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Nano plastics: The new frontier of pollution

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Introduction

Nanoplastics are particulate matter measuring less than a millimeter, constitute a pressing global environmental challenge. These ubiquitous particles infiltrate both biotic and abiotic components of the ecosystem. The indiscriminate use of plastics in daily life, both in their primary form as nanoplastics (e.g., in cosmetics) and as secondary microplastics (resulting from the degradation of larger plastics) poses a substantial environmental concern.

The Growing Prevalence of Microplastics and Nanoplastics

Due to their low manufacturing costs, versatile properties and durability, plastics have become indispensable in contemporary applications. Consequently, global plastic production has exhibited a steady upward trajectory; reaching an estimate of 350 million tons in a year and 0.5% plastic waste ends up in ocean and has risen by 7.11% since 2021.

Environmental Impacts

The low biodegradability of plastics, coupled with inefficient waste management and widespread use contributes to bioaccumulation in lower-trophic organisms such as plankton which in turn disrupt marine food webs. Plastics undergo fragmentation into smaller particles through mechanical abrasion, photo-oxidation and biological degradation generating secondary microplastics. Estimates suggest that secondary microplastics account for 70-80% of microplastics released into the

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environment, significantly outnumbering primary microplastics (15-31%).

Health Implications

Although the detrimental effects of nanoplastics on microbial organisms may be less pronounced, their impact on invertebrates and vertebrates is significantly more severe. Studies have demonstrated that oral exposure to nanoplastics in vertebrates can result in adverse outcomes including reduced somatic growth rates, impaired metamorphosis, decreased reproductive capacity and oxidative tissue damage.

Extensive research has explored the physiological, ethological and developmental impacts of these particles on marine organisms. Studies have investigated the effects of micro and nanoplastics on various developmental stages of various fishes revealing adverse outcomes. These include alterations in organ tissue structure; impaired locomotor and foraging behaviors having negative impacts on growth and the immune system as well as disruptions in lipid metabolism and neurotoxicity. The larval malformation and its developmental alterations were reported in mussel larvae after experimental administration of 100nm polystyrene beads for a long exposure in increased concentrations. Exposure of Zebra fishes (*Danio rerio*) to various microplastics induced intestinal alterations including villous disruption and enterocyte splitting, whereas nanoplastics showed an increase in glutathione S-transferase (GST) activity suggesting oxidative associated damage.

Recent studies have confirmed the presence of microplastics and nanoplastics in the gut of food animals including domestic fowl raising concerns about food safety. A study utilizing early chick embryos as a developmental model investigated the direct adverse effects of polystyrene nanoparticles (PS-NPs) on embryonic and fetal development. The findings revealed that PS-NPs can suppress embryonic development and increase the incidence of congenital abnormalities. Studies have also demonstrated that micro and nanoplastics can breach the intestinal barrier in mammals like rodents, leading to their accumulation in various organs. This can result in gut dysbiosis, decreased mucus secretion, metabolic alterations and neurotoxicity with other pathophysiological effects. Larger mammals such as rabbits have also been observed to absorb microplastics orally.

The primary routes of nanoplastics entering the human body include ingestion, inhalation and dermal absorption. The unique physicochemical properties of nanoplastics including their size, shape and surface area, facilitate their penetration of biological barriers and subsequent bioaccumulation in deeper tissues leading to further pathology.

Detection and Quantification

Hence, early detection of microplastics and nanoplastics in biotic and abiotic matrix is of utmost importance. To effectively address the challenges posed by microplastics and nanoplastics, it is imperative to develop robust methods for their detection and quantification. Scientists are employing a variety of techniques including microscopy, spectroscopy, thermal analysis etc. to identify and measure these particles in different in various matrices of environments.

Spectroscopy has emerged as a powerful tool for the detection and characterization of nanoplastics. By analyzing the interaction between light and matter, spectroscopic techniques can provide valuable insights into the chemical composition, size and shape of these minuscule particles. Raman spectroscopy, Infrared spectroscopy, Fluorescence spectroscopy, Surface-enhanced Raman spectroscopy (SERS) are some among them. These methods are highly specific, versatile and sensitive which plays a pivotal role in understanding the distribution, fate and potential impacts of nanoplastics in the environment and human health.

Nile Red, a fluorescent dye with a selective affinity for polymeric materials offers a rapid and efficient method for the detection and quantification of microplastics. The dye's fluorescence properties exhibited upon adsorption to plastic surfaces under blue light irradiation facilitate its identification. A recent soil study employed Nile Red staining to detect micro and nanoplastics in the faecal samples of earthworms (*Eisenia fetida*), confirming their ingestion of these particles.

Thermal analysis is another powerful tool for the characterization and detection of nanoplastics. By studying the physical and chemical properties of these materials as a function of temperature, thermal analysis techniques can provide valuable insights into their composition, structure and behaviour. Thermogravimetric analyses (TGA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA) are some of the common tools used in detection of nanoplastics in biological and abiotic samples. Thermal analysis can be used in conjunction with other analytical methods, such as spectroscopy and microscopy to provide a more comprehensive understanding of nanoplastic properties.

Conclusion

The growing prevalence of microplastics and nanoplastics represents a significant environmental and health concern. Addressing this issue requires a multifaceted approach; including reducing plastic consumption, improving waste management, and investing in research to better understand the risks associated with these particles. By taking proactive measures, we can mitigate the negative impacts of microplastics and nanoplastics on our ecosystems and human health.

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