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Degradation of nanoplastics in aquatic environments: reactivity and impact on dissolved organic carbon

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The large production of plastic material (PlasticsEurope, 2019), together with the mishandling of plastic waste, has resulted in ubiquitous plastic pollution, which now reaches even the most remote areas of the Earth (Allen et al., 2019; Bergmann et al., 2019). Plastics undergo a slow process of erosion in the environment that decreases their size: microplastics (MPs) and nanoplastics (NPs) have diameters between 1 μm and 5 mm and lower than 1 μm, respectively (Frias and Nash, 2019).

The occurrence, transformation and fate of MPs and NPs in the environment are still unclear. Therefore, the objective of this work is to better understand the reactivity of NPs using an aqueous suspension of polystyrene NPs (PS-NPs) as a proxy, in the presence of sunlight and chemicals oxidants. The results obtained are relevant to both the atmospheric aqueous phase, such as cloud and fog droplets, and surface waters. We investigated the reactivity of PS-NPs with light and with two important oxidants in the environment: ozone (O_3) and hydroxyl radicals ($^{\bullet}OH$). The adsorption of ozone (O_3) on PS-NPs is investigated, showing a significant O_3 uptake. Moreover, for the first time, a reactivity constant with $^{\bullet}OH$ is determined. We found a linear correlation between the kinetic constants measured for three different sizes of PS-NPs and the surface exposed by the particles. Degradation products (short chain carboxylic acids and aromatic compounds), obtained by direct and $^{\bullet}OH$-mediated photolysis of PS-NPs suspensions, are identified by high-resolution mass spectrometry. Irradiation of a PS-NPs suspension under natural sunlight for 1 year has shown the formation of formic acid and organic compounds similar to those found in riverine and cloud dissolved organic matter.

This work is crucial to assess the impact of NPs abiotic degradation in atmospheric and surface waters; indeed, the reactivity constant and the degradation products can be implemented in environmental models to estimate the contribution of NPs degradation to the natural dissolved organic matter in the aqueous phase. A preliminary simulation using APEX (Aqueous Photochemistry of Environmentally occurring Xenobiotics) (Bodrato and Vione, 2014) model shows that in NPs-polluted environments (10^9 particles mL^{-1}) there is potential for NPs to significantly scavenge $^{\bullet}OH$, if the content of natural organic matter is not too high, as observed for surface and cloud water.

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