Contribution ID: **12** Type: **Invited Oral**

Plasma-based approaches for removing micropollutants/emerging contaminants from water; Case study of PFAS

Tuesday, 19 September 2023 15:30 (30 minutes)

Removal of micropollutants (MPs)/emerging contaminants (ECs) is crucial for ensuring water quality and safeguarding human and environmental health due to their carcinogenic, mutagenic and endocrine disruptive effects on living organisms (i.e. humans and animals) (EU Directives 2013/39/EU). These contaminants include pharmaceutically active compounds (PhACs) [1], heavy metals, and xenobiotic organic micropollutants like PFAS [2], [3]. Emerging contaminants pose a challenge to traditional water treatment processes because they often have unique properties, such as being resistant to degradation or occurring in low concentrations [4], [5]. Advanced oxidation processes (AOPs) (e.g. ozone (O3) treatment or hydrogen peroxide (H2O2) with UV light, Fenton and photo-Fenton processes, electrocoagulation, etc.) that rely on the generation of highly reactive OH radicals mainly, have proven to be effective for most of the ECs [4], [5] except for a few highly stable ones e.g. PFAS [6]. The use of extra chemicals in AOPs, however, increases costs as well as threatens the environmental compatibility of effluents that might still contain chemical residues. [7]. For various reasons, non-thermal plasma-based systems have emerged as the most suitable options for utilizing advanced oxidation and reduction processes (AOP/ARP) simultaneously [2] without requiring added chemicals. However,

Contributions from our laboratory to the treatment of MCs/ECs with a main focus on PFAS contaminated water will be discussed. The results will be compared in terms of reactive species generation (e.g. O3, H2O2 and OH radicals) and with a particular emphasis on the selection of the type of efficient plasma discharge with regards to the properties of the contaminant in question. Notably, results of a liquid contact plasma reactor, a newly patented RAdial Plasma (RAP) discharge reactor and a Corona discharge system will be presented. Particularly for PFAS, RAP has demonstrated to be the most energy-efficient method for achieving a high degree of PFAS mineralization with degradation efficiencies >99% for initial concentrations between 41 μg/L to 41 mg/L. Energy efficiencies greater than 2000 mg/kWh for 41 μg/L –4.1 mg/L of PFOA initial concentrations were obtained. Electron density measurements using Optical Emission Spectroscopy (OES) results presented distinctive features of the RAP system compared to a liquid contact plasma reactor. The results obtained with RAP compare most favourably with those of state-of-the-art plasma systems and reinforce the notion that plasma-based technology is among the most effective options available for MCs/ECs degradation in water decontamination.

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Session Classification: Water Treatment

Track Classification: Water Treatment