Mini Review
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Human skin and micro- and nanoplastics: a mini-review

Abstract

Plastic pollution is a worldwide problem. Its extended use has led to human exposure to micro and nanoplastics (MNPs) through inhalation, ingestion, and also through contact with the skin, by direct contact, or because of the pollution of water and air. In general, the adverse effects produced by MNPs on human health are well known, however, they are far from being fully understood. Although it is a less studied route of entry of MNPs into the human body, MNPs can enter the body through the application of cosmetics and other skincare products. Recent research has found a relationship between skin exposure to MNPs and diseases, like skin cancer. The present work reviews published studies, since 2020, related to the entry of MNPs through the skin and its impact on human health.

Keywords: microplastic, nanoplastic, cosmetics, skincare

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Abbreviations: MP, microplastic; NP, nanoplastic; MNP, micro and nano plastic

Introduction

Plastics production has reached more than 400 million tons according to the United Nations Environment Programme, UNEP.[1] They have replaced other raw materials as metal, wood, natural fibers, etc., in products used in daily activities. This is due to its easy production and processing, its corrosion resistance, its lightweight, and the relatively low production costs. However, its excessive use, resistance to biodegradation, and recycling of less than 10% have turned plastic waste into a serious environmental problem, an aspect that is closely related to its fragmentation into particles with sizes less than 5 mm, microplastics – MP or <1 µm, nanoplastics – NP, MNPs.[2,3] They are ubiquitous in all environmental compartments, including air,[4] and the problem has reached such magnitude that now the concept of plastisphere as ecosystems of microbes that thrive on floating plastic waste in waterbodies, has entered the technical literature.[5] Depending on the mechanism of their release, MPs can be categorized into primary and secondary. Primary MPs are purposefully manufactured in that form and are released directly in the form of small-sized particles in the environment by different nonbiological matrixes, for example. Secondary MPs derive from the abiotic and biotic degradation of large plastics after their environment exposure. Sources of secondary MPs include household usage, industrial manufacturing, debris from disposed car tires, etc.[6] MNPs also exhibit cross-contamination since they can be exchanged between different environmental compartments, as has been observed in groundwater, a matrix that should be relatively clean of these contaminants.[7]

MNPs affect humans through three routes of exposure, which in order of importance, in terms of the quantity of plastic particles that penetrate the body, are inhalation, ingestion, and dermal contact (Figure 1). It has been estimated an average daily exposure of 594 ± 269, 382 ± 205, and 1036 ± 493 MPs per person through inhalation of atmospheric air, drinking water, and consumption of food, respectively.[8–10] Furthermore, plastics contain additives, and their surface is capable of transporting other contaminants of emerging concern, including pathogens. Therefore, this chronic exposure to plastics may lead to bioaccumulation and subsequent biological effects because the main polymers that constitute them have a mutagenic or carcinogenic character, in addition to the toxicological endocrine disruptor and carcinogenic properties of the carried additives, and the health hazards of pathogens.[8] Although the inhalation and ingestion routes of exposure to MNPs have been widely studied, less attention has been dedicated to dermal exposure. The objective of this work is to explore recent advances in the dermatological effects of MNPs in humans.

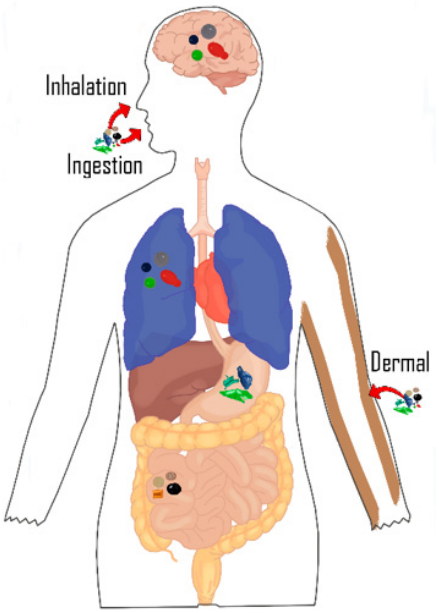

Figure 1 Routes of exposure to MNPs.

General effects of MNP on human health

Exposure to MNPs can lead to health effects through oxidative stress, inflammation, immune dysfunction, altered biochemical and energy metabolism, impaired cell proliferation, disrupted microbial metabolic pathways, abnormal organ development, and carcinogenicity.[11,12] The first contact of MNPs occurs with the epithelial

barriers of our body, which are the main interfaces that control and try to homeostatically balance the communications between our body and the environment, constituting the first line of defense against physical, chemical and immunological aggressions, providing a protective wall against environmental factors. Once in the body, MNPs can cross different barriers such as placental, blood-brain, and blood-testis, depending on the characteristics of MNPs, and exposure dose, route, and time, and may cause cytotoxicity, neurotoxicity, and reproductive developmental toxicity.[13,14] MNPs are identified in the human exposome as one of the environmental stressors that weaken epithelial barriers.[8] In addition to the effects on physical barriers, when MNPs cross them they have effects on different human organs, systems, and their functions such as gut microbiota, immune response, respiratory tract, liver, and lipid metabolism.[15,16]

Considering diseases, some examples are illustrative of the effects of MNPs on human health. Evidence has been reported of the existence of a relationship between the presence of microplastics in nasal washing fluids in patients with allergic rhinitis compared to a control group.[17] Moreover, some reports suggest the possible existence of a connection between the presence of MNP and Parkinson's disease and other dementias.[18] It also has been reported that MNPs are possible oncogenic components of commercial milk and are potential contributors to the development of breast cancer.[19] Considering that MNPs are translocated through the placenta at different stages of gestation,[20] and the rapid development in the prepubertal age and the special sensitivity of children and adolescents to an adequate synchronization of their stages of development, it is necessary to delve deeper into the effects of environmental exposure to these contaminants in these stages of human development.[21] Nevertheless, there is a lot of work to do in the study of the health effects of MNPs as most works have focused on specific types of MNPs to assess their toxicity, and future needs comprise considering realistic concentrations, dose-dependent effects, individual susceptibility, and confounding factors.[11]

MNP and the human skin

Although dermal contact with MNPs is considered the least important route compared to inhalation and ingestion exposure, to some extent this is because this exposure route has not been sufficiently explored. Hence, it must be considered that MNPs can come into contact with the skin through the application of cosmetics and other dermal application products that contain them[22–24] and occasional contact with water and air pollutants, whose harmful effect on the skin is known.[25]

As already mentioned, MPs abound in cosmetic products and those used to transport drugs to the skin, especially in the form of microspheres that have less capacity to scratch the skin and alter its natural development than other alternatives, including natural ones, which are precisely designed for the cosmetic effects sought with sunscreens, deodorants, moisturizing creams, among others.[26] The continued use of MNPs in skin care and similar products has been pointed out as an important factor in contamination, which is why several companies, in the interest of environmental sustainability, have begun to eliminate or ban these substances in their products.[26,27]

MNPs enter the skin through the pores (Figure 2) and begin to affect the normal functioning of this important barrier, which has been demonstrated by the damaging effect on skin cells of zebrafish embryos, observing the alteration of the structure of the apical skin keratinocytes were damaged with doses of 10, 25 and 50 mg/L of polystyrene nanoplastics.[28] During the treatment of human keratinocytes with 30-300 nm NPs, it was observed that the internalized nanoparticles induced cytotoxic, cytostatic, and cytoprotective activity in a concentration-dependent manner, inducing a negative regulation of cell growth and inhibition of oxidative stress-mediated proliferation, observing autophagic structures and premature aging.[29]

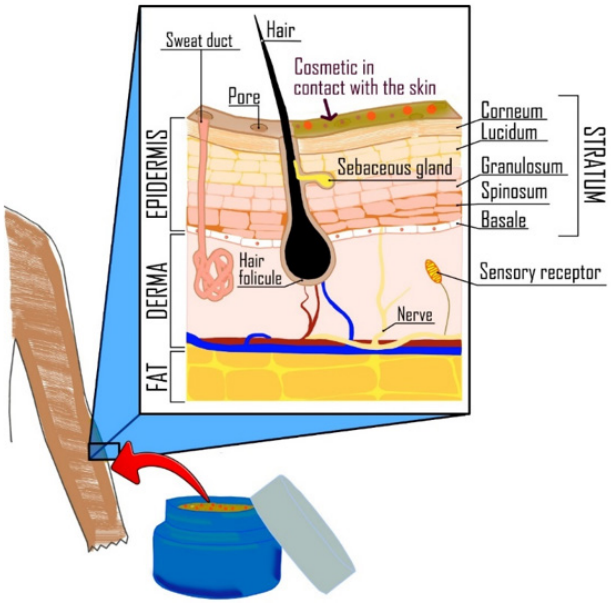

Figure 2 Representation of cosmetics in contact with the skin and its different parts.

Once MPs/NPs come in contact with the skin, an immune response is initiated by the recognition of pathogen-associated molecular and damage-associated patterns by cellular receptors. These receptors are found on keratinocytes, Langerhans cells, dendritic cells, melanocytes, macrophages, and T cells, which lead to a response that potentially compromises the skin's barrier integrity.[30] Although the toxic effects of NPs on the skin are still not well understood, studies with skin cell lines have shown that they can be internalized into skin cells depending on time and dose. It was also shown that they cause damage due to senescence, and pathological lesions in the skin and induce mitochondrial oxidative stress. They also inhibit skin regeneration and aggravate its inflammatory reaction.[31] It has also been proven that NPs penetrate the damaged stratum corneum and reach the dermis. When NPs are in this part of the skin, they increase inflammatory cytokines in keratinocytes and macrophages and induce fibrosis through the stimulation of fibroblasts.[32] In vitro studies have shown that the transport of NPs is facilitated if the stratum corneum is damaged, for example by skin burns, and their accumulation in keratinocytes may induce inflammation and tissue remodeling.[33] These effects on skin cells depend on the size, concentration, and polymer characteristics of the NPs.[34] All these effects have an impact on the normal development of cells and the proliferation of skin cancer cells and promote tumor cell proliferation while causing damage to normal skin.[35] The proliferation of reactive oxidant species increases the risk of oxidative stress and has been suggested to exacerbate alopecia associated with tight junction injuries and apoptosis via the oxidative stress pathway in the skin.[36] As in other organs, exposure to substances associated with MNPs is also increased through the dermal route.[37]

Conclusion

It is known that micro and nanoplastics (MNPs) can enter the body through different vias, such as inhalation and ingestion. However, another important route has been studied in the past years: the skin. Skin is the biggest organ of the human body, and the application of

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skin-care products can lead to the introduction of MNPs into the body, causing important damage to the skin itself, reducing its normal response to damage and lesions, which could lead to the proliferation of cancer or tumor cells in the skin. Although research has been conducted in this regard, further investigation is needed to understand the real implications of MNPs in human health, including skin health.

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Conflicts of interest

The authors declared no potential conflicts of interest of this article.

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