Can atmospheric pressure plasma technology be an efficient reactive chemistry tool for water treatments?

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In previous years many different studies were demonstrating ability of Cold Atmospheric Plasma (CAP) treatments to produce chemical interaction with various types of liquids. During treatments short-lived Reactive Oxygen and Nitrogen (RONS) Species generated in plasma (e.g. OH, O., O_3, NO etc.) interact with liquid target in such a way that, after the treatments, long-lived RONS are deposited and preserved in the samples. In case of pure water treatment, the obtained plasma activated water (PAW) contains species such as H_2O_2, ONOOH, NO_3^-, NO_2^-) [1]. Type of the reactive species depend considerably on type of plasma source, operating parameters but also on the liquid target properties (mostly conductivity) and even on the shape and the size of the sample container. Thus, linking the plasma chemistry with the obtained RONS content is an entangled task [2] and changes in the plasma treatment system could result in unanticipated changes in properties of the liquid sample. In this work, studies related to application of CAP formed over the water samples dealing with both decontamination [3] and production of PAW will be presented. We investigated several types of CAP sources for water treatment: pin-type jet, DBD jet and MW source.

As an illustration, comparison PAW created from distilled H_2O by pin-jet and DBD jet is given Fig.1 Power delivered to the plasma was much smaller for DBD jet (approx. 10 times).

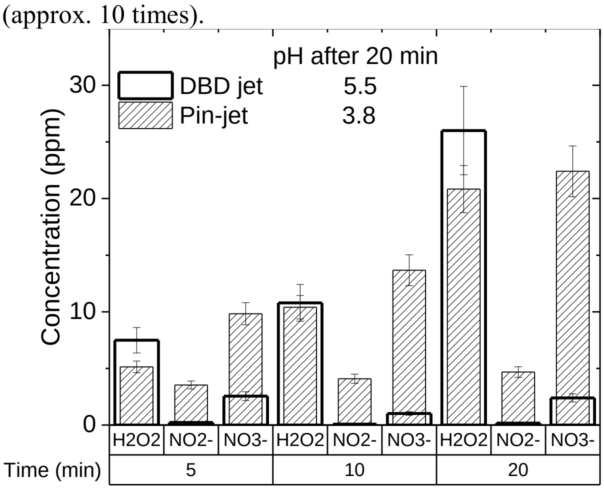

Figure 1. Measurements of RONS concentrations in PAW obtained from dH_2O for 3 treatment times. Plasma formed in air with He as working gas was used in both cases.

In both cases He (2 slm) was used as working gas producing a streamer discharge. The vessel with distilled water was placed 10 mm below the plasma source. The treated volume was 4 ml in the pin-jet case and 2 ml for DBD jet. Just from H_2O_2 concentrations it could seem that changes in the sample volumes could yield similar PAW properties obtained in different systems, but NO_x concentrations and their ratios as well as pH are completely different. So, very similar gas phase plasma chemistry eventually results in completely different PAW properties which has direct influence on further application.

That is one of the reasons why PAW produced with different systems was used in different targeted applications - treating water polluted with micro organic pollutants as well as PAW produced for plant treatment (investigation of PAW influence to aquatic plant Duckweed). We exploited the combination between results of plasma diagnostics such as electrical characterization, optical emission spectroscopy and imaging, and treated physico-chemical liquid properties in order to select important input parameters and tailor desired treatment conditions for obtaining PAW with the properties suitable for particular application. Apart from creating different RONS concentrations we also studied pH adjustment as generating PAW with less acidic conditions can be beneficiary for some applications where low pH can induce negative effects (e.g. application related to seeds and plants).

When CAP is positioned above the water surface the effective surface that is in direct contact with the discharge is generally small. In our experiments we investigated increase of contact surface by increasing the plasma area with making a 3-pin jet and also by introducing recirculation of water in the system. Focusing on establishing relations between different discharge operating regimes, produced plasma-liquid chemistry and the obtained effects in applications we obtained information important for advancing towards achieving plasma reactivity at a larger scale, which is necessary step for many water-related applications.

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