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From Environment to Body: Microplastics' Sources, Pathways, and Health Repercussions

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ABSTRACT

Introduction: Microplastics are common pollutants found in the environment and consumer products. People can be exposed to them through eating, breathing, and skin contact. The sources include contaminated food, drinks, seafood, water, salt, and particles in the air, especially in urban and industrial areas. Research suggests these microplastics may cause physical damage, chemical toxicity, inflammation, oxidative stress, and disruption of hormones [1].

Purpose of work: This systematic literature review focuses on providing a comprehensive overview of microplastics in the human body and the health implications due to their presence in human systems [2].

State of knowledge: Research on microplastics has been gaining significant attention among the scientific community. They were found in human stool, blood, and even placental tissue, suggesting they can be absorbed into the human body [3]. Microplastics can enter the body through ingestion, inhalation, and skin contact, and may accumulate in organs over time. Potential adverse health effects include inflammation, immune responses, reproductive toxicity, and translocation to other organs [4][5].

Material and methods: The methodology involved clearly outlining the objectives, a systematic literature search, and a structured process for screening and analyzing studies. The research involved a comprehensive search of scientific databases, including PubMed and Google Scholar.

Summary: Microplastics are ubiquitous in the human environment and can enter the body through various exposure pathways. They have the potential to cause a range of adverse health effects, including physical damage, chemical toxicity, inflammation, oxidative stress, and hormonal disruption. However, more research is needed to fully understand the long-term health consequences of microplastics in the human body.

Keywords: microplastics; human health; exposure pathways; toxicity; ingestion; inhalation

INTRODUCTION

The widespread use of plastic has increased in the current human environment, providing versatility and convenience, but has also led to escalating environmental and health concerns.

Plastic gradually fragments into microscopic particles known as microplastics, which are defined as plastic particles smaller than 5 mm in size. These particles have been detected in oceans, rivers, soil, air, and even in the human environment [6]. Generally, microplastics are found in food consumed by humans and in the air, suggesting they could impact human health through ingestion or inhalation. Ingested or inhaled microplastics may accumulate in the body and trigger an immune response, leading to particle toxicity. The ubiquity of microplastics is raising increasing concern due to their potential impact on human health [4]. Research conducted to identify the presence of microplastics in food, water, and air has highlighted the basic exposure pathways for humans. Reports of microplastics in human biological samples, including stool and lung tissues, have emphasized the need to understand the different ways these particles enter the human body and their potential impact on physiological systems.

This review aims to highlight critical gaps in the literature and suggest areas for further research, focusing on the pressing requirement for interdisciplinary efforts to address the emerging public health issues associated with microplastics. The findings indicate the importance of informing policymakers and healthcare professionals about the risks related to microplastics, and the need to mitigate exposure through improved environmental and industrial practices.

SOURCES OF MICROPLASTICS

Microplastics can be categorized into primary and secondary sources. These particles enter the human environment through a variety of sources, such as food, beverages, and air, reflecting the widespread nature of plastic pollution. Primary microplastics are intentionally produced as small particles for specific purposes and are directly introduced into the human environment through various activities [7]. Key examples include the use of microbeads in cosmetics, personal care products, and industrial applications like paint, coatings, and abrasives. These materials may escape into the environment during production. Additionally, plastic pallets used as raw material in plastic manufacturing can contribute to microplastic contamination when lost during transport and handling.

Secondary plastics are developed through the gradation of larger plastic items over time due to environmental factors such as UV radiation, mechanical abrasion, or chemical processes. Plastic packaging and single-use plastic include bags, bottles, and containers that are degraded into microplastics during disposal and recycling procedures [8]. The wash of synthetic fabrics like polyester and nylon resulted into releasing microfibre into wastewater that could not be fully captured in the plants. Microplastics are rated from tire particles during driving and it is considered a significant contributor to airborne and roadside microplastics. Discarded fishing nets and ropes fragmented over time resulting in microplastics in the aquatic environment.

Food and beverages constitute a significant source of microplastic exposure for humans. Marine organisms, such as fish and shellfish, can ingest microplastics from their environment, which then enter the human food chain [8]. Water sources, including sea salt, lake salt, and tap water, can also contain microplastics, with bottled water exhibiting higher concentrations compared to tap water [9]. Additionally, food stored in plastic packaging may become contaminated during heating or prolonged storage.

Airborne microplastics represent another crucial exposure pathway, as these particles can settle on food or be directly inhaled by humans [10]. Indoor air can contain microparticles from textiles, carpets, and upholstery, while outdoor air can be contaminated by microplastics from high-traffic areas and industrial activities [11][12]. Other sources, such as incomplete filtration at wastewater treatment plants and the use of plastic-containing fertilizers, contribute to the ubiquitous presence of microplastics in the human environment, from the air we breathe to the food we consume [13][14]. The widespread occurrence of microplastics underscores the urgent need for strategies to reduce their prevalence and mitigate the associated risks.

EXPOSURE PATHWAYS

The empirical research literature indicates that microplastics can enter the human body through various exposure pathways, including ingestion, inhalation, and dermal contact. These pathways reflect the widespread nature of microplastic contamination and its potential health implications.

- **Ingestion**

Ingestion is a well-documented pathway for human exposure to microplastics, which can be contaminated through food, beverages, and water sources. Seafood, including shellfish and certain fish, are primary sources, as these organisms often ingest microplastics from their environment [15]. Additionally, processed and packaged foods can become contaminated with microplastics during heating or prolonged storage. Even dietary sources like table salt, which is derived from sea, rock, and lake sources, may contain microplastics [15].

Research by Pironti et al. has indicated that bottled water tends to have higher concentrations of microplastics compared to tap water, likely due to contamination during the manufacturing and packaging process [8]. Microplastics may also be present in tap water drawn from municipal water supplies and aging pipes, owing to poor infrastructure and extensive storage [8]. Humans can also inadvertently ingest microplastics from the air. Evidence from human stool samples has confirmed the passage of microplastics through the gastrointestinal tract.

- **Inhalation**

Microplastics are prevalent in both indoor and outdoor air, posing significant exposure risks, particularly in urban and industrial areas. Indoor environments, such as those with textile-based furnishings, can harbor microplastics, and activities like vacuuming or shaking fabrics can increase their presence in the air [15]. Similarly, cooking with plastic utensils or heating plastic containers can release microplastics into the indoor atmosphere. Outdoors, road dust particles and industrial operations contribute to the release of microplastics into the atmosphere. In urban settings with heavy traffic, elevated levels of airborne microplastics can be directly inhaled, potentially penetrating deep into the human respiratory system, including the alveoli, which is especially concerning due to the risks posed by these small particles.

- **Dermal Contact**

Although dermal exposure is a smaller pathway compared to ingestion and inhalation, it can still occur through personal care products and water exposure. Microbeads in cleansers, scrubs, and cosmetics that are directly applied to the skin can result in prolonged contact [16]. Additionally, microplastics used broadly for bathing and swimming can come into contact with the skin [17]. While the skin acts as a natural barrier and evidence suggests minimal dermal absorption under normal conditions, it is possible that microplastics could penetrate the skin [18]. Separate research has also indicated that plastic-based drug delivery systems, medical equipment, and agricultural fertilizers may contribute to microplastic exposure through inhalation [19].

HEALTH IMPLICATIONS

The research by Li et al. suggests that the presence of microplastics in the human body could raise various concerns regarding their potential health impacts [7]. The available evidence indicates a range of biological, toxicological, and systemic implications associated with microplastic exposure.

- **Physical Impact**

Microplastics, due to their small size, can infiltrate tissues and cells, potentially leading to physical disruptions. As noted by Karbalaei et al. [20], these particles may accumulate in vital organs and trigger inflammatory responses and oxidative stress. The presence of foreign particles in tissues can result in chronic inflammation, tissue damage, and increased long-term complications. Moreover, microplastics can induce the production of reactive oxygen species, which can damage DNA, proteins, and lipids, ultimately contributing to cell death. Additionally, larger microplastic particles may obstruct the gastrointestinal or respiratory tract, leading to physical discomfort and impaired function [21].

- **Chemical Toxicity**

Microplastics can act as vectors for harmful chemicals due to their ability to absorb environmental pollutants during production or in the environment. Certain additives used in plastics, such as bisphenol A and flame retardants, are known endocrine disruptors. These chemicals can disrupt hormonal balance and potentially increase the risk of hormone-related cancers, such as breast and prostate cancer. Additionally, microplastics can bind to heavy metals, pesticides, and persistent organic pollutants in the environment [18]. When these pollutant-laden microplastics are ingested or inhaled, the adsorbed chemicals can increase the overall toxicity and bioavailability of harmful substances within the human body.

- **Immune System Impact**

Existing evidence suggests that microplastics may trigger immune system responses. Continuous exposure could lead to chronic immune activation, potentially contributing to the development of autoimmune disorders and impairing overall immune function, thereby diminishing the body's ability to fight infections and diseases [22]. Furthermore, research has indicated that microplastics could have a direct cytotoxic, or cell-damaging, impact on immune cells, including microphages and other immune cell types.

- **Gut Microbiota Disruptions**

Ingesting microplastics may disrupt the composition and function of the gut microbiota [23]. Microbial imbalances resulting from this disruption could impair digestive health, immunity, and metabolism. Additionally, the inflammatory response triggered by microplastics could weaken the intestinal barrier, potentially allowing the passage of substances into the bloodstream and leading to systemic effects.

- **Respiratory System Damage**

Inhalation of airborne microplastics poses significant risks to the respiratory system. Research indicates that microplastics deposited in lung tissues can trigger inflammatory responses, potentially leading to pulmonary inflammation [22][24]. Prolonged exposure may also result in the development of serious respiratory conditions, such as pulmonary fibrosis [22][24]. Furthermore, some microplastic particles could potentially act as allergens, contributing to the onset of respiratory ailments like asthma and rhinitis.

- **Carcinogenic Potential**

The available evidence suggests a potential, though limited, relationship between microplastics and cancer in humans. Existing research indicates that microplastics may induce DNA damage and persistent inflammatory states, which could plausibly contribute to cancer development [25][26]. Additionally, certain substances commonly associated with microplastics, such as bisphenol A and persistent organic pollutants, have been recognized as carcinogens [27].

- **Development and Reproductive Health**

Evidence from animal studies suggests that microplastic exposure may have a significant impact on human development and reproductive health [21]. Certain chemicals associated with microplastics, such as phthalates, have been shown to interfere with hormonal signaling and potentially affect fertility [28]. Preliminary research also indicates that microplastics may be able to cross the placental barrier, potentially exposing developing fetuses to their potential toxic effects [28].

Emerging Areas of Concern

The current research on the human health implications of microplastics has expanded, but still has gaps. Emerging evidence suggests that microplastics may impact neural pathways, potentially leading to cognitive and behavioral changes [29]. Additionally, chronic inflammation and oxidative stress induced by microplastics may contribute to the development of cardiovascular diseases. The multifaceted and systemic nature of the health concerns related to microplastic exposure necessitates urgent attention to conduct further research and elucidate the mechanisms of toxicity and exposure. This knowledge is crucial for developing effective public health interventions and regulatory policies [30].

DISCUSSION

The presence of microplastics in the human body is a widespread phenomenon, raising significant concerns related to environmental public health and regulatory issues. A systematic review has highlighted the pathways and potential health implications of microplastic contamination, while various evidence has also underscored its potential harm and critical gaps that require further investigation to address such issues. Domenech and Marcos have represented the entry of microplastics into the human body through ingestion, inhalation, and dermal contact [1]. The primary sources include contaminated food, beverages, and personal care products, with ingestion through food or water being the most significant pathway, while inhalation poses a serious risk, particularly in urban and industrial environments. The research has indicated that the health effects of microplastics are multifaceted, encompassing physical damage, chemical toxicity, and systemic biological responses. The research has suggested that microplastics could induce inflammation, oxidative stress, and hormonal disruptions, potentially leading to long-term impacts such as cancer, respiratory disorders, and reproductive health issues [13][14].

Despite the increasing research on microplastics and their impact on health, several challenges remain in improving the understanding of microplastic impact. The current methods used to detect microplastics in biological samples have been widely researched, but they have limited comparability across studies. Standardized protocols are essential for accurately detecting and analyzing exposure levels. The evidence regarding the health impacts of microplastics is primarily derived from animal studies, while human epidemiological studies are limited, making it difficult to establish a clear relationship between health outcomes and exposure [18]. Furthermore, the long-term bioaccumulation and chronic impacts of microplastics are not well understood, necessitating longitudinal studies to analyze their effects and indications over time. Microplastics can act as carriers for harmful chemicals, but their impact on human health remains unexplored, highlighting the need to focus on analyzing the adsorbed pollutants and their contribution to microplastic toxicity.

The research presented by Prata et al. has important implications for public health and policy, as it provides a clear understanding of the significant risks associated with microplastic exposure [5]. This necessitates a combination of toxicological studies and epidemiological data analysis to develop appropriate public health guidelines. Governments and authorities should consider restricting microplastics in beverages and air. Efforts should focus on reducing the release of microplastics from industrial and consumer activities by improving waste management and implementing strict manufacturing standards. Raising public awareness through various campaigns that highlight microplastic exposure and promote sustainable consumption practices is also crucial. Furthermore, special attention should be directed towards populations with greater occupational exposure to airborne microplastics.

Future Research Direction

Systematic reviews have identified various areas for future research, including the development of more sensitive and comprehensive methods for detecting microplastics in biological samples and environmental media. Researchers could conduct longitudinal and large-scale epidemiological studies to better understand the relationship between microplastic exposure and health outcomes. Previous studies, such as the one by Yang et al. [29], have investigated the combined impacts of plastic and its absorbed pollutants on human health. Future research could explore the potential for microplastic bioaccumulation in healthy tissues and their biodegradation within the body. Additionally, the research should evaluate the effectiveness of intervention strategies and focus on reducing microplastic pollution and exposure, particularly in high-risk regions. Addressing microplastic contamination, a significant global challenge, will require systemic changes and a transition to biodegradable materials to improve waste management and promote a circular economy. Furthermore, efforts to mitigate microplastic pollution should align with global sustainability goals related to health and environmental protection.

CONCLUSIONS

Microplastics have emerged as a ubiquitous and significant pollutant that infiltrates the human body through various exposure pathways, posing substantial health concerns. This systematic review has synthesized current knowledge on the sources, routes of exposure, and health implications of microplastic contamination, underscoring the urgent need for future research.

Microplastics can enter the human body through ingestion, inhalation, and dermal contact, with the most common sources being contaminated food, water, and airborne particles. These exposures can impact human health in various ways, including physical damage, chemical toxicity, immune responses, and potential systemic effects. Importantly, significant gaps remain in understanding the long-term impact and underlying mechanisms of microplastic toxicity in humans [31].

Addressing the microplastic issue requires a multifaceted approach, with research focused on developing standardized detection methods and exploring the interactions between microplastics and adsorbed pollutants. Policymakers should consider restricting microplastic release and contamination, while promoting sustainable material and waste management practices. Mitigating the health risks associated with microplastics necessitates global collaboration, scientific research, and public engagement [31]. Adopting such actions can help protect human health and work towards a system that minimizes the impact of plastic pollution on individuals and the ecosystem.

DISCLOSURE

Authors contribution:

Conceptualization: Alicja Grzelak

Methodology: Alicja Grzelak

Software: Alicja Grzelak

Check: Alicja Grzelak

Formal Analysis: Alicja Grzelak

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