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REVIEW

Microplastic: Characteristics, exposure pathways, toxicity, and implication for human health

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Abstract
Microplastics particles ranging from 1 μm to 5 mm, have gained attention for their omnipresence in marine environments and potential health risks. Initially recognized in the 1990s, microplastics are classified as primary (designed for microscopic dimensions) or secondary (resulting from degradation). Exposure pathways include ingestion, inhalation, and dermal contact, with sources ranging from food and beverages to personal care products. These particles possess unique properties, facilitating their interaction with organic contaminants and potential bioaccumulation in marine life. Their small size allows them to infiltrate ecosystems, raising concerns about their impacts on human health. Studies suggest associations between microplastic exposure and health issues such as inflammatory bowel disease and neurodevelopmental. Microplastics exhibit toxicity through mechanisms like oxidative stress induction and disruption of neurotransmitter levels. They have been detected in human tissues, including the brain, raising concerns about potential neurological impacts. To comprehend the effects on health over time, additional research is required, including biopersistence and tissue accumulation. Regulatory measures and consumer awareness initiatives are crucial to mitigate microplastic pollution and minimize health risks. Strategies to reduce plastic production, enhance recycling, and develop microplastic removal technologies are vital for protecting both human health and the environment. In summary, microplastics pose significant health risks due to their widespread presence and potential toxicity. Understanding their impacts and implementing effective mitigation strategies are essential for safeguarding human health and environmental integrity.

Keywords: microplastic, nanoplastic, polyestherin, blood brain barrier

Introduction

Worldwide since routine large-scale production in the 1950s, an expected 8.3 billion tons of plastic have been created, of which only a fraction remains functional today; 75% of this amount has become waste, the use of plastics continues to increase year after year, with current figures showing plastic creation surpassing 368 million tons in 2019 and the ongoing yearly worldwide plastic creation is assessed at 320 million tons each year, of which 40% are single-use items, chiefly plastic bags.[1] Furthermore, the waste produced was not discarded in the correct manner. As plastics swarm each part of life and afterward separate into more modest particles, the effect that miniature and nano plastics might have on the human body and the climate is a worldwide concern.[2]

Utilizing modern added substances, like colors, plasticizers, and stabilizers, permits plastics to be designed for different nanomaterials. Because of the substance strength of regular plastics, ecological collection is on the ascent. Once discarded, plastic waste is presented to organic, substance and natural components, and will separate into gigantic measures of microplastics (estimating <5 mm) and nanoplastics (<0.1 μm). Past examinations into plastic waste have taken a gander at the impact of microplastics on the

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climate, and this has been broadly examined in both established researchers and the media, including allures for institutional strategies to execute perilous characterizations of the destructive plastics.[2]

Microplastic particles can respond uniquely in contrast to their microsized parters as a reasonable comprehension connection of nanoplastic with the climate, living life forms, which are vital in evaluating conceivable wellbeing danger. The impacts of plastic is zeroing in predominantly on oceanic frameworks and just restricted information are accessible in regards to the effect of microsized plastic particles on human wellbeing, despite the fact that their development in the climate is expanding and in the manner of conceivable exchange to people by means the natural pecking order.[3]

Definition

In the early 1990s there was a relation depicting the conveyance of plastic sections in seawater.[4] No proper size definition was proposed at that point commonly is suggested the material must be related guidely by microscope.[5] The size of microplastics was examined at the main global exploration studio that's facilitated by NOAA, as impacts and destiny of microplastic marine trash in 2008.[6] Arthur et al.[6] as the members embraced a logical definition, proposed an upper size cutoff to the underlying term and microplastics where known as "plastic particles less than 5 mm. This definition was additionally refined in 2011[7], and recognized as microplastics, as from that starting point, into essential (created to be of minute aspects) or optional (coming about because of debasement and fracture processes in the climate). The Cooperative Gathering of Specialists on the Logical Parts of Marine Ecological Security (GESAMP), characterizes microplastics as 'plastic particles < 5 mm in width, and recognized as particles for the nano-size range (1 nm).[5] The definition for microplastics in the year 2018 was "Microplastics are any engineered strong molecule or polymeric grid, with customary or unpredictable shape and with size going from 1 µm to 5 mm, of one or the other essential or auxiliary assembling beginning, which are insoluble in water".[8]

Classification

Microplastics, which are obtained from debasement and scraped macroplastics, or primary microplastics, and designed small size from beginning, such as glitter in cosmetics and microbeads in scrubbers. In the ocean, microplastics can be form of fragments, beads, microfibers and dust from old tires. in shorelines, floating, or sinking in seawater, depending on their specific gravity (Table 1), which can also consumed by marine biota. Macroplastic debris which not properly handled on land will eventually reach the sea and undergo abrasion, becomes microplastic and stays for hundreds of years.[9]

Table 1. Plastics Classification[10]

Polimer	Relative Density	Applications
Polietilen (PE)	0.93-0.98	Plastic bags, bottles, straws.
Polistiren (PS)	1.04-1.11	Plastic cutlery, food containers
Polipropilen (PP)	0.89-0.91	Rope, bottle cap, net
Poliamida (PA)	1.13-1.50	Nylon fiber
Polivinil klorida (PVC)	1.20-1.45	Pipes, containers
Polietilen tereftalat (PET)	1.38-1.39	Soft drink plastic bottles
Polivinil alcohol (PVA)	1.19-1.35	

Plastics which produced in minuscule size are characterized as essential microplastics. Ordinarily utilized in facial-chemicals and beauty care products while their utilization in medication as vectors for drugs is progressively reported.[11] Extensive size meanings of a micro-plastic, virgin plastic creation pellets (commonly 2-5 mm in breadth) can be considered as essential microplastics. Auxiliary microplastics depict small plastic pieces got from the breakdown of bigger plastic flotsam and jetsam, both adrift and ashore.[4] Over the long haul a finish of physical, natural and compound cycles can decrease the underlying uprightness of plastic garbage, bringing about fracture.[7]

Plastics possess unique physical and chemical properties. They are organic polymers that are stabilized by the addition of additives such as bisphenols. Plastics also have adhesive properties that can attract bacteria to form biofilms on their surfaces.[3] Macroplastics pose a threat to the ocean primarily due to physical properties. They can cause entanglement, ingestion, and habitat destruction. On the other hand, microplastics have negative effects mainly due to their biochemical properties. Due to their hydrophobic nature, microplastics can attach to natural foreign substances, for example, polycyclic fragrant hydrocarbons, organochlor pesticides, and weighty metals.[9]

Exposure Pathways of Microplastics

Microplastics have potential to infiltrate human body through ingestion, inhalation, and skin contact. Several studies have investigated various sources such as food, beverages, and air, revealing significant disparities in the prevalence of microplastics. A study conducted in Germany revealed the presence of microplastic contamination ranging from 1-10 µm on untreated and treated drinking water facilities, with the main types being PET, PP, and PE. Additionally, microplastics were found in commercially bottled drinking water, irrespective of the bottle material (plastic, carton, or glass). Plastic bottled water showed the highest levels of microplastic contamination, followed by glass and carton packaging. This suggests that plastic packaging used for mineral water may introduce abrasive plastic microparticles directly into the human consumption.[12]

Marine microplastic contamination poses risks via seafood consumption. Transfer through trophic levels is observed, with notable instances such as PS spheres passing from mussels to crabs. Recent research highlights MP pollution along the food chain, impacting organisms like beach hoppers and fish. Human exposure mainly occurs through mollusks and fish, with varied MP levels. Mollusk MP abundance is documented, but fish data are limited, possibly due to feeding behaviors. Despite significant exposure estimates from mollusks, fish intake is lower. Accurate fish MP quantification is crucial for assessing seafood safety.[12]

Microplastic concentrations in the air display considerable diversity. In urban open-air settings, contamination originating from the atmosphere ranges between 53 to 118 particles per square meter per day. Meanwhile, indoor environments have shown levels of up to 59 microplastic particles per cubic meter of air, mostly comprising synthetic fibers, all mingled with indoor dust.[9] Dermal contact represents another recognized route of exposure to microplastics (MPs), although it appears to be more uncommon contrasted with ingestion and inward breath. MPs are frequently experienced dermally during exercises, for example, body cleaning (e.g., utilizing toothpaste, scours) and wearing apparel. With skin pores going from 40 to 80 µm, nanoparticles (<100 nm), manufactured filaments (<25 µm), monomers, and added substances might actually break the dermal hindrance. Regardless of the shortfall of reported human admission of MPs through this pathway in distributions, this could be credited to elements like example security, strategic impediments, and moral contemplations. Regardless, certain normal plastic added substances like brominated fire retardants (BFRs), bisphenols (BPs), triclosan (TCS), and phthalates are being researched for potential absorption during dermal exposure to MPs.[13]

These nanoparticles (NPs) have the potential to migrate and gather in various organs, such as the liver and kidneys. Many studies have indicated that nanoparticles ranging from 10 to 250 nanometers can breach the barrier and remain in the brain. Polystyrene plastic particles might arrive at the mind through the olfactory framework (nose) or circulatory framework (lungs and digestion tracts). Particularly, polystyrene particles smaller than 100 nanometers can travel through the axons of the olfactory nerve. They can also access the trigeminal and olfactory nerves, passing through the olfactory lot and entering the mind.[14]

The Toxicity of Microplastics

Plastics possess chemical inertness, furthermore, there's been no noticed biodegradation inside the human body up to this point. Despite the body's inability to metabolize microplastic (MP) particles, their impact on metabolism has been extensively documented. Moreover, MPs can serve as carriers for various harmful compounds, some of which can undergo metabolism, exacerbating harm. The absorption of MPs triggers diverse biological effects across different organs.[15]

Studies have indicated a increased incidence of interstitial lung disease and work-related symptoms among Dutch polymer factory workers, as per histopathological analysis, among employees in nylon flock plants in Canada and the USA. Recent findings have also linked ingested MPs to a a higher prevalence of fecal MPs in inflammatory bowel disease (IBD) patients and an increased severity of IBD compared to healthy individuals.[5] In a study conducted by Shan Shan in 2022, it was concluded that PS-NPs have the potential to gather in the mouse brain, activate microglia, and result in neuronal damage. Additionally, PS-

NPs were found to accumulate in hCMEC/3 cells and prompt the production of reactive oxygen species (ROS).[16]

Microplastics and Human Health

In terms of the circulatory system, inhaled MPs must pass via the lower respiratory district, which has a thin layer of discharge, and disperse into the distribution through paracellular transport as well as cell retention. Creating logical evidence supports the idea that people have MPs. While Schwabl et al. reported the presence of MPs in human feces, indicating their limited capacity to break through the intestinal barrier, Ibrahim et al. revealed the strength of MPs in cases from colectomy.[17]

Research has shown that PVC and PS particles smaller than 150 nanometer are transported from the intestinal cavity to the circulatory and lymphatic systems of both humans and animals. To study MP use, migration, and gathering, the mussel Mytilus edulis was employed. Following ingestion, MP builds up in the gut, travels to the circulatory system in three days, and stays there for more than 48 days. The extended identification of MP particles in the hemolymph of Medulis is also significant to hunters (including people, birds, crabs, and starfish).[17]

As a result, microplastics in the circulatory system may prevent blood flow, harming the tissue of blood vessels and altering the activity of the heart. It has been shown that the accumulation of different MP types in the heart is explained by trophic transfer via the circulation. The presence of MP has been shown to obstruct fibrotic processes, newborn cardiomyocyte apoptosis, and cardiovascular contractility in highly developed organisms. Negative interactions between MPs and NP and the growing heart include arrhythmias, reduced contractility in the developing heart and probably in the adult heart, loss of function, early failure of cardiac morphogenesis, and so on.[17]

A second study investigated the presence of microplastics in the human heart and surrounding tissue using laser-based infrared chemical imaging and scanning electron microscopy. Blood and microplastic samples of diverse tissues were taken from individuals undergoing heart surgery. While MP was not present in every tissue test, five different tissue types yielded nine different structures, the widest of which was 469 µm. Blood samples taken both before and after surgery showed the presence of MP members, the largest of which had a diameter of 184 millimeters. Following a medical procedure, the kind and size of MPs in the blood vary. This study provides solid proof that MP is present in the tissue of individuals undergoing heart surgery.[17]

To fully understand how different kinds of MP are introduced during surgery and the possible consequences they may have on human health, more research is required. MP particles can readily pass through biological barriers and become deposited in the digestive system due to their small size. From there, they can travel to many parts of the body, including as the kidneys, liver, blood, and mind. Transgenerational neurotoxicology in MPs is a recent development in the realm of toxicity studies. Recent studies have concentrated on the transgenerational neurotoxicity of nanoparticles (NPs) or microplastics (MPs) derived from the food chain. During embryonic development, these particles cross the blood-brain barrier and affect the function of genes and neurotransmitters essential in neural development. MPs and NPs possess the capacity to penetrate the blood-cerebrum barrier and elicit neurotoxic effects in several species.[18]

NPs cross the placenta after entering a fetus through the trachea or breast milk, impacting neurodevelopment and impairing cognitive function. Furthermore, NPs are more concentrated in the blood-mind barrier in the early underdeveloped stage, possibly as a result of the fetal blood-cerebrum barrier not forming, which gives NPs the ability to inflict neurological damage.[17]

Whether or not these findings raise the possibility of transgenerational neurotoxicity from MP/NP openness, more research is necessary to fully understand the cooperation mechanisms between MP/NPs and the blood-mind blockage during transgenerational migration or transport. Likewise, a plethora of research has examined the neurotoxic consequences of polystyrene and polyethylene micro- and nanoplastics on a range of aquatic species. When spherical polystyrene MP is exposed to Caenorhabditis elegans (nematodes), it causes excitatory toxicity that impairs locomotor activity, lowers survival rates, and shortens average life lengths. Furthermore, this openness results in oxidative stress, a downregulation of brain properties, and disruption of cholinergic and GABAergic neurons.[17]

Despite the perception that these particles may penetrate the atmosphere and perhaps form in human tissues, little is known about the implications of these particles for health, particularly in warm-blooded animals. The physiologic and cognitive effects of MP exposure were examined in a study using a rat model. After being exposed to water containing fluorescently labeled perfect polystyrene MPs for an extended period of time, C57BL/6J mice, both young and old, showed age-dependent changes in immunological markers and behavior in liver and mind tissues.[17]

The analysts looked on the implications of MPs for aging mammalian systems. When polystyrene microplastic particles (PS-MPs) measuring 0.1 and 2 µm were applied to U-2 operating system cells, their reasonability was reduced in vitro, indicating cytotoxicity. C57BL/6J mice fed PS-MP in their drinking water had behavioral changes for an extended period of time; these progressions were more pronounced in older animals. Tissue, systemic circulation, hepatic inflammation, and disruption of the blood-brain barrier are all demonstrated by the evidence. Age-related neuroinflammatory patterns were noted. These results, which show how MPs may change behavior, tissue accumulation, and inflammatory responses with age, underline the importance of more research into MPs' impact on human health. In their most recent work, they tested the blood-brain barrier (BBB) by giving mice different-sized polystyrene particles and allowing them to absorb the particles for a brief period of time. It was found that, in contrast to bigger particles, nanoparticles could effectively enter the brain in less than two hours.[17,18]

The biomolecular corona was shown to be essential in promoting particle passage through the blood–brain barrier using molecular dynamics simulations of the interaction between lipid layers and polystyrene nanoparticles. It was discovered that the presence of cholesterol molecules increased uptake, whereas the protein model inhibited this, offering insight into the particles' passive entry into the brain.[17]

To enhance the understanding of MP/NPs cytotoxicity at the cellular level (through the release of reactive oxygen species effects and cell viability), polyethylene and polystyrene MPs were employed to demonstrate the induced cytotoxic effects in T98G and HeLa cell lines (human brain and epithelial cells). Collaborations between MPs and humans may result in cytotoxicity, hypersensitivity, unintentional invulnerability reactions, and severe reactions like as hemolysis, all of which indicate a known risk to public health. Following a 24-hour exposure to T98G human brain cells, high content analysis (HCA) showed that PE and PS had EC50 values of 41.22 and 9.61 mg/L, respectively.[17]

Conclusions

There is a dearth of information regarding the uptake and toxicity of micro- and nanoplastics, despite their widespread presence in the environment. A few investigations have shown that miniature and nanoplastics are retained through various openness pathways by different creatures, including fish and vertebrates. This study shows that plastic particles can induce oxidative stress, inhibit AChE activity, alter neurotransmitter levels, and alter behavior in several instances associated with neurodevolopmental disorders and neurodegenerative disease, as demonstrated for metal nanoparticles. However, there is a significant knowledge gap regarding the potential neurotoxicity of micro- and nanoplastics.

The effect of plastic contamination on the climate has been generally considered, yet it is as yet indistinct how the utilization of plastic by warm blooded creatures, including people, can affect their wellbeing. The recent findings regarding the transfer of plastic particles serve as an important foundation for additional research and regulatory measures aimed at minimizing their harmful effects on human health. We can make down to earth techniques and suggestions to lessen the mischief related with plastic use and safeguard human wellbeing by better grasping the cycles hidden the harmfulness of plastic particles. MPs can enter the body via ingestion, inhalation, and contact with the skin, all of which are common environmental sources..

Deciding the drawn out wellbeing effects of MP openness should be possible by concentrating on MP biopersistence and its conceivable aggregation in different tissues. To restrict openness to MPs and energize harmless to the ecosystem rehearses, changes in regulation and customer conduct can be affected by expanding public information on conceivable wellbeing dangers related with MPs. Since biological system wellbeing falls apart straightforwardly with human wellbeing, microplastic pollution can adversely affect the climate. In addition to developing technologies that remove MPs from our environment, every effort should be made to reduce the production and use of plastics, increase recycling, and dispose of plastics in a way that is safe for the environment. To reduce the potential harm MPs and parliamentarians may cause to our health, this must be done until these issues are resolved.

The majority of experimental research carried out on laboratory animals nowadays is comparative in nature. Technical and ethical constraints have prevented the conduct of experimental research on humans. Furthermore, petrochemical polymers—which are essentially hydrocarbon derivatives of crude oil do not make up microplastics; they also include other chemicals like phthalates, DDT, and bisphenol A, all of which might have harmful consequences.

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