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Review Paper

From Environmental Pollution to Human Disease: Microplastics exposure, Molecular Toxicity, Environmental Remediation, and Future Perspectives

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Abstract

Microplastics have occurred as persistent ecological contaminants with significant ecological and potential human health implications. The review build on the recent evidence on the sources, environmental distribution, and exposure pathways of human, toxicological mechanisms, remediation strategies, and governance challenges associated with microplastics. Originating from either deliberately made particles or the fragmentation of bigger plastic remains, microplastics are extensively distributed in water, terrestrial, atmospheric environs and can also be detected in food, water, and tissues of human, like lungs, blood, , and the placenta. Exposure of Human occurs primarily through inhalation, dermal and ingestion contact. Following internalization, microplastics may stimulate inflammation, oxidative stress, endocrine disruption, genotoxicity, and mitochondrial dysfunction, while also acting as carriers of heavy metals, tenacious organic pollutants, antibiotic resistance genes, and pathogenic microorganisms through the "Trojan horse effect." Although increasing evidence suggests potential multi-organ toxicity, important exposure thresholds remain uncertainties, long-term health effects, and the biological behavior of nanoplastics. Furthermore, the absence of standardized analytical methods and harmonized monitoring protocols continues to limit reliable risk assessment. Current remediation approaches, including physical, chemical, biological, and circular economy strategies, provide partial solutions but remain insufficient for comprehensive environmental management. Advancing multidisciplinary One Health research, standardized analytical techniques, and coordinated international policies will be essential to moderate microplastic safeguard and pollution environmental and human health.

Keywords: Environmental Remediation, Human Health, Microplastics; Nanoplastics, Toxicity Mechanisms.

Introduction

The fast growth in plastic production world widely has exceed 400 million metric tons annually, and transformed plastics into vital materials while producing a major environmental challenge due to their persistence and poor biodegradability[1]. Among plastic pollutants, microplastics (MPs) which may be defined as a particle of smaller size than 5 mm have attracted worldwide attention because of their extensive persistence, distribution, and environmental potential and human health risks[2].

Microplastics can either be as primary particles specifically made from industrial and consumer products or secondary particles produced by degradation of larger plastics[3]. The particles has been detected in both terrestrial and aquatic environments, the atmosphere, drinking water, food, and human biological samples, such as lungs, blood, placenta, and breast milk (Figure-1), shows widespread environmental and human exposure[4;5]. Rising sign indicates that microplastics can induce inflammation, oxidative stress, endocrine disruption, mitochondrial dysfunction, immune dysregulation, and genotoxicity.

Furthermore, their ability to adsorb persistent organic pollutants, heavy metals, and other harmful chemicals allows them to act as carrier of contaminant transport through the Trojan horse effect (Figure-1)[6;7]. Although ingestion, dermal contact, and inhalation are recognized contact pathways, the long-term health consequences, dosage response relationships, and toxicity thresholds remain poorly understood[8;9]. This review critically studies the sources, ecological distribution, human exposure pathways, biochemical mechanisms of toxicity, remediation strategies, regulatory challenges, and evolving research directions related to microplastics, with the aim of informing future research, risk assessment, and environmental health policy[10].

Origin, Classification and Physicochemical Characteristics of Microplastics: Microplastics are synthetic particles from polymer that the sizes are than less 5 mm, while nanoplastics are

generally classified as polymer particles that is greater than 1000nm[11]. Their mobility, persistence, and physicochemical diversity have made them ubiquitous ecological contaminants with important public health and environmental effects. Exploiting their source, classification, and physicochemical properties are vital due to the factors that determine their ecological fate, biological toxicity, and interactions. According to their source, MPs can be classified as primary or secondary. The Primary microplastics are particles that are made for pharmaceuticals, cosmetics, synthetic textiles, and industrial
abrasives uses, while, the secondary microplastics are particles result from the degradation of larger plastic particles through ultraviolet radiation, mechanical scrape, hydrolysis, oxidation, and microbial activity[3;2]. Synthetic textile fibers and Wear out particles are major contributors to ecological pollution[12].

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Microplastics are mainly produced from polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), and polyethylene (PE), whose chemical structure influences their persistence, toxicity, and density[13]. They occur as fibers, pellets, fragments, foams, films, and beads, with weathering growing surface roughness and contaminant uptake capacity[14;15]. Their size, shape, crystallinity, hydrophobicity, density, and surface chemistry direct transport, ecological distribution, and biological adsorption. Smaller particles, mostly nanoplastics, have greater surface area and can more freely penetrate biological barriers, thus increasing toxicological risks[9;4]. Dynamics Environmental Distribution and Global Transport of Microplastics: Microplastics can now detected through agricultural soils, freshwater and marine environments, polar ice, air, glaciers, and remote hilly areas, spark their persistence and potential long distant transport[16]. Their extensive distribution is determined by increasing plastic production, insufficient waste management, urbanization, and industrial activities, resulting in continuous buildup within ecological compartments. Aquatic environments are major basins for microplastics, receiving inputs from metropolitan runoff, industrial wastes, wastewater, fishing activities, and maritime transport[17]. Waterways act as crucial transportation pathways, conveying plastic remains from earthly sources to oceans, while wastewater treatment plants remain important release sources due to conventional technologies cannot eliminate microscopic particles[18]. Subsequently, aquatic organisms, enabling trophic transfer and increasing human contact through seafood consumption19, ingest microplastics.

Microplastics accumulate in agricultural soils through plastic mulching, sewage sludge, irrigation, compost application, and air deposition, capable of disturbing soil structure, nutrient cycling, crop productivity, and microbial communities[20]. further expansion by their global distribution through atmospheric transport, with fibers and other lightweight particles spread over long distances and dumped in inaccessible areas, like the Arctic and Antarctic[14;21]. The ecological destiny of microplastics rest on mainly on their physicochemical possessions. Low-density polymers remain deferred in water, while heavier density polymers settle down as sediments. Weathering further improves fragmentation and increases their capacity to adsorb toxic chemicals and microorganisms[13]. Climate change may hasten microplastic generation through increased temperatures and ultraviolet radiation, while plastic production contributes to greenhouse gas discharges, strengthening the ecological challenge[22]. These impacts are mostly severe in developing countries where insufficient waste management increases ecological contamination.

Human Exposure Pathways and Internalization Microplastics Mechanisms: The microplastics extensive presence in the surroundings has increased human exposure through absorption, dermal contact, and inhalation, rising concerns about their possible health effects[23]. Their detection in human blood, placenta, lungs, breast milk, and feces reveals their ability to enter and circulate within the body, emphasizing the significance of understanding their absorption and internalization mechanisms[5].

Dietary digestion is one of the primary exposure route source, with microplastics recognized in vegetables, seafood, fruits, drinking water, processed foods, and table salt (Table-1)[24]. Plastic food containers and packaging also contribute through particle movement, mostly during heating or extended storage. Inhalation is another vital pathway, particularly in city environments where airborne fibers originate from synthetic textiles, household dust, tire wear, and industrial releases[25]. Although complete skin provides an effective barrier, nanoplastics may penetrate damaged skin, with occupational exposure posing additional risks[2].

Following exposure, microplastics are absorbed through intestinal endocytosis, persorption, and paracellular transport, allowing their entry into the lymphatic and circulatory systems (Table-1)[9]. Smaller particles, mainly nanoplastics, can store in organs such as the kidneys, brain, liver, and lungs that may cross biological barriers including the placental barriers, and blood–brain rising fears about neurotoxicity and fetal development[27;28]. Cellular uptake occurs through phagocytosis and endocytosis, promoting inflammation, oxidative stress, and organelle dysfunction while enabling the transport of adsorbed toxic chemicals and pathogens[4]. Although bio-monitoring studies confirm systemic exposure, doubts remain regarding long-term accumulation, metabolism, exposure thresholds, and chronic health results[5].

Table-1: Microplastics Human Contact Pathways.

Contact Pathway	Causes	Health Significance
Ingestion	water, Food, salt, seafood,	Gastrointestinal uptake, systemic exposure
Inhalation	Airborne fibers, indoor dust	Respiratory inflammation, lung deposition
Dermal contact	Water, textiles, cosmetics	Limited penetration, potential nanoplastic entry

Biochemical and Molecular Mechanisms of Microplastic Toxicity: Microplastics exert toxicity through several biochemical and molecular pathways that jointly interrupt cellular homeostasis. Following internalization, microplastics and nanoplastics interact with biomolecules and cellular organelles that induce inflammation, endocrine disruption, oxidative stress, genotoxicity, mitochondrial dysfunction, gut microbiota imbalance and immune dysregulation (Table-2)[9].

Oxidative stress is the primary mechanism of toxicity, resulting from the extreme production of reactive oxygen species (ROS) that overpower antioxidant defenses and lipids, DNA, and damage proteins (Table-2), thus promote genomic instability and potential carcinogenesis[29]. Nanoplastics show greater toxicity because of their higher area surface and reactivity. Persistent oxidative stress similarly triggers inflammatory pathways, exciting other immune cells and macrophages to release pro-inflammatory cytokines, like TNF-α, IL-6, and IL-1β that attribute to chronic tissue injury and fibrosis (Table-2)[26]. Microplastics again impair mitochondrial and lysosomal function, decreasing ATP production, disrupting cellular metabolism, and activating apoptosis[4]. Plastic-associated additives including bis-phenols and phthalates, together with adsorbed ecological contaminants, inhibit endocrine signaling, resulting to the developmental, reproductive, and metabolic disorders[7]. Experimental studies similarly reveal chromosomal abnormalities, DNA strand breaks, and epigenetic alterations, signifying both genetic and regulatory effects of exposure[27]. Furthermore, immune dysregulation and gut microbiota imbalance may compromise host defense and metabolic homeostasis. Due to their hydrophobic surfaces, microplastics can uptake persistent organic pollutants, pathogenic microorganisms, and heavy metals, acting as "Trojan horses" that intensify toxicity through co-exposure to various contaminants[7].

Human Specific Organ Health Implications of Microplastics: Increasing evidence of human exposure to microplastics has shown concerns about their organ-specific toxicity. Following absorption, microplastics and nanoplastics can be spread through the circulatory and lymphatic systems, increasing in the several organs where they may prompt oxidative stress, cellular dysfunction, and inflammation[26]. Although prolong human health effects remain incompletely understood, experimental and epidemiological research suggest widespread multi-organ association. The gastrointestinal tract (GIT) are the major route of contact through contaminated food and water. Microplastics can disorder intestinal barrier integrity, alter gut microbiota conformation, and impair nutrient absorption, possibly contributing to the metabolic and gastrointestinal disorders[9]. Inhaled microplastics, mainly fibers, may accumulate in the stimulating oxidative stress, respiratory tract, decreased lung function, and pulmonary inflammation, with chronic exposure potentially irritating respiratory diseases[23].

The kidneys and liver are susceptible to microplastic accumulation due to their involvement in detoxification and filtration. Experimental studies have related exposure to hepatic oxidative stress, renal inflammation, metabolic dysfunction, and impaired filtration capacity[26]. Cardiovascular effects, such as endothelial dysfunction and vascular inflammation, have also been reported, signifying a possible contribution to cardiovascular disease (Table-3)[26]. In addition, nanoplastics may cross the brain blood–barrier, prompting neuroinflammation, neuronal damage, and cognitive impairment[27]. Detection of microplastics in reproductive and placental tissues further rises concerns about endocrine disruption, impaired fertility, and adverse fetal development (Table-3)[28]. Systemic immune dysregulation and metabolic disturbances have also been associated with exposure, with pregnant women, children, infants, older adults, and occupationally exposed workers considered the most vulnerable populations[29].

Table-2: Biochemical Mechanisms of Toxicity.

Mechanism	Biological Effect
Oxidative stress	ROS production, lipid/protein/DNA damage
Inflammation	Cytokine release, chronic tissue injury
Endocrine disruption	Hormonal imbalance via additives
Genotoxicity	DNA damage and mutations
Mitochondrial dysfunction	Energy depletion and apoptosis

Table-3: Organ-Specific Health Effects.

Organ/System	Observed/Potential Effects
Gastrointestinal	Inflammation, microbiome disruption
Respiratory	Airway inflammation, reduced lung function
Liver & Kidney	Detoxification impairment, oxidative damage
Nervous system	Neurotoxicity, BBB crossing
Reproductive system	Endocrine disruption, fertility risks

Microplastics as Carriers of Emerging Contaminants (Trojan Horse Effect): Apart of their direct toxic effects, microplastics act as vectors of biological and chemical contaminants, a process known as the **Trojan horse effect.** By adsorbing and transporting harmful substances, microplastics can increase contaminant bioavailability, bioaccumulation, and toxicity in both environments and humans[11].

Persistent organic pollutants (POPs), including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, and dioxins, freely bind to the hydrophobic surfaces of microplastics, mainly weathered particles with increased surface irregularity[30]. In addition, heavy metals like mercury, chromium, lead, arsenic, and cadmium adsorb onto plastic surfaces or associated biofilms and may be discharged under gastrointestinal conditions, increasing their bioavailability and toxic effects[31]. Microplastics likewise offer substrates for microbial colonization, forming the plastisphere**,** that back the persistence and dispersal of pathogenic microorganisms, like antibiotic resistance genes and antibiotic-resistant bacteria[32]. Co-exposure to microplastics and adsorbed contaminants often produces synergistic toxic effects by facilitating contaminant transport across biological barriers, prolonging tissue retention, and increasing oxidative stress and inflammation[33]. The efficiency of contaminant adsorption base on the particle size, polymer composition, and environmental weathering, with larger and smaller particles mostly showing greater binding ability[11]. Although the Trojan horse effect is gradually recognized as a key pathway for microplastic toxicity, doubts remain regarding contaminant adsorption–desorption dynamics, relative exposure contributions, and human health prolong effects, highlighting the need for more research and enhanced risk assessment.

Detection, Quantification and Analytical Challenges of Microplastics: Accurate detection and quantification of microplastics are vital for assessing ecological contamination and human exposure but remain technical challenges because of the range of particle shapes, sizes, polymer compositions, colors, and ecological matrices. The absence of standardized analytical procedures further restrict the comparability of outcomes across different studies[34].

Analysis starts with sampling that differs according to the environmental medium. Surface scan nets are usually used in aquatic systems, while air, soil, and biological samples require bulk collection or filtration techniques. Following extraction typically includes enzymatic digestion or chemical to remove organic matter, followed by density parting using saline solutions to isolate plastic particles[35]. Nevertheless, recovery efficiency may varies among polymer types, introducing analytical bias.

Optical microscopy is commonly used for preliminary characterization based on the particle morphology, but polymer identity requires spectroscopic techniques like Raman spectroscopy and Fourier Transform Infrared (FTIR) that provide reliable chemical identification confirmation[36]. Thermal analysis uses pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS) permits polymer quantitative identification, while Energy-dispersive X-ray spectroscopy (EDS) coupled with scanning electron microscopy (SEM) offers detailed information on elemental composition and morphology surface.

Detecting nanoplastics remains mostly difficult due to their often drop beneath the resolution of conventional analytical methods. Emerging technologies, including field-flow fractionation (FFF), nanoparticle tracking analysis (NTA), and fluorescence-based imaging, demonstrate promising but are not yet standardized. Moreover, contamination from laboratory materials and airborne particles requires rigorous quality assurance protocols. Harmonized sampling, analytical, reporting procedures are therefore important to enhanced data reliability, enable comparisons among studies, and strengthen environmental risk assessments[36].

Remediation Technologies and Environmental Management Strategies for Microplastics: The persistence and extensive distribution of microplastics make their remediation a major ecological challenge. Due to their physicochemical stability and existence across aquatic, terrestrial, and atmospheric environments, effective management requires integrated physical, biological, chemical, and technological methodologies supported by circular economy ethics[10].

Water waste treatment plants (WWTPs) are the main barrier against release of microplastic into aquatic ecosystems. Conventional treatment processes, like sedimentation, flotation, and filtration, eliminate a substantial proportion of larger particles, while advanced technologies like membrane bioreactors, reverse osmosis, ultrafiltration, and rapid sand filtration achieve higher elimination efficiencies, although complete removal remains difficult[18]. Physical recovery methods, such as surface skimming and fine-mesh filtration, have also been used but faces cost and scalability (Table-4).

Chemical degradation techniques, like photocatalysis, advanced oxidation processes, and hydrolysis, stimulate polymer breakdown but remain largely experimental because of highenergy demands and the toxic formation potential of by-products[37]. Biological remediation offers a more sustainable alternative, with microorganisms like *Ideonella sakaiensis* producing PET-degrading enzymes; but, degradation rates remain slow under natural conditions[38]. Emerging nanotechnology, such as magnetic nanoparticles and nanofibrous membranes, has displayed promising for microplastic capture and degradation, although environmental safety requires further assessment (Table-4).

Prolong mitigation base on decreasing plastic production, improving adopting biodegradable materials, implementing extended producer responsibility (EPR), and recycling policies. In addition, artificial intelligence and remote sensing technologies are improving microplastic monitoring and environmental management. Despite these advances, technological, economic, and regulatory constraints continue to limit large-scale implementation, highlighting the need for preventive strategies and coordinated global action (Table-4)[38].

Table-4: Remediation Strategies.

Strategy	Description
Physical filtration	Wastewater treatment, membrane systems
Chemical degradation	Photocatalysis, oxidation processes
Biological treatment	Microbial and enzymatic degradation
Policy & circular economy	Plastic reduction, recycling, EPR

Regulatory Policies and Global Governance Challenges of Microplastics: Microplastic pollution presents a complex governance challenge due to its transboundary distribution, various sources, and involvement of multiple economic sectors. Unlike conventional pollutants with identifiable point sources, microplastics originate from agriculture, textiles, packaging, fisheries, and urban settings, demand coordinated strategies that require the complete plastic life cycle[10].

The United Nations Environment Programmed (UNEP) is one of International organizations at have strengthened efforts to tackle plastic pollution. (UNEP) is leading consultations toward a legally binding global plastics treaty covering manufacture, waste management, consumption, and environmental leakage. Similarly, microplastics in drinking water have been evaluated by the World Health Organization (WHO) and concluded that current evidence is inadequate to establish definitive health-based exposure limits[39]. Nevertheless, global governance remains fragmented, with many agreements focusing on marine litter rather than microplastics and lacking effective enforcement mechanisms. Regional ideals, like the European Union's Circular Economy Action Plan, have presented restrictions on intentionally added microplastics and promoted sustainable plastic management[40].

National responses vary considerably. While many developed countries have restricted microbeads, strengthened waste management, and expanded recycling infrastructure, developing countries often face inadequate waste collection, limited financial resources, and weak regulatory enforcement, increasing environmental contamination. Governance is additional constrained by the standardized definitions absence, monitoring protocols, analytical methods, and internationally accepted safety thresholds for microplastics in air, water, and food[39].

Economic dependence on plastics, coupled with concerns over production costs and supply chains, often hinders policy implementation. In addition, environmental justice issues arise because many poor and middle-income countries bear a disproportionate burden of pollution despite contributing relatively less to global plastic production. Strengthening international cooperation, harmonized regulations, financing mechanisms, technology transfer, and effective implementation of extended producer responsibility (EPR) policies will be essential for sustainable global microplasticgovernance[37].

Unsolved Scientific Questions and Future Research Frontiers in Microplastics Research: Despite substantial advances in microplastics research, important uncertainties remain regarding their human health effects, ecological impacts, and long-term environmental fate, limiting robust risk assessment and policy development[41]. Solving these knowledge gaps is essential for creating evidence-based regulatory frameworks and effective mitigation strategies.

A major unresolved question is the dose response associate between microplastic contact and health effect outcomes. Although microplastics have been identified in human lungs, blood, and placental tissues, safe contact limits and the consequences of chronic low-dose exposure remain unknown. Similarly, the biological fate of nanoplastics including their absorption, distribution, metabolism, excretion, and long-term retention requires further investigation because of their ability to cross cellular and physiological barriers[9]. The potential association between microplastic exposure and chronic diseases, including cancer, cardiovascular, neurodegenerative, and metabolic disorders, has yet to be confirmed through long-term epidemiological studies. Additional research is also needed to clarify their effects on the gut microbiome, antimicrobial resistance, and the formation and dissemination of antibiotic resistance genes[15].

Key environmental uncertainties include the degradation of microplastics under varying environmental conditions, the generation of secondary nanoplastics, and their long-term transport and persistence. Progress is also constrained by the deficiency of standardized, analytical sensitive methods capable of detecting nanoplastics in complex environmental and biological samples[9].

Future research should adopt a Health approach that integrates human health, animal, and environmental. Advances in genomics, proteomics, metabolomics, artificial intelligence, and machine learning are expected to improve exposure assessment, predictive toxicology, and environmental monitoring. Expanding research in underrepresented regions, particularly Africa, South America, and parts of Asia, will also be critical for developing a comprehensive global understanding of microplasticpollution[32].

Proposed Answers and Emerging Scientific Perspectives on Microplastics: Although evidence on microplastic toxicity is still evolving, several scientific models provide plausible explanations for their environmental and health effects. These frameworks integrate toxicological, biochemical, and environmental findings to explain how prolonged exposure may influence biological systems, while acknowledging that many hypotheses require further validation.

The chronic low-dose accumulation theory proposes that continuous exposure to low concentrations of microplastics may gradually induce oxidative stress, persistent inflammation, and tissue injury, thereby increasing the risk of chronic diseases[41]. Complementing this, the nanoplastic penetration hypothesis suggests that nanoplastics can cross biological barriers, such as the intestinal epithelium, blood–brain barrier, and placenta, allowing them to interact with intracellular organelles and disrupt normal cellular function[9].

The multi-hit toxicity model argues that microplastics amplify the harmful effects of co-existing stressors like persistent organic pollutants, heavy metals, pathogens, and poor nutrition, producing synergistic toxicity that exceeds the effects of individual contaminants[26]. Similarly, the gut brain plastic axis proposes that microplastic-induced alterations of the gut microbiota may influence immune regulation, endocrine signaling, and neurological function, although human evidence remains limited[17]. The endocrine disruption model further attributes toxicity to plastic additives and adsorbed contaminants that interfere with hormonal signaling, potentially affecting reproduction, development, and metabolism[26].

Emerging concepts such as the plasticome, which describes cumulative internal plastic burden, together with precision toxicology using genomics, proteomics, metabolomics, and artificial intelligence, may enable personalized exposure assessment, early biomarker discovery, and predictive health risk evaluation, representing promising directions for future microplasticsresearch[26].

Integrated Conceptual Framework of Microplastics: From Source to Disease Outcomes: The integrated conceptual framework of microplastics describes the pathway from environmental release to potential human health effects. Microplastics originate from industrial products, synthetic textiles, packaging materials, tire wear, agricultural plastics, and mismanaged plastic waste, where fragmentation and weathering generate secondary microplastics[1]. These particles are transported through aquatic, terrestrial, and atmospheric systems, facilitating widespread environmental distribution and interactions with pollutants[20]. Human contact occurs generally through inhalation, ingestion, and, to a lesser extent, dermal contact[18]. Following internalization, microplastics and nanoplastics may cross biological barriers, enter systemic accumulate, and circulation in organs including the kidneys, liver, brain and lungs[10]. Their presence can trigger inflammation, oxidative stress, mitochondrial dysfunction, genotoxicity, and endocrine disruption while associated contaminants may further amplify toxicity through synergistic effects[8]. Although definitive causal evidence in humans' remains limited, this framework highlights microplastics as a One Health issue that links environmental contamination, ecosystem integrity, animal exposure, and human health.

Recommendations and Perspective

Recommendations: Standardized global monitoring systems and harmonized analytical methods are essential to improve microplastic detection, data comparability, and risk assessment. Future studies should prioritize long-term epidemiological investigations, advanced nanoplastic detection technologies, and validated exposure assessment methods. Preventive strategies should focus on reducing plastic production, improving recycling infrastructure, promoting sustainable alternatives, and strengthening extended producer responsibility (EPR) strategies. Greater investment in management of waste, particularly in developing countries, together with a One Health approach and an officially binding global plastics treaty, will be critical for coordinated international action.

Perspective: Pollution of Microplastic has emerged as a major public health and environmental challenge of the Anthropocene. Although important uncertainties remain regarding long-term health effects, current evidence supports immediate preventive action. Integrating scientific research, technological innovation, effective governance, and sustainable manufacture and consumption practices will be vital to decrease environmental contamination and protect human health and ecosystem for future generations.

Conclusion

Microplastics arisen as persistent environmental contaminants with important ecological and potential human health consequences. This review demonstrates that their persistence and extensive distribution across soil, water, food systems, air, and human tissues make them a growing worldwide concern. Beyond their physical presence, microplastics can induce inflammation, oxidative stress, genotoxicity, endocrine disruption, and other biological disturbances, also serving as carriers of toxic chemicals and microorganisms pathogenic. Their transportation through environmental compartments and food webs further amplifies ecological and public health risks. Although the discovery of microplastics in human lungs, blood, and placental tissues underscores widespread exposure, important uncertainties remain regarding health long-term effects, exposure thresholds, and causal relationships with disease. Solving these knowledge gaps will require standardized analytical methods, long-term epidemiological studies, and multidisciplinary One Health research. Ultimately, integrating scientific evidence with effective policies, sustainable plastic management, and international cooperation will be essential to reduce microplastic pollution and protect human health and environmental.

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