Concerns and Challenges of Nanotechnology

Learning objectives
- Environmental, ecological and health hazards of nanoparticles
- Nanotoxicology and its effect

One of the most oft quoted but extremely important sayings can be traced to the late physicist Richard A Feynmann. The expression “There is plenty of room at the bottom”, captured the minds of generations of scientists and triggered a whole new science and revolutionary technology. Nearly five decades after Feynman’s lecture, nanotechnology enhanced products are increasingly used in routine as well as high-end cutting-edge technology applications. More exciting possibilities exist in biomedical, energy and environmental related applications. Nano-engineered materials have witnessed extensive application in pollution control, purification and desalination of water and in effective waste management of hazardous by-products. It is a popular belief that the nano-revolution is set to have a far larger global econo-techno-political impact than the industrial revolution of the nineteenth century or the information technology revolution of the twentieth century.

There are indications that nanotechnology has the power to repair the brain. Fundamental properties of carbon nanotubes, such as higher thermal conductivity, are being used for making faster electrical signal conductors and to form intimate mechanical contacts with cellular membranes, thereby establishing a functional link to neuronal structures, which in turn can dramatically increase the speed of the brain.

Nanomaterials characterized by widely different defect dynamics have unique structural and functional properties in comparison to bulk materials. The high surface area-to-volume ratio of nanomaterials results in their higher chemical and biological activity as the surface atoms are unsaturated in their chemical bonds. With nearly a quarter or more atoms residing at the surface, nanomaterials can be exceptionally reactive. For example, using nanoscale silver fibres for water-purification filters has greatly enhanced the effectiveness of such filters.
Tiny science, huge concern

Nanotechnology can be characterized as passive or active. Passive applications are those in which the nanomaterial or its structure does not change form or function. For example, there are numerous cosmetics and silver-based anti-microbial products (including food containers and no-smell socks) and other products, ranging from tennis racquets to teas, that use nanomaterials.

Nanostructures or nanomaterials are said to be active when they are able to change their form or function. A simple example is an anti-cancer drug in which a dendrimer is designed to find cancer cells and then release a chemical that kills them. The increasing overlap of biotechnology and nanotechnology will eventually lead to nanosystems being used as robots.

Does nanotechnology pose health risks?

As science and technology develop and advance, the environment and ecological systems are at great risk, as there is a deviation from natural forces of equilibrium. From the primitive invention of fire by pre-historic humans to the development of advanced air transport systems, it has been seen that these technologies can also be employed for societal disturbances in the hands/minds of unethical groups of people. There are similar problems associated with nanotechnology.

Some nano-fabrication methods use toxic raw materials or produce toxic by-products (for example, some carbon nanotube synthesis routes). This needs to be fully investigated to understand the extent of the harmful effects of engineered nanoparticles, as the degree of influence is species specific and often depends on the size and geometry of the particle. Extensive research is underway to characterize the nanotoxicological effect of different nanoparticles on aquatic and animal species.

As discussed in Chapter 1, nanoparticles have a unique set of properties (physical, chemical and mechanical), widely different from their own bulk counterparts. A good review on the adverse effects of nanomaterials has been provided by Dr Fadeel of Karolinska Institute’s Division of Biochemical Toxicology, who has summarized the proceedings at the Stockholm Symposium on Nanotoxicology (There’s plenty of room at the forum: Potential risks and safety assessment of engineered nanomaterials, NanoToxicology, 2007). Extensive cross-disciplinary collaborations are therefore required to quantify and evaluate the risk assessment in detail. This will finally lead us to the goal of safe handling of nanotechnologies.

Once the safe limits of different nanomaterials are evaluated and tabulated, measures to mitigate the risks involved in undesirable exposure during manufacturing or service exploitation of nanomaterials can be achieved. There are also concerns on waste management of nano-enhanced products and their contribution to environmental pollution. There is a need for quantitative data followed by intensive scientific insight into the risks to human beings and the environment due to genetically modified organisms (GMOs) in agriculture and service applications.

As a result of these concerns, a new field of research termed as nano (eco-)toxicology has emerged in the last decade. This field studies the effect of engineered nanoparticles on living organisms. In the following sections, we will highlight the health and environmental issues...