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Introduction to the special focus issue: environmental toxicity of nanoparticles

“The main goal of this special focus issue is to introduce the main parameters that affect the potential ecotoxicity of nanoparticles and to describe the state of the art with a few selected examples of interaction of different nanoparticles...”

KEYWORDS: carbon nanotubes ■ ecotoxicity ■ environmental impact ■ nanoparticles ■ structure activity relationship

Nanoparticles, usually defined as any form of a material with dimensions below 100 nm, are part of our everyday life. They may be natural (the ashes from the recent volcanic eruption in Iceland are a good example) or man-made. Among the latter category, there is usually a distinction between intentional nanoparticles designed for specific applications and incidental nanoparticles produced by human activity (e.g., diesel nanoparticles). This special focus issue on the environmental toxicity (also termed ecotoxicity) of nanoparticles is deliberately focused towards engineered nanoparticles. Why care about the potential environmental effects of such nanoparticles? There are many different reasons. The first is the fact that they are often produced on a large scale due to their use in many applications: to cite a few, nanosilver is produced for antibacterial applications, nano-TiO₂ and nano-CeO₂ used due to their catalytic activity (e.g., self-cleaning and cleaning of diesel exhausts, respectively), nano-SiO₂ used in sunscreens (e.g., nonwhitening UV-filters) and carbon nanotubes used to improve electrical and mechanical properties of numerous composite materials, as well as medical applications (e.g., anticancer drug carriers and contrast agents for biomedical imaging or hyperthermia). For most nanomaterials, the annual production already goes beyond hundreds of tons per year, millions of tons in the case of nano-TiO₂ and nano-SiO₂ [1]. Contamination of the environment could then occur at different levels of the lifecycle: during the production itself, the transportation to good manufacturers, the actual use of the products or at the end of the lifecycle (e.g., landfill disposal and incineration). In the case of pharmaceuticals, the release to waste water is expected to occur rapidly. The main environmental targets for nanoparticles are water and

soil, where they are likely to accumulate but also possibly to be progressively transformed, meaning that their potential ecotoxicity is expected to vary with time and depend on the local environmental conditions (e.g., pH, temperature, ionic strength and natural organic matter).

“Why care about the potential environmental effects of such nanoparticles? There are many different reasons.”

The main goal of this special focus issue is to introduce the main parameters that affect the potential ecotoxicity of nanoparticles and to describe the state of the art with a few selected examples of interaction of different nanoparticles (e.g., metals, oxides, fullerenes and carbon nanotubes) with water or soil. The article by Bottero *et al.* gives a general introduction to the main issues dealing with the characterization of nanoparticles and their potential environmental impact, stressing the role of surface functionalization and its influence on the generation of reactive oxygen species [2]. The article by Labille *et al.* reviews the main parameters governing the stability of nanoparticles in water [3]. For different categories of nanoparticles (e.g., metal oxides, metals and carbon nanoparticles, such as fullerenes and carbon nanotubes), the authors discuss the specific physicochemical properties that have a major influence on particle stability and ability to form – or not – stable suspensions. Auffan *et al.* introduce some of the general principles of the influence of the physicochemical properties of nanoparticles on their potential biological effects in the aqueous environment (e.g., generation of reactive oxygen species, coexposure to nanoparticles and soluble pollutants, photocatalytic activity and potential phototoxicity) [4].

Three research articles present the latest results on the environmental impact of either carbon nanotubes in freshwater or seawater, or silver nanoparticles in water or soil [5–7]. In the case of carbon nanotubes in freshwater [6], the investigation of the ecotoxicity of double-walled and multiwalled (*circa* 10 layers) carbon nanotubes highlights the need for a comparison in terms of the number of nanoparticles rather than weight concentration, which is usually the case. These results also show that the carbon nanotubes do not translocate through the intestinal barrier. Toxicity (growth inhibition) was observed, but only from an unrealistic concentration in the environment (10 mg/l), which may only correspond to an accidental situation. The data show that the growth inhibition is likely to be related to ‘mechanical effects’ and no genotoxicity was evidenced.

The investigation of the interaction of the same double-walled carbon nanotubes with marine organisms (e.g., alga, crustacean and fish) and the role of sample preparation is discussed in the work by Kwok *et al.* The results indicate that sonication of the carbon nanotubes’ suspension before exposure typically makes the corresponding carbon nanotubes much less

agglomerated when compared with simple stirring, which has a direct impact (increase) on their ecotoxicity [7].

Finally, the article by Lapied *et al.* compares the ecotoxicity of nano-Ag using an earthworm model, either in water or artificial soil. The apoptotic response has been used to quantify the environmental toxicity and proves to be very relevant for evidencing effects at sublethal concentrations. The results indicate that the higher bioavailability of nano-Ag in water leads to a higher toxicity than in soil [5].

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