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**Removal of persistent organic
pollutants by adsorption onto
innovative materials**

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Introduction

Pesticides in general, and persistent organic pollutants (POPs) in particular, are toxic compounds characterized by environmental persistence, bioaccumulation, long-range transport, and toxicity even at trace concentrations. The irrational and sometimes excessive use of highly hazardous pesticides therefore represents a major and complex challenge. In addition to persisting in soils, these compounds can generate degradation by-products that are, in some cases, even more toxic than the parent molecules.

By promoting runoff and infiltration, rainfall is a major driver of contamination in soils, surface waters, and groundwater. Moreover, soils and sediments generally act as reservoirs for these toxic substances and may constitute a continuous source of water pollution, depending on variations in parameters such as pH, temperature, and redox potential.

Epidemiological evidence indicates that exposure to POPs is associated with an increased risk of numerous adverse health outcomes, including cancer, congenital abnormalities, reproductive disorders, and neurological impairment. It is therefore essential to monitor and reduce the use of these compounds in order to limit their impacts on human health and the environment. International agreements, such as the Stockholm Convention on Persistent Organic Pollutants, were established to regulate their use and improper disposal.

The increasing use of plant protection products has accompanied the development of modern agriculture; however, not all applied pesticides reach their intended targets. Glyphosate and metribuzin, for example, are herbicides used to improve crop productivity, yet they are also associated with adverse health and environmental effects. A substantial fraction of these substances is dispersed into the atmosphere during application through volatilization and spray drift from plants or soils. Transported by wind, they can travel far from their point of origin before being deposited by precipitation into water bodies and onto soils, from which they are further transferred to aquatic environments by runoff and infiltration. Herbicides are therefore among the compounds most frequently detected in water.

Several approaches have been developed to address POP contamination and mitigate its environmental impact:

Incineration, a thermal treatment process in which POPs are destroyed at high temperatures in specialized incinerators. This method can generate gaseous residues that must be captured and treated before release to the atmosphere.

Advanced chemical degradation, including processes such as oxidation, reduction, and dechlorination, which aim to cleave the chemical bonds of POPs and convert them into less toxic or more readily degradable compounds.

Bioremediation, which relies on microorganisms such as bacteria, fungi, or enzymes to degrade POPs in the environment. This

approach is commonly applied to the treatment of contaminated soils.

Plasma treatment, which decomposes POPs using sliding arc plasma (GlidArc). The plasma is generated above the aqueous solution to be treated between two divergent knife-blade electrodes and may also be coupled with dielectric barrier discharge (DBD) processes using a falling film.

Phytoremediation, which involves the use of selected plant species to absorb and accumulate POPs from soil or water. Once these compounds have been taken up, the plants can be harvested and disposed of appropriately.

Catalytic treatment methods, such as photocatalysis, ultrasonic degradation, and ozonation, can also be used to target specific POPs in wastewater or off-gases.

Adsorption is widely used for the removal of POPs from aqueous and gaseous media. These pollutants can be retained on sorbent materials such as activated carbon, zeolites, clays, ion-exchange resins, and nanocomposites.

Among these methods, adsorption is often considered a method of choice because of its operational simplicity and high efficiency in removing organic and inorganic micropollutants.

Accordingly, increasing attention has been directed toward new adsorbent matrices composed of two distinct phases, namely nanoparticles dispersed within a polymer matrix to form a nanocomposite. Such materials combine the properties of the