ANALYSIS OF PH ON PLASMA ACTIVATED MEDIUM IN AQUEOUS SOLUTION IN COLD ATMOSPHERIC PRESSURE PLASMA JETS

Andi Wibowo Kinandana*
Magister of Physics, Faculty of Science and Mathematics, Diponegoro University, Indonesia
andikinandana@st.fisika.undip.ac.id
Muhammad Nur
Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Indonesia
m.nur@undip.ac.id
Sumariyah
Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Indonesia
sumariyah@undip.ac.id

Manuscript History
Number: **IJIRAE/RS/Vol.05/Issue01/JAAE10087**
DOI: 10.26562/IJIRAE.2018.JAAE10087
Received: 07, December 2017
Final Correction: 27, December 2017
Final Accepted: 21, January 2018
Published: **January 2018**
Citation: Kinandana, Nur & Sumariyah (2018). ANALYSIS OF PH ON PLASMA ACTIVATED MEDIUM IN AQUEOUS SOLUTION IN COLD ATMOSPHERIC PRESSURE PLASMA JETS. IJIRAE::International Journal of Innovative Research in Advanced Engineering, Volume V, 22-25. **doi: 10.26562/IJIRAE.2018.JAAE10087**
Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India
Copyright: **©2018 This is an open access article distributed under the terms of the Creative Commons Attribution License, Which Permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited**

Abstract— Cold Atmospheric Pressure Plasma Jets (CAPPJs) was generated by using column dielectric barrier discharge has been investigated. In this study, we evaluated the ability of plasma jet to decrease the pH in aqueous solutions. Plasma jet was generated by a sinusoidal AC high voltage at 12 kV and at frequency 26 kHz. Plasma activated medium (PAM) was produced by exposing aquadest water to the CAPPJs. The duration of exposing plasma jet was set at 5 minutes to 35 minutes, with an interval of 5 minutes. Plasma exposures were performed at the distance at 2 cm between plasma jet tube output and the upper surface of the liquid medium. On the results obtained in this experiment, the pH values at 2.7 in plasma-activated medium with exposure of plasma jet. We found that the pH of PAM decrease by a duration of exposure plasma jet. Cold Atmospheric Pressure Plasma Jets can significantly decrease the pH in aqueous solutions.

Keywords— CAPPJs; Plasma Jet; PAM; Ph; aqueous solutions;

I. INTRODUCTION

Development of Cold Atmospheric Pressure Plasma Jets (CAPPJs) is a new innovation in the field of plasma medicine several years. CAPPJs can be applied to wound healing [1], [2], sterilization [3], coagulation, dental treatment, and also for the inactivation of various cancer cells [4] such as breast cancer [5], head and neck [6], brain [7], skin [8], ovaries [9], lung [10], prostate [11], and colorectal tissue [12]. It has been proven that plasma species can inactivate cancer cells either directly interactions of gaseous species with cells or indirectly by using plasma activated media (PAM) [13].

PAM has many advantages including allowing selective treatment of cancerous organ tissues that are difficult to reach by gaseous species and require endoscopy or catheters, resulting in minimal toxicity for normal tissue, and can survive some days after activation if stored at appropriate temperatures. PAM consists of several reactive species that can be classified into Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) or can be referred to as Reactive Oxygen and Nitrogen Species (RONS) [13].

Many studies of plasma-based sterilization have been performed by utilizing RONS in the inactivation of microorganisms on the surface of the material in dry conditions, where plasma is directly applied. Under such conditions, microorganisms are often physically destroyed by impinging energetic ions and/or electrons or their DNAs are severely damaged by UV from the plasmas. RONS and other free radicals in the gas phase have been also reported to directly damage the microorganisms. For many practical applications, however, sterilization under wet conditions is also important. When bacteria are immersed in a liquid or imbedded in a gel-like material with sufficient water content, neither ions nor electrons can interact directly with the bacteria as they are strongly absorbed by a liquid when applied through the gas to the liquid surface [3], [14]. Nevertheless, as we shall show in this paper, exposure of the Cold Atmospheric Pressure Plasma Jets to a plasma activated media can also reduce pH in the liquid.

In this study, on plasma sterilization in aqueous environments, similar to biological systems, under controlled pH conditions indicated strong practical sterilization effects with plasma irradiation under low pH conditions. The Plasma generating reactive species exerted strong sterilization effects on at pH 4.7 or less (reduced-pH method).

II. METHOD

This research was conducted by Analysis of pH on Plasma Activated Medium in Aqueous Solution in Cold Atmospheric Pressure Plasma Jets. This Cold Atmospheric Pressure Plasma Jets (CAPPJs) was generated by AC high voltage. The cold atmospheric pressure plasma jets system that we used here is similar to the device developed by Nur et al [15]. A sinusoidal voltage at 12 kV and at frequency 26 kHz is applied for the excitation and sustaining of the discharges. Argon plasma jet was generated by using the capillary column as plasma jet tube. AC high voltage source connected to an electrode and HV probe. The capillary column made of quartz glass with an inner diameter of 1.6 mm and an outer diameter of 3 mm with a length of 100 mm. At the center of the length capillary column, we added a Teflon cylinder with a diameter of 2.5 mm and a length of 2 mm. The Teflon cylinder serves as a dielectric barrier (dielectric barrier discharge) to separate the two electrodes. The electrodes used in this study is made of a thin layer of aluminium (aluminium foil) encircling the quartz capillary column. The top electrode length of 20 mm and 30 mm of the lower electrode, the distance between the electrodes of 10 mm and the spacing between lower electrode to the tip of the capillary column is 5 mm. Argon gas (purity of 99.999 %, Samator Gas products) was supplied at a flow rate 2 L/minutes into the capillary column.

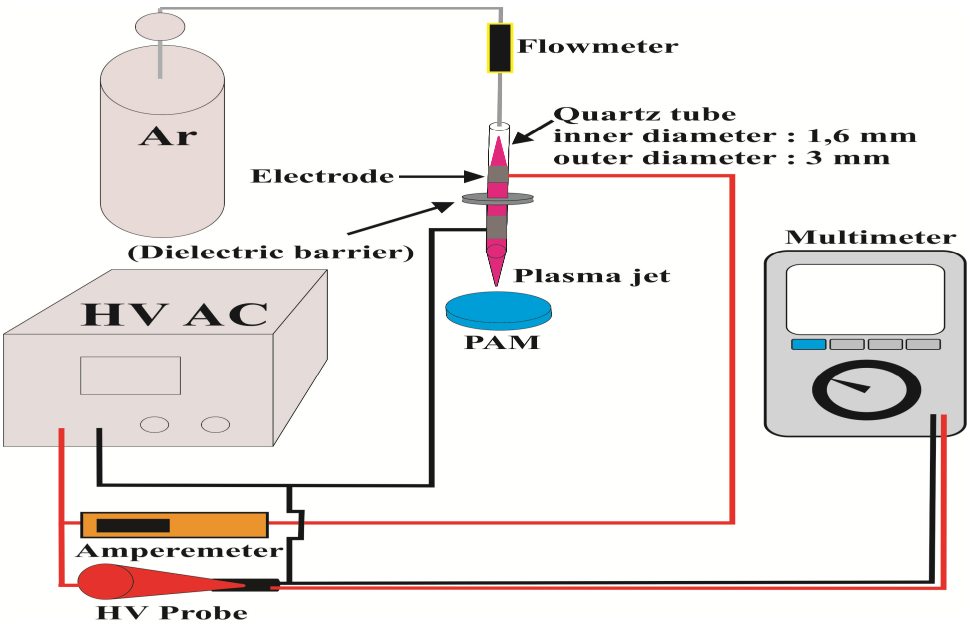

Fig. 1 Schematic of research equipment set-up

IJIRAE © 2014- 18, All Rights Reserved

Plasma activated medium (PAM) was produced by exposing 25 mL of aquadest water to the CAPPJs. The duration of exposing plasma jet was set at 5 minutes to 35 minutes, with an interval of 5 minutes. Plasma exposures were performed under the same experimental conditions (applied voltage, frequency, and gas flow) and at the distance at 2 cm between plasma jet tube output and the upper surface of the PAM.

III. RESULT AND DISCUSSION

In this study, the pH characteristics of plasma activated medium resulted from exposure of plasma jet to aquadest water with an exposure time of 5 to 35 minutes at intervals of 5 minutes with a distance at 2 cm from the jet plasma reactor. This treatment to determine the level of acidity in PAM after treatment using plasma jets. Based on the results obtained pH on PAM can be seen in the graph shown in Figure 2. The pH without plasma jet treatment (0 minutes) showed at 7.2. The samples without plasma treatment were used as control samples. The pH in PAM with plasma jet treatment with for 5, 10, 15, 20, 25, 30 minutes at pH 5.7, 4.3, 3.8, 3.7, 3.6, 3.5 respectively. In the subsequent treatment, the pH of PAM decreased to 2.7 with plasma jet treatment for 35 minutes.

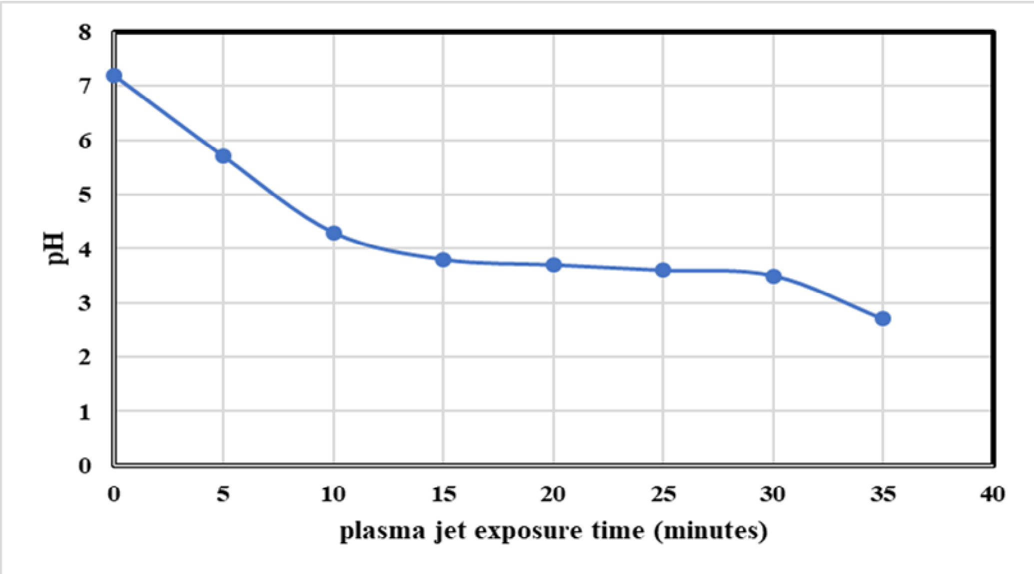

Fig. 2 Graph of pH as functions of plasma jet exposure time

One of the most important chemical effects present in plasma is acidification. Plasma exposure to the solution can significantly decrease the pH [3]. A critical pH for bactericidal effects, which is approximately 4.7. Below the critical pH, bacterial inactivation occurs by the plasma jet application to the solution surface whereas, above the critical pH, bacteria remain intact even with the same plasma application [14]. This acidification of water is important in bacterial killer processes [16]. Based on the results obtained in this experiment the pH at 2.7 in the sample with exposure of plasma jet. This condition indicates that the sample may turn into acid. Furthermore, many researchers also speculated that acidity and reactive species are interconnected in PAM. Lower pH is more favorable for the reactive species to penetrate cell walls. On the other hand, the presence of reactive species reduces the resistance of bacteria to acidic environment [17]. It can be analogized that this process can kill the bacteria that exist in the sample.

IV. CONCLUSIONS

In conclusion, it has been found that Cold Atmospheric Pressure Plasma Jets can significantly decrease the pH in aqueous solutions. Exposure of plasma jet in plasma-activated medium can decrease pH to 2.7 in 35 minutes. This shows that PAM in acidic conditions. So, the treatment by using plasma jet can be used for killing bacteria and sterilization.

ACKNOWLEDGMENT

Andi Wibowo Kinandana would like to acknowledge to Center for Plasma Research, Diponegoro University Indonesia who have supported them all of the facilities for this research.

IJIRAE © 2014- 18, All Rights Reserved

REFERENCES

1. Nasruddin, Y. Nakajima, K. Mukai, H. S. E. Rahayu, M. Nur, T. Ishijima, H. Enomoto, Y. Uesugi, J. Sugama, and T. Nakatani, "Cold plasma on full-thickness cutaneous wound accelerates healing through promoting inflammation, re-epithelialization and wound contraction," *Clin. Plasma Med.*, vol. 2, no. 1, pp. 28–35, 2014.
2. Nasruddin, Y. Nakajima, K. Mukai, E. Komatsu, H. S. E. Rahayu, M. Nur, T. Ishijima, H. Enomoto, Y. Uesugi, J. Sugama, and T. Nakatani, "A Simple Technique to Improve Contractile Effect of Cold Plasma Jet on Acute Mouse Wound by Dropping Water," *Plasma Process. Polym.*, vol. 12, no. 10, pp. 1128–1138, 2015.
3. U. Emi, O. Tomoko, Y. Hiromitsu, I. Satoshi, K. Katsuhisa, M. Nobuko, and M. Yasuko, "Plasma Sterilization of Caries-infected Dentin Model with Reduced-pH Method," *Jpn. J. Conserv. Dent.*, vol. 58, no. 2, pp. 101–108, 2015.
4. M. Keidar, D. Yan, I. I. Beilis, B. Trink, and J. H. Sherman, "Plasmas for Treating Cancer: Opportunities for Adaptive and Self-Adaptive Approaches," *Trends Biotechnol.*, vol. xx, pp. 1–8, 2017.
5. M. Wang, B. Holmes, X. Cheng, W. Zhu, M. Keidar, and L. G. Zhang, "Cold Atmospheric Plasma for Selectively Ablating Metastatic Breast Cancer Cells," *PLoS One*, vol. 8, no. 9, p. e73741, 2013.
6. J. W. Chang, S. U. Kang, Y. S. Shin, K. Il Kim, S. J. Seo, S. S. Yang, J. S. Lee, E. Moon, S. J. Baek, K. Lee, and C. H. Kim, "Non-thermal atmospheric pressure plasma induces apoptosis in oral cavity squamous cell carcinoma: Involvement of DNA-damage-triggering sub-G1 arrest via the ATM/p53 pathway," *Arch. Biochem. Biophys.*, vol. 545, pp. 133–140, 2014.
7. H. Tanaka, M. Mizuno, K. Ishikawa, K. Nakamura, F. Utsumi, H. Kajiyama, H. Kano, S. Maruyama, F. Kikkawa, and M. Hori, "Cell survival and proliferation signaling pathways are downregulated by plasma-activated medium in glioblastoma brain tumor cells," *Plasma Med.*, vol. 2, no. 4, pp. 207–220, 2012.
8. I. Yajima, M. Iida, M. Y. Kumasaka, Y. Omata, N. Ohgami, J. Chang, S. Ichihara, M. Hori, and M. Kato, "Non-equilibrium atmospheric pressure plasmas modulate cell cycle-related gene expressions in melanocytic tumors of RET-transgenic mice," *Exp. Dermatol.*, vol. 23, no. 6, pp. 424–425, 2014.
9. F. Utsumi, H. Kajiyama, K. Nakamura, H. Tanaka, M. Hori, and F. Kikkawa, "Selective cytotoxicity of indirect nonequilibrium atmospheric pressure plasma against ovarian clear-cell carcinoma," *Springerplus*, vol. 3, no. 1, p. 398, 2014.
10. J. Huang, W. Chen, H. Li, X.-Q. Wang, G.-H. Lv, M. L. Khohsa, M. Guo, K.-C. Feng, P.-Y. Wang, and S.-Z. Yang, "Deactivation of A549 cancer cells in vitro by a dielectric barrier discharge plasma needle," *J. Appl. Phys.*, vol. 109, no. 5, p. 53305, 2011.
11. A. M. Hirst, M. S. Simms, V. M. Mann, N. J. Maitland, D. O'Connell, and F. M. Frame, "Low-temperature plasma treatment induces DNA damage leading to necrotic cell death in primary prostate epithelial cells," *Br. J. Cancer*, vol. 112, no. 9, pp. 1536–1545, 2015.
12. M. Ishaq, M. D. M. Evans, and K. K. Ostrikov, "Atmospheric pressure gas plasma-induced colorectal cancer cell death is mediated by Nox2-ASK1 apoptosis pathways and oxidative stress is mitigated by Srx-Nrf2 anti-oxidant system," *Biochim. Biophys. Acta - Mol. Cell Res.*, vol. 1843, no. 12, pp. 2827–2837, 2014.
13. J. Chauvin, F. Judée, M. Yousfi, P. Vicendo, and N. Merbahi, "Analysis of reactive oxygen and nitrogen species generated in three liquid media by low temperature helium plasma jet," *Sci. Rep.*, vol. 7, no. 1, p. 4562, 2017.
14. S. Ikawa, K. Kitano, and S. Hamaguchi, "Effects of pH on bacterial inactivation in aqueous solutions due to low-temperature atmospheric pressure plasma application," *Plasma Process. Polym.*, vol. 7, no. 1, pp. 33–42, 2010.
15. M. Nur, A. W. Kinandana, P. Winarto, Z. Muhlisin, and Nasrudin, "Study of an Atmospheric Pressure Plasma Jet of Argon Generated by Column Dielectric Barrier Discharge," *J. Phys. Conf. Ser.*, vol. 776, p. 12102, 2016.
16. K. Oehmigen, M. Hähnel, R. Brandenburg, C. Wilke, K. D. Weltmann, and T. Von Woedtke, "The role of acidification for antimicrobial activity of atmospheric pressure plasma in liquids," *Plasma Process. Polym.*, vol. 7, no. 3–4, pp. 250–257, 2010.
17. R. Ma, G. Wang, Y. Tian, K. Wang, J. Zhang, and J. Fang, "Non-thermal plasma-activated water inactivation of food-borne pathogen on fresh produce," *J. Hazard. Mater.*, vol. 300, pp. 643–651, 2015.

IJIRAE © 2014- 18, All Rights Reserved