Publ. Astron. Obs. Belgrade No. 103 (2024), 148 - 151 *Poster*
https://doi.org/10.69646/aob103p148

MEASUREMENTS OF REACTIVE OXYGEN AND NITROGEN SPECIES IN PLASMA ACTIVATED WATER BY MICROWAVE DISCHARGE

DESANKA TOPALOVIĆ, NEDA BABUCIĆ, NIKOLA ŠKORO and NEVENA PUAČ

Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia
E-mail desketop00@gmail.com

Abstract. This study focuses on plasma activated water (PAW), which contains reactive oxygen and nitrogen species (RONS). We compared RONS concentrations in PAW produced by two microwave (MW) plasma sources - a homemade S-wave source and a commercial Sairem S-wave source. The homemade source generated higher and more consistent RONS concentrations over time. Both sources are effective, with the choice depending on whether higher reactive species concentrations are needed.

1. INTRODUCTION

Over the past 20 years, non – equilibrium cold atmospheric plasmas (CAPs) have been applied in medicine for treating medical equipment, cancer cells and dental issues. They have also been used in biology, agriculture, water treatment, and food decontamination (Puač et al. 2018). Treatments can be done directly where CAP is in contact with treated sample or indirectly by using PAW. In direct treatment both short-living and long-living RONS play a significant role in triggering desired mechanisms. When it comes to indirect treatment by PAW only long-living RONS are in contact with treated samples (Bradu et al. 2020). For both direct and indirect types of treatments, various CAP sources are used. They differ in electrode geometry, type and frequency of power/voltage supply, type working gas and gas flow etc. One of the CAPs that are not that often used, especially when it comes to direct plasma treatment of samples, are microwave plasma sources. On the other hand, due to its intense nature and high electron density resulting in increased production and concentration of reactive species, it can be used for production of lager volumes of PAW.
In this study, the concentrations of RONS were measured and their variations over time (days after the treatment) were monitored. Additionally, differences between

two microwave sources (a homemade S-wave source and a commercial Sairem S-wave source) were investigated, and the results are presented below.

2. EXPERIMENTAL SETUP

Water treatments were conducted by using two different microwave plasma sources - inductively coupled (IC) commercial Sairem S–wave source and capacitavely coupled (CC) homemade S–wave source (see Figure 1.). Argon was used as working gas, while the synthetic air was used for cooling of the system. Both gases are controlled by gas flow regulators. Sairem Solid state generator, with an adjustable output power range of 0 – 200 W, serves as a microwave power source. The coaxial cable transmits the microwave power from the generator to plasma sources (in Figure 1. 7a and 7b) very efficiently. To prevent overheating, both sources are cooled by water and air flow. The plasma jet is formed inside the quartz tube and, depending on the operating parameters, can extend outside it. During the treatments plasma plume was in contact with treated water and water was mixed homogeneously by using a magnetic stirrer to ensure even deposition of reactive species from the plasma. Treatments were performed with a power of 40 W for an argon flow of 2 slm, and 50 W for an argon flow of 1 slm and 7 slm. Treatments of 32 ml of deionized water containing 25 mg of ZnO were performed by using (a) Homemade S-Wave source and (b) Sairem S – Wave source. Zinc oxide powder was added to water samples before plasma treatments to keep the pH value of treated water in the range of 5. Treatment time was 10 min and the distance between quartz tube and water surface was 9 mm.

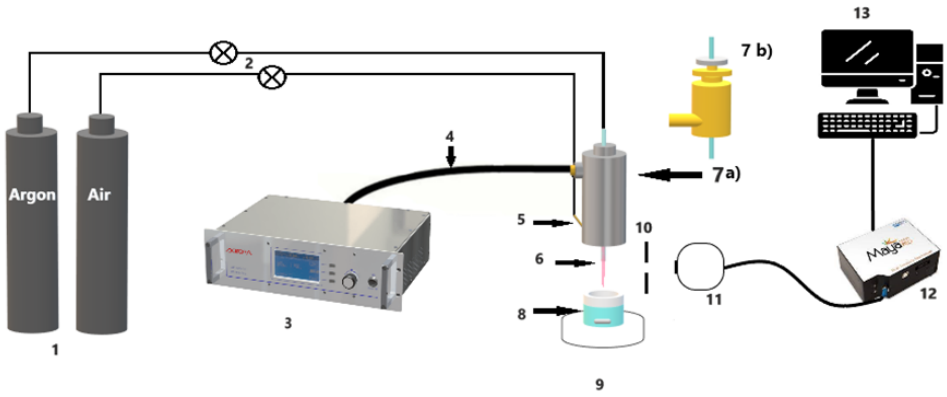

Figure 1. Experimental set up for plasma treatment: 1. Bottles with argon and air; 2. Gas flow regulators; 3. Sairem MW200 generator (0 – 200 W); 4. Coaxial cable; 5. Cooling inlets (air and water); 6. Plasma torch; 7. a) (IC) Sairem S–Wave microwave source, b) (CC) Homemade S–Wave microwave source; 8. Treated liquid; 9. Magnetic stirrer; 10. Holder for optical fiber with a slit of 0.5 mm; 11. Fiber – optic cable.

After the treatment and formation of reactive species in the water, their presence and concentration were determined by using spectrophotometry. Based on monitoring of the dependence of absorbance as a function of the wavelength of the radiation that passed through the analyzed substance, the absorption coefficients were read for all three compounds, at the appropriate wavelengths of 525 nm for nitrites, 357 nm for nitrates and 407 nm for hydrogen peroxide. After the treatment, the stability of reactive species was monitored for a certain period, starting from the day of treatment, by measuring concentration nitrites, nitrates and peroxides. Samples were stored in the refrigerator in the meantime.

3. RESULTS AND DISCUSSION

In Figure 2. we present the time dependence of RONS concentrations in the days after the plasma treatments. Although various combinations of generator power and working gas flow have been tested, the graph shows RONS concentration values for the argon flow of 1 slm and applied power of 50 W. We can see that the concentration of H_2O_2 in treated water obtained by home-made S-Wave is higher than with the commercial Sairem S-Wave. The nitrates and nitrites concentrations are quite similar for both devices. For both devices the concentrations stay almost constant in the days after the treatments.

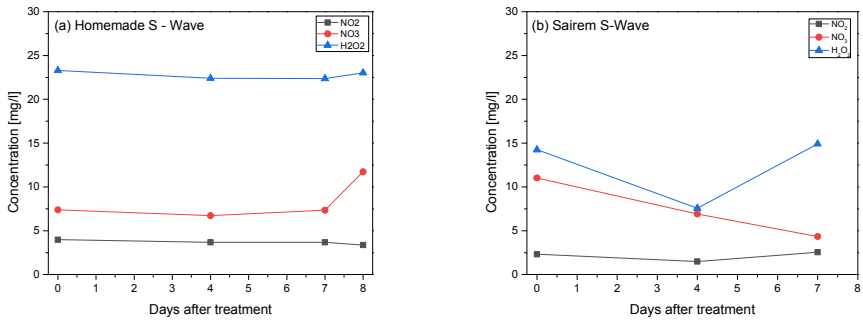

Figure 2: Stability of concentrations of long-living RONS deposited in PAW measured days after the treatment. Treatments of 32 ml of deionized water containing 25 mg of ZnO were performed by using (a) Homemade S-Wave source and (b) Sairem S – Wave source. Treatment time was 10 min; power was 50 W and argon flow was 1 slm; the distance between quartz tube and water surface was 9 mm.

4. CONCLUSION

We treated deionized water samples with different power values of Solid state generator and argon flows. When the treatment was done with homemade S – Wave microwave source, increasing the flow of argon had a greater influence on concentration change than increasing power of Solid state generator. In other hand, while using commercial Sairem S – Wave microwave source, increasing power and flow did not affect concentration of reaction species that much. They were smaller than concentration with homemade S – Wave microwave source. The addition of ZnO kept the pH in the range that does not allow destruction of NO_2^- and creation of NO_3^-.

Acknowledgements: This research was supported by the Science Fund of the Republic of Serbia, 7739780, APPerTAin-BIOM project and MSTDI- 451-03-66/2024-03/200024.

References

1. N Puač, M Gherardi, M Shiratani , (2018) Plasma agriculture: A rapidly emerging field, Plasma processes and polymers **15** (2), 1700174
2. Bradu, C., Kutasi, K., Magureanu, M., Puac, N., & Živković, S. (2020). *Reactive nitrogen species in plasma-activated water: generation, chemistry and application in agriculture. Journal of Physics D: Applied Physics*