Safety of carbon nanomaterials towards the environment

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Abstract

The estimated increasing production of carbon nanotubes (CNTs) and more recently graphene and related materials (GRMs) is driven by many applications – some of which being already on the market (energy storage, paints and composite materials for example). In parallel, questions are also raising about their safe handling and use (mainly for workers, including researchers), but also about their end of life in the environment. The CIRIMAT is focusing for about 20 years on the CCVD synthesis of double-walled CNTs (DWNTs) [1] because they represent unique objects at the interface between single-wall CNTs (SWNTs) and larger multi-walled CNTs (MWNTs). The protection offered by the outer tube allows to modify the interface with the environment (solvent, matrix, etc.) while minimizing interferences with the inner one, and keeping a morphology close to that of SWNTs. We have also developed a synthesis of few-layer graphene (FLG) by sonication-assisted exfoliation of graphite [2]. Together with EcoLab, we have investigated the potential environmental impact of different carbon nanomaterials on the environment using different models (amphibians [3-5], algae [6, 7], but also plants more recently). We will discuss some issues about the influence of sample processing and exposure protocols as well as of the metrics for the comparison of the results [8-10]. In particular, comparing the growth inhibition using the dose expressed in $mg.L^{-1}$, N° of $particles.L^{-1}$ or $m^2.L^{-1}$, we have shown that the surface concentration is the most suitable metric. It allows to unify the data for very different carbon nanomaterials (from 0D to 2D) and thus to become predictive.

For risk assessment of food safety, it is important to determine if carbon nanomaterials are transferred to the edible parts of plants [11]. However, detection of carbon particles in carbon matrices represents a technological bottleneck. We tested different analytical methods, rarely used in biology, to detect CNTs in plant samples such as Raman spectroscopy, bi-photonic microscopy, transmission electronic microscopy, isotopic labelling using ^{13}C, etc. We established that CNTs can enter into plants by the roots, and be transported via the sap to the leaves.

Finally, we are also reducing graphene oxide in order to prepare a range of nanocarbons with similar morphology but a different surface chemistry, and we have shown that this approach can be used to make safer the use of carbon nanomaterials such as graphene oxide for example, by cancelling its genotoxicity.

Acknowledgement.

The research has also received funding from the European Union Seventh Framework Program under grant agreement N°604391 Graphene flagship. We also acknowledge the PRES University of Toulouse and Region Occitanie for financial support through the grant N°2016-16.

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