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Effects of micro and nanoplastics on human health: A narrative review

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ABSTRACT

For over a century and a half, since the creation of the first synthetic polymer derived from cellulose, a new material of high durability, versatility, and low cost has coexisted with humanity, which has since enjoyed its benefits and suffered various consequences, whether from direct or indirect effects of this material on health. The presence in the environment and human contact with micro and nanoplastics derived from these polymers can result in acute and chronic damage, with serious health consequences for all age groups. This narrative review presents some characteristics of the different contamination routes and mechanisms of action in the human body caused mainly by the inhalation and ingestion of micro and nanoplastics, and their effects on the various organs and systems of the human body.

Keywords: *microplastic- nanoplastic - pollution - human health - environmental contamination*

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Introduction

Since 1862, when Alexander Parkes, an English metallurgist, created parkesine from cellulose, recognised as the first synthetic polymer in history, humanity has lived with a new material of high durability, versatility, low cost, and the ability to be moulded into various shapes, which gives it great utility for the production of the most varied objects of daily use [1].
The term plastic derives from the Greek term "plastikos," which means moulding or that which can be moulded, and has been used to designate various types of polymers such as polyethene, polyamide, polyester, polyurethane, neoprene, polystyrene, and polypropylene, among others, which are necessarily present in everyday life and in all environmental compartments of the planet [2].
However, in contrast to the benefits presented by their widespread use, plastics have become a global health problem due to their long durability, difficulty in being degraded, accumulating on the planet and being ubiquitous in the food chain, causing continuous human exposure to these residues that can remain in the environment for long periods, taking up to more than 100 years to degrade [3-6].
Plastics improperly discarded in the environment undergo fragmentation into microplastics (MP) and nanoplastics (NP) through various processes such as oxidation, photodegradation, biodegradation, degradation by abrasion and other mechanisms, which generate an exponential number of particles. Their widespread detection in various locations reveals the scope and ease of dissemination of these wastes [7,1,8]. Plastic particles found in the environment can pose risks to human health in three ways: a) biological: due to the production of biofilms that can carry pathogenic microorganisms, b) chemical: due to the adsorption capacity of the plastic and c) physical: with the creation of barriers that can impede cellular functions [7,8,10-13].
Since 2004, numerous adverse effects on human health have been reported, caused by both MP and NP and by other substances added to their chemical structure in order to alter their characteristics, making them more moldable.
Such substances with plasticising properties, various pigments, flame retardants and stabilisers also pose a risk to human health [11,14-16].

What are microplastics and nanoplastics?

MPs are defined as solid polymer particles with a diameter between 1 µm and 5 mm. NP are particles with a diameter less than 1 µm. They are subdivided into primary: when intentionally produced in small sizes, such as microspheres present in cosmetics, personal hygiene and cleaning products; and secondary: resulting from the degradation and fragmentation of larger plastics by natural erosion, the action of heat, natural light, biological and chemical processes [3,7,17].
The direct impacts of MP and NP on health are influenced by the type of polymer, size and shape of the particles and additives used in plastic processing [1,6,18]. Small particles can easily cross epithelial barriers and enter the systemic circulation [19].

Routes of contamination and mechanisms of action in the organism

Living beings are exposed to PM and NP in various ways, such as ingestion and inhalation (the main ones, and in a continuous and unavoidable manner), in addition to dermal contact, occupational exposure, and treatments that use equipment inserted into the body (IM/IV injections, catheters, etc.) [6,7,14,15,17].
It is estimated that, annually, humans ingest approximately 52,000 PM and NP through food and water alone [15,20] and inhale between 13,000 and 68,000 particles [19,21].
The absorption of these particles in the body is influenced by characteristics such as hydrophobicity, surface electrical charge, functionalization, size, and surrounding protein coat, which can facilitate their entry into the bloodstream [3,22].

After being absorbed into the human body, these fragments are distributed systemically via blood and lymphatic circulation throughout the body [16] and can interfere with metabolic pathways and unbalance various organs and systems through morphological and physiological changes [5,11,15,17,21,23,24], in addition to gradually accumulating in the body due to their low excretion rate [25].

Although epithelial barriers such as the intestinal lining and the respiratory tract epithelium are designed for protection against foreign and harmful agents, microparticles can cross them through different mechanisms, such as endocytosis, paracellular transport, and transcytosis. Endocytosis refers to the internalisation of PM by cells, while paracellular transport refers to the movement of PM between cells [19].

The size of the PM affects the efficiency of its absorption by the gastrointestinal, alveolar, and dermal epithelium. Factors such as size, shape, dose, surface functionalization, charge, and hydrophobicity influence the absorption, translocation, and accumulation of microplastics. The toxicity of microplastics increases as their size decreases. Larger microplastics are likely expelled from the body through faeces or mucociliary clearance [10,12].

The harmful effects of PM and NP on human health are mediated by several mechanisms, including oxidative stress, production of reactive oxygen species, inflammation, apoptosis, immune dysregulation, alterations in cell division, metabolic dysfunctions and even genotoxicity, with the magnitude of these effects depending on the exposed organism, integrity and function of barriers, route of exposure, size, shape, surface chemistry and polymer type of the particles [4-7,9-11,17-21,26,28].

Affected organs and systems

MP and NP can cross biological barriers (lungs, oral, gastrointestinal, and blood-brain barriers) and, through passive diffusion, facilitated diffusion, active transport, and pinocytosis [3,15,25], reach distant organs where they will accumulate and cause alterations that are eventually acute and frequently chronic [11,12,26,29,30]. Host co-exposure to different types, sizes, and sources of plastic can compromise health mainly because the particles often contain various chemical substances and/or microorganisms capable of causing damage to multiple organs [22,31,32].

Children are more likely to develop metabolic disorders due to exposure to microparticles between 0.5 and 5 μm in size, contributing to gut microbiota dysbiosis and intestinal barrier dysfunction (15).

Chronic human exposure to non-cytotoxic concentrations of environmental MP and NP may lead to the potential induction of effects associated with cell transformation and the initiation of the carcinogenic process, such as a higher incidence of DNA damage and increased oxidative stress [7]. Furthermore, due to their persistence, they cannot be completely removed from the body, which can result in chronic inflammation and increase the risk of cancer [21,33-35].

Table 1 shows the effects of MP and NP on different human organs and systems.

Table 1: Effects of MP and NP on different body structures

System/organ	Effects
Oral cavity [11,16,26]	Xerostomia, stomatitis, gingivitis, periodontitis, taste dysfunction
Intestine [4,7,10,11,15,21,24,29]	It alters the mucus layer, increases permeability, causes microbiota dysbiosis, impairs nutrient absorption, causes bloating, abdominal pain, nausea, vomiting, changes in bowel habits, and may exacerbate inflammatory diseases.
Liver [4,10,11,19,21]	Metabolic changes, post-inflammatory fibrosis, increased/accumulated lipids
Blood [10,11,12,21,29]	Aggregation and adhesion of erythrocytes to epithelial cells of blood vessels, risk of thrombosis, impairment of hematopoiesis, induction of hemolytic responses.
Cardiovascular [10,14,20,21,37]	Accumulation in artery walls increases the risk of cardiovascular disease.
Respiratory [2,6,21,22,25,27,29]	It alters the mucus layer, surfactant ultrastructure, and microbiome; increases epithelial permeability, causes bronchitis, hypersensitivity pneumonitis, and pulmonary fibrosis
Nervous [10,12,19,21,25,29,30]	Altered neurotransmitter levels, impaired neuronal function, cognitive impairment
Immune [10,11,29]	Triggering local and/or systemic immune responses, which may weaken the immune system in susceptible individuals
Endocrine [10,11,20,21,26,39]	They carry endocrine disruptors and metabolically disruptive compounds capable of altering the synthesis, expression, secretion, and transport of hormones, increasing the risks of obesity, diabetes, and hormone-sensitive cancers
Urinary [10,11,37]	Parenchymal dysfunctions in the kidneys and bladder
Reproductive [6,10,21,37]	Inhibition of gonadotropic hormones, impaired steroidogenesis, decreased follicle size, decreased testicular and epididymal weight, decreased sperm count
Placenta [3,6,11,23,24,27]	Structural changes within the cytoplasm of the reticuloendothelial system and mitochondria, reduced placental weight, and impaired fetal growth
Skin [15,19]	Local irritation, erythema, sensitization, cellular senescence
Locomotor [37]	Movement and mobility difficulties
Eye [40]	It induces adverse effects on the ocular surface, raises intraocular pressure, and causes abnormalities in the vitreous humor and retina

Conclusion

Embora os plásticos tenham representado um avanço quanto ao surgimento de um novo material de grande aplicabilidade no cotidiano, seus fragmentos e alguns fatores a eles associados têm sido apontados como responsáveis por diversos comprometimentos à saúde e ao meio ambiente. Devido à magnitude do problema, além do surgimento de novos estudos identificando todoss os danos causados por micro e nanoplásticos aos seres humanos, faz-se necessário realizar investimentos com o propóstico de reduzir os impactos negativos desse materias sobre o ambiente e as pessoas. Ainda, é relevante destacar que um amplo processo educativo sobre o uso adequado e o descarte correto desses materiais é fundamental para o controle do resíduo final dos plásticos.

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