wetsus
european centre of excellence
for sustainable water technology

Pharmaceutical residues and other micro-pollutants removal from water with a hyperbolic vortex gas discharge plasma

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Motivation

The accumulation of pharmaceutical residues and micro-pollutants in wastewater in the environment has become a problem of growing concern. Although some compounds are easily biodegradable, many of them are hardly decomposed and pose a health hazard for both aquatic and terrestrial life. The application of gas-phase pulsed electrical discharges [Fig 3.] (plasma technology) is a promising method for the energy efficient oxidative degradation of aqueous organic pollutants. Precursors in oxidative degradation chemistry are reactive oxygen (ROS), and reactive nitrogen species (RNS) [Fig 2.]. These species are generated by plasma operation in humid air. ROS also are produced at the gas/liquid interface by direct water bombardment with energetic electrons creating excited states and ions. Therefore, optimization of the plasma-water interface by combination a plasma with the outstanding mixing capabilities of a hyperbolic vortex is expected to strongly benefit the plasma induced oxidative degradation of aqueous priority materials, since these species are expected to be dissolved effectively by the suction and the highly efficient gas absorption properties of the aqueous hyperbolic vortex[1].

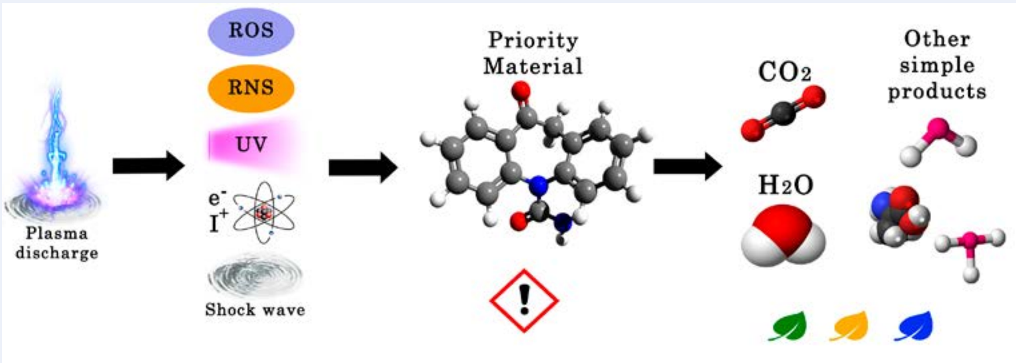

Fig 1. Diagram of the oxidative degradation of micro-pollutant molecules in the water bulk during plasma operation.

Technological challenge

On the one hand, plasma water purification includes various physical and chemical processes, many of which are independent water treatment techniques [Fig 1.] (oxidation, ultraviolet disinfection, ozonation, electrolysis, shockwave water purification etc.). The water vortex also has oxidative degradation-promoting properties by itself, increasing the amount of dissolved oxygen in the water volume as well as other gases. On the other hand, many toxic species can be created in atmospheric discharge plasma such as nitrates, nitrites, etc. Varying the parameters of the discharge, the material of the electrodes and the type of atmosphere changes the amount and type of species created during the interaction of plasma with gas and liquid surface[3] and, as a consequence their adsorption by water. To remove different micro-pollutants in the water volume, different conditions are required as well as different amounts of energy. Therefore, for each of them, it is necessary to find an optimal hyperbolic vortex plasma discharge mode.

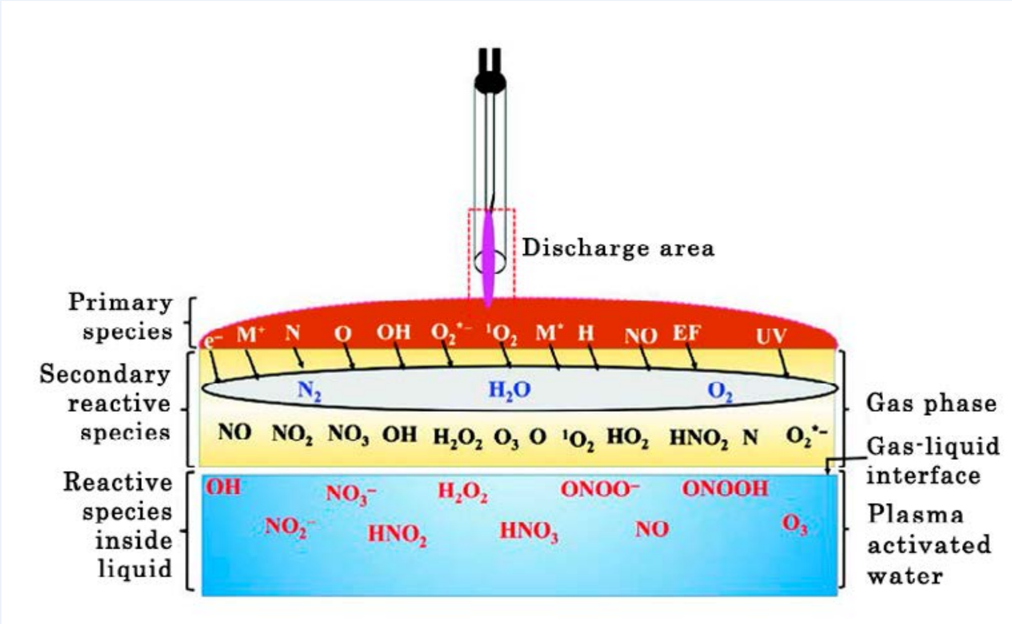

Fig 2. Physicochemical processes of reactive oxygen and nitrogen species formation during plasma-water interaction[2].

Research goals

- Find the optimal plasma discharge for the water purification in terms of price-quality and plasma-formed substances by testing different discharge parameters (field strength, current density, atmosphere, etc.).
- Design and build the water vortex plasma reactor for purification of the water contaminated by model pharmaceuticals.
- Analyze the resulting plasma exposed water and make sure that the pharmaceutical oxidative degradation products it contains are compatible with aquatic and terrestrial life.
- Optimize and improve the plasma technology for water purification, test it to remove other types of micro-pollutants and scaling it up.

a) b)

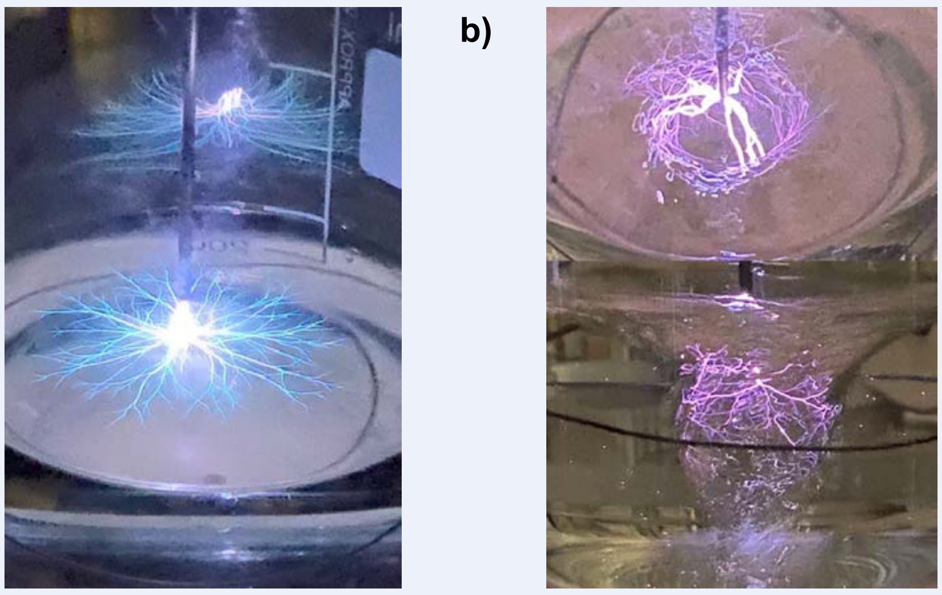

Fig 3. Photo of the plasma discharge: a) above the water surface, b) in the water vortex.

[1] Wetsus patent P182506NL00 (2021)
[2] N. Kaushik et al., Biol. Chem. (2018), 101515
[3] J. Juláka et al., Plasma Phys. Rep. (2018), Vol. 44,125–136

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