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Perspective

Nanoparticles; Emerging Pollutants for the Environment

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Human beings have used metals for a long time since they learnt mining. Ever since then, metal contamination has increased in the environment, though substantial contribution of metal contamination occurred after industrialization in the early 20th century. However, the terms "contamination and pollution" differ in certain aspects. For example, contamination of the environment is accepted as the presence of elevated concentrations of contaminants which are higher than their background levels. On the other hand, pollution occurs after the introduction of contaminants due to anthropogenic activities that must result in some deleterious effects for organisms. In this context, the aquatic environments seem more susceptible than terrestrial ones, because nearly all contaminants released to the environments (water, air, soil) end up in the aquatic systems because of washing up by rainwater.

Recently, the usage areas of metals have widened after nanotechnological developments, as they have been used in the production of metal-oxide nanoparticles (NPs). These small particles (1 - 100 nm) are used in numerous areas in nanotechnology, because of their superior physical and chemical characteristics. Nanoparticles have high surface to volume ratio, high reactivity, special surface structure and unique electronic properties that make them desirable materials for many nanotechnological products. Some of the usage areas of NPs could be named as follows; aluminium NPs (fuel additive/propellant, explosive, wear resistant coating additive), copper NPs (antimicrobial, antibiotic treatment alternatives, nanocomposite coating, catalyst, lubricants, inks), titanium NPs (photocatalyst, antibacterial coating, sterilization, paint, cosmetics, sunscreens), zinc NPs (antibacterial coating, sterilization, paint, photocatalyst, cosmetics, sunscreens), nickel NPs (conduction, magnetic properties, catalyst, battery manufacturing, printing inks), silver NPs (antimicrobial, photography, batteries, electrical) and silica NPs (fabrication of electric and thermal insulators, catalyst supports, drug carriers, gene delivery, adsorbents, molecular sieves, and filler materials). It is suggested that NPs would be the dominant pollutants of the environment if their usages increase day by day and no precautions are taken by the authorities to set some limits for their discharges. Attention was also taken for their toxic effects, as they can pass through the cell membranes and accumulate in tissues of animals and consequently cause hazardous effects on organs, tissues, cells and molecules.

According to some estimation, the economic potential of NPs worldwide is about one trillion Dollar and is increasing day by day, due to their revolutionary potentials intrigue scientists, industrialists, medical professionals, and consumers. NPs are not merely small crystals, but an intermediate state of matter somewhere between bulk and molecular materials. Independent of their sizes, several parameters also play some roles in their magnetic, electrical, optical, mechanical, and structural properties. Many of these characteristics have potential implications in the toxicity of NPs, such as charge, shape, surface area, crystallinity, solubility, elemental composition, and surface chemistry.

Because of large data flow on the utility of metal-oxide NPs, there are great numbers of papers that have been published regarding NP toxicities in different classes of animals living both in the aquatic and terrestrial ecosystems. However, it is not easy to provide completely comprehensive data or establish concrete conclusions on the toxic effects of NPs, as their toxicities depend on many factors such as sizes, surface structures and metal types. Additionally, exposure concentrations and durations as well as biology of species in concern also affect

NP toxicity that hinder proper comparisons of papers in the literature. Once the toxic effects of NPs and mechanisms of occurred toxicity are universally recognised and explained, then some criteria or limits would be set for maximum tolerable concentrations of NPs in feed, wastes, waters and discharges.

The toxicity of NPs can be tested by several standardized approaches such as in vitro and in vivo, investigating the response of biomarker molecules. In vitro tests can serve as a preliminary tool for NP toxicity for subsequent in vivo tests. In vitro studies in the response of biomarkers have several advantages such as having rapid results with low cost and decreasing the number of sacrificed animals. Nevertheless, in vitro tests cannot replace in vivo tests, because behaviour of enzymes and other biomarker molecules can change during exposure to NPs, because of oxidative stress. Especially, enzymes that are used as biomarkers in ecotoxicology studies have shown to alter their turnover rates, affecting the results of in vivo experiments. There are other benefits of in vitro tests, as scientists can repeat the test easily if they are not sure about the results. However, in vivo tests need time and permission from the authorities, as well as huge financial costs depending on the scale of experiments.

Studies have shown that ionic metals and their NP forms may show different modes of actions, ionic metals being more toxic than NP forms of the same metals. Several reasons can be given to explain this situation such as the great diffusion capacity of ionic metals compared to relatively large NPs. Nevertheless, NPs have been documented to be toxic for the organisms, as they significantly altered the levels of biomarkers. However, the toxic effects of NPs seem more evident in vivo experiments rather than in vitro ones. Our own experience showed that in vitro exposure of NPs did not significantly alter the activity of some enzymes, though the activity of the same enzymes decreased following in vivo NP exposures. Therefore, it is suggested that the effects of NPs should be assessed by multiple ways (e.g. vitro and in vivo exposures), using biomarkers belonging to different systems and determining their tissue accumulation patterns. We demonstrated the accumulation of different NPs in different tissues of mussels, fish and rats by means of transmission electron microscopy. Consequently, our data showed that accumulated NPs by animals affected the levels of several biomarkers belonging to different metabolic systems, such as the antioxidant, osmoregulation, and nervous systems.

The route of NPs to enter animals or humans vary greatly depending on exposure sources. NPs can be inhaled by terrestrial animals or humans and taken up via food. NPs in the air would precipitate shortly as they are heavier than air and contaminate the soil or water that can pass to crops or fish and other aquatic organisms. NPs may be able to enter the body via routes such as the gastrointestinal tract, gill, lung and skin (via some creams), then enter into the bloodstream and accumulate different organs, including the brain. NPs reach the capillary junction then they may pose a systemic health problems and cells in the respiratory system such as macrophages and epithelial cells may come into direct contact with NPs after inhalation. In addition to passing through the blood-brain barrier, NPs may have reproductive consequences after penetrating the blood-testis barrier.

In conclusion, NPs bring many benefits to human life, but also have potential to contaminate the environments. Therefore, there must be some limit or criteria set for their usages and discharge to the environment. Scientists anticipate that NPs would be one of the dominant pollutants of the future unless some precautions are not taken.

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