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| **Title** | **Development and characterization of a plasma-based process for the degradation of perfluoroalkyl substances in water** |
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| # months (min.3) | 3 |

**Project description:**

State of the art: Perfluoroalkyl substances (PFAS) are man-made chemicals which represent a major contemporary environmental and health hazard worldwide. They have excellent properties of stability and inertia which make them ideal components in many processes and products but also persistent pollutants in water and soil, capable of diffusing through great distances and of being taken up by living organisms. Moreover, they are not degraded in traditional wastewater treatment plants but need specific processing stages, typically based on sorption on activated carbon and ion-exchange resins. These materials, however, have short breakthrough times and, when exhausted, constitute a waste which requires further treatments. Thus, the search for environmentally friendly novel treatment technologies for the removal of PFAS from water is urgent and very active. Atmospheric pressure plasma (APP) produced above the water surface represents a promising solution [1,2]. APPs are readily generated by electric discharges in air or other gases at room temperature and atmospheric pressure and are a source of energetic electrons, which interact with the gas to produce various reactive species capable of initiating a great variety of processes, with no waste of the delivered energy as heat. APPs have been recently successfully applied in the degradation of long-chain perfluoroalkyl substances, while the degradation of short-chain PFAS, which do not have surfactant properties and therefore do not concentrate at the plasma-liquid interface, still represents a challenge in the application of plasma in the treatment of PFAS-contaminated water [2].

Objectives and activity: The present project aims at developing and investigating a process activated by atmospheric plasma for the degradation of all types of PFAS in water. In particular, new system configurations for the production of atmospheric plasma will be tested and atmospheric plasma will be combined with the addition of UV-sensitive additives in water to produce solvated electrons or reactive radicals in the solution bulk exploiting the radiation emitted by plasma.

The optical emission spectra obtained in plasma produced in different gases or gaseous mixtures will be analyzed to maximize the emission needed to activate the UV-sensitive selected additive dissolved in water. Solutions of PFAS characterized by different properties will be treated and the effect of the additive, additive concentration, solution pH, treatment time will be investigated. The activation of the additives will be also performed through a lamp emitting in the UV or visible range to selectively study and optimize the effect of the photodegradation. A sequential process in which log-chain PFAS are degraded by plasma while the decomposition of their degradation products, generally consisting in short-chain PFAS, is carried out by photodegradation will be also investigated, comparing the efficacy and energy efficiency obtained in the two strategies. A major task of the project will be the characterization of the process through the study of the kinetics and of the reaction intermediates and products of PFAS degradation. Particular attention will be given to the analysis of the gaseous phase to ensure that no hazardous byproducts are released into the environment. Characterization of plasma and of the reactive species produced in the plasma and in water will also be pursued exploiting the acquired knowledge to further develop the plasma reactor and optimize the process performance.

Skills to be acquired and opportunities: The PhD student will use various analytical techniques for the characterization of plasma, the detection of short lived reactive species, like hydroxyl radical, and the analysis of water, including: optical emission spectroscopy, FT-IR, GC/MS, HPLC-UV/Vis and HPLC coupled with mass spectrometry. The student will thus develop skills in the operation of APP reactors, in the analysis of complex mixtures and in the use of chemical mechanistic and kinetic tools. The PhD student will work in a stimulating multidisciplinary and international environment and will have the opportunity to spend a research stage abroad in a research group already involved in a scientific collaboration [1,3,4].

References:

[1] O. Biondo, G. Tomei, M. Saleem, G. B. Sretenović, M. Magarotto, E. Marotta, C. Paradisi. Products, reactive species and mechanisms of PFOA degradation in a self-pulsing discharge (SPD) plasma reactor. *Chemosphere* **2023**, *341*, 139972.

[2] G. Tomei, M. Saleem, E. Ceriani, A. Pinton, E. Marotta, C. Paradisi. Cold Plasma for Green Advanced Reduction/Oxidation Processes (AROPs) of Organic Pollutants in Water. *Chem.-Eur. J.* **2023**, 29.

[3] G. B. Sretenovic, M. Saleem, O. Biondo, G. Tomei, E. Marotta, C. Paradisi. Spectroscopic study of self-pulsing discharge with liquid electrode. *J. Appl. Phys.* **2021**, 129.

[4] G. Tomei, M. Saleem, V. V. Kovačević, I. B. Krstić, E. Marotta, G. B. Sretenović. Low power high electron density discharge over the liquid surface. *Plasma Process. Polym*. Under revision.