson and modified by Nur at. Al. [12]. With a combination of flow rate and increasing current and paying attention to the voltage and length of the plasma beam. It can be seen that the plasma jet output is slightly different at each flow rate. Maximum voltage averaged at 9.3 kV. In this research it was found that the length of the plasma jet is directly proportional to the flow rate of argon gas. The length of the plasma jet at a flow rate of Ar 2L/ is between 4-5 cm, 6 L/minute is 5-6 cm, 10 L/minute is 6-7 cm. A graph of the average plasma jet length as a function of Ar flow rate can be seen in Figure 3, and a photo of the plasma jet length can be seen in Figure 4.

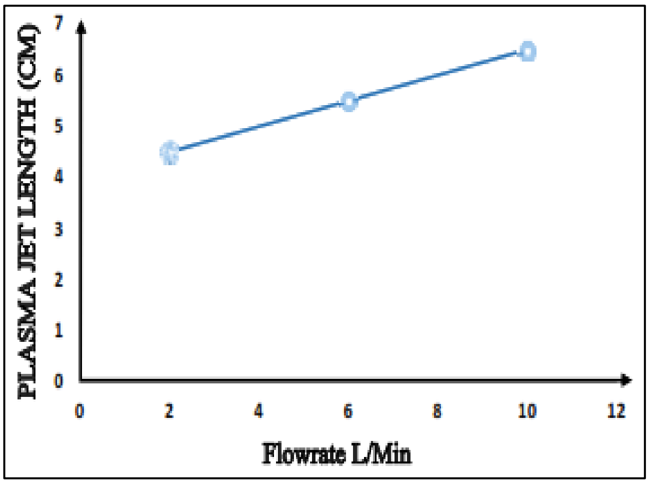

Fig 3: The Length of the Plasma Jet Produced is Influenced by the Flow Rate

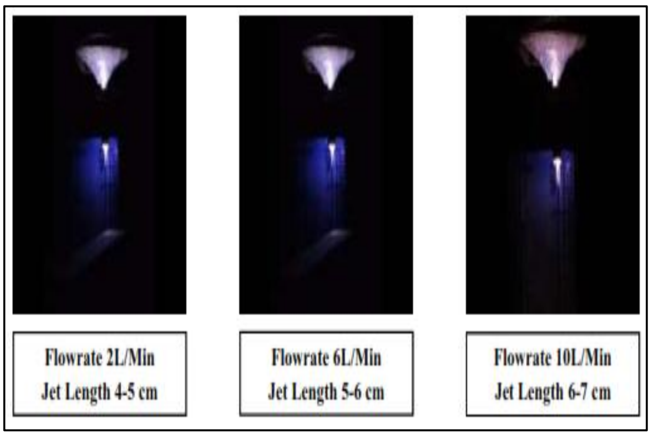

Fig 4: Photographs of the Plasma Jet for Several Flowrates

B. Disolved Ozone in the Aquades as PAM

Figure 5 shows the dissolved ozone concentration in distilled water as a function of time. Dissolved ozone was obtained from a plasma jet with an argon gas flowrate of 2L/min, and distilled water treatment was carried out at a distance of 5 cm and 10 cm from the tip of the plasma jet to the liquid surface. In 20 seconds of treatment it had reached 0.04 mg/L for the distance between the jet tip and the distilled water surface of 5 cm and 0.05 mg/L at a distance of 10 cm.

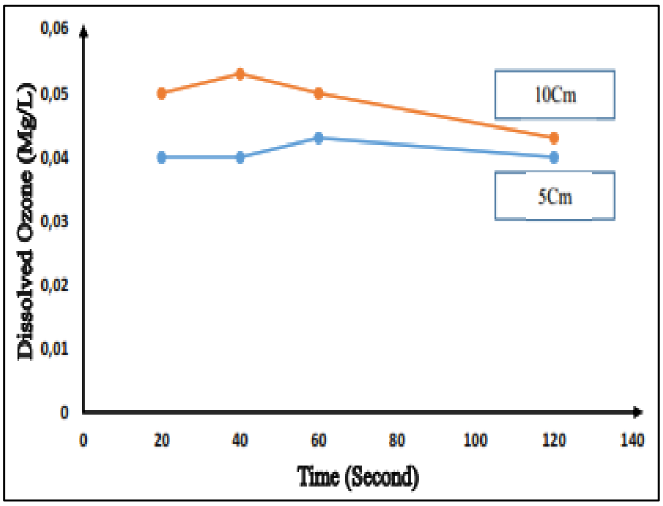

Fig 5: Dissolved Ozone in Distilled Water as a Function of Time at the Distance from the Jet Tip to the Distilled Water Surface with a Distance of 5 cm and 10 cm and a Flow Rate of 2 L/min

As in figure 5, figure 6 below shows dissolved ozone in distilled water as PAM at a flow rate of argon of 6 L/min as a function of treatment time at the distance of the plasma jet tip to the liquid surface of 5 cm and 10 cm.

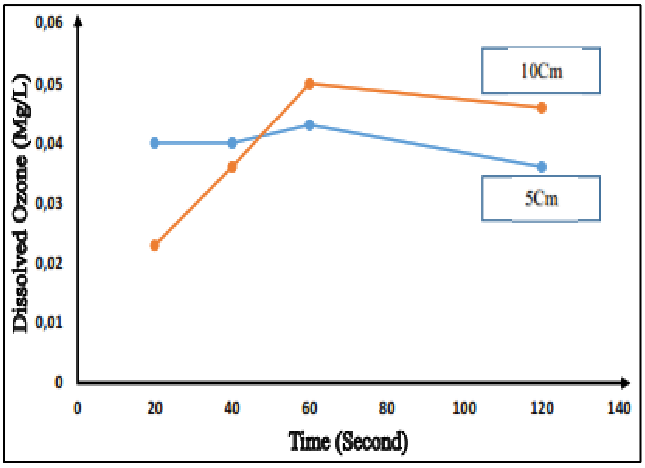

Fig 6: Dissolved Ozone in Distilled Water as a Function of Time at the Distance from the Jet Tip to the Distilled Water Surface with a Distance of 5 cm and 10 cm and a Flow Rate of 6 L/min

For argon gas with a flow rate of 10 L/min, the PAM graph through ozone dissolution in aguades can be seen in Figure 7.

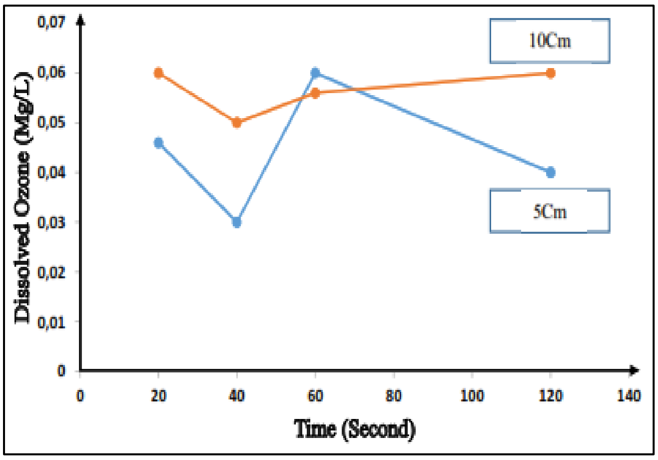

Fig 7: Dissolved Ozone in Distilled Water as a Function of Time at the Distance from the Jet Tip to the Distilled Water Surface with a Distance of 5 cm and 10 cm and a Flow Rate of 10 L/min

C. Argon Jet Plasma Emission Spectrum

Detection of the emission spectrum from the argon plasma jet is available for all argon flowrates used. Argon plasma jet emission spectrum detected for three flow rates is shown in table 1.

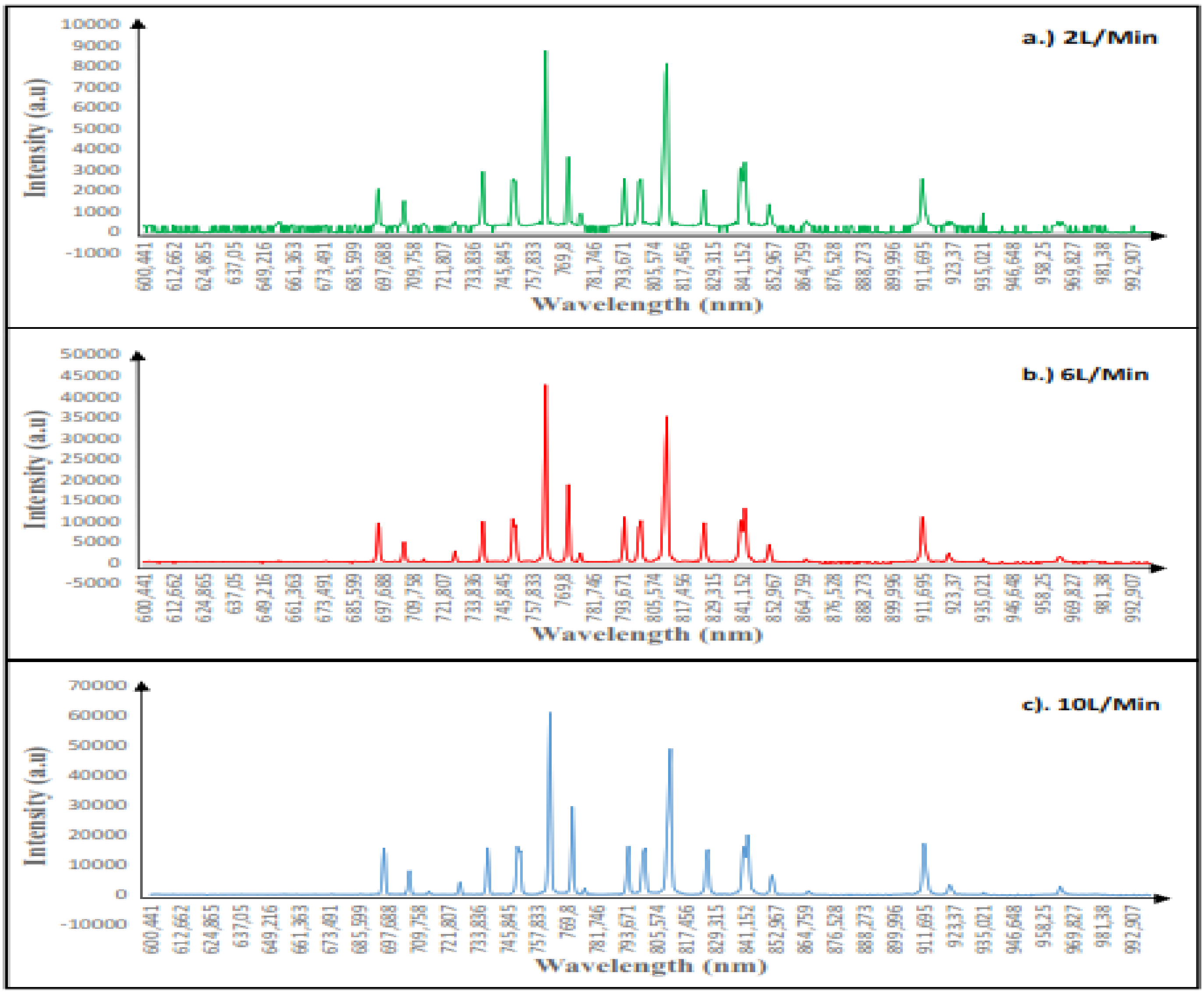

Fig 8: Argon Plasma Jet Emission Spectrum for a.) Flowrate 2 L/min, b.) Flowrate 6 L/min, c.) Flowrate 10 L/min

The results of spectrum detection using OES for flowrates of 2 L/min (green), 6 L/min (red), and 10L/min (gray) can be seen in the graph in Figure 8.

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Table 1: Argon Plasma Jet Emission Spectrum Detected for Three Flow Rates

Observed Argon Enission (nm)	E_k (cm^{-1})	gk	Akl (10^8 s^{-1})	fkl	Denomination of Paschen Transition
695,5	107496	3	0,0670	0,0292	$1_{s3}-2_{p2}$
706,7	107290	5	0,0395	0,0296	$1_{s3}-2_{p3}$
738,3	107290	5	0,0087	0,0714	$1_{s4}-2_{p3}$
747,1	107132	3	0,00025	0,00021	$1_{s4}-2_{p4}$
750,4	108723	1	0,472	0,399	$1_{s2}-2_{p1}$
763,5	106238	5	0,274	0,239	$1_{s3}-2_{p6}$
772,4	106087	3	0,057	0,051	$1_{s3}-2_{p7}$
794,8	107132	3	0,196	0,187	$1_{s3}-2_{p1}$
800,6	106230	5	0,0468	0,045	$1_{s4}-2_{p6}$
801,5	105617	5	0,096	0,092	$1_{s3}-2_{p8}$
811,5	105466	7	0,366	0,3643	$1_{s3}-2_{p9}$
826,5	107496	3	0,168	0,172	$1_{s2}-2_{p2}$
842,5	105617	5	0,233	0,2478	$1_{s4}-2_{p8}$
852,1	106037	3	0,147	0,160	$1_{s2}-2_{p4}$
912,3	104102	3	0,212	0,265	$1_{s3}-2_{p10}$
922,4	106138	5	0,059	0,075	$1_{s2}-2_{p6}$
965,8	104102	3	0,06	0,084	$1_{s4}-2_{p10}$

D. ROS as PAM as a Wound Healing Agent

PAM, in this case ozone dissolved in distilled water, can play a role in stimulating growth factors and the body's antioxidant expression so that the wound healing process can be accelerated. PAM containing ROS also acts as an anti-bacterial which significantly controls the number of bacterial colonies. The wound healing process is a complex process consisting of 3 phases, namely:

- Inflammatory Phase: There is early inflammation (hemostasis phase), and late inflammation which is located from day 0 to day 5 after injury.
- Proliferation Phase: There are 3 main processes, namely: Neoangiogenesis. Fibrolast formation and re-epithelialization occurred from day 3 to day 21 after injury.
- Maturation Phase: Starting on the 21st day until 1 year after injury, aims to maximize the strength and structural integrity of the new wound filling tissue, epithelial growth and scar tissue formation. The wound healing phase is shown in Figure 9. From this figure it can be explained that PAM is a medium that influences healing [17]. PAM is produced by exposing the tip of a plasma jet a certain distance to a liquid medium. Exposure of plasma jets to liquid media has produced Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) in the liquid phase [16]. In wound healing, only ROS are the main agents. PAM, in this case ROS dissolved in distilled water, can play a role in stimulating growth factors and the body's antioxidant expression so that the wound healing process can be accelerated. PAM containing ROS also acts as an antibacterial which significantly controls the number of bacterial colonies. The addition of ozone to therapy also provides a pleasant sensation and reduces treatment pain [8] in adjuvant ozone bagging therapy [8]. The results of this research will give hope for the potential of the wound healing process using fluid that has been given Plasma Jet. The wound healing process is a complex process consisting of 3 phases, namely:

- Inflammatory Phase: There is early inflammation (hemostasis phase), and late inflammation which is located from day 0 to day 5 after injury.
- Proliferation Phase: There are 3 main processes, namely: Neoangiogenesis. Fibrolast formation and re-epithelialization occurred from day 3 to day 21 after injury.
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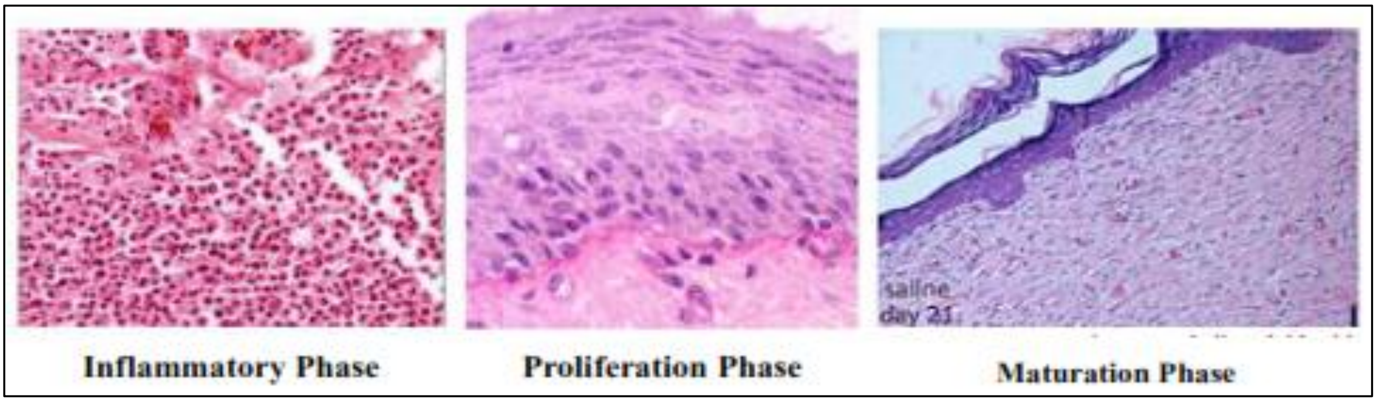

Fig 9: Photos of the Wound Healing Phase [15]

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IV. CONCLUSIONS

Based on the results of the research that has been carried out, several conclusions are obtained as follows:

The concentration of dissolved ozone compounds at a distance of 5 cm and 10 cm was obtained at the largest flowrate, namely 10 L/min, the highest ozone concentration was obtained, namely 0.06 mg/L, so it has the potential to be used in wound healing

The length of the plasma jet is directly proportional to the flow rate, the higher the flow rate given, the longer the plasma jet that comes out of the plasma reactor tube.

The highest spectrum peak is 763 at flow rates of 2 L/min, 6 L/min, 10 L/min. This is in accordance with the wavelength spectrum of Argon gas (600 nm-1,000 nm)

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