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Microplastics in Agricultural Soil: A Hidden Threat to Food Security

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Microplastic pollution is an emerging threat to agricultural soils and long-term food security. Modern agriculture relies extensively on plastics for mulch films, irrigation systems, greenhouse structures, packaging, fertilizers and pesticides. Globally, agriculture used approximately 12.5 million tonnes of plastics in 2019, increasing the potential for plastic residues to accumulate in soil. Through weathering, ultraviolet radiation and mechanical degradation, larger plastics fragment into microplastics, generally defined as particles smaller than 5 mm. These particles can alter soil structure, water movement, nutrient cycling and microbial communities and may interact with contaminants and plant roots. Reported microplastic concentrations in Asian agricultural soils range from 2.5 to 42,960 particles kg^{-1}. In India, a review of 73 studies published during 2020–2024 identified agricultural activities, wastewater irrigation, atmospheric deposition, poor waste management and contaminated amendments as major pathways. In Southern India, reported concentrations range from 45 to more than 4,200 particles kg^{-1}. A 2025 study detected microplastics in agricultural soils of Goa and Udupi, with surface-soil concentrations of 100.93 ± 64.19 and 95.68 ± 30.69 particles kg^{-1}, respectively. Mitigation requires reducing agricultural plastic use, improving recycling, treating wastewater, adopting safer alternatives, and strengthening monitoring and farmer awareness to protect soil health and ensure sustainable food security.

Keywords: Soil health; Plastic pollution; Crop productivity; Agricultural plastics; Soil contamination; Sustainable agriculture.

Introduction

Plastic has become an integral part of modern agriculture, supporting crop production through mulch films, irrigation pipes, greenhouse structures, packaging, fertilizers and pesticides. However, the increasing use and improper disposal of agricultural plastics have created a growing environmental concern: microplastic contamination of agricultural soils. Microplastics are generally defined as plastic particles smaller than 5 mm and are produced through the fragmentation of larger plastic materials or released directly from plastic-containing products. Agriculture used approximately 12.5 million tonnes of plastics globally in 2019, indicating the substantial scale of plastic use in agrifood systems. Once introduced into soil, microplastics can persist for long periods and interact with soil particles, microorganisms, water and plant roots. They may alter soil structure, water movement, nutrient cycling and microbial activity, potentially affecting crop growth and soil fertility. Reported concentrations in Asian agricultural soils range from 2.5 to 42,960 particles kg^{-1}, demonstrating the widespread and variable nature of contamination. In India, agricultural soils are increasingly recognized as potential microplastic sinks due to wastewater irrigation, plastic mulch, poor waste management, contaminated organic amendments and atmospheric deposition.

Studies from Tamil Nadu, Goa and Karnataka have confirmed the presence of microplastics in agricultural soils. Therefore, understanding their sources, impacts and mitigation is essential for protecting soil health, crop productivity and long-term food security.

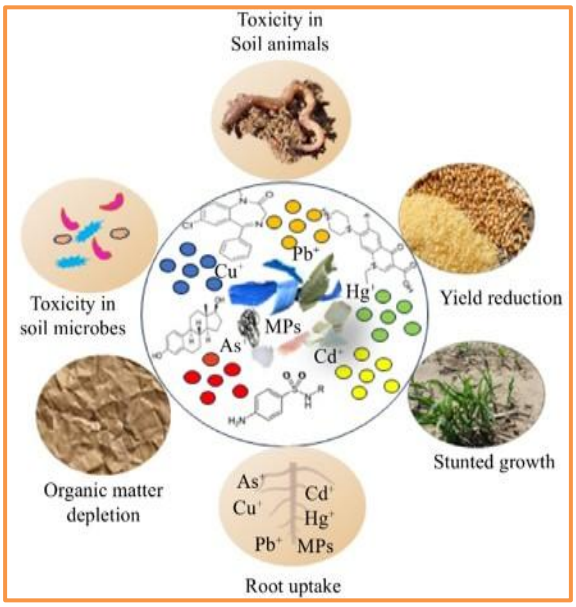

Figure 1: Impact of Micro Plastics

Effects of Microplastics on Soil, Crops, Food and Humans

Microplastics can move from soil to plants, food and humans, creating risks for soil health, crop production and food safety. Their effects depend on their size, amount, type and the conditions of the soil.

1. Effects on Soil

- Change soil structure and porosity
- Affect water movement and soil moisture
- Disturb nutrient cycling
- Reduce or change microbial activity
- Affect earthworms and other soil organisms
- Carry pesticides and heavy metals

2. Effects on Crops

Microplastics can affect root growth, water absorption and nutrient uptake. They may also cause oxidative stress and disturb photosynthesis and other plant processes.

3. Effects on Crop Yield

Changes in soil and plant health may lead to poor germination, lower biomass and reduced crop productivity. However, the effect varies with crop type, soil conditions and microplastic concentration.

4. Effects on Food

Microplastics can potentially enter food through crop uptake, contaminated soil, irrigation water and animal feed. Their presence in edible crops raises concerns about food quality and safety.

5. Effects on Humans

People may be exposed to microplastics through food, drinking water and air. Possible concerns include inflammation, oxidative stress and cellular effects, although their long-term health impacts are still being studied.

Detection of Microplastics in Soil and Food

- **Soil Contamination:** Microplastics can accumulate in agricultural soils through plastic mulch, irrigation water, compost, and sewage sludge.
- **Food Contamination:** Microplastics have been detected in vegetables, fruits, cereals, seafood, salt, drinking water, and processed foods.
- **Sample Preparation:** Samples are dried, homogenized, digested, and filtered to isolate suspected plastic particles.
- **Density Separation:** Density-based techniques help separate microplastics from soil and organic materials.
- **Microscopic Detection:** Stereomicroscopy is used to identify particles based on size, shape, and colour.
- **FTIR Analysis:** Fourier-transform infrared spectroscopy (FTIR) is used to confirm the polymer type of suspected microplastics.
- **Raman Spectroscopy:** Raman spectroscopy enables identification of small microplastic particles and their polymer composition.
- **Pyrolysis-GC/MS:** This technique provides chemical identification and quantitative estimation of plastic polymers.

- **Contamination Control:** Glass equipment, procedural blanks, and protective clothing help prevent laboratory contamination.
- **Environmental Significance:** Monitoring microplastics in soil and food helps assess their movement through agricultural systems and potential risks to human health.

Table 1: Strategies to Reduce Microplastic Pollution

Approach	Description
Reduce single-use plastics	Minimize the use of plastic bags, bottles, packaging and disposable products.
Use biodegradable alternatives	Replace conventional plastics with biodegradable or compostable materials where suitable.
Reduce plastic mulch use	Promote proper collection, segregation, recycling and safe disposal of plastic waste.
Treat wastewater	Improve wastewater treatment to remove microplastics before discharge into water bodies and agricultural fields.
Choose safer food packaging	Encourage food packaging materials that minimize plastic shedding and contamination.

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