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Review Article

Impact of Microplastics on Human health: Time for us to get attentive- before it's too late!!

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Abstract: -

Microplastics, defined as plastic particles smaller than 5 mm, have been detected in common environmental matrices such as drinking water, food, and air. Their pervasiveness has led to increasing human exposure, and their recent detection in human blood raises alarming concerns about systemic bioaccumulation and long-term health effects. Moreover, their adverse impact on biological systems, particularly on gastrointestinal, immune, and vascular health, has also become a growing concern as discussed in this review.

Introduction:

Microplastics have become ubiquitous in the global environment and are now recognized as a significant emerging pollutant. Recent studies indicate that microplastics can enter the human body through multiple exposure routes, including ingestion via food and water, as well as inhalation of airborne particles. Once inside the body, these particles may induce a range of adverse health effects, such as oxidative stress, immune dysregulation, and developmental abnormalities. Although research is still evolving, the detection of microplastics in critical biological matrices such as placental tissue and breast milk underscores the potential for systemic exposure and raises pressing public health concerns (Luo et al., 2019) [1].

Recent studies have consistently reported the widespread presence of microplastics in various environmental matrices and human biological samples. Human exposure to microplastics can occur via multiple routes, including oral ingestion, inhalation, and dermal contact. Emerging evidence suggests that such exposure may induce a range of adverse health effects, such as oxidative stress, DNA damage, organ dysfunction, metabolic disturbances, immune dysregulation, neurotoxicity, and reproductive and developmental toxicity. Furthermore, epidemiological investigations have indicated potential associations between chronic diseases and microplastic exposure, highlighting a growing public health concern regarding their long-term biological impact [1].

Health Hazards of Microplastics[2-7]

1. **Oxidative Stress and Inflammation**
   - Microplastics can trigger oxidative stress in cells by producing reactive oxygen species (ROS).

- This oxidative damage contributes to chronic inflammation and may underlie various diseases including cardiovascular and neurodegenerative conditions.

2. **Immune System Disruption**
    - Microplastics may impair immune cell function.
    - This can lead to a compromised immune response, persistent low-grade inflammation, and increased vulnerability to infections and autoimmune conditions.
3. **Reproductive and Developmental Toxicity**
    - Prenatal and early-life exposure to microplastics has been associated with reduced fertility, hormonal imbalances, and altered fetal development.
    - Animal studies have shown negative effects on sperm quality, ovarian function, and offspring growth.
4. **Genotoxicity and Carcinogenic Potential**
    - Microplastics can cause DNA damage and affect gene regulation.
    - These genetic alterations are precursors to carcinogenesis, raising concerns about long-term cancer risks.
5. **Organ-Specific Toxicities**
    - **Digestive System**: Ingested microplastics can alter gut microbiota, cause inflammation, and disrupt nutrient absorption.
    - **Respiratory System**: Inhaled particles may cause chronic irritation and lung damage.
    - **Endocrine System**: Some microplastics carry endocrine-disrupting chemicals like BPA, leading to hormonal imbalances.
    - **Reproductive System**: Alters reproductive hormones and damages reproductive tissues in experimental models.
6. **Respiratory Hazards through Inhalation**
    - Airborne microplastics, especially in occupational settings (e.g., textile industries), are linked with respiratory diseases such as asthma, fibrosis, and chronic obstructive pulmonary disease (COPD).
7. **Dietary Exposure and Bioaccumulation**
    - Microplastics are found in seafood, salt, honey, bottled water, and even vegetables.
    - Continuous ingestion leads to bioaccumulation in tissues, which may trigger systemic toxicity over time.

Literature Review

Microplastic (MP) pollution is escalating globally, posing substantial threats to ecological systems and human health. MPs, defined as plastic particles less than 5 mm in size, are now considered pervasive environmental pollutants. MPs can alter the gut microbiome, compromise the intestinal barrier, and provoke inflammatory responses in the gastrointestinal (GI) tract. Animal model studies demonstrate a statistically significant correlation between MP exposure and GI health deterioration, underlining the systemic implications of such exposure ([8]).

A pioneering human study by Leonard et al. (2024) [9] analyzed blood samples from 20 healthy volunteers and detected 24 distinct polymer types in 18 participants (90%). These included endocrine-disrupting compounds such as phthalates. The presence of MPs in human blood raises concerns regarding their translocation to other organs and their potential to cause systemic effects, including vascular inflammation, immunomodulation, and thrombotic risks.

The work of Rajendran and Chandrasekaran (2023) [10] offers deeper insights into the toxic-dynamics of micro- and nanoplastics (MNPs) in the bloodstream. Their findings report a cascade of pathological effects, including protein denaturation, hemolysis, impaired immunity, coagulation anomalies, and endothelial cell damage. MNPs interfere with erythropoiesis, disturb stem cell proliferation, and promote red blood cell and platelet aggregation. These cellular-level changes increase the risk of thrombosis and cardiovascular complications. Crucially, MNPs also induce inflammation through immune cell phagocytosis, underscoring their role in systemic immune activation. Protein corona formation, oxidative stress, cytokine dysregulation, and genotoxicity were identified as key mechanisms underlying MNP toxicity. Additionally, the study emphasized significant research gaps, especially in evaluating the combined toxicity of MNPs with co-pollutants, dose–response relationships, human in vivo data, and advanced bioanalytical techniques for MP detection.

Further advancing this area, a recent investigation [11] employed double-shot pyrolysis gas chromatography/mass spectrometry to identify plastic particles ≥700 nm in blood from 22 healthy individuals. This method confirmed, for the first time, the internal exposure to high-production volume plastic polymers in human whole blood. These results substantiate the bioavailability of MPs and call for urgent toxicological assessments to understand their clinical implications.

Cumulatively, the literature underscores the urgent need for robust human studies to evaluate the pathophysiological impacts of MPs on the circulatory system. Evidence now implicates MPs in chronic diseases through vascular inflammation, disruption of endothelial function, immune system perturbation, and haematological toxicity. These findings necessitate policy-level interventions and comprehensive biomonitoring studies to better assess human exposure and associated health risks.

What further Research studies say?

Recent research has provided emerging evidence that microplastics (MPs) are present in human blood, with potential implications for systemic health. Several key studies are outlined below:

Microplastic Presence in Human Blood

- Leonard et al. (2024) [9-16] conducted a pivotal study on 20 healthy volunteers and detected 24 polymer types in the blood of 90% of participants. Five polymers crossed the quantification threshold, with a mean ± SD of 2466 ± 4174 MP/L and plastic concentrations ranging from 1.84–4.65 µg/mL. Predominant fragments included polyethylene (32%), ethylene propylene diene (14%), and ethylene–vinyl-acetate/alcohol (12%). The fragments were primarily white/clear (79%), with a mean length of 127.99 µm and width of 57.88 µm. Endocrine-disrupting phthalates were also detected among plastic additives.
- Leslie et al. (2022) [11] corroborated the presence of MPs in a separate donor group, reporting a mean concentration of 1.6 µg/mL in blood. The major polymers included polyethylene terephthalate, polyethylene, and styrene-based plastics, with polypropylene below quantification limits. This was a pioneering effort to quantify polymeric mass concentrations in human blood, confirming bioavailability and systemic circulation.

Health Impacts from Experimental Models

- Rajendran and Chandrasekaran [10] reviewed in vitro studies showing MPs induce cytotoxicity, genotoxicity, and oxidative stress in blood cells. Such impacts are linked to blood disorders like anaemia, thrombosis, cardiac issues, and immune dysfunction. These results support potential extrapolation of MP toxicity from models to human health implications.

Routes of Exposure and Systemic Risk

- Studies by Winiarska et al. (2023) [13] and Emenike et al. (2023) [14] have emphasized that MPs and nanoplastics (MNPs) can induce cell apoptosis, immune disruption, and gastrointestinal/endocrine dysfunction. Key exposure routes include ingestion, inhalation, and dermal absorption, with respiratory and cardiovascular effects particularly noted from airborne MPs.
- Bhuyan (2022) [15] highlighted MPs in aquatic food chains, noting that fish—being a major protein source for humans—can act as MP vectors. MPs induce neurotoxicity, oxidative stress, and immune modulation in fish, suggesting similar risks upon human consumption.

Knowledge Gaps

- While the detection of MPs in blood is a crucial development, study [12] highlighted the lack of standardized human toxicological studies, particularly focusing on how particle type, size, shape, and dose influence health.
- All these above studies including other studies [14-21] collectively confirm that microplastic particles are bioavailable and circulate in the human bloodstream, posing potential risks through oxidative stress, inflammation, and disruption of normal blood functions. Although preliminary, this evidence calls for deeper investigation into endothelial and red blood cell integrity, systemic effects, and standardized human health risk assessment frameworks.

Micro- and Nanoplastics (MNPs): Emerging Threats to Human and Environmental Health [19-21]

Micro- and nanoplastics (MNPs) have also emerged as a significant environmental concern due to their widespread distribution and potential adverse impacts on both ecosystems and human health. Numerous studies have demonstrated the toxic effects of MNPs and their complexes with other environmental pollutants on aquatic and terrestrial organisms. These synthetic particles are capable of adsorbing and transporting hazardous chemicals, thereby amplifying their toxicity.

Recent evidence has highlighted the presence of MNPs in dynamic biological environments such as the human bloodstream. This discovery opens a new and critical area of investigation, particularly concerning their interactions with blood components. MNPs can adsorb plasma proteins and complement proteins, leading to the formation of a "protein corona." This alters their physicochemical properties and influences their biological behaviour, including cellular uptake, immune recognition, and potential toxicity.

Role of Microfluidic systems [19]

The development of microfluidic systems has greatly enhanced the detection capabilities for MNPs, offering high sensitivity and specificity. These platforms not only improve our understanding of MNP behaviour in biological systems but also contribute to global efforts toward pollution characterization, mitigation, and the pursuit of a greener, healthier planet.

Conclusion:

Given the scale of microplastic pollution and its implications for both environmental and human health, there is an urgent need for accurate detection and risk assessment. Most current research is still environmental, with limited direct human health data. However, more research is needed to understand the cellular and molecular mechanisms of microplastic toxicity and related pathologies.

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- **Conflict of Interest Statement**

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- **Additional Information**

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