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MICROPLASTICS: HEALTH HAZARDS AND THE WAY FORWRAD

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ABSTRACT

Microplastics (MPs) are tiny pieces of plastics, less than 5 mm in size. They cause a type of pollution that has become a public health concern worldwide.. Current studies have increasingly focused on understanding the possible health hazards of MPs exposure on the human body. This review seeks to highlight the exposure pathways, pathophysiology and toxicity of MPs as well as proffer possible solutions.. Previous works and research findings on this subject were accessed through Google Search, PubMed, and Wikipedia websites. In addition, standard textbooks on Pharmacology were consulted. Sources of MP pollution include plastic degradation products, textile fibres, tire degradation products, etc. The MPs have been detected across different ecosystems and have been found to infiltrate the food chain, raising concerns about their potential impacts on human health. On entering the human body MPs move through various tissues and organs and cause health hazards by localized toxicity and by triggering immune response. DNA damage, oxidative stress and inflammatory reaction can occur after prolonged exposure to MPS. At present, determination of reference values of plasma concentration of MPs is difficult because different nanoplastics have different toxicities making standardization difficult and most harmful effects of microplastics occur after prolonged exposure. Measures of limiting exposure to MPs pollution including avoidance of serving or storing hot dishes and drinks in plastic containers, avoidance of perfumes and roll-ons that contain polymers, among others were highlighted.

Keywords: Food Chain, Health Hazards, Microplastics, Oxidative Stress, Pollution, Toxicity.

1 INTRODUCTION

Microplastics (MPs) can be defined as plastic fragments under 5mm in size. Their emergence has caused a significant public health and environmental concern due to their widespread presence in the ecosystem and their ability to infiltrate human tissues. [1] The environmental impact of MPs has been extensively reported, their effect on human

health remain less understood, particularly regarding their role in disease progression across multiple organ system. [2]

Polystyrene and other synthetic polymers like polyethylene, propylene, polyvinyl chloride (PVC), and nylon are MPs widely present in standard products which have harmful effects on biological systems.

Plastic waste consist mainly of the fluorinated polymers [3] such as Perfluoroethylene propylene (FEP), Perfluoroethylene alkanes, Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA), Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA), Polyvinylfluoride (PVF), Polyvinylidenefluoride (PVDF), Polyethylenetherefthalate (PET), Polypropylene (PP), and Polyethylene (PE)

Microplastics have two main sources: Primary and secondary: Primary Sources are plastics designed to be manufactured in tiny sizes. Secondary Sources are mainly textiles fibers, plastics degradation, tire wear particles, and paints and coating. [4]

The primary sources of microplastics (MPs) include personal care products, which are MPs that originate from microbeads in various products such as scrubbing masks or toothpaste. Also included are industrial abrasives which are MPs used in industrial processes like sandblasting, where they short small plastic pellets at a surface to clean it. These pellets are the types that can escape into the environment and contribute to MP pollution.

Secondary Sources of MPs include textile fibers like the synthetic fibers from washing clothes made of polyester, nylon, and acrylic shelled MPs. Plastic degradation is common in larger plastics debris such as bottles, bags and packaging materials which break down into MPs through environmental processes such as exposure to ultraviolent radiation, physical abrasion, and biological degradation. Tire wear particles, abrasion of tires during driving releases MPs into the environment. Paints and coatings like marine and terrestrial paints can contain deletions of MPs as part of the dissolution or erosion process.

Extensive research on human health has led to concern about the effect of MPs on various body organs and systems and the role of MPs in different disease progressions. [5]

The entrance of MPs into the human body primarily occur through ingestion, inhalation, and transdermal absorption, with recent studies detecting their presence in vital organ such as the lungs, gastrointestinal tract, and even placenta tissues. [6]

The MPs are found in nearly every tier of the food chain, from bottled water to sea food. When ingested, MPs may build up in the gastrointestinal tract (GIT), leading to inflammation, alteration of gut bacteria, and possibility of systemic pollution. Disruption in the balance of gut flora is detrimental to maintaining stable metabolism and a vigorous immune system. Prolonged exposure to MPs and the resulting chronic inflammation of the GIT have been linked with conditions such as irritable bowel syndrome (IBS) and inflammatory bowel disease.[7]

Airborne MPs from synthetic textiles, tire degradation and urban dust, endanger respiratory health. MPs may accumulate in pulmonary tissues upon inhalation, resulting in inflammation and compromised lung function. Studies have reported that these inhaled MPs caused inflammatory changes in the lungs, leading to asthma and other chronic obstructive pulmonary diseases. [8]

Recent research indicates that MPs may bypass biological barriers, like the placental barrier, signifying prenatal exposure that may interfere with normal fetal development. [9],[10] . Polystyrene MPs contain deleterious compounds such as styrene monomers which the International Agency for Research on Cancer (IARC) categorizes as possible human carcinogens. [11]

Besides growing evidence of MPs harmful effects, critical knowledge gaps remain. For instance, the mechanisms by which MPs interact with biological systems, their role in the development of diseases like cardiovascular disorders, reproductive toxicity and metabolic syndromes and the long-term consequences of chronic exposures are poorly understood. This review aims to present recent findings on the health hazards of MPs and the way forward. By identifying key knowledge gaps and proposing future research directions, this study could provide a comprehensive resource for understanding the multifaceted risks posed by MPs to human health.

1.1 Sources of Exposure to Microplastics

There are various sources of exposure to microplastics. According to Plastic Solutions Review [12], the following are important sources of microplastics and nanoplastics exposure:

1.1.1 Water

This is the biggest source of exposure and include

- Sachet and bottled water. Particles shed from the plastic packaging; more dangerous when these sachet/bottled waters are exposed to heat.
- Boreholes located near dump sites. Microplastics from dump sites sip into the ground water
- Unfiltered water from boreholes, tap, and streams.

1.1.2 Food

Hot food in plastic/nylon takeaway packs. It is estimated that heat makes plastics and nylon packs shed 1000 times more microplastic particles. Sea foods such as fish, crayfish, and periwinkles accumulate microplasics from polluted river waters thereby contributing to pollution of the food chain. Plastic-seal tea bags release billions of micrplastic particles.

1.1.3 Air

- Burning plastics in open dump sites
- Tyre wears and road dust in urban areas
- Synthetic clothes (polyesters, blankets) release microplastics that float in the room environment
- Car dashboard and other plastic furnishings especially when vehicles are packed in the sun for prolonged periods.

1.1.4 Household items

- Non-stick cooking pots and pans release MPs when scratched.
- Plastic kitchen wares such as cutting boards, plates, spoons, cups, mortars and pestles, especially when the cups, plates and spoons are used to serve hot dishes and teas.
- Cosmetics, perfumes and roll-ons:
- Long lasting microencapsulated fragrance perfumes use tiny MP particles to release fragrance slowly.
- Many roll-ons contain MPs to make them stick to the skin.
- Perfumes and roll-on that contain polymers are the greatest culprits.

1.1.5 Occupational exposure

- Hospital staff exposed to disposable gloves, syringes, IV lines
- Dump site workers
- Oil mining workers exposed to flared gases
- Plastic repair artisans: Artisans who engage in the repair of broken plastic car bumpers, head lamps dashboards and other plastic car components inhale a lot of microplatic particles as they apply heat to these plastics during the repair process.

1.2 Prevention of Exposure to Microplastics

- Avoid serving or storing hot dishes and drinks in plastic containers.
- Do not reuse PET bottles for hot drinks
- Avoid sweeping up dust; better to mop the room with wet cloth.
- Filter drinking water whether stream, tap or borehole.
- Use wooden chopping board, mortars, and pestles in the kitchen
- Avoid the use of non-stick pans and utensils that release Mps when scratched.
- Limit the use of fast food wrappers and microwave ovens.
- Avoid perfumes and roll-ons that contain polymers. Use alcohol based perfumes and roll-ons labeled polymer free.

1.3 Safe Levels of Microplastics?

- Official safe levels of microplastics in the water, air, food and blood have not been determined because of the following reasons. [13]
- Measurement of microplastics and nanoplastics in the blood is difficult; nanoplastics are usually the particles that enter the blood stream.
- Nanoplastics bind to plasma proteins, aggregate, or taken up by immune cells; they do not stay free in the plasma.
- Different nanoplastics have different toxicities making standardization difficult.

- Most harmful effects of microplastics occur after prolonged exposure

1.4 How Microplastics Produce Harmful Effects

- On entering the cell, MPs produce ROS such as superoxide (O_2^-), hydrogen peroxide (H_2O_2), hydroxyl radical (.OH). [14]. These may produce the following effects
- Oxidative stress which damage cell membranes leading to cell death.
- Inflammation as a result of immunological reactions in response to micrplastic particles.
- Carrier effect where microplastic particls adsorb heavy metals, chemicals, pathogens, and carry them through the blood stream into the organs (biofilm effect).
- Endocrine disruption where plastic additives like phthalates and biphenols act as agonist or antagonists on natural hormone receptors thereby disrupting endocrine functions

1.5 Regulations on Microplastics and Health Protection

There are no international laws on the safe levels of microplastic exposre because of the reasons earlier stated. Hoever, effeorts are being made to regulate harmful practices that predispose to microplastic exposure.

In Nigeria, The National Environmental (Plastic Waste Control) regulation was recently enacted.

Key objective of this regulation to safely manage the plastic value chain through the *Extended Producer Responsibility (EPR)* which in part contains the *Polluter Pays Principle* which demands that a person who produces or generates plastics, plastic material, or waste shall bear the cost of remediating the damages such plastics, plastic material, or waste has done to public and environmental health. [3]

Regulations aimed at mitigating the MP's environmental and health effects have been globally enacted. While these regulations represent important steps forward, their effectiveness varies, and more comprehensive measures are needed to address the global crises caused by MPs. Some of these regulations include:

Bans of Expanded polystyrene (Eps): Various countries, including the European Union, Canada, U.S. states such as New York and California, have prohibited EPS in food containers due to its role in MP pollution. [15]

Bans on Microbead: Nations such as United State , United Kingdom, and Canada have enacted bans on microbeads in personal-care items to mitigate primary MP pollution. These enactment was placed when the microbead free waters Act (MFWA) of 2015 banned microbeads in personal-care product. However MFWA varied significantly across the different regions, leading to inconsistencies in implementation timelines, and potential loopholes. [16]

Packaging and waste regulation: The European Union (EU), Canada, and some U.S. states have limited single-use plastics, specifically polyethylene and polypropylene goods to mitigate the degradation of secondary microplastics into the environment. The EU introduced EU Directive 2019/904, known as the Single-Use Plastics Directive (SUPD), to prohibit certain single-use plastic items. The SUPD imposes rules like extended producer responsibility and mandatory product redesign for other plastic products. [17]

2 POTENTIAL HUMAN HEALTH EFFECTS OF MICROPLASTICS

MPs can affect multiple human bodily systems, like the immunological, respiratory, gastrointestinal, cardiovascular, neurological and reproductive systems.

2.1 Microplastics Effects on the Immune System

Microplastics such as polystyrene can cause immunological reactions inside the body through the following ways:

Immune Activation: Entrance of MPs into the blood stream or tissues may lead to an inflammatory response. Chronic exposure is associated with cardiovascular diseases, autoimmune disorders, and cancers.

The Oxidative stress pathways are activated, leading to the production of reactive oxygen species (ROS). Therefore, immune signaling pathways lead to the creation of pro-inflammatory cytokines through NF-kB. The over-activation of these pathways may lead to death of immune competent cells thereby compromising immune defense and causing tissue damage.

MPs interact with other environmental contaminants or microbial infections, enhancing their toxicity through surface binding, which increases immune responses. [18] The phenomenon of protein corona permits MPs to transport lethal substances further into the body system, which leads to chronic immune activation and systemic inflammation

Also, prolonged exposure to MPs is associated with immune-mediated organ damage, particularly the spleen and liver.

2.2 Effect of Microplastics on Respiratory System.

The tiny size of MPs make them easily accessible to respiratory tract where they provoke irritation and inflammation which leads to pulmonary injury such as pulmonary fibrosis, aggravation of asthma and other chronic respiratory disorders. [19] Studies have reported the presence of synthetic fibers and respiratory irritation in the lung tissue of textile industry workers. [20] This slow decline in lung function progresses to secondary pulmonary hypertension, and later respiratory failure.

Researchers investigated the lung inflammation and toxicity of MPs such as polystyrene, polypropylene and polyvinyl chloride (PVC) by intratracheally inoculating 5mg/kg of the different types of MPs in mice. Results showed increase in inflammatory cells and cytokines. [20]

2.3 Effect of Microplastics on Metabolism and Gastrointestinal Tract

The exposure of MPs to the gastrointestinal tract (GIT) occurs mainly through contaminated food or water. GIT inflammation, constipation, dysbiosis occur in chronic exposure to MPs because these particles accumulate in the digestive tract. The biological effects of MPs in the GIT result from their ancillary motion and the adsorption of biomolecules on their surface. Moreover, MPs significantly impact the association between gut bacteria and their hosts leading to an imbalance called dysbiosis with consequent intestinal toxicity. [21]

2.4 Effect of Microplastics on Cardiovascular System

The cardiovascular system (CVS) is complex and involves multiple pathways. Exposure to MPs causes certain ailments through inflammation, oxidative stress, endothelial dysfunction.

Studies have revealed that polystyrene MPs (PsMPs) may activate the Wnt/B-Catenin signaling pathway. [22] This leads to cardiac fibrosis, oxidative stress, and motality in Wistar rats. Result showed that PsMPs increase Troponin 1 and creatine kinase-MB (Ck-MB) levels in serum, causing myocardial structural damage, apoptosis, and collagen proliferation.. Furthermore, the findings discovered a potential mechanism for PsMPs-induced cardiovascular toxicity through oxidative stress and fibrosis.

2.5 Effect of Microplastics on the Nervous System

MPs, such as polystyrene, may affect the nervous system and penetrate the blood brain barrier, potentially inducing neuroinflammation and contributing to cognitive Impairment. [23]

Research on animal models indicates that chronic exposure to MPs may result in behavioral deficiencies and neurodegenerative disorders such as Alzheimer's and Parkinson's diseases. [24],[25]

2.6 Effect of Microplastics on the Endocrine System

Endocrine disruption is perceived as a possible consequence of chronic exposure to MPs. They can encapsulate and adsorb various substances from their environment, known as endocrine-disrupting compounds (EDCs). These EDCs are exogenous compound or mixture that can disrupt the regular endocrine-related mechanism leading to adverse health consequences. [26] Common EDCs include phthalates, esters, biphenol A (BPA) octyphenol, and nonyphenol, produced as reaction agents or additives produced from plastics. On ingestion, MPs release EDCs which interfere with the endocrine system. This disrupts hormonal balance, reproductive functionality, and may induce hormone-sensitive malignancies. [27]

2.7 Carcinogenic Potential of Microplastics

MPs may increase cancer risk through chronic inflammation. Persistent inflammation caused by MP accumulation in tissues may increase cancer risk, particularly gastrointestinal or lung cancers. [28] Researcher reported that in the epithelial cells, MPs can provoke oxidative stress, generating ROS which engages with cellular constituents, including protein, lipids and DNA, resulting in carcinogenic potentials in such cells. [29]

2.8 Effect of Microplastics on the Reproductive System

MPs, especially those infused with chemical compounds, may adversely affect reproductive health. It s reported that MPs interfere with the neuroendocrine system by affecting the synthesis of sex hormones through the disruption of hypothalamic-pituitary-gonadal (HPG) axis resulting in placenta dysfunction, endometrial hyperplasia, ovarian atrophy, and fibrosis among other reproductive abnormalities. [18] MPs also disrupt the blood-testis barrier in the male reproductive system leading to impaired spermatogenesis. [30] They cause endocrine dysfunction by releasing endocrine-disrupting substances such as di-ethyl-hexyl) phthalate (DEHP), heavy metals and various phosphorus pesticides. [31]

Similarly, developmental concerns in offspring are caused by exposure to MPs during gestation, which may impact fetal development. [32] Research using animals indicates that maternal MP exposure may reduce birth weight and produce other developmental complications in the fetus. [33] Following exposure to PSMPs male mice exhibited decrease serum levels follicle, stimulating hormone, luteinizing hormone, and testosterone, alongside increased estradiol levels. In female mice, the reversed is the case of these changes. [34] Hence the potential reproductive endocrine disorder caused by MPs maybe due to interference on the HPG axis and reduced steroidogenesis that could distort sex hormone balance, thereby delaying gonad maturation. This may reflects a possible way by which MPs challenge embryos and foetal growth.

2.9 Effect of Microplastics on the Skin

While cutaneous exposure to MPs is deemed a less critical route of exposure relative to injection and inhalation, possible issues mostly remain when the context is occupational and cosmetic. Research on MPs reveals several mechanisms contributing to oncogenic potential over the dermal system. Tiny MPs has extraordinary capability to penetrate cellular and physiological blockades, inducing toxicity effects across multiple levels. [35] Experiments involving micro-level have shown that they may induce elevated amount of ROS in carcinogenic cells of the skin.

This ROS is shown to induce danger-associated molecular patterns. It is also related to interruption of the inflammatory process, toll-like receptors and cytokine synthesis. [36] Researchers have observed that concurrent exposure of mice to polystyrene and DEHP inhibited cutaneous wound repair and induce inflammatory response and oxidative stress. [37]

MPs in cosmetics can induce skin irritation, especially in those with sensitive skin or those subjected to elevated concentration of MPs. [38].

3 CONCLUSION

This study highlights the universal presence of microplastic (MPs) in the environment, their potential human health impacts, and the urgency for coordinated action to mitigate these risks. MPs have emerged as a significant environmental and public health concern due to their widespread presence in the ecosystems and potential to infiltrate human tissue. MPs originate from various sources including plastic waste, synthetic textiles, and personal care products and have been increasingly detected in human environment (including the food chain), water and air. MPs may harm human health, trigger inflammation, and cause cellular stress. Evidence is mounting that MPs can have global consequences on the general population by possible inciting inflammatory responses leading to chronic diseases. They can interfere with endocrine function, suppress immune responses, and serve as vectors for harmful chemicals and pathogens.

The Way Forward

The way forwards involves the reduction in plastic pollution and additional research into toxicity to reduce the potential health risks that may not yet be fully understood with regards to its impact on human well being. It is also important for potential future studies to further investigate the impacts of MPs on human health as well as to elucidate their mechanisms in biological systems and assess possible risks regarding certain diseases. Improved identification will help in better tracking of MPs within the human body and long-term studies may establish additive health effects. Furthermore, investigation of the association between MP exposure and long-term ailments such as cancer or cardiovascular pathologies will be crucial.

To address this growing global threat of MPs, a multifaceted approach which will combine technological innovation, policy interventions, and public enlightenment is needed. The enforcement of the already enacted laws on the use of alternative eco-friendly materials that reduce plastic consumption will help to ameliorate the problem of environmental microplastic pollution. Awareness creation, especially at the grassroots level, on the dangers of improper use and disposal of plastics will go a long way in solving the problem of microplastic pollution and exposure. Thus, with the

implementation of robust policies, technological advancement, and fostering public awareness, MP pollution and exposure can be reduced.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

No conflicts of interest to be disclosed.

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