

OLEKSIUK, Klaudia, KRUPA-KOTARA, Karolina, GRAJEK, Mateusz, WYPYCH-ŚLUSARSKA, Agata, GŁOGOWSKA-LIGUS, Joanna & SŁOWIŃSKI, Jerzy. Health risks of environmental exposure to microplastics. *Journal of Education, Health and Sport*. 2023;13(1):79-84. eISSN 2391-8306. DOI <http://dx.doi.org/10.12775/JEHS.2023.13.01.012>
<https://apcz.umk.pl/JEHS/article/view/40548>
<https://zenodo.org/record/7358305>

The journal has had 40 points in Ministry of Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of December 21, 2021. No. 32343. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical Culture Sciences (Field of Medical sciences and health sciences); Health Sciences (Field of Medical Sciences and Health Sciences). Punkty Ministerialne z 2019 - aktualny rok 40 punktów. Załącznik do komunikatu Ministra Edukacji i Nauki z dnia 21 grudnia 2021 r. Lp. 32343. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przynależność dyscypliny naukowej: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
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The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 19.10.2022. Revised: 20.11.2022. Accepted: 23.11.2022.

Health risks of environmental exposure to microplastics

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Abstract

Plastics are materials widely used in all sectors. The subject of interest in recent years has become so-called microplastics, whose composition and structure are causing new environmental hazards. The presence and accumulation of microplastics in the environment threaten the ecological balance, the water environment, food sustainability and safety, and ultimately human health. Human exposure to microplastics is primarily through the oral route, so the main source of human exposure to microplastics is diet. Despite many studies focusing on microplastic contamination in seafood, fish, and shellfish, estimating total human exposure to microplastics via the oral route is difficult, due to the lack of research on other foods in this area. The risks to human health from inhaling microplastics remain unclear. According to the WHO, there is no reliable evidence of the harmful effects of microplastic on the human body, but the phenomenon requires further research. Likely health effects of human exposure to microplastic include respiratory and gastrointestinal effects, oxidative stress, and cancer. There is a need to raise public awareness about environmental exposure to microplastics and effective waste management.

Keywords: health risks, exposure, microplastics

Introduction

Plastics are materials consisting of synthetic polymers, therefore not found in nature but artificially created by man, or modified natural polymers and modifying additives. They are widely used in all sectors because of their lightweight, high plasticity and flexibility, thermal and electrical insulation, chemical resistance, durability, and low manufacturing cost. Global demand for plastics continues to grow, thus plastic waste management remains a global challenge. Global plastics production is estimated to have reached nearly 360 million tons in 2018 [1], while global plastics production reached 367 million tons in 2020 [2,3]. The increasing consumption of plastics each year poses increasing risks, both from the direct management of very large amounts of plastic waste and the problem of lack of demand for recycled products and from the direct impact of plastics on the environment and human health. Geyer et al. showed that by 2015 only 9% of plastic waste had been recycled, another 12% had been incinerated, and most of the waste generated was destined for landfill or entered the environment [4]. Popularity, misuse, and management problems cause plastic waste to accumulate in the environment. Therefore, in recent years, there has been increasing attention to the need to phase out plastics and significantly reduce their introduction into the environment, especially the aquatic environment.

The subject of interest in recent years has become so-called microplastics, which are small (less than 5 mm in diameter) plastic pellets and small fragments from the breakdown of plastics, whose composition and structure are the cause of new environmental hazards [5,6]. The negative health effects of some substances added to plastics (for example, phthalates or bisphenol A) to improve their performance also remain a problem.

Microplastics can be divided into two large groups: primary microplastics, produced intentionally, are, for example, components of industrial, pharmaceutical, or cosmetic products (paints, adhesive coatings, microbeads), and secondary microplastics, formed from the breakdown of larger plastic particles, as a result of the degradation process [7]. The differentiating feature of the aforementioned types of microplastics is also the route by which they enter the environment. Primary microplastics are released into the environment in their manufactured form, while secondary microplastics are formed as a result of the weathering and degradation of larger plastics that previously found their way into the environment. The release of secondary microplastics into the environment occurs through three mechanisms: the natural breakdown of microplastics under the influence of atmospheric conditions and microbial activity, the decomposition of macroplastics into microplastics by the direct action of organisms, and the resuspension of microplastic particles found in soil or bottom sediment. In the environment, plastic waste undergoes biotic degradation (carried out by microorganisms) and abiotic degradation (photodegradation, caused by exposure to UV radiation or weathering) [8,9]. Currently, microplastic particles are ubiquitous. They are found in both marine [10] and terrestrial ecosystems [11]. Their presence in saltwater, surface water bodies, wastewater, and groundwater has been demonstrated [9,12,13].

The presence and accumulation of microplastics in the environment threaten the ecological balance, the aquatic environment, food sustainability and safety, and ultimately human health [14,15,16]. Microplastic particles can enter the human body via the dermal, inhalation, and oral routes. Although the dermal route is of lesser importance, airborne exposure is an important route for microplastics to enter the human organism [17]. However, studies have shown that human exposure to microplastics is primarily through the oral route, so the main source of human exposure to microplastics is through the diet [15,18,19]. Microplastic particles have already been identified in many foods, such as fish and fish products, seafood [20], fruits and vegetables [21], table salt [22], and highly processed foods [23]. Microplastics, once they enter the human gastrointestinal tract, are mostly excreted [24], but the consequences of microplastics in the human body are still not fully understood. Therefore, the main objective of this review is to analyze the sources of microplastic and the health risks arising from it.

Microplastics in food

The issue of human population exposure to microplastics contained in food has become a serious concern due to the increasing accumulation of microplastics in the environment. Despite several studies focusing on the issue of microplastic contamination in seafood, fish, and shellfish, estimating total human exposure to microplastic via the oral route is difficult, due to the lack of research on other foods in this area [25]. To date, much attention has been paid to the environmental impact of microplastics, while the health risks of human oral exposure have not yet been sufficiently studied. Several researchers have expressed the view that current knowledge does not provide solid data to reliably characterize the health risks from oral exposure to microplastics [26].

With the increasing production of plastics, a huge amount of waste is generated, which then ends up in the environment and oceans [27]. Plastic waste in the oceans comes mainly from land-based waste (80%). The remaining 20% of waste comes from fishing and trawling [28]. It is estimated that about 8 million tons of plastics enter the seas and oceans each year [29]. Being at the top of the food chain, humans consume plant and animal foods, including fish and seafood, which have previously incorporated microplastics into their bodies by various means. Microplastics present in sea salt and in food, fragments of which come from the manufacturing process, machinery, and packaging, also enter the human body. Due to their small size, microplastic particles are not captured during water treatment processes, so they can be detected in all water environments, including drinking water [30]. Microplastics are also present in water and beverages sold in plastic bottles. Microplastic contamination of drinking water is the most worrisome problem due to the direct and long-term exposure of the entire population, including the most vulnerable groups, such as children, the sick, and convalescent patients. Therefore, the presence of microplastics in tap water and so-called bottled water has become the subject of numerous studies in recent years. Microplastic contamination affects not only water, fish, and seafood, but also other food products. Colored and transparent fibers, granules, and fragments of microplastic have been identified in honey samples, sugar, beer [27], and highly processed products [23]. Since then, the range of food products tested for microplastic contamination has expanded greatly. Admittedly, research still focuses primarily on seafood and fish contamination, but plant-based foods, seaweed, and rice are also being analyzed. At the same time, contamination of vinegar, salt, milk, white wine, energy drinks, and soft drinks is being assessed [27].

Despite the growing number of data on the occurrence of microplastics in various parts of the food chain and foodstuffs, they are still insufficient. The main problem is the lack of a standardized methodology for determining microplastic contamination in food [27]. Therefore, the assessment of food contamination is complex and difficult to interpret.

Microplastics in the air

The presence of microplastics in the environment has been widely studied, with most research to date focusing on plastic particle contamination of surface waters, coasts, and continental waters, including in remote locations such as the polar regions, as well as soils and sediments. Over the past decade, there has been

increasing attention to another element of the environment, namely air. Sampling and analysis is a complex and multi-step procedure, with the techniques used varying greatly from study to study. As a result, the physicochemical properties of airborne microplastics are not well characterized. Consequently, the health effects of inhalation exposure are poorly understood [31]. The presence of microplastic fibers in precipitation, outdoor air, and indoor air has been demonstrated [32]. In indoor air, microplastic is found in higher concentrations than outdoors, causing concern because people spend most of their time indoors [33]. Higher levels of microplastic in the air have been observed in urban areas than in rural areas [34]. This difference is attributed to increased anthropogenic activity and higher population density in urban areas. The distribution and behavior of microplastic particles suspended in ambient air are similar to other air pollutants: their concentration, transport, dispersion, and removal depend on emission sources, meteorological conditions, and long-distance transport, among other factors [33]. Some fibrous microplastic fragments can enter the respiratory system. Most are likely to undergo mucociliary clearance, but some may persist in the lungs, causing inflammation, especially in people with impaired clearance mechanisms [32]. Particularly high concentrations of microplastics are found in indoor air, due to erosion and breakage of consumer, household, and building products, although little information is available on their sources and concentrations, as well as the risks they may pose [33]. Synthetic textiles are considered the main source of microplastics in indoor air, given that the small fibers easily detach from clothing and other products during wearing, cleaning, and drying. Young children are most vulnerable to exposure to these pollutants, as they breathe faster and take in more air relative to their body weight due to their greater activity. In addition, infants and toddlers play with plastic toys, often biting them.

Although the presence of microplastics in the air is a fact, the risks to human health from their inhalation remain unclear [35]. Questions such as how microplastic fragments can contribute to the pathogenesis of various lung diseases, whether microplastic can enter the blood, whether harmful health effects can be linked to the desorption of pollutants in the respiratory system, whether microplastic particles can cause physical damage to tissues, or to what extent microplastic acts as a carrier of organic pollutants or pathogens are still not answered [33]. Although the human body has mechanical defenses to prevent the deposition of microplastic fibers (e.g., sneezing), clearance mechanisms cannot exclude the occurrence of inflammatory changes caused by interrelated mechanisms: dust overload, oxidative stress, cytotoxicity, and translocation [36]. Plastics and their additives (dyes, plasticizers) can lead to the development of negative health effects, including reproductive toxicity, induction of carcinogenesis, and mutagenicity [32]. Inhaled microplastics have been linked to negative health effects in workers exposed to airborne microplastics [36].

Microplastic toxicity

It is believed that microplastics can serve as a carrier for the spread of toxic chemicals in the marine environment. In addition to PCBs, organochlorine compounds, polyaromatic hydrocarbons, DDT, and HCH insecticides, also heavy metals such as copper, arsenic, cadmium, lead, and chromium [37]. Microplastics can not only absorb and bind toxic pollutants from the environment but can often release these compounds back. In plastic production, various additives (e.g., stabilizers, plasticizers) that are used as processing compounds in relatively high concentrations can then be released as they break down [13,29]. Microplastics are also able to absorb and concentrate antibiotics, endocrine-disrupting chemicals, bacteria, viruses, and spore forms of potentially dangerous organisms on their surface [34].

The main evidence pointing to microplastic toxicity comes from animal studies and in vitro experiments on human cells. They suggest possible risks from exposure to microplastics, especially those resulting from oral exposure [38,39,40]. The health effects caused by the presence of microplastics in the body can be divided into physical and chemical [39]. The former is related to the presence of microplastic particles themselves in the body and their accumulation, which is mainly due to their size, shape, and concentration. The size and shape of microplastic particles, as well as the target cells and organs, play a key role [41]. The smaller the size of microplastic particles, the greater the risk of toxic effects. In addition, the toxic effects of fibers are greater than those of spherical forms. Chemical effects are related to the polymer composition, the leaching of chemical additives present in the plastic, and the presence of toxic compounds adsorbed on the surface of microplastics [38].

Studies conducted to date on the toxicity of microplastics have indicated various toxic effects, however, the most commonly mentioned was the induction or exacerbation of oxidative stress, with the generation of reactive oxygen species [38,42], a very dangerous condition that can lead to the development of many diseases, including cancer. Other toxic effects cited have included disruption of lipid metabolism, microflora disruption, neurotoxicity, inflammation, and immune response, cytotoxic effects, and disruption of mitochondrial membrane potential [40,42,43]. When inhaled or ingested, plastic microbeads can accumulate and exert local molecular toxicity by inducing or enhancing the immune response. Chemical toxicity can occur due to the local leaching of component monomers, endogenous additives, and adsorbed environmental contaminants. Chronic exposure is expected to pose a greater risk due to the cumulative effect that may occur. This is expected to be dose-dependent [44]. In addition, it has been found that due to the additives (e.g. plasticizers, flame retardants, stabilizers, and antioxidants) present in microplastics, it is possible to induce oxidative stress, endocrine

disruption, lipid metabolism disorders, and the cancer process in many organisms, including the human body [45,46].

Impact of microplastics on human health

The World Health Organization (WHO) reported in 2019 that there is no reliable evidence of the harmful effects of microplastics on the human body. However, it stressed that the phenomenon requires further research. Many scientists are sounding the alarm that microplastic particles penetrating the human body may be responsible for several negative effects, including endocrine disruption, certain cancers (such as liver, breast, lung, and colon), and neurological conditions. Exposure to microplastics is also seen as one of the putative risk factors for infertility in the general population. This is primarily due to bisphenol A, added to plastic, which resembles female sex hormones in structure and negatively affects the reproductive system. Clear evidence of environmental exposure to microplastic is its presence in human tissues and organs. It is present in the placenta [47], meconium samples [48], human feces [49], also in lung tissue, colon, nasal mucosa, hair, saliva, and blood [38,50]. Plastic microparticles can also adversely affect the immune system and contribute to the development of autoimmune diseases. The most important putative health effects from environmental exposure to microplastics include respiratory effects (as a result of inhaling microplastic particles), digestive effects (as a result of ingesting microplastic particles), the occurrence of oxidative stress, and increased cancer risk. The accumulation of microplastic particles in the liver can likely lead to the development of inflammation, liver disease, and metabolic problems, while the accumulation of microplastic in lung tissue can lead to chronic lung disease. The exact effects of microplastic on the human body and its toxicity can be determined by the amount of microplastic ingested and inhaled, the characteristics of the particles (such as their size and shape), as well as the time of exposure, its size and the personal characteristics of the host.

A systematic review by Yong Min Cho and Kyung-Hwa Choi [51], summarizing the current state of knowledge in the area of microplastic effects on human health, indicates that there is no clear scientific evidence defining the health effects of microplastic presence in the body. The authors concluded that human exposure to microplastic following inhalation and oral routes results in the existence of multiple exposure scenarios. The only marker of exposure in humans is the detection and measurement of fecal microplastic concentrations. According to the authors, the health effects of human exposure to microplastics include respiratory effects, gastrointestinal effects, as well as oxidative stress, and cancer. However, there are few studies describing the effects of microplastic exposure on the general population [51].

Summary

Plastics are materials with many properties that make them extremely popular in everyday life and various industries. Studies show that plastic waste is a global pollutant and is widely distributed in virtually all ecosystems [52]. Based on the available literature, the issue is still under-researched [26]. A WHO report published in 2019 concludes that while the evidence gathered so far does not conclusively demonstrate the harmful effects of microplastics present in drinking water and food on human health, further in-depth research and analysis in this area is needed.

In their systematic review, Yong Min Cho and Kyung-Hwa Choi made several observations that should be taken into account in future studies on assessing microplastic exposure and its effects on human health. Since microplastic particles have different forms, chemical compositions, and exposure pathways, the mechanisms of human exposure to microplastics and the patterns of their effects on the human body vary. There is a need for continued research in this area to estimate the total exposure of the general population to microplastic and to perform an integrated risk assessment of microplastic exposure [51]. A comprehensive risk analysis, followed by dietary recommendations that take into account high-risk foods with higher microplastic content, would be a good tool to reduce the potential negative effects of microplastics in food.

It is also important to raise public awareness of environmental exposure to microplastics and effective waste management.

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