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Impact of microplastics on human health: exposure mechanisms and potential health implications

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Abstract

Microplastics are a pervasive environmental contaminant and represent a newly emerging threat to human health. They enter the body through various pathways, including food consumption, drinking water, and inhalation. The present study is concerned with the issue of dietary and inhalational exposure to microplastics. The presence of microplastics has been identified in a range of food products and drinking water, with analyses of faecal samples also indicating their passage through the human digestive tract, thereby suggesting the potential for their absorption by the body. It is also important to consider the potential for inhalational exposure, given the presence of microplastics in the air. This suggests that inhalation by humans may also be a possibility. Furthermore, these particles have been identified in sputum samples from patients and lung tissues, indicating the potential for bioaccumulation and the induction of inflammatory responses.

While there is documented evidence of microplastics in the human body, there is currently a lack of specific data on their impact on human health. The available evidence from animal studies and in vitro models indicates that microplastics have the potential to traverse epithelial barriers in the digestive and respiratory systems, resulting in inflammatory responses, oxidative stress, and, in extreme cases, tissue fibrosis. Furthermore, microplastics may act as carriers for heavy metals and toxic chemicals, thereby increasing the risk of neurotoxicity, nephrotoxicity, and potentially carcinogenic effects. Further research, including long-term clinical studies, is required to gain a full understanding of the impact of microplastics on human health.

Aim of the Study

The objective of this study is to identify potential sources of microplastic exposure, investigate the presence of particles within the human body, and assess the biological mechanisms by which microplastics may penetrate and interact with body cells. Additionally, this study will examine the potential health effects associated with microplastic exposure.

Materials and methods

A review of the literature collected in the PubMed database was performed to gather information found under the key words “microplastic," “inflammation,” "oxidative stress" "respiratory diseases," "inhalation," "lung tissues," “pulmonary fibrosis,” "gut microbiome," “transdermal penetration,” “in vitro models” and “heavy metals”.

Summary

Microplastics are pervasive in the environment and can enter the human body primarily through the ingestion of food, the consumption of water, and inhalation. A number of studies have demonstrated the presence of microplastics in a variety of food products and human tissues, including the lungs and digestive tract. Despite the growing body of evidence indicating the bioaccumulation of microplastics, the full impact of these particles on human health remains unclear. The current research indicates the potential for microplastics to cause inflammatory states, oxidative stress, and other health issues. Further research is required to more accurately define the risks associated with microplastic exposure and to develop effective health protection strategies.

Key words: microplastic, inflammation, oxidative stress, respiratory diseases, inhalation, lung tissues, pulmonary fibrosis, gut microbiome, transdermal penetration, in vitro models, heavy metals.

Introduction and Results

Microplastics are defined as plastic particles with a diameter of less than 5 mm. Two distinct categories of microplastics can be identified:

The term 'primary microplastics' describes those microplastics intentionally produced in small sizes. One example of such a microplastic is the microbead used in cosmetics.

Secondary microplastics, which are more hazardous to human health, are formed by the breakdown of larger products, including producing particles from tires while driving, synthetic fibre fragments from clothing, and plastic degradation due to ultraviolet radiation. [1, 2, 3]

The scientific evidence indicates that humans come into contact with microplastics on a daily basis. Microplastics can enter the human body through several pathways, the most significant of which are through food, drinking water, and inhalation. There are limited scientific reports on the possible transdermal penetration of particles, with those capable of crossing the skin's cellular barrier being nanometre-sized particles [4]. This study will focus on the dietary and inhalational pathways.

The presence of microplastics has been identified in a range of food products, including vegetables, fish, seafood (particularly shrimp), sea salt, and even bottled water. [5,6,7,8] A considerable body of research has sought to ascertain the prevalence and composition of microplastics in human faecal matter. These studies have demonstrated the potential for these particles to traverse the human digestive tract, raising the possibility of their absorption by the body. The samples were analysed using advanced analytical techniques, including spectroscopy and microscopy. The presence of different types of plastic polymers, such as polyethylene, polypropylene, polystyrene, and others, was identified, indicating that individuals are exposed to particles from various sources. [9] The relationship between the consumption of plastic bottles and the abundance of microplastics in faeces was also examined, showing a moderate correlation. [10]

Another potential pathway for microplastic particles to enter organisms is inhalation. A substantial body of research has documented the presence of microplastics in the atmosphere, both indoors and outdoors. A study conducted in Dongguan, China, identified three main types of polymers present in the air: polyethylene, polypropylene, and polystyrene. The microplastics were found in a variety of forms, including fibres, foams, fragments and films, with fibres being the most prevalent. [11] Another study conducted in Paris demonstrated the presence of microplastics in atmospheric precipitation at concentrations of 29-280 particles/m^2 per day. [12] This issue is not exclusive to large, industrialised urban centres. A study conducted in the French Pyrenees, in remote and sparsely populated areas, also demonstrated the presence of microplastics in atmospheric air. An analysis of air mass trajectories indicates that microplastic particles can be transported over distances of approximately 100 km through the atmosphere. [13] These particles can enter the human body through inhalation. In 2022, an analysis of sputum samples from 22 individuals with various respiratory diseases was conducted. The presence of microplastics was confirmed in all sputum samples, with 21 distinct types identified, the majority of which exhibited a diameter of less than 0.5 mm.[14] Another study evaluated the occurrence of microplastic particles in human lung tissues obtained during autopsies, with particles observed in 13 out of 20 tissue samples. The most frequently identified polymers were polyethylene and polypropylene. [15]

Although studies have documented the presence of microplastics in the human body, which is a concerning fact, specific data on their impact on health are still lacking. The difficulties encountered in researching the health effects of microplastics can be attributed to three main factors: the lack of standardised research methods, the absence of uniform detection and analysis methods for microplastics in biological samples, and the challenge of identifying exact sources and levels of exposure, given that microplastics are present in many aspects of daily life.

As a consequence of the constraints inherent to human studies, the available information concerning the potential health effects of microplastics is derived from animal studies and in vitro research.

Impact on the Digestive and Respiratory Systems

The objective of this study is to gain insight into the mechanisms by which microplastics can traverse epithelial barriers in the digestive and respiratory systems. This is a crucial step in evaluating their potential health implications. In vitro models that closely resemble the intestinal and lung epithelial barriers were employed. The models were designed to closely replicate authentic biological conditions, thereby facilitating the investigation of microplastic interactions with epithelial tissues. The study demonstrated that microplastics can be internalised by epithelial cells in both intestinal and lung models. The passage of microplastics through these barriers may result in their accumulation in various internal organs, which could have implications for human health. Moreover, exposure to several microplastic particles tested resulted in the activation of pro-inflammatory cells and disruption of barrier integrity. [16]

In order to ascertain the potential impact of microplastics on the digestive system, a study was undertaken in which mice were exposed to 2μm polyvinyl chloride (PVC) for a period of 60 days. The findings indicated that PVC diminished mucus secretion within the intestinal tract and augmented intestinal permeability, in addition to influencing alterations in the gut microbiome.[17] In a further study, also utilising mouse models, the accumulation of microplastics in a range of tissues and the biological responses triggered by their presence were assessed. The study revealed that microplastics could accumulate in various mouse tissues, including the liver, kidneys, and other organs. This accumulation was associated with inflammatory reactions, oxidative stress, and metabolic disturbances. [18]

Furthermore, scientific research indicates that microplastics can function as vectors for heavy metals, including lead, mercury, and cadmium, as well as toxic chemicals. This may result in enhanced bioaccumulation in marine organisms [19,20,21], which, in turn, may enter the human food chain and potentially induce neurotoxic, nephrotoxic, and carcinogenic effects. [22]

In order to evaluate the potential health effects of inhaled microplastic particles, the impact of inhaling coarse particulate matter from urban pollutants on oxidative and inflammatory parameters in mouse lungs and intestines was analysed. The mice were exposed to an aerosol of coarse particulate matter in a specially constructed chamber for a period of 15 days. The findings indicated that exposure to these particles resulted in oxidative stress and an increased recruitment of immune cells to the lungs. Furthermore, elevated cytokine levels were observed in both the lungs and colon, indicating inflammation. To ascertain whether these adverse effects could be alleviated, the researchers employed N-acetylcysteine (NAC), a recognised antioxidant. The administration of NAC was observed to reduce oxidative stress and inflammation induced by inhaling coarse particulate matter, indicating its potential utility in the context of therapies pertaining to air pollution exposure. [23] In a further study, microplastics were administered directly into the airways of mice via intratracheal instillation. Subsequently, lung tissues were examined for pathological alterations and analysed for a range of biomarkers indicative of oxidative stress and the activation of signalling pathways. The study revealed that polystyrene microplastics have the potential to induce oxidative stress in lung tissues. Oxidative stress is defined as a condition characterised by an overproduction of free radicals, which can ultimately result in damage to cells and tissues. Furthermore, the study demonstrated that exposure to microplastics resulted in the activation of the Wnt/β-catenin pathway, which plays a pivotal role in regulating cellular processes such as cell proliferation and differentiation. The activation of this pathway was found to be associated with the development of pulmonary fibrosis. In conclusion, the study demonstrated that polystyrene microplastics could induce alterations that result in lung fibrosis. Pulmonary fibrosis is a serious condition characterised by the stiffening of lung tissue and a loss of elasticity, which impairs respiratory function. [24]

In the meantime, it is recommended to limit exposure to microplastics by steering clear of products with plastic microbeads. To effectively decrease the amount of microplastics in the environment, a thorough strategy is needed. This can be accomplished by adopting new technologies and recycling methods, enacting suitable regulations, and informing the public about the problem. [25,26]

Discussion:

Limitations and Considerations

The absence of standardisation represents a significant challenge in this field. The absence of uniform standards for the detection and analysis of microplastics in biological samples may result in variability in results and difficulties in comparing studies. The following research limitations must be considered: most available data has been derived from in vitro and animal studies. There is a paucity of clinical studies on humans that provide direct evidence of the impact of microplastics on human health. The difficulty in identifying exposure sources is a further challenge. The pervasive presence of microplastics renders the identification of specific sources and levels of exposure a challenging endeavour, thereby complicating the process of risk assessment. The scale of the study is as follows - some studies have a restricted scope in terms of both the number of participants and geographical coverage, which may limit the extent to which their findings can be generalised.

Future Research Directions:

- Long-term clinical studies are required to ascertain the health effects of exposure to microplastics.
- The development and standardisation of methods for the detection and analysis of microplastics in biological and environmental samples are of paramount importance.
- To gain a comprehensive understanding of the full extent of microplastic impact, research must be extended to various body systems, including the nervous, endocrine, and immune systems.
- It is also necessary to investigate the interactions between microplastics and other pollutants, such as heavy metals or chemicals, to assess the potential for synergistic health effects.

Practical Implications:

The objective of this study is to raise awareness of the issue. The research provides significant insight into the pervasive presence of microplastics and the potential associated health risks, which can inform public awareness initiatives on this matter. In terms of regulatory measures, the findings could inform the development of regulations aimed at reducing microplastic emissions, both during the production process and in consumption. Technological innovations may also prove beneficial in this regard. It is imperative to develop innovative technologies for water and air purification and to promote the utilisation of more environmentally-conscious materials. It is recommended that the following health advice be followed: The findings of this research can inform the development of preventive measures by public health specialists, such as the avoidance of single-use plastics and the selection of alternative materials.

Conclusions

The current evidence base indicates that microplastics may have a detrimental impact on human health. Despite the growing body of research in this area, many health effects related to microplastics remain to be elucidated. Long-term research is required to gain a deeper understanding of the mechanisms of action and the full extent of health risks. In the interim period, it is advised that exposure to microplastics be reduced by avoiding products containing plastic microbeads. A comprehensive approach is required to reduce the quantity of microplastics present in the environment. This may be achieved through the implementation of innovative technologies and recycling strategies, as well as the introduction of appropriate regulatory measures and the dissemination of information to the public regarding the issue.

Disclosure

Author's contribution

Conceptualization: Anna Marszałek and Piotr Kuczyński; Methodology: Marcelina Teresa Marzec; Software:Katarzyna Kutyła; Check: Paulina Wasiewicz- Ciach and Katarzyna Kutyła; Formal analysis: Weronika Zofia Marzec and Maciej Choiński; Investigation: Piotr Kuczyński and Wojciech Jan Mokot; Resources: Aleksandra Łakoma; Data curation: Aleksandra Łakoma; Writing - rough preparation: Anna Marszałek and Weronika Zofia Marzec; Writing - review and editing: Aleksandra Wydra-Rojek and Paulina Wasiewicz-Ciach; Visualization: Wojciech Jan Mokot; Supervision: Maciej Choiński; Project administration: Marcelina Teresa Marzec and Aleksandra Wydra-Rojek; Receiving funding - no specific funding.

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