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Microplastic Pollution and Its Effects on Insects: A Hidden Crisis in Our Ecosystems

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ABSTRACT

Microplastic pollution is a growing environmental concern with significant implications for insect populations and ecosystems. Insects, due to their diverse ecological roles, are particularly vulnerable to microplastics, which can affect their physiology, behavior and ecological functions. Exposure to microplastics can lead to immune suppression, reproductive disruption and changes in energy metabolism, while also altering insect behavior and interactions with other species. The co-occurrence of microplastics with other pollutants, such as pesticides and persistent organic pollutants, exacerbates these effects. This article highlights the urgent need for research and management strategies to mitigate the impact of microplastics on insect biodiversity and ecosystem health.

***Keywords**:* Microplastic, physiology, behavior and pollutants

INTRODUCTION

Microplastic pollution has become a critical environmental issue, with significant consequences for ecosystems globally. These tiny plastic particles, often less than 5 millimeters in size, are widespread in both aquatic and terrestrial environments, posing severe threats to biodiversity. Insects, being one of the most diverse and abundant groups of organisms, are particularly susceptible to microplastic contamination due to their ecological roles and interactions with their habitats (Khedre et al., 2024). As pollinators, decomposers, and vital components of food webs, insects play a crucial role in maintaining ecosystem balance. Recent research has shown that microplastics can disrupt insect physiology, behavior, and reproduction, leading to population declines and altered ecosystem dynamics. Given these threats, there is an urgent need for

increased research to understand the full scope of microplastic impacts on insects and for the development of effective management strategies to mitigate these effects and protect biodiversity.

Exposure Pathways and Uptake Mechanisms

Insects can be exposed to microplastics through various pathways, including ingestion, inhalation and dermal contact. In aquatic environments, mosquito larvae and other aquatic insects may ingest microplastics directly from water or through contaminated food sources (Griffin et al., 2023; Polenogova et al., 2024). In terrestrial ecosystems, insects may encounter microplastics in soil, where these particles can be ingested during foraging or burrowing activities (Sucharitakul et al., 2024; Kokalj, 2024). Once consumed, microplastics can gather in the insect's body, potentially causing physical and chemical damage. Studies shown that microplastics can cause intestinal blockage and microtrauma in mosquito larvae, leading to suppressed immune responses and altered enzyme activity (Polenogova et al., 2024). Similarly, in terrestrial insects, microplastics originated to affect the gut microbiota, which is crucial for digestion and nutrient absorption (Liaqat et al., 2024).

Physiological Effects on Insects

1. Immune Suppression and Oxidative Stress

Exposure to microplastics has been shown to suppress the immune response in insects. For instance, in *Aedes aegypti* mosquito larvae, dietary administration of polypropylene (PP) and polystyrene (PS) microplastics led to a significant decrease in phenoloxidase activity, a key component of the insect immune system (Polenogova et al., 2024). Additionally, microplastics can induce oxidative stress, as evidenced by changes in malondialdehyde (MDA) levels and the activity of detoxifying enzymes such as glutathione-S-transferase (GST) in exposed insects (Polenogova et al., 2024; Xu and Kong, 2024).

2.Energy Metabolism and Reproduction

Microplastics can also disrupt energy metabolism and reproductive processes in insects. In Drosophila melanogaster, chronic exposure to polytetrafluoroethylene (PTFE) microplastics led to changes in glucose and lipid levels, with sex-specific effects observed in males and females (Xu and Kong, 2024). Besides, studies have described abridged fecundity and altered oviposition behavior in insects exposed to microplastics, highlighting the potential for population-level impacts (Shen et al., 2023; Liaqat et al., 2024)

3.Hormesis and Dose-Dependent Responses

Remarkably, few scientists detected hormetic effects of microplastics on insects, where low doses of microplastics may have beneficial effects, while high doses are detrimental. For example, low concentrations of microplastics have been shown to increase the survival of certain insect species, possibly due to the stimulation of stress response pathways (Shen et al., 2023). However, this phenomenon is not universal and may depend on the specific type and size of microplastics, besides insect species and life stage.

Ecological Impacts on Insect Populations and Ecosystems

1.Changes in Behavior and Ecology

Microplastics can alter insect behavior, including foraging, oviposition, and mating behaviors. For example, exposure to microplastics has been shown to affect the foraging behavior of certain insect species, potentially leading to changes in food web dynamics (Liaqat et al., 2024). Additionally, microplastics can hinder pollination, as some pollinators may transport microplastic particles to flowers, potentially disrupting plant-insect interactions (Liaqat et al., 2024).

2.Trophic Transfer and Bioaccumulation

Microplastics can also be transferred through food webs, with insects serving as vectors for the bioaccumulation of microplastics in higher trophic levels. For instance, microplastics ingested by insects can be passed on to predators, potentially leading to biomagnification in food chains (Liaqat et al., 2024; Sucharitakul et al., 2024). This raises concerns about the long-term consequences of microplastic pollution for ecosystem health and resilience.

3.Interactions with Other Stressors and Pollutants

Microplastics in the environment often co-occur with other pollutants, such as pesticides, heavy metals, and persistent organic pollutants (POPs), creating complex interactions that can exacerbate their adverse effects on insects and ecosystems. For example, microplastics can modify the toxicity of insecticides, as shown in studies where polyethylene microplastics altered the efficacy of the insecticide *Bacillus thuringiensis israelensis* (Bti) in *Chironomus riparius* larvae, depending on the size of the particles (Khan and Johnson, 2024). These interactions highlight the intricate dynamics between microplastics and other environmental stressors, complicating their environmental impact. Additionally, microplastics can adsorb POPs, which are known to adversely affect insect physiology and ecology. This adsorption increases the bioavailability and toxicity of these pollutants, potentially leading to enhanced bioaccumulation and biomagnification within food webs, further endangering insect populations and the organisms that rely on them (Liaqat et al., 2024; Kokalj, 2024). Together, these synergistic effects pose a significant threat to insect health, ecosystem functioning, and biodiversity.

Implications for Ecosystem Services and Agricultural Sustainability

Insects are indispensable for keeping bionetwork services, including pollination, decomposition, and pest control, and microplastic pollution can significantly disrupt these functions. Microplastics can affect pollinators by altering their behavior and health, reducing their reproductive success and potentially leading to declines in plant fertility and crop yields (Liaqat et al., 2024). In terrestrial ecosystems, microplastics can also impact soil health by affecting soil-dwelling insects like earthworms and springtails, which play a decisive part in decomposition and nutrient cycling. The impairment of these insects can result in reduced soil fertility and weakened ecosystem resilience, with potential costs for agrarian production and food security (Kokalj, 2024).

Management Strategies and Solutions

In parallel with research efforts, effective management strategies are urgently needed to 3 mitigate the impact of microplastics on insect populations and ecosystems. These strategies could include the development of biodegradable plastics to reduce the persistence of microplastics in the environment and the implementation of improved waste management practices to limit plastic leakage into ecosystems. Additionally, promoting circular economy approaches, which focus on reducing plastic production, encouraging recycling and minimizing waste, would significantly decrease the input of microplastics into the environment (Kokalj, 2024; Shen et al., 2023). Addressing these contests drive collaboration across scientific, industrial, and policy-making sectors to ensure the protection of insect biodiversity and ecosystem health

CONCLUSION

Microplastic pollution poses a significant threat to insect populations and ecosystems, with far-reaching implications for ecosystem services and agricultural sustainability. The effects of microplastics on insects are complex and multifaceted, involving physiological, behavioral, and ecological changes. While significant progress has been made in understanding these effects, further research is needed to address knowledge gaps and develop effective mitigation strategies. By advancing our understanding of microplastic pollution and its impacts on insects, we can better protect ecosystems and promote environmental sustainability in the face of this growing global challenge.

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