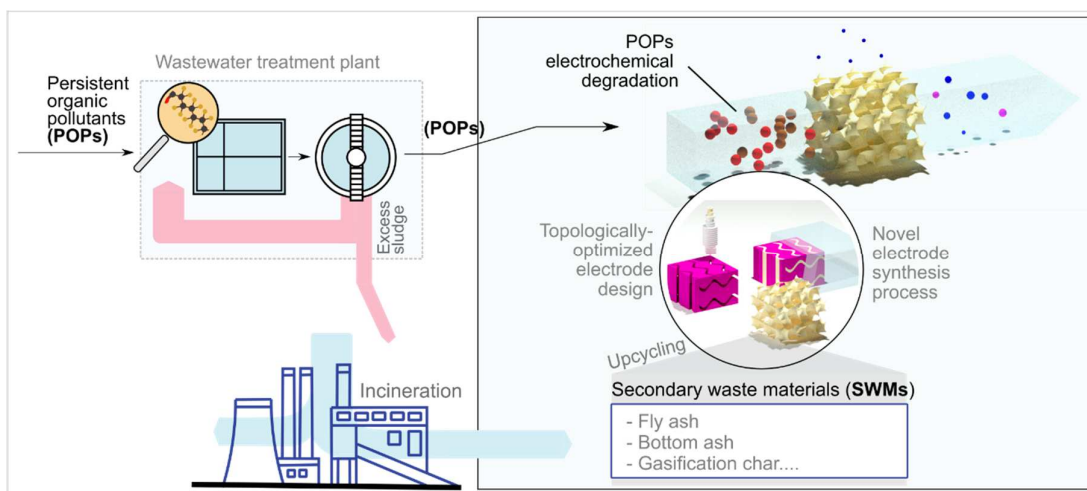


Upcycling secondary waste materials into topologically-optimized hierarchically porous composites to tailor the electrochemical degradation pathway of persistent organic pollutants

Persistent organic pollutants (POPs) are a class of chemical compounds which are extremely resistant to natural decomposition in the environment and the public concern over their toxicological effects on human health and the environment has increased since the exposure to POPs can disrupt endocrine, immune, reproductive, and nervous systems. Conventional wastewater treatment technologies have demonstrated limited capability in degrading POPs. Electrochemical oxidation (EO) is based on the application of an electric current or a potential difference between two electrodes and is a recent, reliable, and effective technique used for the destruction of recalcitrant, non-biodegradable pollutants. However, the process's effectiveness and efficiency strictly depend on the electrode materials, which usually contain critical raw materials (CRMs) or, as for lead-dioxide-based electrodes, can constitute a hazard due to the release into the effluent of the coating corrosion products. Moreover, the optimization of the electrode shape and morphology is often neglected, limiting the potential of such technique.

The goal of the project is to architect novel carbon heterostructures, by an innovative hybrid synthesis method, involving additive manufacturing and a plasma-based functionalization, for highly efficient electrodes able to degrade persistent organic pollutants (POPs) into harmless ones. Moreover, secondary waste materials (SWMs), such as sewage sludge ash and coal fly ash, will be employed as a valuable filler and catalysts for the electrode synthesis process, by incorporating them into polyacrylonitrile (PAN) matrices through a hybrid synthesis method.



The research will consist of four main tasks: firstly, the electrode shape will be designed and optimized using computational fluid dynamics (CFD) simulation. Secondly, by using a novel approach, combining additive manufacturing with a controlled phase-inversion method and chemical vapour deposition, the electrodes will be manufactured. Moreover, for the first time, secondary waste materials will be used for electrode synthesis, to divert them from landfills, in a circular economy vision. Thirdly, the novel architecture materials will be characterized by different techniques. Fourthly, the electrodes will be tested to degrade POPs. In particular, different tools will be used to understand how to optimize all the material features to better tailor the desired process. Multivariate data analysis will be employed for structure-property relationship mining. CFD simulation will be also employed to support the experimental results. Process parameters will be optimized by a systematic application of experimental design (DOE) using the Taguchi approach.

Expected results will include the development of a novel synthesis method and a set of tools to design more effective and efficient carbon-based electrodes for the degradation of emerging pollutants. This project will be beneficial to fundamental science in deeply understanding the relationship between electrode morphology, composition and catalysed reactions. Meanwhile, the applications of hierarchically porous carbon electrodes found application also in other tremendously important and topical sectors, such as energy storage and conversion and desalination devices.