Plasma activated water – stability and antimicrobial effect

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The interface region between plasma and water based liquids offers the perfect conditions for active chemical species like hydrogen peroxide, hydroxyl radical, nitrites and nitrates to be generated. The so formed molecules further diffuse in the treated samples, changing their physical and chemical properties. The current work records the changes induced by a He/Ar μ-jet discharge on distilled water samples. The electrical conductivity, pH value, nitric acid concentration and hydrogen peroxide concentration are measured immediately after treatment and for time intervals up to 21 days. A good stability of the plasma activated water can be observed. Furthermore, the antimicrobial effect of the plasma activated water is proved. The effects of the discharge gas, treatment time as well as storage time are all investigated.

1. Introduction

When plasmas and liquids interact, at the interface region between the two media specific chemical processes occur, producing modifications of the physical and chemical attributes of the liquids [1]. The so activated liquids have proven to hold special properties offering them the possibility of acting as chemical agents in several biological processes [1]. The current work proposes the application of plasma activated water (PAW) in bacterial decontamination and investigates the time evolution of the PAW characteristics as well as its antimicrobial character.

2. Experimental details and results

2.1. Water activation

The water activation by plasma treatment experiments were carried out using a low temperature atmospheric pressure μ-jet setup. It consists of a powered electrode (vertical needle - 0.6 mm i.d., supplied with at a sinusoidal voltage - 1.7 kV, 10.2 MHz) through which the discharge gas (He or Ar) is flown at a 0.3 l/min rate. The distilled water samples are placed 3 mm below the needle. The discharge is formed in the space between the electrode and the surface of the liquid. The treatment time intervals are up to 50 minutes. The physical and chemical properties of the PAW samples were measured immediately after treatment and for time intervals up to 21 days. During this period the samples were stored in closed containers at room temperature.

The pH, electrical conductivity, H_2O_2 and HNO_3 concentrations change strongly with the treatment time. After 50 minutes of treatment using the helium discharge the obtained values are: 1.79 pH units, 1747 μS/cm, 0.9 mM H_2O_2 and 3.6 mM HNO_3. Also, the discharge gas plays a substantial role in determining the final properties of the PAW samples. In the case of the Ar discharge, for the 50 minutes treatment time, the resulted quantities were: 2.19 pH units, 1269 μS/cm, 1.19 mM H_2O_2 and 2.6 mM HNO_3. The analysis of the water properties with the storage time revealed that the properties of the PAW remain stable in time for at least 21 days. For samples treated for 50 minutes with the He μ-jet the measured values after 21 days are: 1.9 pH units, 1820 μS/cm, 0.8 mM H_2O_2 and 3.6 mM HNO_3.

2.2. Bacterial decontamination

The antimicrobial effect of the PAW samples was investigated using *Staphylococcus aureus* (*S.aureus*) as test microorganism. An overnight bacterial culture grown in nutrient broth media was incubated for 24 hours with PAW in 1:1 volume ratios of growth media and PAW. The growth inhibition effect of PAW was estimated by measuring the optical density of the bacterial suspension at 620 nm. Control samples of bacteria incubated with 1:1 volume ratios of nutrient broth and distilled water and samples without dilutions of the nutrient broth were used.

The effects of the water treatment time, discharge gas and storage time were investigated. The PAW shows strong antimicrobial effects. The *S.aureus* sample incubated with the 50 minutes helium discharge treated water shows an OD value of 0.09 a.u. while the water control sample shows an OD value of 0.17 a.u., results that demonstrate a significant influence of the PAW.

3. References

[1] P.J. Bruggeman *et al.*, *Plasma Sources Sci. Technol.*, **25**, 5, (2016) 53002.