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Nanotoxicology: A Threat to the Environment and to Mankind

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Abstract

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Nanotoxicology represents a new and growing research area in toxicology. It deals with the assessment of the toxicological properties of nanoparticles (NPs) with the intention of determining whether (and to what extent)they pose an environmental or societal threat. Inherent properties of NPs (including size, shape, surface area, surface charge, crystal structure, coating, and solubility/dissolution) as well as environmental factors (such as temperature, pH, ionic strength, salinity, and organic matter) collectively influence NP behavior, fate and transport, and ultimately toxicity. The nanotoxicology researchers focused on the relationship between nanomaterial characteristics (size, shape, surface area etc.) and toxic responses (cytotoxicity, genotoxicity, inflammation etc.). This article aims to give a brief summary of what is known today about nanotoxicology.

Keywords: Nanomaterials, characterization techniques, nanotoxicology

Introduction

Nano sized materials are increasingly used in the fields of industry, science, pharmacy, medicine, electronics, communication and consumer products. The “nano” is derived from the Greek word “nanos” meaning “dwarf” [1]. A nanomaterial (NM) defined as a substance with at least one dimension <100 nm in length. There are numerous nano-sized materials in our life. They can take different forms such as tubes, rods, wires or spheres.Depending on their origin, they can be categorized as either engineered or incidental NMs. Engineered nanoparticles (NPs) are particles generated to use the size-related properties inherent in the nanoscale (e.g. conductivity, spectral properties, biodistribution). Incidental NPs, are defined as particles either from unintended anthropogenic sources (e.g. combustion derived) or of natural origin (e.g., particles generated in forest fires) [2].

Nanotoxicology is the study of the toxicity of NMs. It has emerged only recently, years after the beginning of nanotechnology that is considered one of the key technologies of the 21st century, when numerous NMs had already been introduced into some industrial processes and consumer products. [3] quated "discipline of nanotoxicology would make an important contribution to the development of sustainable and safe nanotechnology". Growing concerns about the nanotoxicology were derived from prior experiences with air pollution [4] and asbestos [5]. Nowadays many NPs, for example carbon nanotubes which are much smaller than asbestos, might have asbestos-like effects on cells [6].

Vance et al. [7] reported a 30-fold increase in nano-based products between 2011 and 2015 (Figure 1) and an estimated global market of over $1 trillion in 2015 [8]. Metal NPs (specifically, carbon and silver NPs) represent the largest and fastest growing group of NPs (Figure 2). Hence, human and environmental exposure is already occurring and is predicted to increase dramatically. This growth in nanotechnology has not advanced without concerns regarding their potential adverse environmental impacts. Several reviews have reported on the toxicity of various NPs [9, 10]. However, much is still unknown.

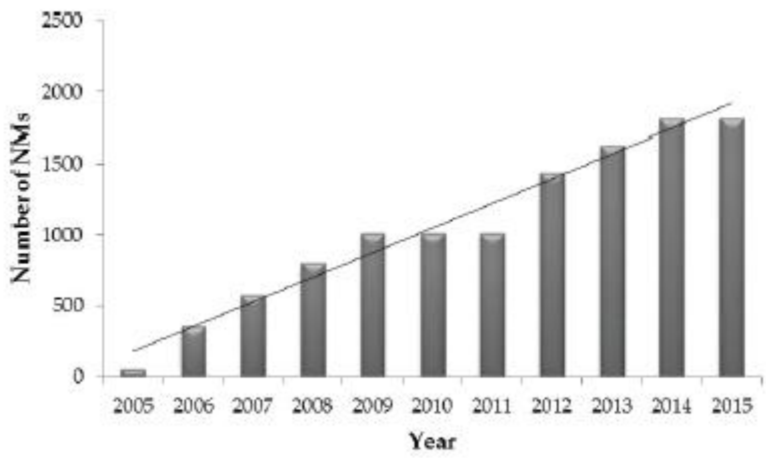

Figure 1. Nanomaterial growth trend 2010–2015 [7].

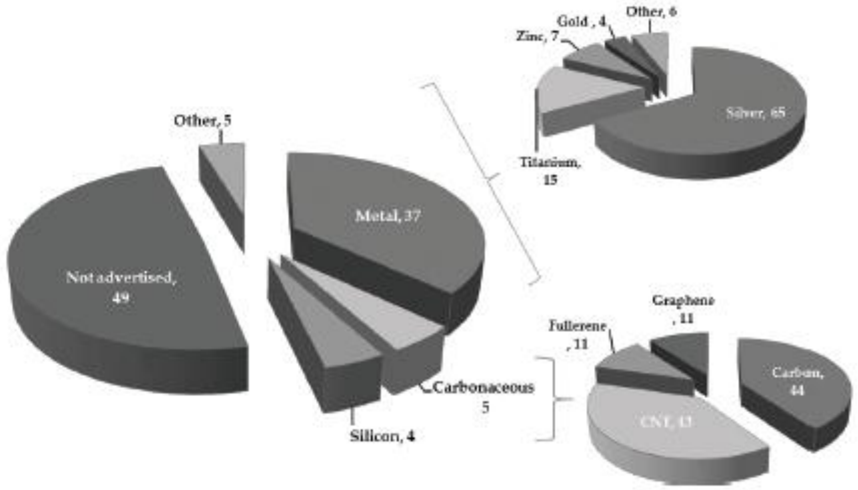

Figure 2. Composition of nanomaterials (adapted from Vance et al. [7]).

Due to the surge in nanotechnology, there have been significant increases in the number of various NPs released into the aquatic environment. Figure 3 provides a summary of the possible routes in a typical aquatic environment to nanoparticles, potential interactions, and the possible clearance routes. Aquatic ecosystems are susceptible to environmental contamination since they are at the receiving end of contaminants, particularly from runoff sources.

Significant in environment

Identified sources of NPs in the aquatic environment include production facilities, production processes, wastewater treatment plants, and accidents during the transport. In addition, aquatic ecosystems are known to sequester and transport contaminants, including NMs. Baun et al. showed that NPs may adhere to algae which may then be consumed by filter-feeders and transfer to higher trophic levels. In the aquatic environment, NPs may aggregate thus reducing the NPs available for direct uptake in the aqueous phase by aquatic organisms. However, aggregated NPs may settle into sediment thereby posing a threat to benthic organisms. In the aquatic environment, NMs are generally associated with sediments [11]. Sediments and soil represent porous environmental matrices which typically have large specific surface areas.

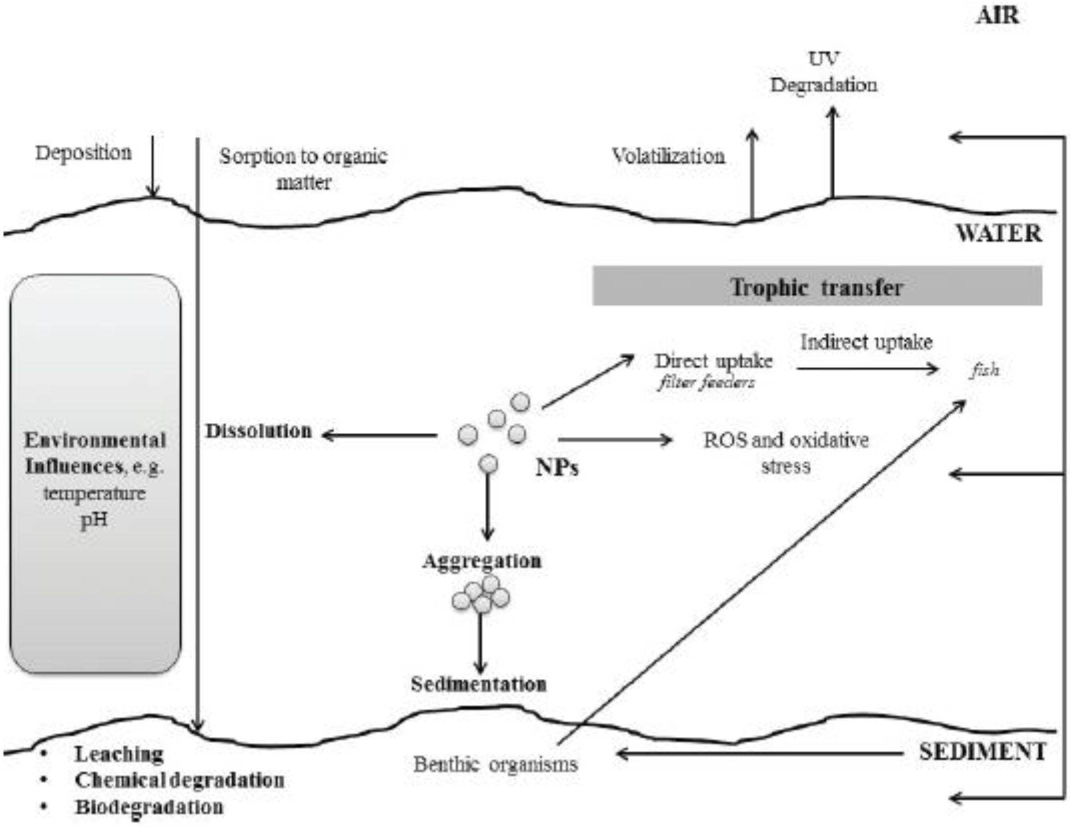

Figure 3. Possible pathways of nanoparticles in the aquatic environment.

There is a huge demand for a definition of NMs [12,13]. On the other hand, the life cycle assessment of NMs has been recognized as a significant tool for regularly evaluating the potential environmental impacts of manufactured nanomaterial during their complete life cycles [14], and it is schematically presented in Figure 3.

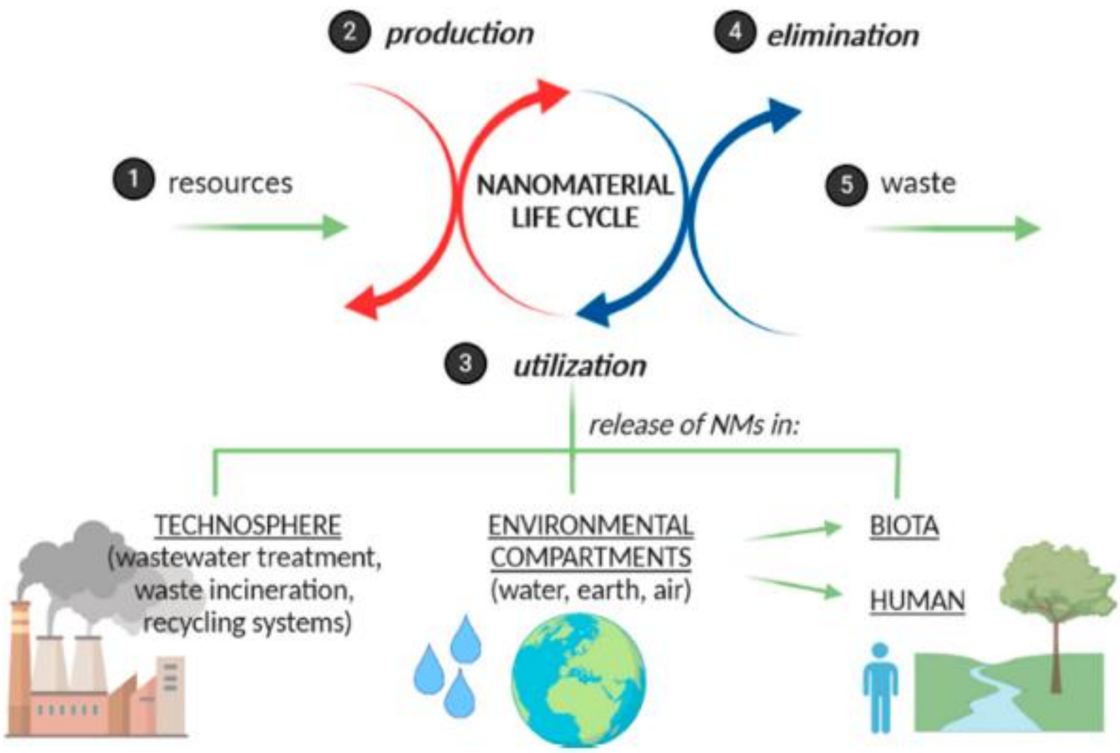

Figure 3. The impact of nanomaterial life cycle on the environment

Toxicity Tests

Toxicity tests can be performed on cell cultures (in vitro) and in living organisms (in vivo) such as fish, mice, or rats [15,16]. There are several standardized toxicological tests that are available to assess the biological response of a chemical substance. However, there is no standardization for the assessment of nanoparticles toxicity. It causes many difficulties in the comparison of the results regarding the toxicity of the tested ingredients. Most of the toxicity tests for NMs have been performed in vitro, using cultures of mammalian cells that were extracted from the most different parts of the body (e.g.,: brain, lungs, heart, skin and liver) [17]. Although in vitro tests are less expensive than in vivo and the results may be obtained in a shorter time, it is not possible to infer potential implications related with the human health based on the in vitro only [18].

Conclusion

NMs, depending on the size, shape, elemental materials and the surface functional groups were observed to have a range of detrimental effects on cells. However the toxicological data about NPs has been collected mainly from occupational and environmental research with natural NMs.Nano sized particles are known to be generated in certain place conditions. There is a still serious lack of information about the toxicity of NPs. Exposure to NPs is inevitable since NPs become more widely used but there is still doubts and much more to be understood regarding their safety. Possible interactions between NPs and livingorganisms and the results of long-term NP exposure are not yet fully understood.

Although our knowledge on the toxicity of various NMs in the aquatic environment has increased over the past few years, there is still a lack of knowledge regarding exposure concentrations, bioaccumulation in tissues, as well as environmental factors which could potentially affect its toxicity or bioaccumulation. Exposure to NPs is inevitable since NPs become more widely used, but there remains much more to be understood regarding their safety.

However, nanomaterials are being used by several industries and are thus present in many products. Nanomaterials may cause an array of potential toxicological and hazardous effects. Moreover, they can have detrimental effects on many ecosystems. The toxicological risks of using nanomaterials need to be screened, to map the potential risk of causing undesirable effects on the human health and on the environment. Based on recent scientific reports, it has been observed that commonly used methods have helped to design more effective nanomaterials while keeping the hazards of the substances at a minimum. In nanomedicine, the significance of nanotoxicology is particularly important to avoid the toxicity of drug nanocarriers.

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