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Review Article

Origin and Effects of Microplastics on Soil Health, Microbial Community and Plants

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ABSTRACT

Microplastics are a growing threat to entire ecosystems, their presence in soil and water ecosystems has received a lot of attention lately. The detection, occurrence, characterization, and toxicology of microplastics in freshwater and marine ecosystems have been the subject of recent research; yet, compared to aquatic environments, our knowledge of the ecological impacts of microplastics in soil ecosystems is relatively restricted. To address the potential ecological and human health risks caused by microplastics in soil, we have compiled literature here that studies the sources, migration of microplastics in soil, negative impacts on soil health and function, trophic transfer in food chains, and the corresponding adverse effects on soil organisms. This paper aims to fill in information gaps, clarify the ecological impacts of microplastic pollution in soil, and suggest future research directions related to microplastic pollution and the ensuing soil ecotoxicity. To lessen the dangers associated with microplastic contamination, this review also focuses on controlling the amount of microplastics in soil and developing management and remediation strategies.

Keywords: *Microplastics, marine and soil ecosystem, ecotoxicology, ecological impacts, remediation measures.*

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INTRODUCTION

Millions of tons of plastic and their relevant mixed material are produced each year to facilitate normal people's routines (Guo et al., 2020). According to PlasticEurope (2017), 335 million tons of plastic were produced in 2016, and UNEP estimated an average annual growth rate of 8.6% since the 1950s. The current level of plastic production in different demographic areas is very high output, but their disposal rate is very low, and all demographic data shows an increase in plastic accumulation (Dhahlbo et al., 2018; & van Velzen et al., 2019). Since 79% of the world's plastic waste is piled in landfills, soil is probably a significant source of microplastics (Geyer et al., 2017). Growing evidence has also shown that microplastics are present in terrestrial ecosystems (Cao et al., 2017). According to recent estimates, farmlands in Europe and North America contribute between 63 and 430 thousand tonnes of microplastics annually, exceeding the microplastics' extrapolated annual emissions to ocean surface waters (Nizzetto et al., 2016).

Microplastics have been found in home garden soils in Campeche, Mexico, where the mean concentration was 0.87 ± 1.9 particles g−1 (Huerta Lwanga et al., 2017). Farmlands in Shanghai, China have reported 62.5 microplastic items per kilogram of deep soil and 78.0 items per kg of shallow soil (Liu et al., 2018). Additionally, Scheurer and Bigalke (2018) discovered microplastics in almost 90% of Swiss floodplain soils at depths ranging from 0 to 5 cm. They calculated that the mean concentration of microplastics was 5 mg kg−1, with a highest value of 55.5 mg kg−1. In nonurban soil reserves, including isolated high mountain regions, microplastics have also been reported to make up as much as 0.002% of the dry weight of the soil.

Data regarding microplastic magnitude in normal and agricultural soils was received from the publication of Guo et al. (2020).

Country	Areas	Magnitude of plastic
Sydney, Australia	Industrial Area	4191mg per kg
Switzerland	Flood Plains	5mg per kg
Campeche SE, Mexico	Home garden soil	0.87 particles per kg
Shanghai, China	Shallow and deep soil	62.5 and 78 items per kg

According to Liu et al. (2017), microplastics have several deleterious effects on terrestrial environments, especially soil, and their microbiome life is the mainstream victim. Microplastics cause deleterious effects on marine and soil environments, especially in the soil when the earthworms ingest microplastics, and these cases are increasing day by day due to the addition of microplastics to environments. Among the 425 snail specimens, Panebianco et al. (2019) observed that microplastics were present in over 50% of the snails, with an average of 0.92 ± 1.21 particles per 5 snails.

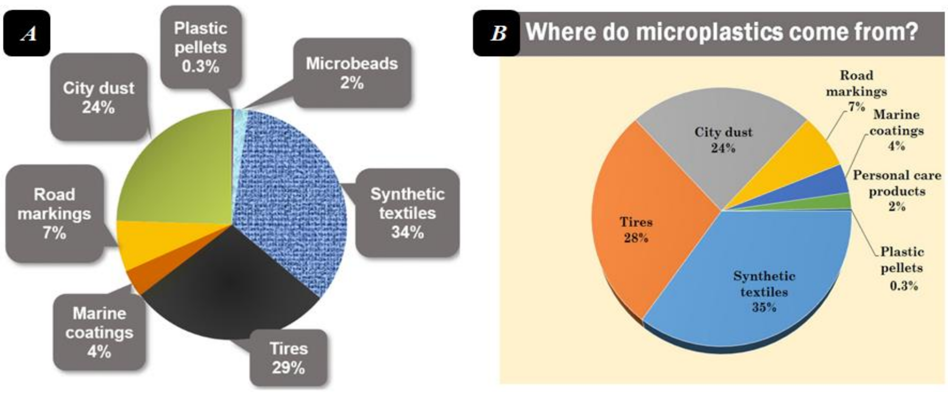
In conclusion, in the microplastics introduction section, the authors can say that microplastics are now a serious concern for different types of living beings in different environments around the globe (Safi et al., 2022). The paper aims to: (1) provide an overview of the origin and movement of microplastics in soil; (2) assess their impact on soil and human health; and (3) talk about the possible concerns they pose to the environment and human health. We hope to use the body of knowledge we have developed on the migration and toxicology of microplastics in soil—developed through the integration and summarization of prior research—to reduce the number of microplastics in soil and establish remediation and management strategies that will lessen the risks associated with microplastic pollution.

2. Origin and movement of microplastics in soil

Microplastics exist in soil as primary and secondary, mainly primary sources are waste from the cosmetics industry, wastewater from polluted areas, and pesticides from agrochemical industries (Cole, 2011; Thompson, 2015; Duis & Coors, 2016; & Auto et al., 2017). Secondary sources include the smaller size production of primary microplastic particles resulting from agents such as wind, UV light, waves, and high temperature (Andre, 2011; Cole et al., 2011; & Rocha-Santos & Duarite, 2015). Furthermore, secondary microplastics may develop due to fragmentation brought on by the repetitive usage of plastic products.

Besides, plastic emissions associated with vehicle travel, including tire wear and tear, brakes, and road markings, are another important source of microplastics in the environment (Gieré et al., 2018). According to Kole et al. (2017), the average amount of microplastic released into the atmosphere worldwide as a result of road vehicle tire abrasion is 0.81 kg/year per person.

Significantly dissimilar from the origins of microplastics in the ocean, which primarily stem from land-based sources (contributing approximately 80%), coastal tourism, recreational, and commercial fishing (e.g., applications of plastic fishing gear, etc., contributing approximately 18%), marine vessels, and marine industries (e.g., aquaculture, oil-rigs, etc.) (Doyle et al., 2011), microplastics enter soil through a variety of routes, such as landfills (He et al., 2019), soil amendments (UBA, 2015), land application of sewage sludge (Corradini et al., 2019), wastewater-irrigation (Mason et al., 2016), compost and organic fertilizer residues of agricultural mulching films (Ramos et al., 2015), tire wear and tear (Kole et al., 2017), and atmospheric deposition (Liu et al., 2019). Besides, plastic trash in the soil can be fragmentized into microplastics by biological processes of soil organisms, e.g., feeding activities, digesting, and excretion processes (Chae & An, 2018).



Data regarding microplastic showed in the pie chart pick from the Malankowska et al. (2021)

The vertical and horizontal distribution of microplastics in the soil can be influenced by several factors, including soil biota, soil features such as soil macropores (pores > 75 µm), soil aggregation and soil cracking, and agronomic practices such as ploughing and harvesting (Rillig et al., 2017). According to Gabet et al. (2003), the general literature on microparticle migration in soil via bioturbation, plant processes like root growth and uprooting, as well as animal inputs like larvae, earthworms, vertebrates, etc., might act as preferential pathways for the movement of microplastics. For instance, native fungal mycelia can effectively translocate bacteria that break down pollutants and bridge air-filled pores, which may also aid in the movement of microplastics (Wick et al., 2007).

The most likely sources of vertical soil microplastic transport are soil cracking, pores, agronomic practices (such as harvesting and ploughing), plant root elongation, the ingestion and egestion of geophagous soil fauna (particularly anecic earthworms), and the digging habits of other soil animals. On the other hand, hunting, the activities of epigeic earthworms, and agronomic practices can promote the horizontal distribution of microplastics in soil.

3. Impact of microplastics on soil and human health

3.1 Soil physical-chemical properties

Furthermore, since humic-like materials can enhance soil stability, water-holding capacity, nutrient availability, etc., the accumulation of high-molecular-weight humic-like materials encouraged by microplastic addition suggests that microplastics contribute to improving soil quality (Liu et al., 2017) Based on the previous findings, microplastics can change the water cycle in soils, increase soil water shortages, and affect the migration of pollutants into deep soil layers along fissures (Rillig et al., 2017).

3.2 Soil fertility and nutrient status

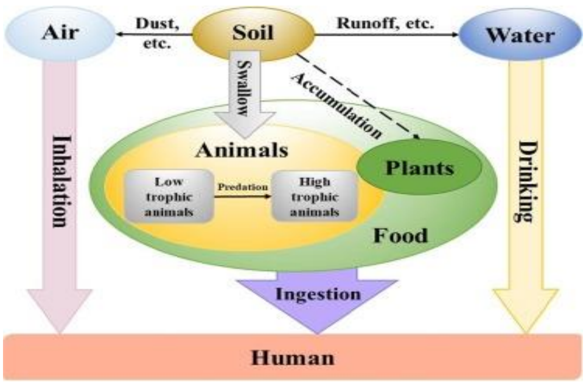
High catalytic capacity soil enzymes are closely linked to a variety of soil biochemical processes; these enzymes are important regulators of soil nutrient cycling for nutrients like C, N, and P as well as an indicator of soil fertility (Allison & Jastrow, 2006; & Riaz et al., 2022a; 2022b; 2022c). High levels of microplastics (28% w/w) greatly increased the accumulation of DOM throughout a 30-day experiment (Liu et al., 2017) and facilitated the release of soil nutrients, including dissolved organic carbon (DOC), dissolved organic nitrogen (DON), and dissolved organic phosphorus (DOP) (Ali et al., 2022a). The accumulation of DOM, however, decreased when the microplastic level was lowered to 7% w/w. The impacts of the microplastics were minimal from days 0–7, and the soil nutrient concentrations did not noticeably rise until days 14–30. Accordingly, the concentration and duration of exposure to microplastics significantly impact the effects of microplastics on soil (Liu et al., 2017).

3.3 Soil contamination

Furthermore, Judy et al. (2019) discovered that the inclusion of microplastics considerably disrupted the microbial community's structure and markedly reduced substrate-induced respiration (SIR) rates, suggesting that microplastics were responsible for the alterations in soil microbial function. According to Marschner and Kalbitz (2003), DOM is closely related to water eutrophication and the greenhouse effect because it serves as a substrate and a significant source of carbon for microorganisms. As a result, changes to DOM caused by microplastics may have an impact on microbial communities and soil function. Changes in soil enzyme activity may be a sign of possible impacts of microplastics on soil microbes, as the activity of soil enzymes can reflect microbial activity and the availability of substrates for microorganism absorption (Ali et al., 2021, 2023a, 2023b).

3.4 Ecological and health risks

Regarding the microplastic contamination of soil, the ecological and health risks resulting from microplastic exposure are of significant concern. Microplastics may be concentrated in the human body through various exposures (Zhu et al., 2019). Pathways, such as inhalation of dust, consumption of food, or direct drinking water contaminated by microplastics (Prata et al., 2018).



The demographic representation was used from the paper of Guo et al. (2020).

3.5 Microplastic effects on plants

There is a lack of relevant research and uncertainty surrounding the impact of microplastics on higher plants. Existing research indicated significant effects of microplastics on plants, including wheat (Triticum aestivum) (Qi et al., 2018), perennial ryegrass (Lolium perenne) (Boots et al., 2019), Vicia faba (Jiang et al., 2019), cress (Lepidium sativum) (Bosker et al., 2019), and spring onion (*Allium fistulosum*). With hydroponic *Vicia faba*, polystyrene microplastics (PS-MPs) could cause clear growth suppression, genotoxic, and oxidative damage. Using laser confocal scanning microscopy, a significant number of 100 nm PS-MPs was seen to collect at the tips of the roots (Jiang et al., 2019).

Judy et al. (2019) presented some disparate data indicating that exposure to microplastics did not significantly alter wheat biomass or seedling emergence. Thus, a great deal more research is required to fill in the information gaps about the effects of microplastics on plants, and further studies will be highly interesting.

4. Removal of microplastics from the soil environment

The amount of microplastics that enter soil ecosystems through sewage irrigation can be decreased by including microplastic removal techniques in wastewater treatment, for example. Further development of microplastic removal technology is desperately needed. Due to its potential to save energy and safeguard the environment, bioremediation has garnered a lot of interest in the removal of microplastics in recent years. Microorganisms can be used in bioremediation to break down polymer polymers, which serve as a carbon source and give the microorganisms energy (Caruso, 2015). For instance, Yang et al. (2014) reported that two bacterial strains with the ability to degrade PE were recovered from the intestines of Indian meal moth larvae (Plodia interpunctella): Enterobacter absurdum YT1 and Bacillus sp. YP1. Consequently, multiple organisms are needed for the biodegradation of microplastics to minimize secondary environmental pollution (Ali et al., 2022b, 2022c, 2022d). These organisms include the following: the first one must be able to break down complex polymers into smaller molecules of short chains (such as oligomers or their constituent monomers); the second must be able to use the oligomers or monomers and excrete simple waste compounds; and the third must be able to use the wastes that are excreted. However, the biodegradation of microplastic can scarcely achieve 100% due to its incorporation into humus, natural products, and microbial biomass (Narayan, 1993).

CONCLUSION

Microplastics are tiny, unevenly mixed plastic particles that are ubiquitous in arable soils and can infiltrate soil ecosystems through sewage irrigation, mulching films used in agriculture, landfills, and other sources. Several variables, including soil biota and soil characteristics, affect microplastics' vertical and horizontal migration within soil. Additionally, when microplastics are incorporated into soil aggregates, the structure of the soil is altered. Microplastics have a high adsorption capacity for dangerous chemicals, exacerbating soil pollution and heightening negative impacts on creatures and human health. They can also interact with other soil elements, impacting the health and function of the soil. In addition, because of their small size, soil organisms readily eat microplastics and spread via the food chain, resulting in mechanical and physiological harm when consumed.

Furthermore, microplastics may accumulate and move throughout plants, potentially affecting their growth. To reduce the dangers associated with microplastic pollution, we have identified several sites for prospective remediation solutions and future studies on soil microplastics. Microplastic-degrading bacteria offer a viable, eco-friendly method for bioremediating soil contaminated by microplastics.

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