Nanotoxicity

Introduction:

With the fast development of nanotechnology, industries are currently involved in nanotechnology-related activities, among which the manufactured nanoscale materials or engineering nanoparticles are using in a wide range of products. It is known that nanostructured materials or nanoscale particles possess many novel properties such as self-assembly, size effects, large surface area, ultrahigh reactivity and quantum effects because of their very small size and unique structures.

According to data collected by the National Nanotechnology Initiative (NNI), the quantity of manufactured nanoscale material is growing significantly every year. Business Communications Company has projected a $10 billion global demand for nanoscale materials, tools, and devices in 2010 (see website: http://www.nano.gov/). This large increase in demand and production could lead to enormous exposures of humans and other organisms to nanomaterials/nanoparticles. What happens with these very small-size materials when they entered our body, in particular what can be expected with the increased surface reactivity which may lead to completely different biological effects in vivo as compared to the bulk material of the identical chemical composition and the same quantity.

Of cause they can either be positive and desirable, or negative and undesirable, or a mix of both, these mostly depend on how to utilize them. Nanotoxicology is defined as the study of the nature and mechanism of toxic effects of nanoscale materials/particles on living organisms and other biological systems. It also deals with the quantitative assessment of the severity and frequency of nanotoxic effects in relation to the exposure of the organisms.

In fact, scientists have studied the healthy effects of exposure to airborne nanoparticles for years and have shown some unexpectedly adverse health effects of nanosized particles in vivo. For instance, the epidemiological investigations have found the associations of incidence of a disease and mortality with the concentrations and the sizes of the airborne particles in the environment. The increase of mortality might result from the abundant increase of nanoparticles.

Recently, the biological/toxicological effects of manufactured nanomaterials and nanoparticles have attracted much attention and been seriously discussed (Service, 2003; Kelly, 2004; Brumfiel, 2003; Zhao et al., 2008). From the fact that the sizes of the nanoparticle and the biological molecule are comparable (Figure1), one easily bethinks of such a consequence that the nanoparticle may easily invade the natural defense system of human body or other species and easily enter the cells to affect cellular functions. The existing knowledge reminds that when molecules are small enough, it is possible for them to slip past the guardians in our respiratory systems, skip through our skin into unsuspecting cells, and (sometimes) cross through the blood-brain barrier (BBB). More essentially, the life process is mainly held out by a series of biochemical reactions in vivo. Manufactured nanoparticles possess ultra huge surface area, ultrahigh reactivity, highly efficient catalysis, and nanostructures, etc., do they interfere the normal biochemical reactions in vivo when entering the human body? Are these interferences beneficial or harmful to the life process? How to avoid the harmful effects, and how to utilize the beneficial effects? For instance, one sees the similarity in geometric structures of manufactured nanocage (fullerene) and the biological protein (clathrin) in Figure 1, they all consist of the pentagon and hexagon rings. In fact, many knowledge gaps need to be filled in.

For instance, the large alteration in physicochemical properties of nanomaterials as compared to the bulk material of the same chemical form, and the large alteration in physicochemical characteristics between different sizes of the same nanomaterials will undoubtedly lead to different biological effects in vivo. So the existing database of safety evaluation for the bulk materials, including the effects on health and the environment is probably no longer valid when extrapolating and applying them for the safety assessment of nanomaterials.

The similarity between the structures of manufactured nanocages (fullerene) and proteins (coated veside and clathrin). In any application or even at the initial stages of the research and development, these nanoparticles easily enter the environment via various routes, and ultimately enter human body through direct routes such as dermal and oral exposures, nanodrugs, or through indirect routes such as the food chain, etc. For nanoparticles, except the very strong size-effects, other unique properties such as the tremendous surface, anomalous interface, complicated reactivity, quantum effects, etc. can also lead to changes in physicochemical properties which naturally alter the biological activities in vivo.

These have been demonstrated by the reported data and will be summarized and discussed in the following sections of this chapter (Warheit et al., 2004; Lam, 2004; Chen, 2007; Feng et al., 2009; Fischer et al., 2007; Wang et al., 2005; Zhao et al., 2007; Nel et al., 2009). Thus, in this chapter, the toxicological effects of nanomaterials will be clarified in detail at whole-animal, cellular and molecular levels based on the experimental findings from both the in vivo to in vitro models.