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Review Article

Risk assessment of microplastics in plant: A review

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Abstract: Microplastic pollution has emerged as a pressing environmental and health concern due to its widespread presence across various ecosystems. This comprehensive review delves into the risks posed by microplastics (MPs) in plant systems, examining their sources, distribution, and potential impacts on plant health and food security. As microplastics degrade from larger plastic waste, they infiltrate terrestrial, aquatic, and atmospheric environments, with both primary and secondary sources contributing to their pervasive nature. MPs, typically less than 5mm in size, accumulate in agricultural soils through wastewater, atmospheric deposition, and industrial activities, posing a significant threat to plants and soil health. The presence of MPs in soil can disrupt root development, soil aeration, and microbial communities, potentially leading to reduced agricultural productivity and food safety concerns. Moreover, plants absorb MPs from contaminated soils, which may subsequently enter the food chain, impacting human health. Current risk assessment frameworks, such as those developed by the European Food Safety Authority (EFSA) and the Environmental Protection Agency (EPA), aim to evaluate microplastic risks in food and ecosystems. However, significant uncertainties remain regarding toxicity thresholds and exposure routes. Despite the growing body of research, there are still gaps in understanding the full extent of the impacts of microplastics. Therefore, further interdisciplinary studies are necessary. Addressing these gaps and developing robust regulatory frameworks is essential to mitigate the risks posed by microplastic pollution, ensuring environmental sustainability, and safeguarding public health.

Keywords: Microplastic; Risk assessment; Soil; Plant

1. Introduction

Microplastic pollution has emerged as a global environmental and human health concern due to the widespread presence of plastic particles in various ecosystems [1, 2, & 3]. As human populations grow and industrial and agricultural activities expand, plastic waste accumulates in water bodies, soil, ecosystems, and even human health [4]. The scale of plastic production and waste is staggering. According to the World Economic Forum, plastic production is projected to grow at a rate of 4% annually, leading to significant environmental and economic challenges [5]. Since the 1940s and 50s, industrial production has generated billions of tons of plastic, and a substantial portion of this waste remains unrecycled or poorly managed [6]. If trends continue, over 12 billion tons of plastic could end up in landfills or the environment by 2050 [3]. Furthermore, due to inadequate management, the amount of plastic waste is projected to surge nearly 600 times its 1950 levels by 2060, with an estimated 265 million tons entering the environment annually [7]. A recent environmental concern is the degradation of plastics into microplastics (MPs) and nanoplastics (NPs) size because the nanoscale plastics are difficult to detect and can be transported in air soil and water compartments [8]. Toxicologist Matthew Campen’s team reported in Nature Medicine (2025) that microplastic levels in the human brain, liver, and kidneys were approximately 50% higher in 2024 brain samples compared to those from 2016 [9].

Microplastics, defined as plastic particles smaller than 5mm, have become prevalent in terrestrial and aquatic environments [2, 10]. These particles can enter ecosystems through various processes, such as the degradation of larger plastic debris found in wastewater treatment facilities, release from industrial processes, personal care products, and bio-solids products that end up on agricultural lands [11, 12, & 13]. Microplastics originate from a diverse range of synthetic resins, including high-density polyethylene (PE), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC), polyethylene terephthalate (PET), and Polyurethane (PUR) resins, as well as polyester, polyamide, and acrylic (PP&A) fibers [14, 15, & 17]. Microplastics in ecosystems are categorized into two main types of plastic pollution: primary and secondary sources [16]. Primary microplastics are defined as plastics sized under 5mm such as microbeads, synthetic fibers, industrial abrasives, tire wear particles, and paint particles [11, 17]. While secondary microplastics are tiny plastic pieces that are produced as a result of the breakdown of bigger plastic trash at sea and on land [18, 19]. Secondary sources of microplastic pollution include the degradation of plastic waste, discarded fishing gear, single-use plastics, and cigarette filters [11, 20].

Atmospheric deposition plays a crucial role in spreading microplastics over long distances, impacting both remote and urban areas [21]. Their presence has been documented in marine, freshwater, air, and soil ecosystems [22, 23]. Yang, S., et.al, (2025) [24] observed that higher fluxes originate from the oceans, with comparatively lower contributions from land-based sources, including bare soils and human activities [25, 26]. Microplastics have accumulated in river environments, potentially concentrating in specific pollution hotspots and posing a high risk of toxicity. They can be ingested or cause entanglement, leading to physical deformities, impaired growth, or even fatal consequences for marine life [27]. The accumulation of microplastics can alter soil physical properties, disrupting root growth and reducing soil aeration, which is essential for healthy plant development [28,29]. Recent studies have indicated that elevated microplastic levels in soils adversely affect soil fauna, plants, and microorganisms, posing a potential risk to human health through the accumulation and transmission of microplastics via the food chain [30,31]. Numerous studies have focused on how microplastics in agricultural soil affect crop growth and threaten food supply [32]. The rising awareness of environmental stressors affecting food production amidst climate change underscores the critical need to explore their interactions with microplastic pollution and their consequences for plant health and productivity [33]. Researchers at Presidency University in Kolkata reported that heat stress enhances the accumulation of polystyrene nanoparticles in plant roots by increasing the activity of specific membrane proteins [34].

This study aimed to evaluate the impacts of microplastic accumulation on soil properties, plant development, and potential risks to food safety and human health. The research was based on secondary data gathered from articles and books published by credible and relevant sources.

2. Distribution and Impact of Microplastic in Soil

2.1 Microplastics enter the environment through various pathways, including wastewater discharge, atmospheric deposition, and industrial and anthropogenic activities [35]. Wastewater discharge from urban areas and industrial effluents is the most significant contributor to aquatic pollution, as it releases high concentrations of waste directly into ecosystems. This concern has become even more critical during the COVID-19 pandemic [36, 37]. Microplastics have been documented in marine, freshwater, and soil ecosystems [2, 38]. Transport mechanisms such as river water flows and natural air further contribute to their widespread distribution [39].

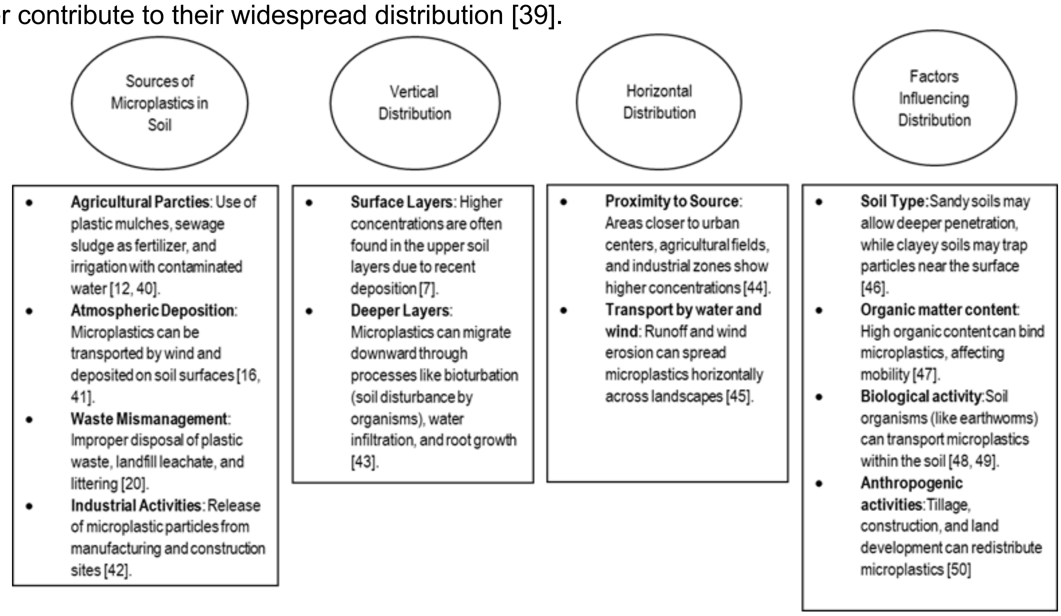

Figure 1. Distribution of microplastic in soil.

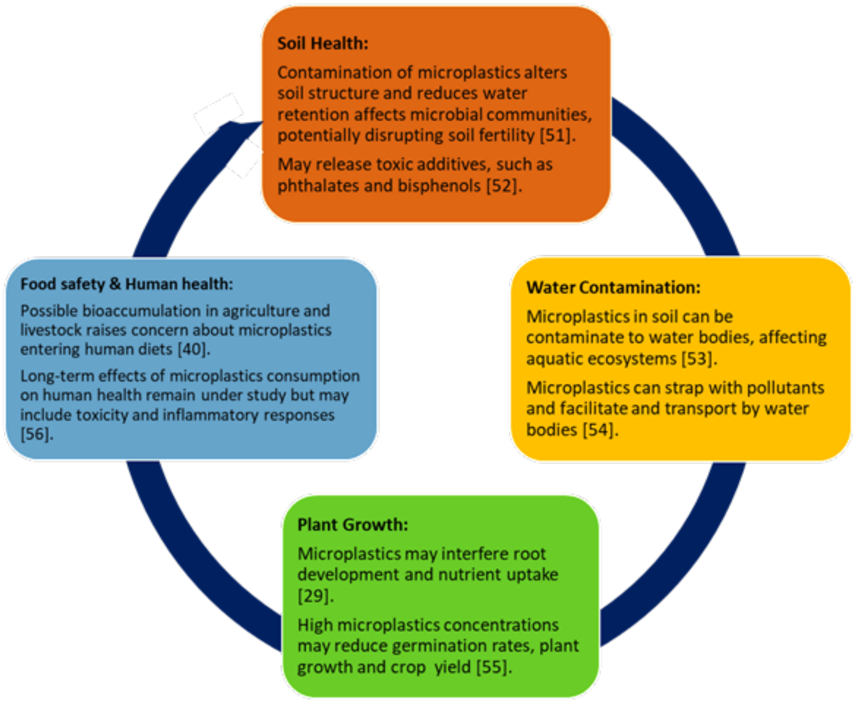

Figure 2. Environmental impact of microplastic pollution.

2.2 Ecological and food security implications

2.2.1 Marine ecology and health risk

Microplastics, ingested by marine organisms from plankton to fish and seabirds, pose an ecological risk [57]. This can lead to bioaccumulation, where microplastics accumulate in an organism over time [58]. Ingestion can cause internal injuries, blockages, and even starvation [13, 60, & 61]. Moreover, microplastics can absorb harmful pollutants like pesticides and heavy metals [52], introducing toxic substances into the food web [59]. Their high stability and diffusion in sediments disrupt aquatic habitats and affect the organisms that rely on these ecosystems [60]. Many marine species consumed by humans, such as fish and shellfish, have been found to contain microplastics, posing risks to human health [61].

2.2.2 Plant systems and food security

Crops grown in contaminated soils can absorb microplastics, potentially affecting soil chemical properties, food quality, and safety [62]. Microplastics cause oxidative damage to plants, disrupting their root surface and vascular system [63]. However, the World Health Organization recommends consuming fruits and vegetables daily as essential for maintaining good health. [64]. Conti, G. O. et al. (2020) [65], determined that edible fruits and vegetables purchased from supermarkets contain varying amounts of microplastics [66]. The Estimated Daily Intake (EDI) of microplastics through plant-based food consumption represents the number of microplastic particles a person may ingest daily from vegetables, fruits, and grains. Overall food-related intake estimates range from 0.0002 to 1,531,524 particles per day. [67]. Microplastics can directly impact plant growth by blocking roots and entering plant organs. They can also disrupt photosynthetic rates and affect antioxidant enzyme activities, ultimately influencing overall plant performance. Therefore, the presence of micro- and nanomaterials poses significant challenges to food security and human health [68].

Table 1. Findings of microplastics concentration in plant**.**

Plants Name	Scientific name	Findings	Concentrations	Field of Study	References
Lettuce	*Lactuca sativa*	Microplastics were found in Lettuce in varying concentrations; the highest levels were detected on roads with heavy traffic or near commercial and residential buildings rather than in urban gardens.	Lower levels between- 6.3 ± 6.2 MPs/g Higher levels between 12.7 MPs/g and 29.4 MPs/g	Urban vegetable garden in Lisbon, Portugal	Canha, N., et.al 2023 [44]
Onion	*Allium cepa*	The study observes that the accumulation of microplastics in tubulin deacetylation leads to increased susceptibility to damage under the combined stress of Microplastics and high temperature.		India	Maity, S., et.al 2024 [34]
Rice	*Oryza sativa*	Approximately 90% of the sample showed microplastic concentrations greater than 20 particles/100g, which were predominantly fibrous and transparent, with four types of microplastics detected. Microplastic exposure negatively impacted rice grain quality,	Average microplastics were found 30.3 ± 8.61 particles/100 g, ranging from 18 to 42 particles/100 g.	India	Bhavasr P. S. et.al 2024 [69]

Plants Name	Scientific name	Findings	Concentrations	Field of Study	References
		resulting in a 10.62% reduction in head rice yield for Y900 (India) and a 6.35% increase for XS123 (japonica). Microplastics can disrupt crucial biological pathways, leading to alterations in crop productivity and quality.		China	Wu, X. et.al 2022 [70]
wheat	*Triticum aestivum L.*	Wheat seedlings, despite their ability to ensure root growth under limited nutrient conditions, experienced reduced shoot biomass and height at high polyvinyl chloride concentrations. Moreover, this exposure had an adverse effect on soil structure and chemistry.			Zhang, K., et.al 2024 [66]

3. Risk mitigation strategies and future perspectives

Current risk assessment approaches for microplastics integrate hazard identification, exposure assessment, and risk characterization [7, 71, & 72]. For instance, the European Food Safety Authority (EFSA, 2016) has developed a framework to assess the risks of microplastics in food, incorporating exposure estimates and toxicological thresholds. Similarly, the Environmental Protection Agency (EPA) employs an ecological risk assessment model to evaluate the effects of microplastics on aquatic ecosystems [73]. However, uncertainties in microplastic quantification, toxicity thresholds, and exposure routes challenge comprehensive risk evaluation. Standardized methodologies are necessary to enhance the reliability of risk assessment (EFSA, 2016) [67, 68]. Despite the growing body of research, many aspects of microplastic pollution remain poorly understood. Addressing these knowledge gaps is crucial for developing effective mitigation strategies [64, 71].

4. Conclusion

In conclusion, microplastic pollution presents complex risks to both ecosystems and human health [1]. Although progress has been made in understanding their sources, distribution, and impacts, comprehensive risk assessments are still in development [12, 16, 44]. In daily life, local communities often rely on native plants for food and medicinal purposes, which may unknowingly accumulate micro- or nanoplastics [43, 63, 64, and 68]. Alarmingly, no studies have been conducted to assess microplastic contamination in local edible plants [43, 55 & 56]. This significant knowledge gap highlights the urgent need for focused research in this area. Bridging these gaps through interdisciplinary studies and robust regulatory frameworks is essential for mitigating the risks of microplastic pollution and promoting environmental sustainability [10, 16, & 33]. Addressing this issue requires a thorough understanding of microplastic sources, pathways, impacts, and solutions. Future research must be globally coordinated, interdisciplinary, and policy-driven to enable effective mitigation of this pervasive environmental threat.

6. Patents

Author Contributions: For research articles, R.C. Conceptualized the study, S.C. and A.P. supervised the research, data curation and formal analysis were carried out by P.S. The original draft was prepared by R.C., with review and editing by S.C. and A.P. All authors have read and agreed to the published version of the manuscript.

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