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MICROPLASTICS: IMPACT ON THE ENVIRONMENT AND MITIGATION EFFORTS

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Microplastics (MPs) are plastic particles smaller than 5 millimeters, emerging as a major environmental issue due to their widespread presence and persistence. They are classified into primary and secondary types: primary microplastics are intentionally manufactured small particles found in products like facial scrubs and textiles, while secondary microplastics result from the degradation of larger plastic items, such as bottles and fishing gear. Plastics are valued for their durability, versatility, lightweight nature, cost-effectiveness, chemical resistance, and insulating properties, but these same attributes contribute to their environmental impact. Microplastics are pervasive, contaminating water, food, and soil. They affect ecosystems and wildlife, with adverse effects on aquatic species, soil health, and microbial communities. In humans, MPs can cause gastrointestinal and respiratory issues and may disrupt endocrine functions and contribute to chronic diseases. Mitigation strategies include improving waste management, reducing single-use plastics, and developing biodegradable alternatives. Advances in technology, like mutant enzymes and photocatalytic robots, offer hope for addressing plastic pollution. Public awareness and educational campaigns are essential for tackling the microplastics crisis and encouraging responsible plastic use and recycling.

Keywords: Microplastics, environment, pollution, public health.

INTRODUCTION

Microplastics (MPs) are small plastic particles that measure less than 5 millimeters (0.2 inches) in diameter. They are a form of plastic pollution that has become a significant environmental concern due to their widespread presence and persistence in various ecosystems. Microplastics are typically categorized into two main types: primary and secondary. Primary microplastics are intentionally manufactured to be of small size for specific uses. Common sources include: Microbeads – tiny plastic beads used in personal care products such as facial scrubs, toothpaste, and shower gels for their exfoliating properties; plastic pellets (nurdles) – small granules used as raw material in the production of larger plastic items; microfibers – fine synthetic fibers shed from clothing and textiles during washing and wear. Secondary microplastics originate from the degradation of larger plastic debris. Larger plastic items break down into smaller fragments due to environmental factors such as UV radiation, physical abrasion, and chemical processes. Examples include: plastic bottles and bags – common single-use items that degrade into smaller pieces over time; fishing gear – lost or discarded fishing nets and ropes that fragment into microplastics[1].

While microplastics are primarily known for their negative environmental and health impacts, some qualities inherent to plastics, in general, can be seen as advantageous in specific contexts. These qualities are often the reasons why plastics, and subsequently microplastics, are so widely used in various industries. Some of these qualities include:

1. *Durability and Longevity*: Plastics are highly durable, resistant to corrosion, and can withstand various environmental conditions without breaking down quickly. This makes them suitable for long-lasting applications. The same durability means that plastic products can have a long life span, reducing the frequency of replacements and waste in certain applications.

2. *Versatility and Flexibility*: Plastics can be molded into virtually any shape, allowing for a wide range of applications from packaging to automotive parts. They can be engineered to have specific properties, such as being flexible or rigid, transparent or opaque, making them suitable for diverse uses.

3. *Lightweight: Plastics* are generally lightweight compared to materials like metal or glass. This reduces transportation costs and energy consumption, particularly in industries like aviation and automotive, where reducing weight can lead to significant fuel savings.

4. *Cost-Effectiveness*: Plastics are relatively inexpensive to produce, which makes them an economical choice for manufacturers and consumers. The production of plastics often requires less energy compared to materials like metals, contributing to cost savings and lower energy consumption.

5. *Chemical Resistance*: plastics are resistant to many chemicals, making them ideal for use in packaging for food, pharmaceuticals, and hazardous materials, as well as in medical devices and laboratory equipment.

6. *Insulating Properties*: plastics are good insulators of electricity, which is why they are widely used in electrical and electronic applications. Certain plastics provide good thermal insulation, useful in construction and packaging industries.

7. *Hygiene and Safety*: plastics are used in medical and food packaging due to their ability to be easily sterilized and maintained in a hygienic state. In applications like childproof containers and safety gear, plastics provide necessary protection and compliance with safety standards.

8. *Innovative Applications*: microplastics in controlled forms are used in medical applications such as drug delivery systems, where their small size and durability are beneficial. Innovations in microplastics have led to their use in creating lightweight composites for aerospace and automotive industries, enhancing performance and efficiency.

Nowadays, plastic production totals 368 million metric tons and, unfortunately, is growing significantly each year. Research indicates that at least 14 million tons of microplastics have accumulated on the world's ocean floor to date[2], with an estimated 1.5 million tons more entering the oceans each year[3].

A recent study indicates that individuals consume an average of 39,000 to 52,000 microplastic particles annually. This estimate is based on research evaluating the microplastic content in various foods. When including estimates for inhaled microplastic particles, the total can reach approximately 74,000 particles. Additionally, consuming tap water adds another 4,000 particles, while drinking bottled water increases the number by 9,000 particles[4].

IMPACT OF MICROPLASTICS

Microplastics fragments are ubiquitous in the environment, from the highest point on Earth, Mount Everest[5] to the Arctic deep-sea sediments[6]. MPs have a wide range of detrimental effects on the environment, impacting ecosystems, wildlife, and potentially human health.

Water

Rivers are the main transport routes for plastic waste from land to the oceans, moving 1 to 2.5 million tons annually. MPs have been detected in high concentrations, particularly in Asian water bodies, followed by North and South America, and European rivers due to varying regulations[7]. MPs are found as films, fibers, shreds or foam and are prevalent even in tap water. A study found that 81% of 159 global tap water samples contained MPs, averaging 5.5 particles per liter[8]. MPs also contaminate soils, including greenhouses, gardens, agricultural lands, floodplains, industrial, and coastal areas. Urban runoff and stormwater carry microplastic particles from litter into water systems. Wastewater treatment plants are not fully effective at removing MPs, allowing them to enter rivers, lakes, and groundwater. Fragmentation of larger plastic items due to weathering releases MPs into the environment, which can then be transported by wind, runoff, and wave action to various water bodies.

Recent studies have detected microplastics in mineral water contained in plastic bottles made of polyethylene terephthalate (PET). Analysis of 30 bottles from 10 different brands revealed microplastics in all samples, with concentrations ranging from 3.16 ± 0.7 particles/L to 1.1 ± 0.8 particles/L.[9] Poor-quality, thin, and easily deformable plastic bottles tend to release more and smaller microplastic particles. Additionally, microalgae in the water column can interact with microplastics, adsorbing them on their surfaces. This interaction can block their pores, limiting the transfer of energy, oxygen, carbon dioxide, and nutrients, thus affecting their functionality[10].

Food salt

Sodium is crucial for maintaining balance in the human body and is primarily ingested as table salt (sodium chloride, NaCl). Sea and lake salts are typically made by evaporating seawater or brine through natural processes involving sunlight, heat, and wind. There are worries that contaminants from the water may be transferred into sea salt during this evaporation and concentration process.

A study by Yang *et al*. found that sea salts from China contained up to 681 microplastic particles per kilogram, although the specific chemical makeup of these microplastics was not analyzed. Another study which studied the occurrence of MPs in most of the commercial salts revealed that some salt brands contained between 1 to 10 MPs/Kg of salt. They extracted 72 particles, 41.6% of whom were plastic polymers, 23.6% were pigments, 5.50% were amorphous carbon, and 29.1% remained unidentified. The particle size (mean ± SD) was 515 ± 171 μm. The most common plastic polymers were polypropylene (40.0%) and polyethylene (33.3%) in form of fragments, filaments and films[11].

Soil

Microplastics can carry harmful environmental contaminants, such as persistent organic pollutants (POPs) and heavy metals, from sources like wastewater, urban runoff, and landfill leachates. These pollutants, which include substances like polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and herbicides, can adhere to microplastics and be transferred to soil, potentially impacting soil biota and plant life. Studies show that microplastics can absorb heavy metals and act as vectors, transporting these contaminants into deeper soil layers or making them available for plant uptake. Microplastics can also cause physical harm to soil animals, with impacts like gut damage and impaired metabolism in larger animals, and survival issues in smaller organisms like earthworms. Plants growing in contaminated soil may experience reduced biomass. Overall, the presence of microplastics in soil poses significant ecological risks, affecting growth, reproduction, and health of soil organisms and plants. Further research is needed to fully understand these effects[12,13].

The transport and impact of microplastics within soil are influenced by several factors:

– Soil Texture: Microplastics accumulate more in soils with higher clay and silt content due to smaller pore sizes and higher retention potential.

– Organic Matter: Organic matter can bind to microplastics, facilitating their movement through the soil.

– Soil Organisms: Earthworms and other organisms create burrows and channels, aiding microplastic transport[7].

Microplastics alter soil properties by increasing compaction, reducing water and air infiltration, and negatively affecting root growth and nutrient availability. They can also form soil aggregates, impacting soil structure and stability. Additionally, microplastics influence nutrient cycling by adsorbing nutrients like nitrogen and phosphorus, reducing their availability for plants and microorganisms[14]. They can also disrupt microbial communities, affecting essential nutrient cycling processes such as nitrogen fixation and organic matter decomposition.

Aquatic species

Invertebrates

MPs decrease foraging activity and fertility, slow larval growth, increase oxygen consumption, and reactive form production. However, comparative studies on the effects of MPs are limited.

Mammals

Mammals are exposed to microplastics thorough ingestion, inhalation, dermal contact, transplacental transfer, and trophic transfer. MPs can accumulate in the gastrointestinal tract, causing blockages, nutrient absorption issues, and gut microbiota disruption. Additives in plastics, like plasticizers, can leach into tissues, causing endocrine disruption, reproductive issues, and developmental problems. Moreover, MPs can induce oxidative stress, inflammation, and immune system dysregulation, leading to health issues. MPs move up the food chain, leading to bioaccumulation in mammalian tissues, posing health risks.

Fish

MPs were found in intestines, back muscles, and gills of fish in the northeast Atlantic, causing increased lipid peroxidation in muscles, gills, and brain. MPs can also lead to disruption of acetylcholinesterase activity in the brain. Studies have shown that small MPs (≤5 µm) cause more significant toxic effects than larger ones. MPs affect feeding behavior, musculoskeletal system effectiveness, and breeding activity. They accumulate in tissues, worsening histological and biochemical changes. Nanoparticles cause hyperactivity or weakness, affect cortisol levels, heart rate, blood sugar, inflammatory response, and hepatic lipolysis. Larger particles (5 mm) can lead to liver steatosis, changes in liver and intestine, lipid metabolism disruption, and gene expression changes related to oxidative stress[15].

Microorganisms

Microplastics interact with microbial communities in various ways, leading to significant ecological implications.

Microorganisms colonize microplastics, forming biofilms that consist of a complex matrix of microorganisms and extracellular polymeric substances (EPS). This colonization can alter the physical and chemical properties of microplastics, affecting their fate and transport in the environment.

Microplastics provide surfaces for microbial attachment, creating microhabitats that support microbial communities. These microorganisms can degrade microplastics enzymatically, influencing the persistence and breakdown of plastics. Microplastics can alter microbial community composition and structure. Specific microbial taxa colonizing microplastics can shift community dynamics, potentially favoring certain species, which can impact ecosystem functioning and nutrient cycling[15].

Regarding microbial activity, MPs have varied effects. They can stimulate microbial growth and increase nutrient cycling rates, but also reduce microbial respiration and impair enzymatic activity, highlighting the complexity of microplastic-microbe interactions.

Changes in microbial diversity and function due to microplastics can disrupt carbon and nitrogen cycles. Reduced microbial activity can slow organic matter decomposition, leading to carbon sequestration and impacting global climate patterns. Similarly, impaired nitrogen cycling can reduce nitrogen availability for plants, leading to potential nutrient limitations in ecosystems.

Human health

Microplastics have several potential effects on human health, primarily through ingestion, inhalation, and skin contact. Once ingested, microplastics can accumulate in the digestive system and potentially cause gastrointestinal issues. The ingestion of microplastics can lead to three main stages of health impacts:

Digestive blockage and damage: microplastics can physically block or damage the digestive tract.

– Chemical release: they can release toxic chemicals into the body.

– Organ assimilation: The chemicals and microplastics can be absorbed by various organs, including the liver and kidneys, causing further harm. They might disrupt gut microbiota, cause inflammation or damage to the intestinal lining, or affect liver function, potentially leading to conditions such as non-alcoholic fatty liver disease (NAFLD) (Lee Y, 2023). They are detected in human feces, with polyethylene and polypropylene being common types. About 90% of MPs are excreted from the body[7].

Microplastics can also become airborne and be inhaled. This is a particular concern in urban environments with high levels of pollution or from sources like vehicle exhaust and industrial emissions. Inhaled microplastics can lodge in the respiratory tract and lungs, potentially causing or exacerbating respiratory conditions, such as asthma or chronic obstructive pulmonary disease (COPD). There is also concern about the potential for microplastics to enter the bloodstream and affect other organs.

Direct contact with microplastics, particularly in personal care products like exfoliating scrubs, can lead to skin irritation or allergic reactions. The impact of long-term exposure is still under investigation.

There is concern about the long-term effects of microplastics accumulating in the body and their potential to cause chronic health issues, including endocrine disruption, reproductive health problems, and cancer[14]. There is evidence that microplastics may affect neurological health. They could contribute to neurodegenerative diseases by inducing oxidative stress and inflammatory responses, impacting brain function and behavior[17]. However, comprehensive studies are still needed to fully understand these risks.

Overall, while there is growing awareness and research into the health impacts of microplastics, many of these effects are still being studied, and more research is needed to determine the full extent of their impact on human health.

MITIGATION EFFORTS

To address the global plastic pollution crisis, a multifaceted approach is needed. Immediate actions include establishing comprehensive monitoring programs to identify sources, distribution, and abundance of microplastics in land environments, reducing single-use plastics and enhancing waste management and recycling systems.

Developing standardized methods to detect and measure microplastics and nano-plastics is essential. Regular sampling and analysis of soil, sediment, and vegetation are essential to track microplastic presence and concentration over time. Promoting environmentally friendly and cost-effective alternatives to traditional plastics, such as biodegradable options, is crucial. Recent advances include a mutant enzyme that rapidly breaks down plastics and bacteria like "Ideonella sakaiensis" that can digest PET plastics (Sevilla ME, 2023).

Other promising methods involve photocatalytic robots that degrade microplastics using light-driven technology. Additionally, addressing heavy metal contamination from plastics is important, with research focusing on effective detection and removal methods.

Moreover, it is of utmost importance to promote biodegradable or compostable materials, to raise public awareness about the impacts of microplastics on land ecosystems, as well as to conduct educational campaigns to inform individuals about the sources and consequences of microplastic pollution and to include educational programs in schools, community workshops and to implement strict regulations and policies to encourage proper waste disposal and recycling

CONCLUSIONS

In conclusion, the pervasive issue of microplastics presents a complex and multifaceted challenge that extends across environmental, ecological, and human health domains. Their impact on the environment is profound, affecting water bodies, soils, and ecosystems in ways that disrupt natural processes and harm wildlife. The advantages of plastics have led to their widespread use, but these same characteristics contribute to the persistence of microplastics in the environment. The health implications for humans – ranging from potential gastrointestinal damage to respiratory and systemic effects—highlight the urgent need for further research to fully understand and mitigate these risks.

Promoting sustainable alternatives, such as biodegradable materials, and developing innovative technologies for plastic degradation are crucial steps. Regulatory measures should be implemented to support responsible production, waste disposal, and recycling practices. Furthermore, public awareness and education campaigns are essential to foster a culture of environmental stewardship and to drive behavioral changes that reduce plastic pollution.

The path forward demands a concerted global effort, combining scientific research, technological innovation, regulatory action, and public engagement to mitigate the impact of microplastics and protect both our environment and human health. As we advance, it is imperative to maintain vigilance and adapt strategies in response to emerging data and evolving challenges, ensuring a sustainable future free from the pervasive threat of microplastic pollution.

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