

# Chapter 17

## Understanding Toxicity of Nanomaterials in Biological Systems

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### ABSTRACT

*Nanotechnology is a growing applied science having considerable global socioeconomic value. Nanoscale materials are casting their impact on almost all industries and all areas of society. A wide range of engineered nanoscale products has emerged with widespread applications in fields such as energy, medicine, electronics, plastics, energy and aerospace etc. While the market for nanotechnology products will have grown over one trillion US dollars by 2015, the presence of these material is likely to increase leading to increasing likelihood of exposure. The direct use of nanomaterials in humans for medical and cosmetic purposes dictates vigorous safety assessment of toxicity. Therefore this book chapter provides the detailed toxicity assessment of various types of nanomaterials.*

### INTRODUCTION

The field of nanotechnology is a fast-growing research niche (Ostiguy et al., 2006). Nanoparticles are particles that have at least one dimension in nanoregime, i.e., less than 100 nm. Nanotechnology is a comprehensive term that involves the ability to work with materials at a nanometre scale. Nanotechnology has a potential applications in a range of sectors including energy (production, catalysis, storage), materials (lubricants, abrasives, paints, tires, and sportswear), electronics (chips and screens), optics, and remediation (pollution absorption, water filtering and disinfection), cosmetics (skin lotions and sun screens), and medicine (diagnostics and drug delivery) to food (additives and packaging) (Joner, Hartnik, & Amundsen, 2007; Rana & Kalaichelvan, 2013). The word "nano," is derived from the Greek "nanos" meaning "dwarf", and is becoming increasingly widespread in scientific literature. "Nano" word has

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become so popular in modern science that many “nano-“derived words have recently find their places in dictionaries, including: nanometer, nanoscale, nanoscience, nanotechnology, nanostructure, nanotube, nanorod nanowire, and nanorobot and many more. Many new words like nanoelectronics, nanocrystal, nanovalve, nanoantenna, nanocavity, nanoscaffolds, nanofibers, nanomagnet, nanoporous, nanoarrays, nanolithography, nanopatterning, nanoencapsulation, etc. are used in respected and reputed publications, such as Science and Nature that are not yet widely recognized. The nanometer denotes one billionth of a meter or  $10^{-9}$  meters and is a metric unit of length. The word ‘nano’ is popularly used as an adjective to describe objects, systems, or phenomena with characteristics arising from nanometer-scale structure and emphasize the atomic granularity that produces the unique phenomena observed in nanoscience. Most of the exciting properties begin to be apparent in systems smaller than 1000 nm, or 1 micrometer, 1  $\mu\text{m}$ . Birth of the concept of nanotechnology is usually linked to a speech by Richard Feynman at the December 1959 meeting of the American Physical Society (Feynman, 1959) where he asked a very funny and strange question to the scientific audiences, “What would happen if we could arrange the atoms one by one the way we want them?”

Nanomaterials are materials possessing structural components smaller than 1 micrometer in at least one dimension. Many authors, however, limit the size of nanomaterials to 50 nm (Kittelson, 2001) or 100 nm (Borm et al., 2006), the choice of this upper limit being justified by the fact that some physical properties of nanoparticles approach those of bulk when their size reaches these values. However, a legitimate definition extends this upper size limit to 1 micron, the sub-micron range being classified as nano (Buzea, Pacheco, & Robbie, 2007b).

Nanoparticles are particles potentially as small as atomic and molecular length scales ( $\sim 0.2$  nm) or with at least one dimension falling in nanoregime. Nanoparticles can be amorphous or crystalline and their highly active surfaces can act as carriers for gases or liquid droplets. Nanoparticulate matter should be considered as a distinct state of apart from the solid, liquid, gaseous, and plasma states owing to their distinct properties like large surface area and quantum size effects.

Nanomaterials being versatile in nature has various applications in biology and medicine such as Fluorescent biological labels (Fu et al., 2007), drug and gene delivery (Yan & Chen, 2013) (Malmsten, 2013), bio detection of pathogens (Yang, Li, & Jiang, 2008), detection of proteins (Yi Zhang et al., 2013), probing of DNA structure (Mahtab & Murphy, 2005), Tissue engineering (Cipriano & Liu, 2013), tumour destruction via heating (hyperthermia) (Dutz & Hergt, 2014), MRI contrast enhancement (Na, Song, & Hyeon, 2009) etc

## **NANO VS. BULK MATERIALS AND NANOTOXICOLOGY PUBLICATION STATISTICS**

Nanomaterials behave significantly different from bulk materials due to two primary factors which are surface effects and quantum effects (Roduner, 2006). These two factors affect the mechanical, electrical, optical and magnetic as well as chemical reactivity of the materials. Compared to the microparticles, nanoparticles have a very large surface area and high particle number per unit volume due to the high fraction of atoms at the surface. For example the ratio of surface area to volume (or mass) for a carbon particle with a diameter of 60 nm is 1000 times larger than a particle with a diameter of 60  $\mu\text{m}$ . Since the material in nanoparticulate form presents a much large surface area, due to which chemical reactivity of the material is greatly enhanced roughly 1000 folds. The atoms situated at the surface has lower

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