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REVIEW

Micro and nanoplastics: a global threat to health and the environment

Micro y nanoplásticos: una amenaza global para la salud y el ambiente

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ABSTRACT

Over recent decades, the mass production of plastics has significantly transformed consumption patterns and industrial processes, with environmental and health consequences. Among these, the growing presence of micro- and nanoplastics, tiny particles derived from the degradation of larger plastics or manufactured directly, stands out. These particles were detected in various ecosystems and in the human body, which generated scientific concern. The studies reviewed revealed that these pollutants acted as vectors of toxic substances, affecting biodiversity and posing a risk to human health by causing inflammation, endocrine disruptions and transgenerational effects. Despite advances in detection technologies and mitigation strategies — such as recycling, the circular economy and biodegradation — challenges persisted in the standardisation of methodologies, toxicological knowledge and regulatory development, making an interdisciplinary and coordinated approach urgent.

Keywords: Microplastics; Toxicity; Ecosystems; Health; Regulation.

RESUMEN

Durante las últimas décadas, la producción masiva de plásticos transformó significativamente los patrones de consumo y los procesos industriales, generando consecuencias ambientales y sanitarias. Entre ellas, destacó la creciente presencia de micro y nanoplásticos, partículas diminutas derivadas de la degradación de plásticos mayores o manufacturadas directamente. Estas partículas fueron detectadas en diversos ecosistemas y en el cuerpo humano, lo que generó preocupación científica. Los estudios revisados revelaron que estos contaminantes actuaron como vectores de sustancias tóxicas, afectando la biodiversidad y representando un riesgo para la salud humana, al causar inflamación, disrupciones endocrinas y efectos transgeneracionales. A pesar de los avances en tecnologías de detección y estrategias de mitigación —como el reciclaje, la economía circular y la biodegradación—, persistieron desafíos en la estandarización de metodologías, el conocimiento toxicológico y el desarrollo normativo, lo que hizo urgente un enfoque interdisciplinario y coordinado.

Palabras clave: Microplásticos; Toxicidad; Ecosistemas; Salud; Regulación.

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INTRODUCTION

In recent decades, the mass production of plastics has significantly transformed consumption patterns and industrial processes worldwide. This transformation, driven by the physical and chemical properties of polymers, has contributed to economic and technological development, but has also generated serious environmental and health consequences. One of the most worrying is the growing presence of micro- and nanoplastics, tiny particles that result from the degradation or direct manufacture of plastic products. These emerging contaminants have not only been detected in various ecosystems, including the most remote on the planet, but also in the human body, raising alarm among scientists and international organizations.[1,2]

This review aims to analyze the impact of micro- and nanoplastics on both the environment and human health, highlighting their origin, exposure routes, toxic effects, detection techniques, and main mitigation strategies. Through the analysis of updated scientific literature, we aim to contribute to understanding a phenomenon whose magnitude and complexity require an interdisciplinary approach, as well as a joint commitment between governments, scientific communities, and civil society.

DEVELOPMENT

The exponential growth in the production and use of plastics has been one of the most distinctive features of modern society, with applications ranging from industry to the home. Their durability, low cost, and versatility have made them essential materials for developing various human activities.[3] However, this same durability has led to an unprecedented environmental crisis. According to Geyer et al.[4], between 1950 and 2015, more than 8,3 billion tons of plastic were produced, of which only 9% was recycled, while the rest was incinerated or dumped into the environment.

One of the main problems arising from the massive use of plastics is the generation of microplastics (MP) and nanoplastics (NP). Microplastics are defined as solid particles between 1 µm and 5 mm in size, while nanoplastics are particles smaller than one µm, even reaching nanometric ranges between 1 and 100 nm (ISO/TR 21960:2020, cited in Lehner et al.[1]). These fragments can be generated intentionally (primary microplastics) or derived from the degradation of larger plastics (secondary microplastics) through processes such as photodegradation, oxidation, hydrolytic degradation, or mechanical abrasion.[1,5]

Various studies have revealed that these pollutants are present in terrestrial, aquatic, and atmospheric ecosystems and even in remote environments such as the poles and glaciers.[2] According to studies by Plastics Europe,[6] more than 368 million tons of plastic were produced in 2019, suggesting that the volume of microplastics in the environment has also increased proportionally. This situation is exacerbated by inefficient recycling systems and inadequate waste management, especially in developing countries.[7]

Microplastics act as vectors of pollutants because they can adsorb toxic substances such as heavy metals, pesticides, and persistent organic compounds, thereby increasing their toxicity.[8,9] Once ingested by living organisms, these contaminants can enter the food chain and bioaccumulate, causing adverse effects on human and animal health.[10,11]

From a human toxicology perspective, micro- and nanoplastics can enter the body through the digestive, respiratory, or dermal routes and cause effects such as oxidative stress, chronic inflammation, endocrine disruption, neurotoxicity, and metabolic alterations.[12,13] The type of polymer, its size, shape, and the chemical additives present in its structure largely determine its level of toxicity.[14,15]

For example, bisphenol A (BPA) and phthalates, common additives in plastics, have been extensively studied for their ability to interfere with the endocrine system, affecting fertility, fetal development, and thyroid function.[16] Similarly, recent studies have documented the presence of microplastics in the human placenta, suggesting prenatal exposure that could have transgenerational implications.[17]

In the environmental sphere, microplastics affect biodiversity and alter ecological cycles. In marine environments, for example, they interfere with numerous species' feeding and reproductive behavior, from zooplankton to large fish and marine mammals.[18,19]

These emerging pollutants are detected and analyzed using techniques such as FTIR, SEM, ICP-MS, and TEM, which allow their composition, origin, and morphological characteristics to be identified.[20] However, standardization of these methodologies remains challenging.[5]

Given this situation, various mitigation strategies have been proposed, ranging from improved waste management to implementing a circular economy based on reduction, reuse, and recycling.[21] Biotechnological methods are also being developed, such as using microorganisms capable of biodegrading certain plastics.[22,23]

In terms of regulations, international organizations such as the UN, WHO, and the European Union have begun to take regulatory measures to limit the use of microplastics in consumer products and promote scientific research on their effects.[24] Although legislative progress is still in its infancy in Argentina, bills have been introduced to ban microplastics in cosmetics and improve packaging management.[25,26]

The study of micro- and nanoplastics is an emerging field that requires an interdisciplinary approach, given their ubiquitous and persistent nature and potential to generate environmental and health impacts. As Perilla-Portilla et al.[27] warn, we face an invisible threat that requires urgent attention from science, politics, and society.

CONCLUSIONS

The available scientific evidence strongly demonstrates that micro- and nanoplastics constitute a global, persistent, and expanding threat whose implications go beyond the environmental sphere to directly affect human health. Their ability to act as vectors of contaminants, their persistence in ecosystems, and their presence in human biological tissues position them as one of the main challenges of the 21st century concerning pollution.

Although advances have been made in detection technologies and mitigation strategies, gaps in knowledge regarding toxicity

mechanisms, chronic exposure, and synergy with other chemicals require further research. Likewise, there is an urgent need to strengthen regulatory frameworks and public policies that reduce the production and indiscriminate use of plastics, while promoting sustainable alternatives within a circular economy framework. In this context, the approach to micro- and nanoplastics must be comprehensive, based on scientific evidence, and focused on the well-being of people and the planet.

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