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Review Article

A review on threats of microplastics on human health

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Abstract

Microplastics pose a significant threat to humans and the environment due to their small size and environmental persistence. When not filtered out during sewage-treatment, they can penetrate the human body, harm marine species, and induce ecotoxicity through polymer matrices. This can lead to malnutrition, inflammation, decreased fertility, and marine creature death. The buildup of microplastics in the human body, including road paint, tires, city dust, washing machines, and cleaning supplies, is a concern due to its complex toxicity in marine fauna. Further investigation is needed to understand the causes, distribution, and effects of microplastics in diverse ecosystems.

Keywords: Microplastics, Health effects, Environmental pollutants, Human exposure, Waste management.

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1. Introduction

Environmental contaminants known as microplastics are common in polar areas, isolated islands, and seas. Because of their potential negative consequences, microplastic exposure poses a serious and growing danger to ecosystems. To present a current overview of our knowledge on the origins, compositions, and harmful impacts of microplastics on both individuals and the environment, we have studied the literature. Although humans are exposed to microplastics through a variety of routes, little is known about the harmful effects of microplastics on humans. Most of the research on microplastics has concentrated on creating standardized techniques for tracking the presence, distribution, and movement of microplastics in the environment as well as creating alternatives. The harmful consequences of microplastics, which can differ based on their kind, size, shape, and concentration, are poorly understood about human health. Thus, more research is needed to understand the molecular and cellular pathways behind microplastic toxicity and associated illnesses.

Microplastics are tiny plastic particles, generally less than five millimeters in size, that have become a growing concern for environmental and human health. These particles originate from the breakdown of larger plastic waste or are intentionally manufactured for use in products like cosmetics and cleaning agents. Due to their small size, microplastics can easily enter natural ecosystems, spreading through oceans, rivers, soil, and even the air we breathe. Over time, they accumulate in marine organisms, animals, and eventually, in humans through the food chain. The persistent and non-biodegradable nature of microplastics makes them especially dangerous. They can carry toxic chemicals, disrupt biological functions, and pose serious risks to both environmental sustainability and public health. As plastic production and usage continue to rise globally, addressing the issue of microplastics has become an urgent priority for researchers, policymakers, and communities alike. Microplastics are widely used around the world. Unfortunately, plastics contribute greatly to environmental contamination due to their poor biodegradability. The smallest known plastic particles are microplastics (1 µm-5 mm) and nanoplastics (1 nm- 1 µm). Nano- and microplastics can enter the human

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body through the digestive tract by ingesting contaminated food and drink, the respiratory system by inhaling them, or the skin by encountering clothing and cosmetics.

Plastic bioaccumulation in the human body can lead to a variety of health problems, including neurological symptoms like fatigue and vertigo, inflammatory bowel disease, respiratory disorders such as lung cancer, asthma, and hypersensitivity pneumonitis, and even changes in gut microbiota. Most studies have found that nano- and microplastics are genotoxic and cytotoxic, and can cause cell death. Understanding the cellular and molecular mechanisms that underpin plastics' actions may help us to anticipate future hazards to people. They may be classed based on fragment size and origin. Microplastics may be divided into two categories: primary and secondary. Primary microplastics are plastic particles that have been purposely created and can be found in industrial or consumer products. Microplastics are also known as microbeads. Microbeads are currently prohibited in South Korea and abroad. Secondary microplastics include plastic-containing objects like waste and fibers, as well as deteriorated plastic goods that have been exposed to the environment.

2. Materials and Methodology

Writing this review article involved a systematic approach to collecting, evaluating, and synthesizing existing research on the topic. The purpose of this review article is not to present new experimental results but to provide a critical overview of current knowledge, identify gaps, and suggest directions for future research. This section outlines the structured methodology followed in developing the review.

1. **Identification of the Research Topic -** The first step involved selecting a relevant and timely topic with sufficient existing literature. The choice was guided by growing scientific interest and social relevance. The topic was refined through preliminary reading and consultation with experts in the field, ensuring that the review would address current challenges and unanswered questions.
2. **Literature Search Strategy -** A comprehensive search of peer-reviewed journals, books, and academic databases was conducted using platforms such as Google Scholar, PubMed, ScienceDirect, and Scopus. Keywords and phrases related to the topic were used in various combinations (e.g., “microplastics,” “environmental impact,” “toxicology,” and “remediation strategies”). Filters were applied to select articles published in the last ten years, although foundational works beyond this range were also included for context.
3. **Inclusion and Exclusion Criteria -** Studies were selected based on relevance, methodological rigor, and publication in reputable journals. Only articles written in English and available in full-text were included. Studies with inconclusive or poorly supported results were excluded to maintain the credibility of the review.
4. **Citation and Referencing -** To ensure academic integrity and support the synthesis of ideas, all data and conclusions drawn from other works were properly cited. This also allows readers to trace original sources and verify information.
5. **Rationale for Writing the Review -** The increasing volume of scientific publications on the chosen topic makes it difficult for researchers and policymakers to stay updated. Therefore, this review aims to consolidate current knowledge, provide clarity on debated issues, and offer insights into emerging trends. By identifying research gaps, this article also aims to stimulate further investigations and inform evidence-based policy decisions.

3. Discussion

The question of whether microplastic contamination endangers ecosystems and human health is of great concern. Nonetheless, this problem is plagued with uncertainty. As a result, information on microplastic exposure and impact levels is required to assess the dangers that microplastics represent to human health and the environment. Organisms exposed to microplastics may experience one of two sorts of detrimental impacts: chemical or physical. The former identifies the particle size, shape, and concentration of microplastics, while the latter determines the harmful compounds linked with them. Even though data on microplastic exposure levels in ecosystems and animals has grown considerably in recent decades, little is known about the chemicals connected with microplastics. Microplastics can contain two types of chemicals:

1. Polymeric raw materials and additives (e.g., monomers or oligomers) derived from the plastic itself, and
2. Chemicals absorbed from the environment.

To improve the performance of plastic goods and raise their resistance to ozone, temperature, light radiation, mold, bacteria, and humidity, as well as mechanical, thermal, and electrical resistance, additives are chemicals that are purposely added during the production process. These chemicals offer plastic properties like color and transparency. These include plasticizers, flame retardants, UV stabilizers, inert or reinforcing fillers, lubricants, pigments, and antioxidants. Charging materials include wood and rock flour, clay, kaolin, graphite, glass fibers, cotton flakes, cellulose pulp, jute or linen, and so on.[1]

Reinforcing fillers, often known as inert fillers, are compounds that are significantly stronger than the basic resin.[2] Inert fillers are chemicals that improve the strength, working, and flow qualities of plastics, as well as their shrinkage. When mixed with the polymer, these fillers (such as carbon black in rubber) form an interface volume at the filler-resin contact surface. This interface layer's superior properties are what give the composite polymer its greater modulus and mechanical properties, such as tensile or impact strength. Fillers with smaller particle sizes frequently have a stronger reinforcing effect since their action is surface-related. Silica, glass, talc, chalk, asbestos, alumina, rutile, carbon black, carbon nanotubes, and clays are among the materials.[3] Because plastics are especially vulnerable to the deteriorating effects of heat, light, and UV radiation, stabilizers prevent thermal breakdown during manufacture, as well as oxidation and subsequent polymeric chain breaking (using phenols and aromatic amines). Lead, barium, and cadmium salts, both inorganic and organic, are the primary components.[4]

Because plastic is present in the natural world everywhere, humans cannot escape being exposed to it. MPs are a type of waste that is poorly biodegradable. They can enter the human body mainly through the respiratory, digestive, or injured skin systems, and they can collect in different tissues by overcoming biological membrane barriers. The number of studies on microplastics' influence on health is growing. According to the EU classification and labelling rule,[5] several compounds that are deemed harmful are found as common constituents in ordinary products. A substance's capacity to have negative consequences is known as its toxicity. A single cell, a collection of cells, an organ system, or the body may be affected. The most dangerous chemicals are those that can cause cancer, DNA mutations, hazardous reproductive effects, environmental recalcitrance, accumulation in the food chain or body, and other detrimental consequences, such as hormone disruption.[6-7] The neurological system, which includes the brain, the reproductive system, the liver, kidneys, and heart, is the internal organ most impacted. Numerous chemicals that are often used to produce plastics are hazardous. It has been established that phthalates, bisphenol A (BPA), and several of the brominated flame retardants used in food packaging and home goods are endocrine disruptors that can harm people's health if consumed or breathed.[8]

Particularly concerning are endocrine-disrupting chemicals (EDCs), which are defined as compounds that are exogenous to the human or animal organism and have hormonal action that modifies the endocrine system's homeostasis. These substances disrupt the endocrine system's growth and have an impact on the operation of organs that react to hormones. The potential of endocrine disruptors to: (a) imitate natural hormones, (b) counteract their action, (c) change their pattern of synthesis and metabolism, or (d) alter the expression of certain receptors may result in their endocrine and reproductive impacts.[9-11] EDCs have been linked by recent research to several illnesses and ailments, including neurodevelopmental disorders (learning disorders, autism spectrum disorders), metabolic disorders (diabetes, obesity), reproductive issues (genital malformations, infertility), and hormonal cancers (breast, prostate, testes). Concern is raised by the increasing prevalence of several diseases in Europe and throughout the world, in addition to the scientific data that has previously been demonstrated. Furthermore, these compounds are easily available to the public through a variety of sources.[8]

3.1. BPA

BPA is a synthetic carbon-based molecule with the formula $C_{15}H_{16}O_2$. It has two 4-hydroxyphenyl groups in its structure, which give it a faint phenolic smell. Acetone and two equivalents of phenol were condensed to create it for the first time in the 1890s.[11] BPA is a widely utilized plasticizer in industry, notably in food packaging and polycarbonate plastic manufacturing.[12-13] Because BPA-based polycarbonate plastics can endure high temperatures and high-impact collisions, they are tough and durable. Because of these characteristics, they are valuable as components of food packaging and safety devices, as they can withstand heating in microwave ovens. BPA helps to increase the shelf life of food and beverage products since it is a component of epoxy resins in protective coatings, such as the insides of aluminium and metal cans (as well as the lid closures of glass jars and bottles).[14] Despite its remarkable persistence, the compound's instability in plastic products facilitates leaching, which is why it is discovered in large quantities in aquatic habitats, particularly effluent from landfills.[15-16]

3.2. Phthalates

Phthalates are esters of phthalic acid (1,2-benzene dicarboxylic acid) having two carbon chains of variable length. In terms of manufacturing volume, phthalates are the biggest family of synthetic chemicals and are a class of compounds that are manufactured in enormous amounts.[17] An estimated 6,000,000 t of phthalates are manufactured annually worldwide, according to reports.[18] Over the last 20 years, this production has stayed rather consistent. Their main use is as plasticizers, which are added to basic plastic materials to give them certain properties, including elasticity, pliability, and flexibility.[19]

They are oily liquids that are colourless, odourless, and have poor water solubility and volatility.[20] The detrimental impact that some phthalates have on ecosystems and people has made them a cause for worry. Several phthalates are endocrine disruptors, and there is evidence that they may also have an impact on human or animal reproductive systems or cause cancer.[21-23] The issue is exacerbated by the fact that several phthalates have comparable mechanisms of action, which means that exposure to the various phthalates by humans and the environment may raise the total risk. Consequently, the potential combination effects resulting from exposure to additional phthalates and other drugs must be considered.[24] Phthalates come in a wide variety of forms, and there are signs that their impact on the environment and human health varies.

4. Heavy Metals

Heavy metals are naturally occurring elements with relatively significant atomic mass and density compared to water. Having a density of at least 5 g/cm−3 is a common way to identify heavy metals from other "light" metals. Some broader definitions require that "heavy metals" have an atomic mass larger than 23 or an atomic number greater than [20.25-27] However, these categories are confusing and misleading since they include non-metals. Accordingly, some authors[28] have suggested that the term "heavy metals" is more appropriately defined when referring to (1) transition elements; (2) rare earth elements, which are further subdivided into lanthanides and actinides, including La and Ac itself; and (3) a heterogeneous group that comprises the metal Bi, the metalloids Ge, As, and Te, as well as the elements that form amphoteric oxides (Al, Ga, In, Tl, Sn, Pb, Sb, and Po). Although the atmosphere, lithosphere, hydrosphere, and biosphere all naturally contain heavy metals, human exposure to these metals and environmental pollution have mostly resulted from anthropogenic activity.[27]

Arsenic, cadmium, chromium, lead, and mercury are categorized as "known" or "probable" human carcinogens by the US Environmental Protection Agency (USEPA) and the International Agency for Research on Cancer (IARC) due to evidence from epidemiological and experimental studies that link exposure to these elements to an increased risk of cancer in both humans and animals.[28] Their toxicity is dependent on a wide range of parameters, including the chemical species, dose, the way the person is exposed to the element, age, sex, heredity, and the exposed subject's nutritional status. Numerous negative impacts and human illnesses result from cellular and tissue damage caused by excessive concentrations of heavy metals.[29-34] As metal–oestrogens with high affinity to oestrogen receptors, the metals Al, Sb, As, Ba, Cd, Cr (II), Co, Cu, Pb, Hg, Ni, Se, Sn, and V are considered dangerous and may be linked to breast cancer because of their capacity to mimic oestrogen activation.[35-37] According to certain theories, cadmium has a role in oxidative stress, DNA damage, cellular death, methylation of DNA, lipid peroxidation, and a rise in bone fractures in women who have gone through menopause.[38]

For instance, it has been demonstrated that titanium oxide, an ingredient included in many plastic goods, causes cytotoxicity to human epithelial lung and colon cells.[39] Lead has a number of negative effects on human health, including altering the genes that control cellular tumors, influencing the DNA repair system, generating reactive oxygen species (ROS), and affecting the central nervous system, which can result in damage to cognitive and motor abilities, convulsions, coma, and death. Cancer of the kidneys, liver, lungs, and bladder may result from arsenic poisoning. The kidney and the central nervous system are the two target organs that mercury impacts. Mercuric mercury is the cause of elemental mercury's toxicity. The blood–brain barrier is quickly crossed by inflated elemental mercury vapours, and the oxidation that results in mercuric mercury initiates a bond with brain macromolecules.[40-41] If we consider the interactions between microplastics, which are metal vectors, and biota, the exposure of living things to such inorganic pollutants is constantly rising.[42]

Concerns regarding the effects of microplastics on human health have been voiced by the World Health Organization,[43] which has also drawn attention to their existence in the environment.[44-47] Microplastics have been found in sugar, salt, alcohol, and bottled water, making contaminated food a key entry route into the human system.[48-52] An estimated 80g of microplastics per day might be consumed by humans through plants that absorb MPs from contaminated soil. Additionally, marine animals that humans eat, such fish, bivalves, and crabs, contain microplastics.[53]

Because synthetic particles smaller than 150 µm may penetrate the gastrointestinal epithelium in mammalian bodies and cause systemic exposure, exposure through food is therefore conceivable. A smaller percentage (0.1%) of these particles, which are larger than 10 µm, can reach organs and cellular membranes, although only 0.3% of them are anticipated to be absorbed.[54] Although exposure concentrations are expected to be minimal, technical, and analytical challenges have limited data on micro and nanoplastics in the environment.[55]

Particles less than 2.5 µm can enter the gastrointestinal system after ingestion either by paracellular persorption or endocytosis by M cells, which transports them to the mucosal lymphoid tissues. Because microplastics are persistent and have special characteristics, the toxicity that results is through inflammation.

Inhalation, wind, atmospheric depositions, and industrial emissions are some of the ways that microplastics can reach the human body. In males, these particles can result in autoimmune illnesses, cytotoxic and inflammatory consequences, and respiratory discomfort.[56-61] The lung's wide alveolation surface allows nanoparticles to enter the bloodstream and spread throughout the body. The cytotoxic and genotoxic effects of 50 nm polystyrene particles on lung epithelial cells and macrophages have been shown. The lung's wide alveolation surface allows nanoparticles to enter the bloodstream and spread throughout the body. The cytotoxic and genotoxic effects of 50 nm polystyrene particles on lung epithelial cells and macrophages have been shown. Diffuse interstitial fibrosis, granulomas with fiber inclusions, chronic bronchitis, interalveolar septa lesions, and acute bronchial responses are possible reactions to inhaled particles. Skin contacts with water when washing or while using scrubs and cosmetics that include micro and nanoplastics is the last route of exposure to microplastics. Here, table 1 outlines harmful chemicals commonly found in microplastics, their primary uses, and adverse effects on human and environmental health while **Figure 1** summarizes overall sources and transport of microplastic, and the efforts required about microplastic pollution including research, scientific gaps, and society action.

Table 1: Table outlining harmful chemicals commonly found in microplastics, their primary uses, and adverse effects on human and environmental health

Chemical	Primary Use	Harmful Effects
Bisphenol A (BPA)	Plastic production, epoxy resins	Endocrine disruption, reproductive toxicity, developmental disorders[62]
Phthalates (e.g., DEHP, DBP)	Plasticizers in PVC, toys, packaging	Hormonal imbalance, reduced fertility, liver and kidney damage[63]
Polybrominated diphenyl ethers (PBDEs)	Flame retardants in electronics, textiles	Neurotoxicity, thyroid dysfunction, carcinogenic potential.[64]
Polychlorinated biphenyls (PCBs)	Insulating fluids, banned but persistent in environment	Immunotoxicity, endocrine disruption, cancer risk.[65]
Nonylphenol	Detergents, industrial cleaners	Estrogenic activity, aquatic toxicity, reproductive abnormalities in fish[66]
Heavy metals (e.g., Lead, Cadmium, Mercury)	Pigments, stabilizers in plastics	Neurotoxicity, developmental delays, kidney damage[67]
Polycyclic aromatic hydrocarbons (PAHs)	Contaminants from fossil fuels, absorbed on plastics	Carcinogenicity, DNA damage, oxidative stress[68]
Per- and polyfluoroalkyl substances (PFAS)	Water-resistant coatings, non-stick cookware	Immune suppression, thyroid disruption, increased cancer risk[69]

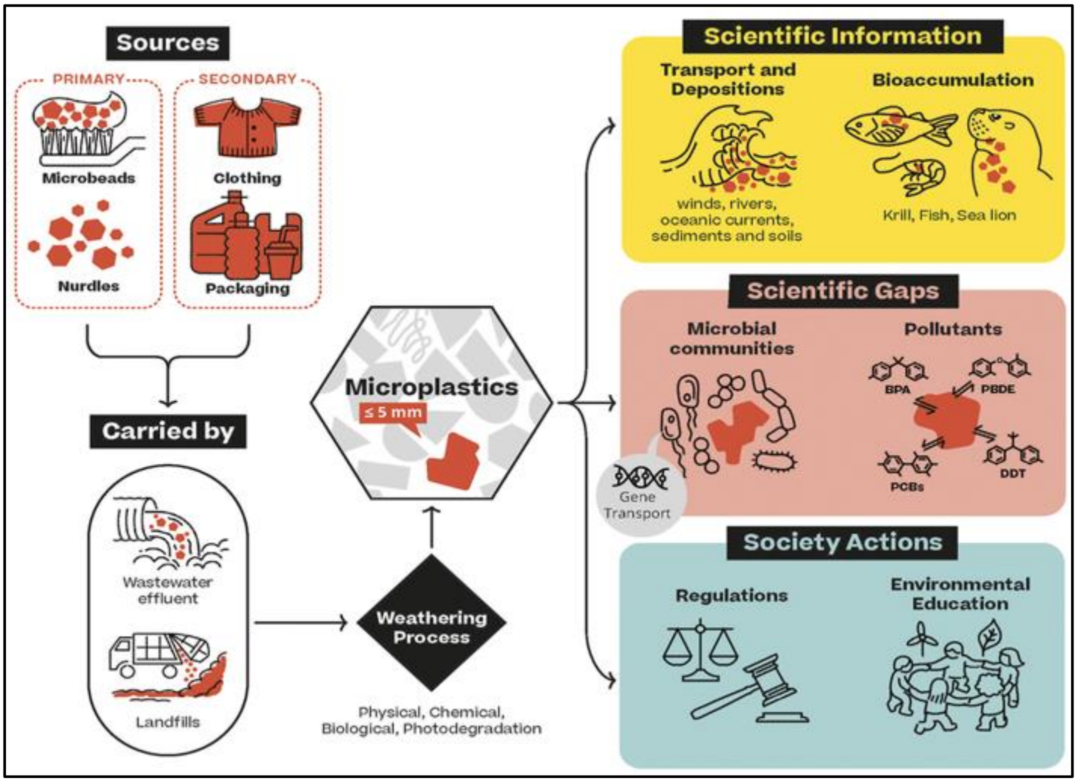

Figure 1: Overall sources and transport of microplastic, and the efforts required about microplastic pollution including research, scientific gaps, and society action[70]

It is improbable that microplastics will be absorbed via the skin since the corneous layer can only penetrate particles smaller than 100 nm. Numerous characteristics of microplastics, including their size, shape, chemical makeup, and hydrophobicity, have the potential to be harmful and affect how cytotoxic the particles are to cells and tissues. They are very conductive to heavy metals, antibiotics, and hydrophobic and persistent organic contaminants that might enter the human body through the absorption of microplastics. Human absorption models of nanomaterials made by different industrial production techniques can be used to evaluate the potential impacts of microplastics and nanoplastics on other human organs, however testing is currently ongoing.

5. Conclusion

Microplastics, found in oceans, isolated islands, and polarregions, pose a significant threat to ecosystems due to their direct and indirect potential as environmental contaminants. The definition of microplastics, including size cutoff and materials involved, is not agreed upon globally. Microplastics are often created intentionally or due to improper handling or disposal of large synthetic polymer items, such as plastic packaging. They are released into the environment, where they break down. Microplastics are a combination of hazardous chemicals added during manufacturing to enhance polymer characteristics and prolong their life. This study aims to highlight the most toxic and dangerous chemicals found in all plastic products and provides a comprehensive overview of studies investigating the abundance of these chemicals in microplastics.

To address the detrimental consequences of microplastics in nature, significant research areas include developing better detection and quantification technologies, particularly for nanoplastics, as well as understanding their environmental destiny and transport processes. Long-term effects on organisms and human health must be evaluated through toxicological research. Developing biodegradable alternatives and green materials is critical to decreasing plastic reliance. Research on effective waste management, legislative frameworks, and remediation technologies such as filtration and biodegradation is critical. Furthermore, investigating public awareness techniques and behavioural science might influence sustainable consumption behaviors. Together, these sectors provide a comprehensive strategy for reducing microplastic pollution and protecting ecosystems.

For countering the negative impacts of microplastics, a multidisciplinary research strategy focusing on numerous crucial areas is required. First, improved detection and quantification techniques are required, particularly for detecting nanoplastics in various environmental media such as water, soil, and air. These developments will allow for more precise estimates of pollution levels. Second, understanding the environmental fate and mobility of microplastics can aid in predicting their movement, accumulation, and interaction with other pollutants. Understanding the toxicological effects on organisms is another critical field that necessitates long-term research to assess physiological, reproductive, and genetic consequences. Human health risk evaluations are also necessary, particularly when examining exposure routes via food and water. Furthermore, the development of biodegradable alternatives and environmentally friendly materials can assist in lessening dependency on existing plastics. To avoid future microplastic creation, novel waste management solutions such as enhanced recycling and circular economy models must be investigated. Remediation technology, including filtration systems, microbial degradation, and chemical breakdown processes, should be tailored to both aquatic and terrestrial ecosystems. Finally, research on public awareness, behavioural change, and policy efficacy is critical for promoting collective action. These interrelated study topics serve as the foundation for a comprehensive and sustainable response to microplastic contamination and its long-term effects on ecosystems and human health.

6. Source of Funding

None.

7. Conflict of Interest

None.

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