# Review of Recent Advances in Ecological Effects of Microplastics on Plant Health and Soil Environment

Environmental Risk of Plastic Materials

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**Contents**

**Abstract**

Microplastics ( <5 mm in diameter) have recently been recognized as a critical environmental issue due to their particle sizes, low degradation rate and potential threats to the ecosystem. In terms of polymer type, shape, and size, microplastics in soil ecosystems are diverse. As a result, there is limited knowledge about how they affect terrestrial ecosystems.

This review carefully analyzes the occurrence, distribution, and potential ecological risks of microplastics in soil ecosystems, considering the physical and chemical characteristics of the soil, the cycling of nutrients through the soil, the presence of soil fauna, and the potential threat to plant health in agroecosystems. This review is based on recent studies conducted on the subject.

## 1. Introduction

Microplastics, generally defined as plastic particles <5 mm, have raised a great deal of concern in terms of pollution in the marine environment (Sun et al., 2022; Ya et al., 2021). The exposure and subsequent effects of microplastics in aquatic ecosystems have been well documented from cellular to population level as the accumulation rate of microplastics is still increasing in marine ecosystems (Cózar et al., n.d.; Galloway & Lewis, 2016; Redondo-Hasselerharm et al., 2020). Previous studies have reported that the presence of microplastics may pose a potential threat to organisms in the aquatic environment (Qiang & Cheng, 2021). Due to the small size of microplastics, they can be ingested by organisms, causing potential physical and chemical damage (Ya et al., 2021). It has been reported that the occurrence of microplastics in the ocean is mainly due to the growing input and fragmentation of large amounts of plastic waste, with an approximation of 80% of microplastics in the ocean coming from terrestrial systems (Jambeck et al., 2015). Thus, plastic accumulation in terrestrial ecosystems represents a long-term plastic reservoir which may impact freshwater and marine ecosystems for decades to come (Jambeck et al., 2015; Ya et al., 2021).

Growing research has recognized that the abundant presence of microplastics in terrestrial environments is undeniable, which potentially alters the soil ecosystem properties and processes (D. Huang et al., 2022; Sun et al., 2022; Ya et al., 2021; Zhou et al., 2021). Generally, two types of microplastics exist in the environment, primary and secondary microplastics. Primary microplastics are tiny particles designed purposely for commercial use, such as cosmetics, as well as microfibers shed from clothing and other textiles, as well as for fishing nets. Secondary microplastics are particles that result from the breakdown of larger plastic objects such as plastic water bottles and are caused by exposure to environmental factors, mainly UV radiation, physical abrasion, thermal oxidation and microbial processes (National Geographic Society, 2022; Ya et al., 2021).

There are generally three main sources of microplastics in the soil ecosystem. One of the main sources of plastics in the terrestrial ecosystem is plastics used in agriculture (agro plastics). In 2018, it was estimated that over 6 million tons of plastics materials were employed in agricultural activities such as agricultural mulching (Sintim & Flury, 2017; Zhou et al., 2021), with only about 6 – 26% going into recycling (Alimi et al., 2018; Zhou et al., 2021). This means a greater percentage of more than 70% remained in the terrestrial environment leading to possible fragmentations into microplastics. Sludge from wastewater treatment plants is another well know source of microplastics. It has been reported that sewage treatment plants remove about 99% of microplastics from wastewater which is accumulated in the resulting sludge from the process (Ya et al., 2021; L. Zhang et al., 2020). It is well known that most of the sludge from wastewater treatment finds application as constituents for composting or applied directly to farmlands. Therefore, a large number of microplastics get into the agricultural soil and become the key sources of soil microplastic pollution (L. Zhang et al., 2020). Also, landfill disposal of larger plastic objects contributes significantly to microplastics in terrestrial ecosystems. At landfills, plastics may be exposed to the aforementioned environmental factors that promote fragmentation of the larger objects into microplastics (D. Huang et al., 2022).

Recent studies have reported that terrestrial ecosystems are the major source of microplastics in the marine environment, yet there is limited knowledge on the ecological effects of microplastics on the soil environment and plant health. Given that soil acts as a sink for microplastics, this review aims to discuss the recent ecological effects of microplastics on the soil environment and plant health. Discussions about the occurrence, potential ecological risks and impacts on soil ecosystems, considering soil physical structure, soil fauna, and the potential threat to plant health in agroecosystems, are presented herein to provide a profound understanding of the current studies on ecological risks of microplastics on the soil environment.

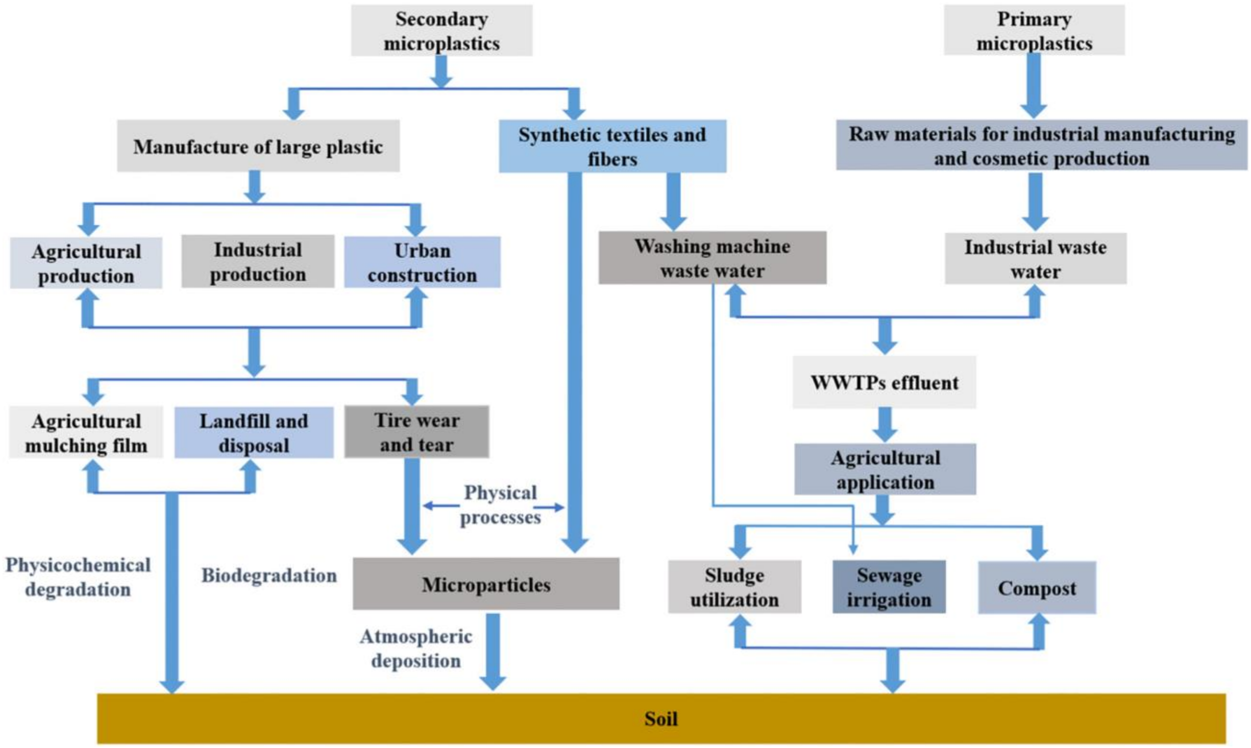


Figure 1: Sources of microplastics in terrestrial ecosystems. WWTPs indicate wastewater treatment plants. Adapted from (Ya et al., 2021)

## 2. Effects of Microplastics on soil structure

### 2.1. Effect on soil physicochemical properties

The presence of microplastics in soils causes changes in the physical characteristics of the soil, such as its bulk density, ability to hold water, stability of its aggregates, and water repellency (Ya et al., 2021). The spaces between soil particles can be reduced by microplastics, which can result in soil compaction. This may result in a reduction in soil porosity and an increase in bulk density, which may inhibit root development and nutrient uptake. According to studies, the polymer type, shape, and size of microplastics play a significant role in their impact on the physical and chemical characteristics of the soil (Sun et al., 2022). Polyester microfibers had no discernible impact on soil bulk density and saturated hydraulic conductivity in pot and field trials, according to research by (G. S. Zhang et al., 2019). They claimed that polyester fiber might increase soil's ability to store water while considerably reducing the amount of soil's water-stable aggregates.

### 2.2. Effect on soil nutrient cycle

By binding to minerals like nitrogen, phosphorus, and potassium, microplastics can have an impact on the availability of soil resources to plants and microbes. Recent research suggested that microplastics might alter the carbon and nutrient cycles by affecting the amount of dissolved organic matter in the soil. (Ren et al., 2020) made the interesting observation that adding 5% microplastics to soil had no discernible impact on the amount of dissolved organic carbon present, but sped up the production of aromatic functional groups. Leucine aminopeptidase and N-acetyl-glucosaminidase are important enzymes that impact the soil nitrogen cycle, and it has been shown that polystyrene microplastics impede their activity (Awet et al., 2018). Again, according to (S. Huang et al., 2023), both LDPE and PVC considerably boosted nitrate reductase activity and soil nitrification rate. This finding implies that exposure to microplastics may have a major impact on the soil nitrogen cycle in farming ecosystems.

## 3. Effects on soil fauna and microorganism

### 3.1. Effects on soil fauna

Studies on the impact of microplastics on soil fauna indicated that although high concentrations (1-2%) reduced earthworm development, low concentrations (0-0.5%) did not affect earthworm growth and survival. This implies that microplastics may directly harm soil fauna, which was reliant on the microplastic content. The main determinant of microplastics' toxicity to soil fauna and potential for bio-absorption into the food chain is also their ingestion (Zhou et al., 2021). Additionally, it has been suggested that microplastics might concentrate and absorb dangerous substances on their surface, raising the risk to living things (Ya et al., 2021).

### 3.2. Effects on microorganisms

Both low density polyethylene (LDPE) and polyvinyl chloride (PVC) microplastics may have an impact on the transformation of soil nitrogen, according to recent research by (S. Huang et al., 2023). They found that, as soil nitrification was boosted, the addition of microplastics increased the relative abundance of the species of nitrifying bacteria known as Nitrosospira (S. Huang et al., 2023). Furthermore, (Kong et al., 2018) investigated the impact of the plasticizer dibutyl phthalate (DBP) on the microbial community of the soil vegetable ecosystem. They noted that the number of bacteria in soils steadily declined as the quantity of dibutyl phthalate increased, but there was no obvious correlation with endophytic bacteria. Additionally, during the time of dibutyl phthalate breakdown, the relative abundance, structure, and composition of soil bacterial communities exhibited successional change (Kong et al., 2018).

Furthermore, it has been proposed that bacteria exposure to PP, PE, and PS causes heterogeneity in how well the bacteria work. (Sun et al., 2022) found that microplastic particles, fibers, and films caused greater variation in bacterial communities as did microplastics with different polymer types. This finding suggests that the more synthetically introduced shapes (such as fiber and film) diverge from naturally occurring shapes (such as particles), the more adverse effects they may have on the soil environment. Similar to this, a strong association between concentration changes and community divergence was found, showing the possible danger brought on by the rise of microplastics in the soil (Sun et al., 2022).

## 4. Effects on plant health

The basis of the food chain comprises plants as producers. The main concern is whether plants can absorb microplastics and whether the accumulation of microplastics may harm food safety. Microplastics could either have direct or indirect effects on plants (Zhou et al., 2021). Most of the direct effects that have been explored involved the physiological effects of microplastics on plants, with a specific focus on germination. When exposed to polylactic acid (PLA) microplastics, perennial ryegrass (Lolium perenne) seeds germinated significantly slowly, and PLA content was inversely associated with the height of shoots (Chen et al., 2020). Similarly, it was reported that seeds exposed to microplastics for 8 hours experienced a delayed germination process, which may be caused by the microplastics physically obstructing the seed capsule's pores and preventing the seeds from absorbing water (Bosker et al., 2019).

Also, microplastic-containing sludge added to the soil accelerated tomato plant growth but delayed and decreased fruit production. According to research on the effects of DBP, the compound may build up in plant tissues, and higher soil contamination levels have a greater cumulative impact. DBP buildup also affects the quality of vegetables in several other ways, such as by raising nitrate levels and lowering soluble protein levels (Kong et al., 2018). This suggests that additives that may leak out of microplastics might have negative impacts on plants and potential negative effects on food components. Moreover, PET microplastics could also cause oxidative stress, and Lepidium sativum treated with PET consistently had greater levels of chlorophyll a (chl-a) than the control (Pignattelli et al., 2021).

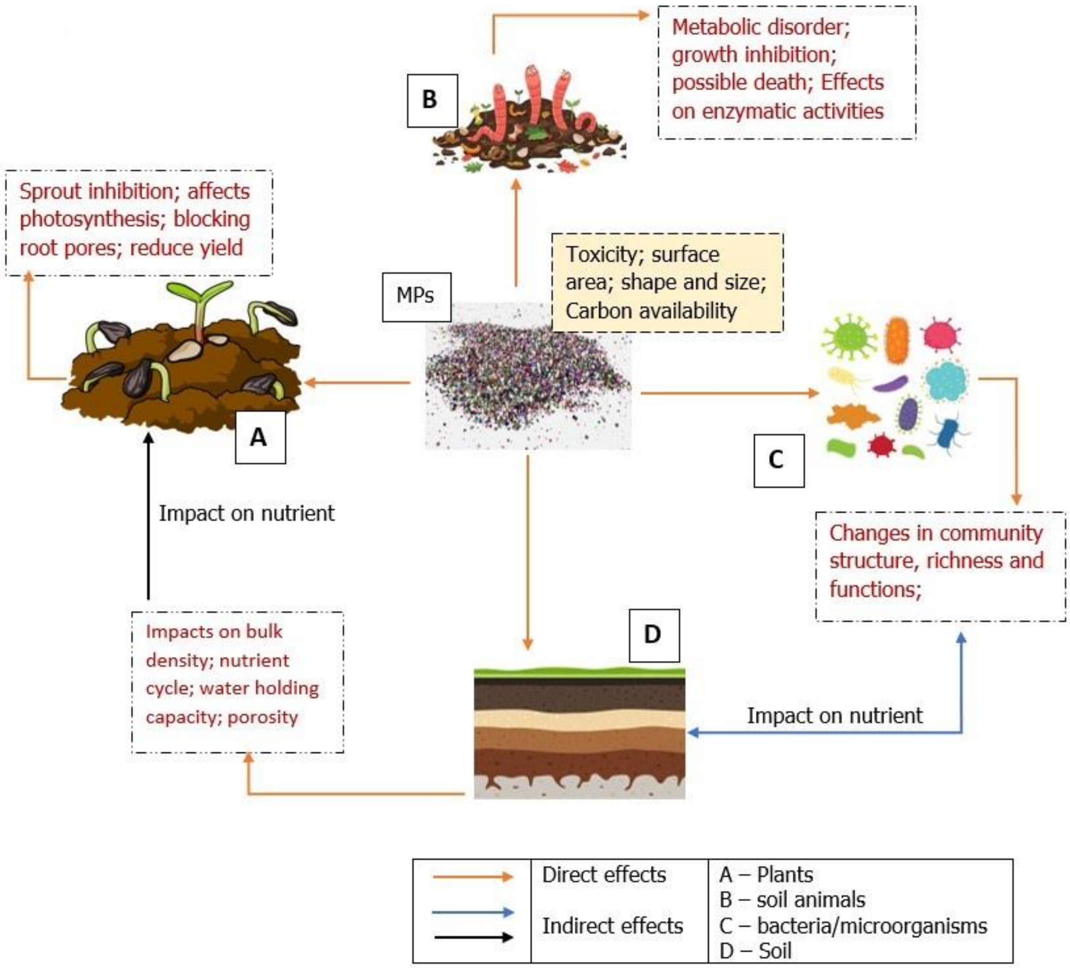


Figure 2: graphical illustration of the effects of microplastics on soil properties, plant health, soil fauna and microorganism

## 5. Conclusions and future suggestions

The impacts of microplastics on soil characteristics, soil fauna, and plant health have seen increasing research works in recent times, which have been reviewed in this review. The buildup of microplastics will affect plant and soil health, whether directly via the toxicity of additives and/or pollutants that have been adsorbed or indirectly through the ability to permanently change the physicochemical properties of the soils.

The greatest threshold concentrations that the soil-plant system can tolerate as well as the lowest concentrations of microplastics that negatively impact soil characteristics and plant development remain unclear. The majority of current research on the impacts of microplastics on soil ecosystems involves high concentrations of microplastics (>1%), which is crucial for investigating the ecological consequences and in particular for risk assessment, management, and remediation. As a more realistic representation of its in-situ ecological consequences, delivering a dosage of microplastics that is closer to its genuine concentration in the environment is also important.

The study on how microplastics affect plants now only includes a few common species and short-term trials. To forecast the consequences on an individual, community, or ecosystem level, greater research on the short- and long-term effects of microplastics on a range of plants is necessary. With sufficient data suggesting that microplastics may accumulate in fruits and vegetables, it is important to pay more attention to the effects of microplastics, particularly nanoplastics, as well as the effects of additives that could leach from microplastics on plant development in agroecosystems. Since sludge also contains other pollutants including metals and organic matter that might have an impact comparable to that of microplastics, studies utilizing sludge require additional clarity and in-depth description in terms of the dangers posed by microplastics. It is also important to consider the combined impact of microplastics and other contaminants on plants.

Additionally, soil microbes are necessary for the cycling of soil nutrients and the preservation of soil functions. Further research is required to understand how microplastics affect the microbial population of soil and, in particular, essential microbial activities, such as the microbial-driven greenhouse gas emission mechanism, which plays a crucial role in global climate change. Therefore, in-depth research on the harmful consequences of microplastics at the microbiological or even molecular levels is required. Additionally, research has shown that nanoplastics, in particular, are significantly more damaging to soil organisms than microplastics with lower particle sizes. Therefore, while evaluating the possible dangers of microplastics, it is important to consider their different particle sizes, shapes, and kinds in addition to their dosage.

Overall, there is still great work to be done concerning the impacts of microplastics on soil ecosystems. These works discussed herein could serve as a road map for planning and instituting research on this subject.

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