Effects of Manmade Nanomaterials on the Environment

***Dr. Rashmi Pathak**

Abstract

Due to advancements in nanotechnology, nanomaterials are increasingly incorporated into various consumer products. The market value of engineered nanomaterials has reached €20 billion worldwide, and they are utilized in diverse industries such as energy, sensing, food technology, electronics, medicines, cosmetics, and materials. However, there are concerns about the potential adverse impacts of this technology on the environment. This review aims to provide an overview of published research on the potential effects of nanoparticles on ecosystems, their ecotoxicology, risks to human health and the environment, and the lack of information specifically in the context of In

Keywords: Engineered, Nanomaterial, Nano ecotoxicology, Bio-Nano Interactions

Introduction

Although nanoparticles have existed for millions of years, our growing capacity to alter matter at the nanoscale has focused attention on nanotechnology research internationally. Roco et al. forecasted that by 2020, there would be an estimated 6 million individuals working globally in the area of nanotechnology. Nanotechnology's fast advancement has opened up new possibilities for high performance applications and innovative product creation. The management and disposal of manmade nanomaterials, however, has raised concerns that they may have new, unfavourable effects on human health and the environment.

Governments all across the globe have begun putting laws and regulations in place to assess the threats that nanomaterials pose to human health and the environment. Reviews have mostly focused on the drawbacks and dangers of engineered nanoparticles.

Manmade nanoparticles

Nanomaterials are a category of substances that possess unique properties due to their extremely small size. The European Union defines "engineered nanomaterials" as intentionally created materials that contain particles either individually, as aggregates, or as agglomerates, with at least 50% of the particles falling within the size range of 1 nm to 100 nm in at least one external dimension.

Extensive research has been conducted on the toxicological and health effects of nanoparticles, focusing primarily on substances such as fullerenes, carbon nanotubes, quantum dots, ZnO, and titania nanoparticles. However, the data on nanoparticle toxicity is often inconsistent and conflicting, as different test methods are employed, making it challenging to understand and interpret the results.

Assessing the potential effects of nanomaterial interactions with the environment is complicated by ambiguous signals. Although there have been advancements in the precise characterization of nanomaterials, detecting and quantifying engineered nanoparticles (ENPs) in water and soil samples remains challenging. Additionally, nanoparticles pose challenges in terms of identification due to their interactions with other pollutants, which can influence their ecotoxicity. Moreover, nanoparticles undergo chemical changes in the environment and biological systems, altering their characteristics and reactivity. Furthermore, the presence of naturally occurring nanoparticles with the same composition as artificial nanoparticles further complicates their characterization in natural contexts.

Numerous studies have outlined the physicochemical principles governing particle behavior in an ecotoxicological context, as well as various methods that can be used to locate and measure ENPs in different biological and chemical matrices. Hyperspectral imaging (HSD) has been utilized by researchers to examine the interaction of optically active nanoparticles with biological media and cells, as demonstrated by White et al., Roth et al., and others.

Manmade nanoparticle toxicity

Nanomaterials are used widely because of their small size, large surface area, and enhanced reactivity. However, these very characteristics also increase the likelihood that they will cross cell membranes and enter inside cell organelles, unlike bulk materials with the same chemical composition. The findings of several in vivo and in vitro experiments comparing the behaviour of nanoparticles with those of their bulk counterparts indicate that their toxicity is increased. The impact of nanoparticles on organisms and their absorption, assimilation, and transfer are the subject of several research. Some of the most extensively researched ENPs are metal nanoparticles, carbon-based nanomaterials, and quantum dots.

An major pathway of nanoparticle toxicity is revealed to include the formation of reactive oxygen species (ROS). Oxidative stress is caused by the production of free radicals and ROS, such as hydroxyl radicals.

Large NP surface areas increase their intrinsic toxicity because organisms interact with them more readily.

Manmade nanoparticles' Eco toxicity

It's important to include both toxicity and ecotoxicity when evaluating the effects of nanomaterials. While toxicity focuses on a compound's negative consequences after absorption, ecotoxicity examines a compound's methods of absorption, bioavailability, and dependency on the environment. Ecotoxicity may change as a result of changes caused by variables including pH, temperature, and salinity.

There are worries that pollution may change the course of organic nanoscale processes. Nanoparticles may become less toxic or less readily absorbed by organisms via interaction with other species. Engineered nanomaterials tend to aggregate and clump together, and this relies on the form, size, and surface area of the individual particles.

Multiple designed nanoparticles are harmful to species even at low concentrations, according to evidence from multiple research, despite the fact that ecotoxicity studies on manufactured nanoparticles are lacking. Data on reactivity, transport, absorption processes, and persistence in the environment are needed to evaluate the hazard that ENPs pose to species.

Eco toxicity of nanoparticles made of carbon

C60 fullerenes are among the first synthetic nanoparticles whose ecotoxicity is being researched. Although various articles ascribed the hazardous effects to a THF breakdown product, Oberdörster was one of the first to explore that C60 may induce oxidative damage in fish (big mouth bass; Micropterus salmoides) even at concentrations as low as 0.5 mg/l.

Since then, there has been discussion and evaluation of C-60's negative health impacts. C-60 has been linked to oxidative, genotoxic, and cytotoxic reactions. Depending on the shape and chemical alterations of fullerenes, these effects change. Although Gharbi et al. demonstrate C-60 to be a potent anti-oxidant in a separate, contradictory work. The work entailed using C(60) to treat acute carbon tetrachloride poisoning in rats, demonstrating how C(60) might help shield rats' livers from free-radical damage in the absence of a polar organic solvent.

Variations in CNT toxicity are highlighted by Liu Y, et al via changes in elements including size, shape, contaminants, surface charge, and aggregation. They go through how CNT toxicity develops via oxidative stress, DNA damage mutation, and development to malignancy, as well as how different exposure routes affect the behaviour of the substance. Numerous research show that CNT toxicity is dependent on exposure circumstances, carbon nanotube type, structural features, surface qualities, chemical composition, dispersion state, and concentration.43-45

Despite the fact that further research is needed to provide a more thorough understanding of the toxicity of CNTs

Inorganic nanoparticles' Eco toxicity

Various produced items include inorganic ENPs, primarily Ag°, titania, ceria, zinc oxide, and iron oxides, which are linked to biota. According to Bottero et al., there is a significant correlation between biological malfunctions and the physico-chemical properties of very tiny nanoparticles. Even at very low concentrations, Ag and CeO2 are proven to be active. TiO2's photoactivity caused toxicity by producing ROS.

Xia et al. evaluated the cytotoxic effects of TiO2, ZnO, and CeO2 to clarify the connection between physicochemical qualities and cellular uptake and translocation. Reactive oxygen species (ROS), inflammation, and apoptosis are three mechanisms through which ZnO works. CeO2 nanoparticles prevented the generation of reactive oxygen species after being absorbed by cells, but TiO2, although having a similar uptake mechanism to CeO2, did not have either a protective or detrimental effect. This suggests that metal oxide nanoparticles may cause a range of biological reactions, from cytoprotective to cytotoxic.

Research has provided evidence of the cytotoxic and genotoxic potential of ZnO nanoparticles (NPs), which are extensively utilized in various industries such as electronics, textiles, paints, cosmetics, catalysts, biosensors, and medical devices. Multiple studies have shown that human lung epithelial cells are adversely affected by ZnO NPs, leading to disruption of mitochondrial activity, induction of apoptosis, and interference with glucose metabolism in these cells. In experiments with mice, single doses of ZnO nanoparticles were administered through injection, resulting in uptake by Leydig and Sertoli cells. This uptake triggered cytotoxicity due to DNA damage caused by an elevation in reactive oxygen species. Johnson et al. demonstrated that exposure to ZnO NPs led to an increase in the production of reactive oxygen species (ROS), which subsequently induced autophagocytosis in immune cells. Other studies have observed apoptosis in pulmonary epithelial cell lines and DNA damage in human epidermal cells as a consequence of oxidative stress and ROS, even at extremely low levels of ZnO NP exposure.

Experimental research using nanotitanium have shown genotoxicity in aquatic creatures and recorded lung damage and inflammation, as well as toxicity through oxidative stress in human cells (with potential in self-cleaning glass, affordable solar cells, and cosmetics).

A study investigating the impacts of brief exposures discovered that employees working in TiO2 production facilities exhibited elevated levels of oxidative stress, as well as damage to DNA, proteins, and lipids, as evidenced by the analysis of exhaled breath condensate (EBC).

Another kind of nanoparticle that has been commercialised and used in a variety of goods is silver. A significant proportion of AgNPs penetrate aquatic habitats, where they bioaccumulate and release Ag+ and cause the creation of ROS. Kwok et al. proposed that disturbance of sodium control was the cause of AgNPs' toxicity by observation of gene expression pattern. They discovered that the size of the silver nanoparticles affects their ability to dissolve, but that coatings also have an impact on toxicity and agglomeration. In contrast, Guo et al. revealed that the genotoxicity of AgNPs is significantly influenced by the size of the AgNPs. To determine the impact of nanosilver compared to ionic silver, a comparison of the genotoxicities of silver acetate and silver nitrate has been conducted.

QDs with uses in semiconductor technology, lasers, TV and computer displays, and medicine delivery might be hazardous to people's health. Quantum dots' absorption, transport, and toxicity are influenced by environmental variables as well as characteristics including size, charge, the quantum dots' outer coating, and their stability under oxidative and photolytic conditions.

Environmental Risks and Hazards

A lot of the information from toxicity research is based on trials done with organisms in lab settings, but findings aren't necessarily the same when the experiment is done in real surroundings. Although there have been many articles on nanotoxicology, it is still not apparent how serious the possible negative effects may be or if the advantages of new nanotechnology exceed the dangers. The existing research on the ecotoxicity of nanomaterials lacks a lot of the data necessary to assess possible risks and relate exposure to risk.

Evaluation of the form of the nanomaterial in the environment, transit, transformation, bioavailability, and bioaccumulation are necessary for hazard assessment. To assess risks, Gebel et al. recommend categorising nanoparticles based on exposure pathways and modes of action. Numerous current investigations use various models to assess the toxicity of various NPs, yet there is often a discrepancy between predicted values and actual observed values.

Studying sets of ENPs is required to quantify aspects including physicochemical attributes and biological response outcomes, which will aid in the development of dose-response relation data.

Conclusion

Nanotechnology has numerous applications across various aspects of our lives. It is important to conduct research in order to closely observe the presence and potential hazards of nanoparticles in environments where the risks remain uncertain. By doing so, we can ensure that the benefits of nanotechnology and nanoscience outweigh the associated challenges.

***Associate Professor**
Department of Chemistry
Government Bangur P.G. College
Pali (Raj.)

References

1. Guzman K.A.D., Taylor M.R. and Banfield J.F. (2006). Environmental Risks of Nanotechnology: National Nanotechnology Initiative Funding, 2000–2004. Environ. Sci. Technol., 40(5), 1401-1407. doi: 10.1021/es0515708
2. UNESCO Science Report (2015). towards 2030.
3. Roco M.C., Mirkin C.A. and Hersam M.C. (2011). Nanotechnology research directions for societal needs in 2020: summary of international study. J. Nanopart. Res., 13, 897-919. doi:10.1007/s11051-011-0275-5
4. Nowack B. and Bucheli T.D. (2007). Occurrence, behavior and effects of nanoparticles in the environment. Environ. Pollut., 150, 5-22. doi:10.1016/j.envpol.2007.06.006
5. Wiesner Mark R., Lowry Greg V., Alvarez Pedro, Dionysiou Dianysios and Biswas Pratim (2006). Assessing the risks of manufactured nanoparticles. Environ. Sci. Technol., 40(14),

4336-4345. doi: 10.1021/es062726m

6. Maynard A.D. (2007). Nanotechnology: Overviews and Issues. Nanotechnology-Toxicological Issues and Environmental Safety, Springer Publications, Netherlands, 1-14,
7. Roco M.C., Harthorn B., Guston D. and Shapira P. (2011). Innovative and responsible governance of nanotechnology for societal development. Nanotechnology Research Directions for Societal Needs in 2020, Springer Netherlands, 561-617.
8. Grieger K.D., Hansen S.F. and Baun A. (2009). The known unknowns of nanomaterials: describing and characterizing uncertainty within environmental, health and safety risks. Nanotoxicology, 3(3), 222-233. doi: 10.1080/17435390902944069
9. Hristozov D. and Malsch I. (2009). Hazards and risks of engineered nanoparticles for the environment and human health. Sustainability, 1(4), 1161-1194. doi: 10.3390/su1041161
10. Savolainen K., Alenius H., Norppa H., Pylkkanen L., Tuomi T. and Kasper G. (2010). Risk assessment of engineered nanomaterials and nanotechnologies-a review. Toxicology, 269(2-3), 92-104. doi:10.1016/j.tox.2010.01.013