



News and opinions

Biodiversity change behind wide applications of nanomaterials?

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ABSTRACT

Nanomaterials, like carbon nanotubes, graphene, metal and metal oxide nanoparticles, are increasingly applied in a wide range of areas with numerous benefits to economy and society. Large-scale production and applications of nanomaterials can increase the possibility of exposure to living organisms, pose risks to human health and ecosystems, and potentially lead to biodiversity losses. Previous environmental impact and safety studies that targeted nanomaterials typically focused on their toxicity, fate and behavior; little attention was paid on biodiversity consequences. Evidence for acute biodiversity change derived from nanomaterials is very limited. Several organizations and researchers have started to discern the relationship between biodiversity and nanotechnology. Nevertheless, more efforts are desired to explore the impacts of nanomaterials on biodiversity.

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Reproductive and developmental toxicity of nanomaterials

Global biodiversity has continually declined in the past decade (2000–2010) [1]. A prerequisite in impeding biodiversity losses is to collect as many decline reasons as possible [1,2]. New emerging nanomaterials such as carbon nanomaterials and metal nanoparticles could be considered as one of these reasons, as reproductive and developmental toxicity of nanomaterials has been observed [3], possibly becoming a new threat to biodiversity. Among numerous nanomaterials [3,4], single-walled carbon nanotubes (SWCNTs) can cause embryo death, angiogenesis inhibition and growth retardation in chicken [5]; multi-walled carbon nanotubes (MWCNTs) are able to lead to the death of zebrafish embryos and developmental arrest [3]; C₆₀ can induce the abnormalities and death of mice embryos [6]. Carbon nanomaterials were reported to pose a threat to the reproduction and growth of invertebrates, such as *Daphnia magna* [7] and earthworms [8]. Dissemination of nanomaterials in soil and water may be detrimental to the growth of plants where they can accumulate and produce phytotoxicity. The growth inhibitions of red spinach by MWCNTs [9], and graphene-induced decrease in shoot and root lengths of tomato, red spinach and cabbage [10] have been revealed. In addition to carbon nanomaterials, the adverse impact of metal-based nanomaterials on the living organisms after environmental exposure also received significant attention. Metal nanoparticles such as nano-Ag and nano-TiO₂

inhibited the growth of *Lemna paucicostata* [11], and impacted the reproduction and development of *Drosophila melanogaster* and CD-1 mice [12]. The chronic toxicity of gold nanoparticles with different surface functionalities (21-day exposure) to *Daphnia magna* was investigated, indicating that it experienced decreased reproduction or reduced body size [13]. Biodiversity change may occur if normal reproduction and development of species are prevented.

Compositional shifts in microbial communities caused by nanomaterials

Evidence from microbial community studies also supports that nanomaterials would result in biodiversity changes. Soil microbial community composition significantly shifted with the treatments using metal-based engineered nanomaterials, where the biomass of Gram-positive bacteria, Gram-negative bacteria and fungi significantly decreased as compared to the control without these nanomaterials [14]. The bacterial community structure or composition was changed by Ag nanoparticles in biosolids [15]. The incorporation of TiO₂ nanoparticles in soil decreased the diversity in bacterial community [16]. Rodrigues et al. [17] reported that soil fungal community could not recover after soil was exposed to SWCNTs, and soil bacterial community was transiently influenced. The authors further reported that fungi and bacteria related to nutrient cycling in soil were adversely affected by SWCNTs. Another study done by Priester et al. [18] showed that nanomaterials inhibited the growth of nitrogen-fixing bacteria. Taking the previous findings together, the native nutrient cycling and ecosystem functions may be altered in the presence of nanomaterials. After an extensive liter-

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ature review, Simonin et al. [19] suggested that biodiversity losses and microbial community variations in the environment containing nanomaterials are associated with nanomaterials.

Behaviors and acute-chronic toxicity of nanomaterials

The adverse effects of nanomaterials on the biodiversity and environment can be affected by multiple factors, such as sensitivity and exposure time (short- and long-term). Nanomaterials refer to the materials at approximately 1–100 nm nanoscale, which have a large modification of physico-chemical properties and exhibit different behaviors as compared to bulk chemicals or materials [11]. The small size makes them capable of more easily entering the cells in contact with proteins and other molecules than bulk chemicals and materials [20,21]. Nanomaterials may induce more serious adverse effects on living organisms. For example, nano-Ag, nano-ZnO and nano-TiO₂ at high concentrations have shown to have more toxic effects on the survival, reproduction and growth of earthworms than bulk metal forms in soils amended with sewage sludges [22]. Both acute and chronic exposure experiments of nanomaterials over short and long periods of time were carried out, showing that the effects of nanomaterials on tested organisms are often different between acute and chronic treatments [23–27]. For example, in a study related to MWCNT exposure in *Daphnia magna*, the sensitivity of chronic lethality hazard testing is more than 5 times that of the acute toxicity of MWCNTs [25]. Also, Panacek et al. [23] demonstrated that Ag nanoparticles presented the acute toxicity to *Drosophila melanogaster* at high concentrations above 20 mg L⁻¹ and chronic toxicity at a low concentration of 5 mg L⁻¹. The observed differences between these two treatments are due to highly dynamic features of ecosystems, environment, and the interactions between nanomaterials and the tested organisms.

The road ahead

Overall, despite limited information on biodiversity consequence of nanomaterials, the available data point to the fact that wide applications of nanomaterials would lead to biodiversity change. Thus, there is an urgent need to assess biodiversity change caused by various nanomaterials under environmentally realistic conditions, especially those used widely, e.g. carbon nanomaterials, and Ag, ZnO and TiO₂ nanoparticles. Biodiversity like climate, air and water is global. Nanomaterial applications are also global. These two “globalities” require us to make more cooperated and coordinated efforts all over the world. Before taking actions to protect biodiversity from nanomaterials, the consensus methods and standards for measuring the impact of nanomaterials on biodiversity need to be made [28]. It is crucial to develop related regulations and policies to prevent the biodiversity losses derived from nanomaterials, as the current environmental regulations often do not take into account the nanomaterials [28,29]. Moreover, establishment of reliable models is fundamental to predict the interactions between nanomaterials and the living organisms and their effects on biodiversity [30].

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