

CHEMISTRY ASSOCIATED WITH PLASMA-LIQUID INTERACTIONS: CHALLENGES AND OPPORTUNITIES

Thursday, 21 September 2023 10:35 (30 minutes)

Plasma-liquid interactions are important in many applications ranging from environmental remediation to material science and health care. Depending on the type of non-equilibrium electrical discharge plasma, its contact with liquid (i.e., generated either directly in the liquid, in the gas phase over, or in contact with a liquid), and the chemical composition of the surrounding environment, various types of physical processes and plasma-chemical reactions can be initiated. A number of primary and secondary species can be formed by plasma in the liquid either directly or transferred from the gas phase discharge plasma in contact with the liquid. Among these processes, the oxidative properties of reactive oxygen species (OH radical, atomic oxygen, ozone, hydrogen peroxide) and nitrogen species (nitric oxide, nitrogen dioxide radical) are generally accepted to play a central role in the chemical and biological effects of plasma produced in gas-liquid environments. These species can react at or penetrate through the plasma-gas/liquid interface, dissolve into the bulk liquid, and initiate secondary chemical processes in the liquid. Many of these chemical species are not stable in the liquid, and subsequent reactions can take place, giving rise to new transient species such as OH•, O₂⁻, NO• and NO₂• radicals, which have highly cytotoxic properties and cause prolonged chemical and biological activity of plasma-treated solutions after the exposure to the discharge. The properties of such so-called plasma-activated liquids (PAL) and the duration of their activity are affected by many factors which determine the type, quantity, and lifetime of the reactive species being formed in plasma-treated liquid. Great attention is paid to the chemistry and biocidal effects of peroxyxynitrite and acidified nitrites for aqueous solutions treated by air-liquid-phase plasmas. Formation of reactive oxychlorine species and subsequent Cl-related chemistry and biocidal effects might be initiated by plasma in saline solutions. The composition of cell culture media gives additional complexity to the aqueous chemistry in plasma-activated liquids because of the presence of organic compounds. Therefore, the yield of a total plasma-chemical process is due to the synergistic contributions of numerous different elementary reactions taking place simultaneously. Because of the complexity of the reactions, giving rise to both stable and non-stable intermediates and reactions products, detailed characterization of aqueous chemistry induced by plasma presents one of the challenges in plasma-liquid interactions that need to be addressed to control the chemical processes in the plasma treated liquid and the properties of PAL important for the use of plasma in specific applications. For example, a different approach should be applied when plasma will produce PAL with “stored” chemical/cytotoxic activity, produce fertilizer (i.e., to fixate nitrogen into water), or clean water from organic pollutants. These issues must be considered in the design/optimization of the suitable plasma source, i.e., whether to use a „hot“ plasma source of RNS or rather a „cold“ plasma source of ROS/RONS. This talk will briefly overview the basic principles of electrical discharge plasmas in liquids, emphasizing the main chemical processes initiated by plasma in treated liquids.

Speaker's Affiliation

Institute of Plasma Physics of the Czech Academy of Sciences

Member State or IGO/NGO

Czech Republic

Primary author: LUKES, Petr (Institute of Plasma Physics of the Czech Academy of Sciences)

Presenter: LUKES, Petr (Institute of Plasma Physics of the Czech Academy of Sciences)

Session Classification: Atmospheric Pressure Plasma

Track Classification: Atmospheric Pressure Plasma