European Commission

Science for Environment Policy

Collecting data to explore the ecological threat of nanomaterials

1 October 2015
Issue 429

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Source: Garner, K. L., Suh, S., Lenihan, H. S., & Keller, A.A. (2015). Species Sensitivity Distributions for Engineered Nanomaterials. *Environmental Science & Technology*. 49: 5753−5759. DOI: 10.1021/acs.est.5b00081

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The overall ecological impact of 10 engineered nanomaterials has been modelled for the first time using toxicity data from multiple living species. These models will allow researchers to assess the effect nanomaterials may have on both ecosystems and people.

Engineered nanomaterials (ENMs) are small-scale substances measuring less than 100 nm in at least one dimension. They are increasingly used for a variety of purposes, such as electronics, medicine, food and military applications. While ENMs are often made of familiar materials such as silver and titanium dioxide, their small size, varied shapes, coatings and surface functionalities mean they can have higher toxicity than the corresponding ionic or bulk form. However, relatively little is understood about their environmental impact.

Species sensitivity distributions (SSDs) are a tried and tested way of estimating the ecotoxicological impacts of a chemical. In this study, researchers created the first SSDs for 10 nanomaterials, including uncoated and polyvinylpyrrolidone (PVP)-coated nano-silver, nano-aluminium oxide, nano-buckminsterfullerene (n-C_{60}), carbon nanotubes (CNTs), nano-copper and nano-copper oxide.

Laboratory data from published studies on the toxicity of each ENM to different species was combined to create a model of its overall toxicity. The potentially affected fraction (PAF) of species that would be harmed from exposure to a particular concentration could then be estimated and used to establish threshold levels, above which the function of an ecosystem may be at risk. Toxicity data on the equivalent bulk form of the substance and ions of the associated metal were also collected for comparison.

A minimum of four data points is required to construct an SSD, and the collected data varied from eight to 64 data points for ENMs. However, while data on chronic, sublethal toxic effects — which best correspond to the low-level, long-term exposure to toxins in the environment — are often best for calculating SSDs, limited data meant only acute exposure SSDs could be calculated. Furthermore, a low amount of data on marine and terrestrial toxicity meant only freshwater acute toxicity SSDs were developed.

The results indicate that factors such as the presence of a coating can have a large impact on the acute toxicity of ENMs. For example, PVP-coated silver nanoparticles were considerably more toxic for most species than uncoated nanoparticles. However, ionic silver was the most toxic, except at low levels, when only minor toxicity differences were observed compared to the PVP-coated nanoparticles. Nanoparticle solubility, which corresponds with availability and release of metal ions, also strongly predicts acute toxicity.

- **Silver (Ag):** Uncoated n-Ag was toxic to some species at µg per litre concentrations, though other species tolerated far higher concentrations. PVP-coated n-Ag was considerably more toxic for most species. There were only minor differences between Ag-PVP and ionic silver (Ag^{+}).
- **Copper (Cu):** Of two copper nanoparticles (n-Cu and n-CuO) and ionic copper (Cu^{2+}), n-CuO was consistently less toxic than either n-Cu or Cu^{2+}.
- **Zinc oxide (ZnO):** Bulk ZnO, n-ZnO, and ionic zinc (Zn^{2+}) were all found to have similar SSDs, indicating that most of the toxicity for this ENM is due to dissolved Zn^{2+}.
- **Aluminium oxide (Al_2O_3):** n-Al_2O_3 was less toxic than ionic aluminium (Al^{3+}), except at high concentrations.

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- **Carbonaceous nanomaterials:** n-C_{60} was found to be more toxic than CNTs overall. However it is important to note that CNTs have an especially large range of properties, such as tube diameter and length, which would ideally be separated to calculate individual SSDs.
- **Cerium (Ce) and titanium (Ti) oxides:** n-CeO_2 appears to be more toxic than n-TiO_2, despite the fact that n-TiO_2 shows phototoxicity while n-CeO_2 tends to quench photoactivity.

These results offer an initial gauge of the ecotoxicological impact of different ENMs. As more data becomes available the SSDs will become more reliable, and researchers will be able to probe the impacts of physicochemical characteristics such as size and shape. No current SSD used enough species to represent a comprehensive ecosystem, which would be helped by toxicity data on a wider variety of species. ENMs built using chronic toxicity measures could also provide more insight on long-term toxicity.

Combining these preliminary results, and others that follow, with models that estimate the exposure of individuals or populations could offer an increasingly potent insight into the risk nanomaterials pose.