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Controlling the transport of reactive species from cold plasma into water bulk and aerosols

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Abstract:

Reactive species generated by cold atmospheric plasma of electrical discharges can be transported into liquids, particularly water, to produce a chemically active plasma-activated water (PAW). PAW represents a great potential for disinfection and wastewater treatment, especially to inactivate pathogenic microorganisms, and acts as a source of nitrogen to promote the plant growth. PAW can be prepared by a variety of plasma-liquid interacting systems. Systems where plasma interacts with liquid aerosols bring multiple advantages, exhibiting high chemical reactivity within small liquid microdroplet volumes [1].

We experimentally studied the transport of typical air plasma long-lived reactive oxygen and nitrogen species (RONS): HNO_2, NO_2, NO, H_2O_2, and O_3 into water. To better understand the transport mechanisms, RONS were generated either one by one by external sources, or in mixture by a hybrid streamer-transient spark plasma discharge, in contact with bulk water or aerosol of charged electrospray (ES) or non-charged nebulized microdroplets with a large gas/plasma-water interface. [2]

We found that NO's contribution to nitrite (NO_2^-) ion formation in PAW was negligible, NO_2 contributed to about 10%, while the dominant contributor to NO_2^- was gaseous HNO_2. A higher transport efficiency of O_3, and a much higher formation efficiency of NO_2^- from gaseous NO_2 or HNO_2 than those predicted by Henry's law was observed, compared to the transport efficiency of H_2O_2. The improvement of the transport/formation efficiencies by aerosol microdroplets, with their surface area significantly enhanced compared to the bulk water, is most evident for the the weakly soluble O_3. NO_2^- formation efficiency was strongly improved in ES microdroplets with respect to bulk water and even to nebulized microdroplets, which is likely due to charge effects enhancing the formation of aqueous NO_2^-.

This study contributes to a deeper understanding of the transport mechanism of gaseous plasma RONS into water that can optimize the design of plasma–liquid interaction systems to efficiently produce selected RONS in water.

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