Characterization of Microwave Surface-Wave Launchers operating at Atmospheric pressure for Water Treatment

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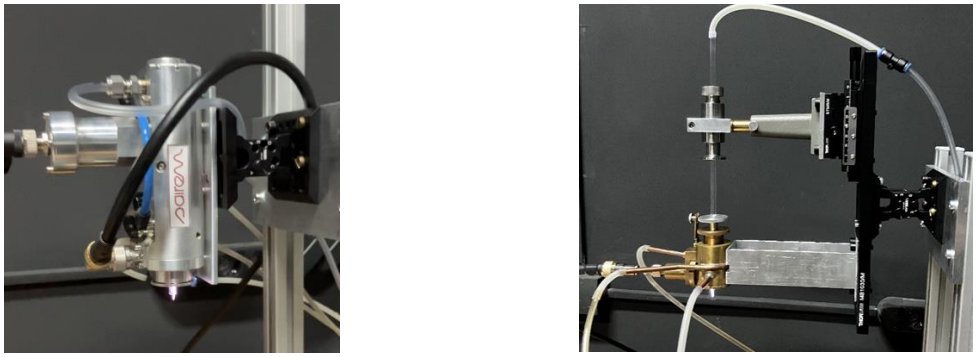
In recent years, spanning over large ranges of electron densities and temperatures, atmospheric pressure non-equilibrium plasmas have gained renewed interest for their ability to treat liquids and heat-sensitive materials, opening new applications in medicine, disinfection, water treatment, nanoparticle synthesis, food processing, and agriculture [1]. In this work we present results obtained by microwave (MW) discharge, chosen due to its electrodeless nature that prevents liquid contamination with nanoparticles during treatments resulting from electrode sputtering, as observed in some instances [2]. MW discharge was used for production of plasma-activated water (PAW). Interest in PAW has surged for its wide applications in biological sciences, agriculture, and the food industry. PAW's effects result from reactive oxygen and nitrogen species (RONS) generated in the liquid due to the plasma exposure and their concentration depends on the discharge parameters. RONS involvement correlates with diverse plant signaling pathways, governing metabolic processes, plant development, and stress responses [3]. This interaction can enhance germination rates, accelerate processes, and improve plant growth. Additionally, microwave-generated plasma serves as an efficient source, delivering higher RONS concentrations while treating bigger water volumes compared to other plasma sources, potentially amplifying its efficacy.



(a) (b)

Fig. 1: (a) Sairem S-Wave Launcher; (b) Home-made S-Wave Launcher

In the work presented here we have compared two different MW plasma sources, inductive Sairem S-Wave Launcher and capacitive home-made S-Wave Launcher, both powered by a Sairem GMS200W generator (see Fig. 1). One of the aims of research was the study of differences between devices in relation to the type of coupling. Tested powers were in range from 25 W to 60 W with argon as working gas (from 1 slm to 7 slm). We have used an O.D.=6/I.D.=4 mm quartz tube placed inside the launchers. By using Optical Emission Spectroscopy, the plasma emission inside and outside the tube was recorded. Due to their importance in the formation of reactive species, the lines of OH, N_2 and O were additionally analyzed. Fig. 2 shows examples of spectra for both investigated MW devices. The emission of the OH band is higher in the case of the inductive Sairem S-Wave Launcher (see Fig. 2(a)), indicating higher dissociation of water molecules from water vapor present as humidity. In the case of capacitive home-made S-Wave Launcher (see Fig. 2(b)) , the N_2 lines are more evident. With increasing power and gas flow, it is observed that plasma emission from the inductive Sairem S-Wave is higher with significantly increased temperature of plasma and

surrounding gas. In case of capacitively coupled S-Wave by changing the parameters, especially the gas flow, it was possible to obtain plasma at room temperatures.

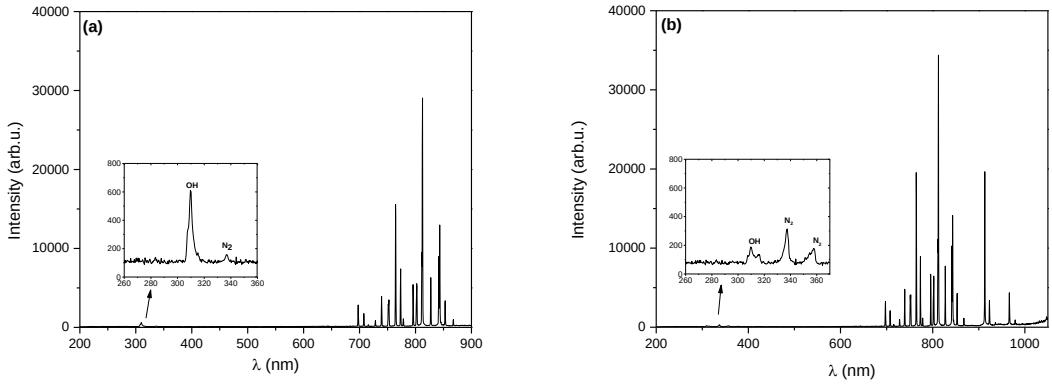


Fig. 2: Emission spectra of (a) inductive Sairem S-Wave Launcher; (b) capacitive home-made S-Wave Launcher, outside the quartz tube. Parameters: Ar flow of 2 slm, power of 28 W. Distance from the quartz tube was 3 mm.

By analyzing the spectra obtained using different lengths of quartz tubes through which the plasma is extended, and different distances from the end of the tubes, we came to the conclusion what combinations of parameters would give the highest concentrations of OH and N_2 lines, responsible for chemical reactions in the process of bacterial decontamination. Since the device creates colder plasma, the treatment of water was performed by using home-made S-Wave Launcher for 10 min, with a generator power of 50 W and an argon flow of 1 slm (scan the QR code). The value of the water temperature measured immediately after the treatment was 42,2°C. The water sample contained 32 ml of deionized water with 50 mg of zinc oxide powder added to water for the purpose of preventing the decomposition of RONS and preserving the pH value (pH=5), according to work [2]. The graph in Fig 3. shows the concentrations of nitrates, nitrites and hydrogen peroxide measured via calorimetric methods, immediately after treatment, as well as days after.

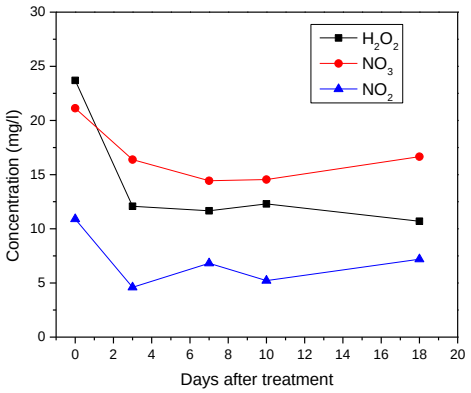


Fig. 3: Concentrations of NO_2, NO_3 and H_2O_2 measured in different days after the treatment.

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