Reg. No.: COOP/2023/KOTA/201080/26/142

AGRICULTURE FORUM FOR TECHNICAL EDUCATION OF FARMING SOCIETY

Kota, Rajasthan

Microplastic Contamination in Indian Soils: An Emerging Challenge for Sustainable Agriculture

Authors

Kanika[1], Anant Sharma[2], Priyanshi[2], Swapnil Srivastava[3] and Ajay Verma[4]

Ph.D. Scholar, [1]Department of Soil Science and Agricultural Chemistry, [2]Department of Agronomy, [4]Department of Extension Education, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya- 224229 (Uttar Pradesh), India [3]Department of Agricultural Biotechnology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110 (Uttar Pradesh), India

INTRODUCTION

Microplastic contamination has emerged as one of the fastest-growing environmental concerns worldwide, extending beyond marine ecosystems to terrestrial environments, particularly agricultural soils. Microplastics are plastic particles measuring less than 5 mm in diameter and are classified as primary microplastics, intentionally manufactured for industrial and commercial applications, or secondary microplastics, generated through the fragmentation of larger plastic debris by physical, chemical, and biological weathering processes. Due to their persistence, mobility, and potential toxicity, microplastics are now recognized as emerging contaminants that threaten soil health, ecosystem functioning, agricultural productivity, and food security.

India is among the world's largest consumers and generators of plastic waste. According to the Central Pollution Control Board (CPCB), the country generates more than 4 million tonnes of plastic waste annually, with increasing quantities entering terrestrial ecosystems because of inadequate collection, recycling, and disposal systems. Agricultural soils are becoming important sinks for plastic residues through multiple pathways, including plastic mulch films, greenhouse coverings, drip irrigation systems, seedling trays, fertilizer and pesticide packaging, coated fertilizers, wastewater irrigation, sewage sludge, compost, and atmospheric deposition. Globally, the Food and Agriculture Organization (FAO) estimated that approximately 12.5 million tonnes of plastic products were used in agricultural production and an additional 37.3 million tonnes in food packaging during 2019. Although agricultural plastics improve crop productivity, irrigation efficiency, and resource-use efficiency, their improper disposal results in long-term accumulation of plastic residues in soils. Since conventional plastics degrade extremely slowly, they gradually fragment into microplastics that persist in soil for decades and may eventually form nanoplastics.

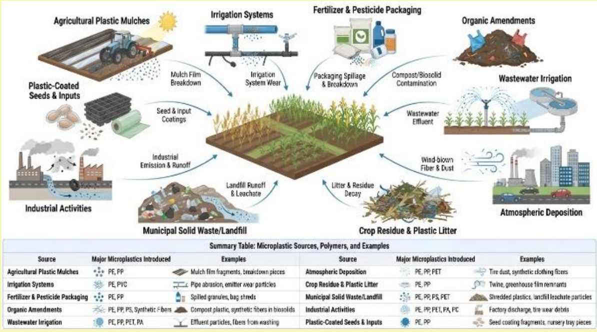

Figure 1: Major sources of Microplastic in Agricultural soils

Effects of Microplastic on Soil

1. Effects on Soil Physical Properties

- Alter soil aggregation and reduce aggregate stability.
- Modify soil bulk density, porosity, and pore-size distribution.
- Influence water infiltration, hydraulic conductivity, and water-holding capacity.
- Affect soil aeration and root penetration.
- Increase soil susceptibility to erosion and structural degradation.
- Alter soil temperature and moisture dynamics, influencing plant growth.

2. Effects on Soil Chemical Properties

- Change soil pH and electrical conductivity (EC).

- Adsorb and transport heavy metals (Cd, Pb, Zn, Cu) and organic pollutants.
- Reduce nutrient availability and nutrient-use efficiency.
- Influence soil organic carbon dynamics and cation exchange capacity (CEC).
- Disrupt nitrogen and phosphorus cycling.
- Increase the persistence of pesticides and antibiotics in soil.

3. Effects on Soil Biological Properties

- Reduce microbial biomass and microbial diversity.
- Alter the composition of bacterial and fungal communities.
- Suppress beneficial microorganisms involved in nutrient cycling.
- Decrease the activity of soil enzymes such as:
    - Dehydrogenase
    - Urease
    - Acid phosphatase
    - Alkaline phosphatase
    - β-glucosidase
- Affect symbiotic microorganisms, including mycorrhizal fungi and plant growth-promoting rhizobacteria (PGPR).

4. Effects on Soil Fauna

- Reduce earthworm growth, reproduction, and survival.
- Decrease burrowing activity, affecting soil aeration.
- Alter feeding behaviour of earthworms and nematodes.
- Reduce abundance and diversity of soil mesofauna.
- Disturb soil food webs and ecosystem functioning.

5. Effects on Nutrient Cycling

- Reduce decomposition of organic matter.
- Inhibit nitrogen mineralization and nitrification.
- Alter phosphorus transformation and availability.
- Reduce microbial respiration.
- Affect carbon sequestration potential.
- Increase greenhouse gas emissions (CO_2, CH_4, and N_2O) under certain conditions.

6. Effects on Crop Growth and Productivity

- Inhibit seed germination.
- Restrict root elongation and root biomass.
- Reduce nutrient and water uptake.
- Induce oxidative stress in plants.
- Decrease chlorophyll content and photosynthetic efficiency.
- Lower crop yield and biomass.
- Facilitate uptake of nano-sized plastics into edible plant tissues, posing potential food safety risks.

7. Effects on Environmental Sustainability

- Reduce overall soil fertility and resilience.
- Impair ecosystem services provided by healthy soils.
- Contribute to long-term accumulation of persistent plastic residues.
- Increase the risk of contaminant transfer through the soil–plant–food continuum.
- Threaten sustainable agricultural production and food security.

Table 1: Major Microplastic Sources and Polymers Reported in Indian Agricultural Soils

Region/State	Dominant Microplastic Types	Major Sources
Coimbatore, Tamil Nadu	PE, PP, PS, PVC	Plastic mulch, fertilizer bags, irrigation materials
Goa & Karnataka	PE, PP, PET, Polyester, HDPE	Agricultural plastics, sewage sludge, irrigation water
Indore, Madhya Pradesh	PE, PET, PP	Urban compost, wastewater irrigation, plastic litter
Punjab (North India)	Predominantly PE and PP (potentially associated with mulch films and irrigation plastics); systematic field-scale quantification remains limited	Plastic mulch, irrigation pipes, fertilizer packaging
Uttar Pradesh (Indo-Gangetic Plains)	Evidence suggests a high risk of PE, PP and PVC inputs; comprehensive field surveys are still lacking	Canal/wastewater irrigation, fertilizer bags, plastic packaging
Haryana	High potential occurrence of PE and PP associated with intensive agriculture; quantitative field data remain scarce	Plastic mulch, PVC irrigation pipes, agricultural packaging

**Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyester (PES) and Polyvinyl chloride (PVC)*

Sustainable Management Strategies

At the Farm Level

- **Reduce the use of single-use plastics** in agricultural operations to minimize plastic residues entering the soil (FAO, 2021).
- **Adopt biodegradable and compostable mulch films** as environmentally friendly alternatives to conventional polyethylene mulches (UNEP, 2023).
- **Ensure proper collection, segregation, and disposal of agricultural plastic waste**, including mulch films, irrigation pipes, fertilizer bags, and greenhouse covers, to prevent soil contamination (CPCB, 2022).
- **Promote recycling and reuse of agricultural plastics** through authorized recycling systems and collection centres (FAO, 2021).
- **Optimize plastic use through precision agriculture** to reduce unnecessary plastic inputs and improve resource-use efficiency (FAO, 2021).

Soil Management Practices

- **Increase soil organic matter** through the application of compost, farmyard manure (FYM), green manures, and cover crops to enhance soil structure and resilience against microplastic-induced degradation (Hanif et al., 2024).
- **Apply biochar** to improve soil aggregation, stimulate microbial activity, and immobilize contaminants associated with microplastics (Lehmann & Joseph, 2015; Ma et al., 2024).

- **Adopt conservation agriculture** practices such as minimum tillage, crop rotation, and residue retention to maintain soil quality and reduce environmental degradation (FAO, 2021).
- **Implement integrated crop residue management** to discourage plastic burning and reduce the accumulation of plastic debris in agricultural fields (CPCB, 2022).
- **Use certified organic amendments** free from plastic contaminants to minimize secondary microplastic inputs into agricultural soils (FAO, 2021).

Policy and Institutional Measures

- **Strengthen the implementation of the Plastic Waste Management Rules, 2016 (amended 2022)** to improve plastic waste collection, recycling, and environmentally sound disposal (CPCB, 2022).
- **Promote Extended Producer Responsibility (EPR)** to ensure manufacturers are responsible for the collection and recycling of agricultural plastics (UNEP, 2023).
- **Develop national standards and long-term monitoring programmes** for assessing microplastic contamination in agricultural soils (UNEP, 2023).
- **Support research and innovation** for developing biodegradable agricultural plastics and sustainable alternatives to conventional polymers (Hanif et al., 2024).
- **Enhance farmer awareness and capacity-building programmes** on responsible plastic use, waste management, and sustainable agricultural practices to reduce microplastic pollution (FAO, 2021).

- **Promote circular economy approaches** by encouraging the reuse, recycling, and recovery of plastic materials across agricultural value chains (UNEP, 2023).

Key Message

Prevent • Reduce • Recycle • Restore

- **Prevent** plastic leakage into agricultural soils.
- **Reduce** dependence on single-use plastics.
- **Recycle** agricultural plastics through authorized collection and recycling systems.

Restore soil health by adopting sustainable soil and waste management practices.