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Impact of Microplastic Pollution on Soil Health

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Abstract

Microplastic pollution in soil is a growing concern due to its potential impact on soil health and ecosystem functioning. Microplastics can enter soil ecosystems through various pathways, including direct disposal of plastic waste, use of plastic mulch in agriculture, and application of sewage sludge to soil. The potential risks associated with microplastics in soil include soil contamination, soil erosion, plant uptake, chemical leaching, and impact on soil biota. Mitigation measures such as the reduction of plastic use, proper disposal of plastic waste, reduction of plastic mulch use, treatment of sewage sludge, and monitoring and research are essential to address this issue. Understanding the impacts of microplastic pollution on soil health is crucial for protecting soil health and ecosystem functioning.

Keywords: Microplastics, Soil contamination, Soil health, Soil biota, Mitigation measures

Introduction:

Plastic is one of the most widely used materials in the world. Its durability and versatility have made it a popular choice for a wide range of applications, from food packaging to household items to electronic devices. With the immense pace of increasing population growth, the production of global plastics has also increased tremendously, which is almost doubled in last two decades producing 460 million tonnes (Mt) in 2019. It is also estimated that if capping is not done in manufacturing, plastic production is projected to be tripled from its 2019 levels, *i.e.* 1231 Mt by 2060 (OECD, 2022). The present scenario of demographic data, plastic production, low recovery rate, and use/disposal patterns; all points to increasing accumulation of plastic waste in our oceans, posing a significant threat to

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marine life, and now plastic pollution has also become a significant concern in soil ecosystems.Plastics are persistent and even though these are recyclable, only 9% are reclaimed (Fig. 1) while major portion stay in environment which are subjected to fragmentation through various biotic and abiotic agents producing small fragments and particles known as microplastics.

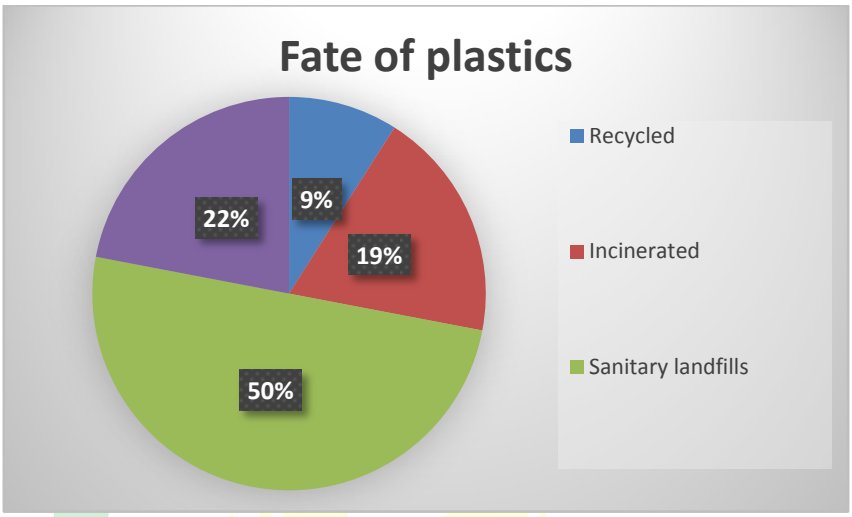

Fig. 1 Fate of plastics (OECD, 2022)

Microplastics are small plastic particles that are less than five millimeters in size. They are widely used in products such as cosmetics, cleaning agents, and textiles. Microplastic pollution in soil is a growing environmental concern that is receiving increasing attention from researchers and policymakers. Microplastics can enter soil ecosystems through various pathways, including the direct disposal of plastic waste, the use of plastic mulch in agriculture, and the application of sewage sludge to soil.The impact of microplastic pollution in soil is not yet fully understood, but there is growing evidence to suggest that it can have adverse effects on soil health and the wider ecosystem. This article will explore the impact of microplastic pollution in soil in more detail, examining the pathways of microplastic pollution in soil, the potential risks associated with microplastics, and the measures that can be taken to mitigate the impact of microplastic pollution in soil.

Pathways of microplastic pollution in soil:

Microplastic pollution can enter soil ecosystems through various pathways, including the direct disposal of plastic waste, the use of plastic mulch in agriculture, and the application of sewage sludge to soil. The direct disposal of plastic waste is one of the most significant contributors to microplastic pollution in soil. Plastic waste can be deposited in landfill sites,

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where it can degrade into smaller plastic particles that can then be carried into soil ecosystems through rainfall and wind. Plastic waste can also be littered in the environment, where it can accumulate in soil. The use of plastic mulch in agriculture is another pathway for microplastic pollution in soil. Plastic mulch is commonly used in agriculture to control weeds, conserve soil moisture, and regulate soil temperature. However, plastic mulch can degrade over time, releasing microplastics into the soil. The application of sewage sludge to soil is another pathway for microplastic pollution in soil. Sewage sludge is the semi-solid material that remains after wastewater treatment. Sewage sludge can contain microplastics that have been flushed down the drain, such as microbeads from cosmetics and microfibers from textiles. When sewage sludge is applied to soil, these microplastics can be released into the soil ecosystem.

Migration of microplastics in soil

Migration of microplastics can be either horizontally or vertically and its distribution is influenced by several factors *viz.*, soil biota, soil features (soil macropores, soil aggregation and soil cracking) and agronomic practices (plowing and harvesting). The biotic factors responsible for dispersion of microplastics could include plant processes such as root growth and their uprooting and contribution from various animals (larvae, earthworm, vertebrates, etc.). Fungal mycelia may also contribute in the movement of microplastics through translocation of pollutants in their growing phase. Agents for lateral dispersion of microplastics include epigeic earthworm, mosquito larva, mites, collembola, moles, etc. Agents responsible for vertical dispersion of microplastics are burrowing animals, anecic earthworms, soil cracks, agronomic practices (e.g. plowing and harvesting), plant root elongation, and ingestion and egestion activities of soil fauna (Guo *et al.*, 2020).

Potential risks associated with microplastics in soil:

The impact of microplastic pollution in soil is not yet fully understood, but there is growing evidence to suggest that it can have adverse effects on soil health and the wider ecosystem. Some of the potential risks associated with microplastics in soil include:

- Soil contamination: Microplastics can contaminate soil, reducing its quality and fertility. Microplastics can also impact the microbial community in soil, which can affect nutrient cycling and soil structure.

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- Soil erosion: Microplastics can exacerbate soil erosion by reducing soil stability and increasing the risk of runoff and erosion.
- Plant uptake: Microplastics can be taken up by plants, which can impact their growth and development. There is also concern that microplastics in soil could enter the food chain, posing a risk to human health.
- Impacts on soil fauna: Microplastics can affect soil fauna, such as earthworms and insects, which play a vital role in soil health and ecosystem functioning.

Impact of microplastics on soil physical health:

Microplastic pollution is a growing concern for the environment and human health. While most research has focused on the effects of microplastics on aquatic ecosystems, recent studies have shown that microplastics can also impact soil health, including soil physical properties. The effects of microplastic pollution on soil physical health include changes in soil structure, soil water-holding capacity, and soil aeration, among others. One of the most significant impacts of microplastic pollution on soil physical health is the alteration of soil structure. Microplastics can change soil structure by physically altering soil aggregates, which are important for soil porosity and water infiltration (Qiu *et al*., 2022). This can lead to soil compaction, reducing soil aeration and water-holding capacity, which can negatively impact plant growth and productivity. Furthermore, microplastics can also impact soil water-holding capacity. Studies have shown that microplastics can decrease soil water-holding capacity by physically blocking water movement and clogging soil pores (Wang et al., 2023). This can lead to reduced plant growth and increased runoff, which can result in soil erosion and water pollution.Additionally, microplastics can also impact soil aeration. Soil aeration is critical for soil microbial activity, as many soil microorganisms require oxygen for respiration. Microplastics can decrease soil aeration by physically blocking soil pores, leading to decreased soil microbial activity and nutrient availability (Lozano *et al*., 2021).Recent studies have shown that microplastic pollution can have a range of negative impacts on soil physical health. For example, a study conducted in Italy found that the addition of microplastics to soil led to a decrease in soil water-holding capacity, increased soil compaction, and reduced plant growth (de Souza Machado *et al*., 2018).

Impact of microplastics on soil chemical health:

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Microplastic pollution is a major environmental concern globally, with negative impacts on ecosystems and human health. While most research has focused on the impact of microplastics on aquatic environments, recent studies have shown that microplastics can also impact soil health, including soil chemical properties. The effects of microplastic pollution on soil chemical health include changes in soil pH, nutrient availability, and soil organic matter, among others.One of the most significant impacts of microplastic pollution on soil chemical health is the alteration of soil pH. Microplastics can increase the acidity of soil by releasing acids during their degradation, leading to a decrease in soil pH (Zhao *et al*., 2021). This can have significant implications for soil microbial activity and nutrient availability, as many soil microorganisms are sensitive to changes in soil pH. Additionally, microplastics can also alter nutrient availability in the soil. Studies have shown that microplastics can adsorb nutrients such as nitrogen, phosphorus, and potassium, reducing their availability for plant uptake (Dong *et al*., 2021). This can result in decreased plant growth and productivity, leading to a negative impact on agricultural productivity and food security. Furthermore, microplastics can also affect soil organic matter, which is critical for soil fertility and productivity. Studies have shown that microplastics can adsorb organic matter, reducing the amount of available organic matter in the soil (Shi *et al*., 2022). Soil organic matter is critical for soil nutrient cycling, water retention, and microbial activity, so a decrease in organic matter can have significant negative impacts on soil health and productivity. A study conducted in China found that the addition of microplastics to soil led to aincrease in soil pH and a reduction in soil organic matter, leading to a negative impact on soil microbial activity and nutrient availability (Zhao *et al*., 2021).

Impact of microplastics on soil biological health:

Microplastic pollution is a growing environmental concern that can have a range of negative impacts on soil biological health. Soil biota, including bacteria, fungi, protozoa, nematodes, and arthropods, play crucial roles in soil nutrient cycling, organic matter decomposition, and soil ecosystem functioning. Microplastics can affect soil biological health by altering the composition and diversity of soil microbial communities, disrupting soil food webs, and affecting soil nutrient cycling.One of the most significant impacts of microplastic pollution on soil biological health is the alteration of soil microbial communities. Microplastics can impact soil microbial communities by clogging soil pores, reducing soil

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aeration, and altering soil water-holding capacity. This can lead to changes in soil microbial diversity and composition, which can impact soil nutrient cycling and organic matter decomposition (de Souza Machado *et al*., 2018).Furthermore; microplastics can also impact soil food webs. Soil food webs are complex networks of interactions between soil biota, including predators, prey, and decomposers. Microplastics can disrupt soil food webs by altering the availability of soil organic matter, which can impact soil nutrient cycling and soil ecosystem functioning (Sajjad *et al*., 2022). This can ultimately lead to decreased soil fertility and productivity.Additionally, microplastics can also affect soil nutrient cycling. Soil nutrient cycling is a critical process that involves the transformation of nutrients between organic and inorganic forms. Microplastics can impact soil nutrient cycling by altering soil microbial communities and disrupting soil food webs (Li *et al*., 2022). This can lead to reduced nutrient availability, which can negatively impact plant growth and productivity. A study concluded that microplastics reduced soil microbial biomass and activity, leading to decreased soil nutrient availability (Blöcker*et al*., 2020). Similarly, a study conducted in Italy found that the addition of microplastics to soil led to changes in soil microbial community composition and decreased soil enzyme activity (Santini*et al*., 2023).

Mitigating the impact of microplastic pollution in soil:

To mitigate the impact of microplastic pollution in soil, severalmeasures can be taken,including:

- Reducing plastic waste: The most effective way to mitigate the impact of microplastic pollution in soil is to reduce plastic waste. This can be achieved by using less plastic, recycling more, and promoting the use of biodegradable alternatives.
- Proper disposal of plastic waste: Proper disposal of plastic waste is essential to prevent it from entering soil ecosystems. Landfills should be properly managed to prevent plastic waste from degrading and releasing microplastics into the environment.
- Alternative mulching materials: Alternative mulching materials, such as biodegradable mulches made from plant-based materials, can be used in agriculture to reduce the use of plastic mulch.

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- Monitoring and regulation: Monitoring and regulating the use of plastics in various industries, such as cosmetics and textiles, can help to reduce the amount of microplastics entering soil ecosystems.
- Remediation techniques: Techniques such as soil washing, phytoremediation, and bioremediation can be used to remove microplastics from soil.

Conclusion:

Microplastic pollution in soil is a growing environmental concern that requires urgent attention. Microplastics can enter soil ecosystems through various pathways, including the direct disposal of plastic waste, the use of plastic mulch in agriculture, and the application of sewage sludge to soil. The impact of microplastic pollution in soil is not yet fully understood, but there is growing evidence to suggest that it can have adverse effects on soil health and the wider ecosystem. To mitigate the impact of microplastic pollution in soil, measures such as reducing plastic waste, proper disposal of plastic waste, alternative mulching materials, monitoring and regulation, and remediation techniques can be taken. By taking these measures, we can work towards reducing the impact of microplastic pollution in soil and protecting soil health and ecosystem functioning.

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