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Microplastic in food chain-Major health issues-An update

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Abstract

Microplastics, which are tiny plastic particles measuring less than 5 mm in length, have been found to have significant negative impacts on both human health and the environment. Due to the alarming increase in contamination worldwide and excessive production of plastics and synthetic materials, there is an urgent need to investigate the effects of those substances on human health. It has been observed that there exists a definite correlation between exposure to micro- and nanoplastic particles and the onset of several cancers and other health disorders. Of particular concern are plastic additives, chemical compounds that are intentionally or unintentionally added to plastics to improve functionality or as residual components of plastic production. Microplastics and nanoparticles enter the human body even when consuming drinking water, food and during normal breathing. Contamination may occur also through the migration of nanoplastic particles from the packaging materials into food products. Micro- and nanoplastic fibers are also present in other foods, including beer, honey, table salt, tea bags and sugar. The sources of airborne microplastic include synthetic fabrics from clothing, rubber tire erosion, household objects, building materials, landfills, abrasive powders and 3D printing. Microplastic in the food chain have potential health risks on human includes, cancer, immunotoxicity, intestinal diseases, pulmonary diseases, cardiovascular disease, inflammatory diseases, loss of male and female sterility, adverse effects on pregnancy and maternal exposure to progeny. The actual impact of microplastics and nanoplastics on human health cannot be clearly and completely defined, since it requires extensive, multi-disciplinary long-term research.

Keywords: Bisphenol A (BPA); Cancer; Food Chain; Microplastic; Male sterility, Nanoplastic; Phthalates

1. Introduction

The beginnings of the extensive use of plastics date back to the early 1950s. It is estimated that over 9 billion tons of plastic have already been produced, 3/4 of which currently constitutes waste[1-30]. In the past few years, over 360 million metric tons (Mt) of plastic have been produced worldwide each year, 40% of which is single-use packaging [1-40]. Most of it is discarded into the environment [1-25-56]. The term "microplastics" was first coined 19 years ago by

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Thompson et al. (2005) [36], who studied oceanic plastic pollution in the UK [1-30–65]. Since then, microplastics have attracted the attention of the scientific community, governments, and non-governmental organizations,[1-30–64]. Recently, microplastics have been found in freshwater ecosystems, including rivers, lakes, estuaries, wetlands, and groundwater[1-30–65]. Plastic products consist of various kinds of polymers in combination with versatile and processable mixtures of a variety of chemicals (> 13,000) [1-30–65]. Overall, more than 3200 monomers, additives, processing aids (e.g., lubricants), and non-intentionally added substances used in plastic manufacturing potentially exhibit hazardous properties [60]. Additive chemicals improved the performance, functionality, stability and durability of polymers and plastic products. However, if plastic products are exposed to water, the chemicals can leach from the products and become bio-available [60-65]. Microplastics consists of particles that range in size from 0.1 to 5000 **μ**m, and nanoparticles ranges from 0.001 to 0.1 **μ** m, which are water-insoluble solid particles or polymer matrices of regular or irregular shape [1-40-65]. Microplastics were generally classified into primary and secondary types based on their origin[1-40-65]. The primary microplastics were the virgin plastic production pellets, which extensively exist in domestic and industrial products like hand and facial cleaners, cosmetics, and shower gels [1-30–65]. Primary microplastics particles are the ingredients of cleaning agents, toothpastes, scrubs, hand soaps or biomedical products[1-50-65]. The secondary particles are those obtained by fragmentation processes under the influence of UV radiation or physicochemical processes, such as pH or salinity [50–65]. These include household garbage, plastic films or emissions from vehicles [1-30–65]. Microplastic pollution is becoming a major issue for human health due to the recent discovery of microplastics in most ecosystems [1-30–65]. Microplastics have been found in biological samples such as faeces, sputum, saliva, blood and placenta [1-30–65]. Cancer, intestinal, pulmonary, cardiovascular, infectious and inflammatory diseases are induced or mediated by microplastics [1-30–65]. Microplastics, tiny plastic particles, can enter the food chain through various routes, including direct ingestion by marine and terrestrial organisms, and can also be transported through the atmosphere and soil, ultimately affecting human health and ecosystems[1-30–65]. Microplastics are tiny particles of synthetic polymers and plastics and their products that are less than 5 millimeters in size[1-30–65]. Microplastics can either be intentionally added to products, for example in cosmetics or cleaning products, or be a waste product from the decomposition of larger plastic parts [1-30–65]. Microplastics enter the environment through many different pathways, where they are difficult to degrade and can pose a potential threat to wildlife and human health[1-30–65].

Microplastics induce toxic effects on humans and animals, such as cytotoxicity, immune response, oxidative stress, barrier attributes, and genotoxicity, even at minimal dosages of 10 μg/mL [1-30–65]. Ingestion of microplastics by marine animals results in alterations in gastrointestinal tract physiology, immune system depression, oxidative stress, cytotoxicity, diferential gene expression, and growth inhibition [1-30–65]. Furthermore, bioaccumulation of microplastics in the tissues of aquatic organisms can have adverse effects on the aquatic ecosystem, with potential transmission of microplastics to humans and birds [1-30–65]. Microplastics, which are tiny plastic particles measuring less than 5 mm in length, have been found to have significant negative impacts on both human health and the environment [1-30–64]. In the following section, this review paper of literature highlights the effect of toxicity of microplastic in the food chain particularly on human health has been updated and discussed.

2. Microplastics: Toxic Chemicals

The polymer backbone of floating plastics breaks down and can release low molecular-weight dissolved organic matter like carboxylic acids, monomers, more complex hydrocarbons or halogenated compounds under simulated marine conditions [1-30–64]. The photodegradation can be a key mechanism for fragmentation of plastic debris floating in the oceans [1-30–65]. Additionally, photodegradation of plastics induces the formation of micro- and nanoplastic particles [1-30–65]. Microplastics pollution poses a health concern [61]. The more plastic created, the more the subsequent generation will have to face an irreparable health danger [1-65]. However, research has mostly concentrated on a small number of plastic compounds, a wide variety of health conditions, including endocrine disruption, reproductive toxicity, cancer risk, problems with metabolism and nutrition, and interference with neurodevelopment have been reported [1-30–65]. Microplastics is the most often composed of polypropylene (PP), polystyrene (PS) or polyethylene (PE) [1-30–65]. Polypropylene is relatively chemically resistant. It has a crystalline structure with a high level of rigidity. Its hardness is due to the presence of methyl groups in the molecular chain [1-30–65]. Polypropylene is characterized by a high melting point [61]. Polypropylene comes in three types, as a PP homopolymer (HPP) containing propylene monomers in a semi-crystalline solid form, as a random copolymer (RCP), containing, apart from propylene, a small addition of ethylene as a co-monomer, and an impact copolymer (ICP), which contains a mixture of HPP and RCP with ethylene content of about 50% [1-30–65]. Polypropylene Polystyrene is highly thermoplastic [1-30–65]. It is used for the production of toys, toothbrushes, CDs or polystyrene [1-30–61]. Polystyrene is also used in the production of food containers. It is formed as a result of the polymerization of styrene components [1-30–65]. Polystyrene is thermostable, and therefore provides excellent thermal insulation as it is also chemically resistant [1-30–65]. Polyethylene consists of long chains formed by ethylene monomers. It is a stable polymer [1-30–65]. In addition, it is an excellent electrical insulator, characterized by high strength and flexibility [1-30–65]. It is the most popular plastic [61]. Additives are substances that give plastic the desired properties, and they include inert or reinforcing fillers, plasticizers, antioxidants, UV stabilizers, lubricants, dyes and flame retardants [1-30–61]. Inert fillers provide strength, improve flow and shrinkage of plastics and include asbestos, glass, rutile, silica, talc, clays, chalk, aluminum oxide, soot and carbon nanotubes [1-30–65]. Plasticizers are placed between the chains of molecules, ensuring an improvement in elasticity, mobility and plasticity [1-30–65]. Stabilizers ensure thermal and chemical stability and they consist of organic or inorganic salts of barium, lead and cadmium [1-30–65]. Dyes are used to give color to the polymer. They are divided into inorganic containing heavy metals and organic ones containing phthalocyanine, azo, and anthraquinone groups and many other chromophores [1-30–65]. Calcium and magnesium stearate are components of lubricants and adhesives, and their addition facilitates the flow of the substance [1-30–65]. Flame retardants contain chlorine, bromine, phosphorus and aluminum hydroxide to protect the material in the event of fire [1-30–65]. However, many of these additives, are toxic. They adhere to the microplastic surface and interact with the environment [1-30–65]. In recent years, the toxicity of heavy metals that adhere to microplastics has been studied and the reports obtained proved high concentrations of Cr, Ni, Fe, Co, Cd, Al, Zn, Mn, and Cu [1-30–65]. Polychlorinated biphenyls (PCBs) are formed by the fusion of 1 to 10 hydrogen atoms with chlorine atoms in the biphenyl ring [1-30–65]. Polycyclic aromatic hydrocarbons (PAHs) are compounds whose structure consists of many aromatic rings. [1-30–65]. On the microplastic surface, the presence and quantification was demonstrated for 3-methylphenanthrene, 9-methylphenanthrene, 2-methylphenanthrene, 1-methylphenanthrene, pyrene, benzo[b]fluorene, 2-methylpyrene, 1-methylpyrene, benzo[b]fluoranthene, chrysenic, 4-methylpyrene, benzo[j]fluoranthene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[e]pyrene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, benzo[ghi]perylene, 4H-cyclopen ta[def]phenanthrene, coronene, perylene, fluoranthene, phenanthrene, and anthracene [1-30–65]. Therefore, the addition of polycyclic aromatic hydrocarbons (PAHs) may lead to the increase in the toxicity of microplastics [1-30–65]. Bisphenol A (BPA), a diphenylmethane derivative, is a component of the monomer in polycarbonate and is used in the production of food and drink containers [1-30–65]. Nevertheless, it is highly unstable, which results in easy leaching, which correlates with its abundant presence in the aquatic environment[1-30–65]. Despite this, there is still insufficient research on the adsorption of bisphenol A (BPA) in microplastic [1-30–65].

A cause for concern is **bisphenol A** (BPA), structural similarities to hormones, which allows mimicking and nterference with the endocrine system [1-30–65]. Phthalates are ester derivatives of 1,2-benzenedicarboxylic acid. Phthalates are strongly lipophilic, which makes them firmly absorbed in the soil, which also allows us to conclude that they have a high sorption capacity in microplastics [1-30–65]. Many phthalates, in particular (di (2-ethylhexyl) phthalate (DEHP) and dibutyl phthalate (DBP)), are toxic chemicals used in the preparation of microplastics[1-30–63]. Plastic has numerous additives that improve its properties. The most investigated species are bisphenol A (BPA), vinyl chloride (VC), and benzyl butyl phthalate (BBP) [1-30–65]. In recent years, it has been shown that exposure to BPA during pregnancy reduces the survival rate and birth weight of offspring [1-30–65]. It also exerts a hormonal effect, as it mimics the estrogenic hormone, thus increasing the likelihood of developing carbohydrate disorders and cardiovascular disease[1-30–65]. A list of carcinogenic, neurotoxic, and hormone-disrupting chemicals are common constituents and waste products of plastic manufacture, and they invariably make their way into environment via water, land, and air pollution [1-30–65]. Vinyl chloride (in PVC), dioxins (in PVC), benzene (in polystyrene), phthalates and other plasticizers (in PVC and others), formaldehyde, and bisphenol-A, or BPA, are some of the most well-known substances (in polycarbonate) [1-30–65].

3. Microplastics: Major Health Issues

Since 1950, about 9 billion tons of plastics have been produced globally [1-30–65]. About half of the plastics have ended up in landfills or have been dumped in the natural environment [1-5], and only less than 10 % have been adequately recycled [1-30–64]. On the basis of literature survey by Baj et al., (2022) [1], micro- and nanoplastic particles can be found almost everywhere, being especially harmful for humans [1-50]. Their absorption, primarily via inhalation and digestive routes, might lead to a dangerous accumulation of those substances within the human body[1]. Due to the alarming increase in contamination worldwide, excessive production of plastics and synthetic materials, there is an urgent need to investigate the effects of those substances on human health [1-63]. So far, it has been observed that nano- and microplastics might be extremely harmful, leading to serious health conditions, such as cancers of various human body systems [1-65]. On the basis of literature survey by Baj et al., (2022) [1], micro- and nanoplatics have been already reported to be potential carcinogenic/mutagenic substances that might cause DNA damage, leading to carcinogenesis[1-65]. Thus, the effects of micro and nanoplastics exposure on human health are currently being investigated extensively to establish clear relationships between those substances and health consequences[1-50]. Furthermore, Baj et al., (2022) [1] are of the opinion that there exists a definite correlation between exposure to micro- and nanoplastic particles and the onset of several cancers [1-65]. One of the study reported that when consuming fruit and vegetables, exposure to plastic reaches up to 80 g microplastics per day [1-30–61]. Microplastics and nanoparticles enter the human body even when consuming drinking water and during normal breathing [1-30–63]. Humans are liable to small plastic particles via the following three routes: oral (intake of contaminated water and food), respiratory and dermal (via skin cleansers/facial scrubbers) [1-30–61]. The primary plastic entry point into the human systems is the gastrointestinal tract [1-30–63]. Involuntary plastic ingestion by humans may happen via the food chain with consumption of contaminated food and drinks [1-30–61]. Contamination may occur also through the migration of nanoplastic particles from the packaging materials into food products[1-30–61]. Micro- and nanoplastic fibers are also present in other foods, including beer, honey, table salt, tea bags and sugar [1-30–65]. Additional exposure results from drinking water in plastic bottles [1-30–63]. In bottled mineral water from nine countries, the contamination with microplastic was estimated from 0 to over 10,000 particles/L (size range of 6.5–100 μm) [1-30–65]. According to the literature survey, micro- and nanoplastic particles are present in widespread marine products, including fish, mussels, lobsters, oysters, sea cucumbers, and scallops [1-30–61]. One of the study confirmed that 20 microplastic particles per 10 g of human stool samples, which confirms their involuntary ingestion [1-30–65]. Another entry point of plastics into the human body is via the respiratory system [1-30–65]. The sources of airborne microplastic include synthetic fabrics from clothing, rubber tire erosion, household objects, building materials, landfills, abrasive powders and 3D printing [1-30–65]. Nanosized particles bear the potential to penetrate the capillary blood system and be distributed throughout the human body [1-30–65]. *In vitro* studies have shown that nanoplastic particles are absorbed by alveolar epithelial cells [1-30–65]. The last route of exposure of plastics into the human body is through the skin [1-30–65]. Skin constitutes the outer shell of the body that protects the body against heat, light, injury, and infection [1-30–65]. Skin can come into contact with plastic particles, especially when cosmetic products containing nanoplastic are used [1-30–65].

Studies have reported that plastic particles can affect the diversity and composition of gut microbiota [1-30–65]. With respect to the effects on the cardiovascular system, a study on developing zebra fishes proved that the main site of accumulation of nanoplastic particles was the pericardial sac [1-30–65]. The reproductive impact of micro- and nanoplastic has been investigated in a variety of organisms[1-30–65]. The main target of plastic particles seems to be the embryo life cycle influencing the embryo and offspring development[1-30–65]. Moreover, sperm cells may be damaged by oxidative stress and inflammation caused by plastic particles [1-30–65]. The presence of micro- and nanoplastic in the nervous system may exert a toxic effect that is caused mainly by oxidative stress and inhibition of the AchE enzyme [1, 10, 61]. AchE is responsible for the degradation of acetylcholine, hence, for normal nerve signal transmission [1-30–65]. Its inhibition may lead to over excitation of the neurons and neurological disorders. Nanosized particles are potentially more neurotoxic, as smaller sizes may more easily penetrate the blood–brain barrier [1-30–65]. Both animal studies and *in vitro* trials showed that the accumulation of plastic particles leads to inflammation [1-30–65]. Micro- and nanoplastic particles, recognized as foreign agents by the immune system, may induce the immune response and ultimately cause host toxicity[1-30–65].

In human gastric adenocarcinoma, lung carcinoma, leukemia, and histiocytic lymphoma cells, polystyrene nanoparticles increase the expression of IL-6 and IL-8 genes [1-30–65]. Macrophages are the main phagocytic cells that uptake plastic particles[1-30–65]. Oxidative stress can induce cell apoptosis, which is considered the key pathway of micro- and nanoplastic toxicity[1-30–65]. Moreover, plastic particles have various functional groups and chemical bonds (such as phenyl groups, amide groups), which may be related to oxidative stress [1-30–65]. Many in vitro studies have identified increased oxidative stress and apoptosis in human cells, including hematological cells, alveolar epithelial cells, lung cancer cells, and colon carcinoma cells, following polystyrene exposure[1-30–65]. Plastic particles can also absorb substances such as metals, PAHs, phthalates, PFAAS from the surrounding environment [1-30–65]. Although these substances are either not absorbed or degrade rapidly in the human body, plastic particles facilitate their penetration and make them stay in the body longer [1-30–65]. The adverse effects include acute inflammation of the liver caused by plastic-associated metal or carcinogenicity of PAHs [1-30–65].

The plastic industry emits a large amount of harmful gaseous pollutants into the air, including carbon monoxide, dioxins, and hydrogen cyanide [1-30–65]. These gases damage the air and their presence at large concentrations in the air is harmful to both human and animal health [1-30–65]. Both carcinogenic and non-carcinogenic effects can impact human health; healthcare practitioners should be aware of their local recycling plants [1-30–65]. Exposure can occur from ingestion, dermal contact, as well as via inhaling. However, occupational workers present higher risks of exposure to the toxic elements, potentially altering and inhibiting their metabolic functions[1-30–65].

Endocrine disruptors are substances that can alter and interfere with endocrine functioning, also known as hormonally active agents, endocrine disruptive chemicals, or endocrine disrupting compounds [1-30–65]. Cancerous tumours, birth abnormalities, and other developmental diseases can result from these changes [1-30–65]. Endocrine disruptors, which can be found in a wide range of consumer and industrial products, might interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body and are responsible for development, behavior, fertility, and the maintenance of homeostasis, as well as the onset of malignant and non-malignant diseases [1-30–65]. Polychlorinated biphenyls may pose a significant threat [1-30–63]. Except for solid tumors, micro- and nanoplastics particles might also be a threat regarding the potential onset of liquid malignancies. A recent study by Leslie et al. (2022) [56] proved that plastic particles (primarily polyethylene terephthalate, polyethylene, and polymers styrene, along with poly (methyl methacrylate)) might accumulate in the human bloodstream [1-30–65].

Inhalation of plastic particles may cause various lung reactions, including alveolitis, persistent pneumonia, inflammatory, and fibrotic modifications in the bronchial and peri-bronchial tissue and lesions in the interalveolar septa (pneumothorax) [1-30–65]. The actual impact of microplastics and nanoplastics on human health cannot be clearly and completely defined, since it requires extensive, multi-disciplinary long-term research [1-30–61]. Undoubtedly, plastic's carcinogenic/mutagenic impact on cells has already been broadly reported [1-30–63]. Except being potentially harmful themselves, microplastics might also be contaminated with other substances, including harmful organic chemicals or trace metals, whose exposure to living organisms might be toxic [1-30–61]. So far, the knowledge regarding the relationship between the exposure to nano- and microplastics and the onset of carcinogenesis is relatively scarce and has only been investigated with regards to several types of cancer, such as hepatocellular carcinoma or pancreatic cancer [1-30–65].

Consuming microplastics have been found to promote inflammation and prolong arthritic foot swelling in mice challenged with the chikungunya virus [1-30–65]. Microplastics are a growing concern as a category of organic pollutants that have gained significant attention from researchers since 2014 [1-30–65]. As the impact of microplastics continues to increase, it is essential to develop sustainable solutions to mitigate their harmful effects and reduce their presence in the environment [1-30–65]. To increase public awareness of microplastic concerns and promote the development of effective solutions, several measures must be implemented, including educational initiatives to raise individuals' awareness of microplastics and media sources like television shows, journals, and social media platforms [1-30–65]. Various human biological specimens, such as faeces, sputum, saliva, blood, bronchoalveolar lavage fuid, placenta, and other organs, have been found to contain microplastics, suggesting that these particles may induce detrimental effects on human health [1-30–65]. These effects can include potential health risks such as cancer, immunotoxicity, intestinal diseases, pulmonary diseases, cardiovascular disease, inflammatory diseases, and adverse effects on pregnancy and maternal exposure to progeny [1-30–65]. Further research is also needed to understand acute and chronic microplastic toxic effects on humans and animals and to develop suitable alternatives to single-use face masks and medical industry plastic waste[1-30–65].

4. Conclusion

On the basis of literature survey it is found that microplastics are routinely ingested and inhaled by humans and other organisms. Of particular concern are plastic additives, chemical compounds that are intentionally or unintentionally added to plastics to improve functionality or as residual components of plastic production. Additives are often loosely bound to the plastic polymer and may be released during plastic exposures. Plastics, over the last half-century, have established a worldwide presence in nearly all societies and are widely detectable as pollutants in the environment. Humans regularly interact with plastics through food packaging, clothing, toiletries, household items, furniture, automotive parts, medical equipment, electronics, toys, 3D printing, and office supplies. All plastics experience weathering, leading to the release of microplastics (1 μm to 5 mm) and nanoplastics (<1 μm). For instance, humans are routinely exposed to plastic particles through respiratory, oral, and dermal routes. As a result, plastic has been detected in human tissue and secretions, such as the lungs, colon, breast milk, and placenta. Common additives used for performance enhancement include plasticizers, flame retardants, heat and light stabilizers, antioxidants, lubricants, pigments, antistatic agents, slip agents, biocides, and thermal stabilizers. Microplastics have been associated with endocrine-related cancers, biliary tract cancer, hepatocellular carcinoma, and pancreatic cancer.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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