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Microplastic pollution in agriculture soil: An updated review

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Abstract

Microplastic contamination in agricultural soil is one of the major problems worldwide as it contaminates the food chain. In modern agriculture, plastic utilization introduces microplastics into soils through diverse practices, including plastic mulching, sewage irrigation, contaminated rain water entering into agricultural land, rivers, ponds, and lakes, soil amendment, fertilizer coatings, littering, run off, and atmospheric deposition. The potential transfer of microplastics through the food chain raises concerns regarding human health. Microplastics change soil properties such as soil structure, fertility, and functioning as well as the diversity of microbes, which may have implications for plant and animal health and pose possible risks for the safety and quality of food, ultimately jeopardizing human health. Therefore, cost effective detection methods should be developed for the quick identification of micro plastics in soil system. Addressing these challenges is crucial for ensuring soil health, food security, and environmental sustainability.

Keywords: Agriculture Soil; Contamination; India; Microplastics; Plant Health; Soil Fertility

1. Introduction

Microplastic contamination in agricultural soil is one of the major problems worldwide as it contaminates the food chain [1-30]. Agricultural soils face contamination risks due to direct plastic inputs, irrigation with polluted water, rain water entering agricultural land, and atmospheric deposition, raising concerns about long-term soil degradation and food safety [1-30]. According to the review of literature by Solanki et al., (2024) [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13], microplastics impact soil ecosystems, potentially altering microbial communities, nutrient cycling, and overall soil health, leading to cascading effects on plant, animal and human life [1-30]. The slow degradation of plastics exacerbates the persistence of microplastics in the environment [1-30-45]. The proliferation of microplastics in soil poses an ongoing challenge, as current levels continue to rise due to persistent plastic use and inadequate waste management [1-30-50]. They are not visible to the naked eye being >5mm in size. Microplastic is 0.1µm- 5mm and neoplastic is less than 0.1µm in size [1-30]. Due to improper waste management system, their small size, they are easily carried away by air and water mixing well into the ecosystem [1-60]. The use of plastic mulching in agriculture, a primary source of microplastics in soil, presents a dilemma, as alternatives must be developed and adopted to reduce environmental harm without compromising crop productivity [1-50]. Daily life is very easy and

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comfortable with the use of plastics. Because they are lightweight, robust, corrosion- resistant, durable, non-biodegradable, and cost less in the pocket [4]. They are produced by the polymerization of various monomers and other additives, petroleum being a major ingredient [4].

Plastic films are indeed a significant contributor to microplastic pollution in agricultural soils. In modern agriculture, plastic utilization introduces microplastics into soils through diverse practices, including plastic mulching, sewage irrigation, contaminated rain water entering into agricultural land and rivers, lakes, soil amendment, fertilizer coatings, littering, run off, and atmospheric deposition [1-60]. However, research on microplastic contamination in soil is concentrated mainly on mulched agricultural lands [1-60]. Implementing precautionary measures to minimize microplastic contamination from different sources could significantly mitigate the entry of microplastic into soil ecosystems [1-60]. Plastics can break up into microplastics (particles smaller than 5 mm) because of photo degradation, mechanical abrasion, and bioturbation [1-60]. Also, cosmetics and products made in factories can directly release microplastics [1-60]. There is a growing concern about microplastic pollution in land systems have been growing recently. Microplastics in farm soils could have effects on farm ecosystems and food security that is more dangerous [1-60]. Due to the risks that microplastics pose to the ecosystem through the food chain, it is important to know how they behave in agricultural soil systems [1-60, 96]. Additionally, various additives were added into various types of plastic products for various purposes [1-60]. Plasticizers were added to soften plastics, primarily in polyvinyl chloride, flame retardants were widely used in consumer products ranging from household items to polystyrene insulation foams, and antioxidants were used in many polymers, including PE and polypropylene, to stop the ageing process in outdoor settings [1-60]. Agricultural soil systems serve as major microplastics reservoirs and are exposed to them in a variety of ways [1-60].

The potential transfer of microplastics through the food chain raises concerns regarding human health impacts [1-30, 96]. Research is needed to figure out the extent of these risks and implement strategies to minimize exposure [1-30]. The absence of strict regulations governing plastic production, use, and disposal contributes to the persistence of microplastic pollution [1-60]. A coordinated global effort is necessary to address these gaps [1-30]. Because of its ecological importance, soil acts as an important microplastic sink, affecting soil and plant health and microbial activity [1-30]. Solanki et al., (2024), [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13] reported that a variety of factors contribute to microplastic pollution in agricultural soils, including plastic mulching, manure, agricultural products (silage nets, twine), sewage sludge, weathering, and other indirect processes [1-60]. These microplastics migrate, threatening soil integrity and biodiversity [1-60]. Soil microplastics are analyzed for size, volume fraction, and polymer [1-60]. Common materials include polyethylene, polypropylene, polyamide, polystyrene, polyvinyl chloride, and polyesters [1-60]. Techniques, including optical microscopy and spectroscopy, extract and analyze microplastics [1-60]. The integrated environmental assessment highlights the complex relationship between microplastics and soil ecosystems, providing insights into potential risks and suggesting strategies to combat this looming environmental threat [1-60]. Developing and adopting more biodegradable alternatives is essential for reducing long-term environmental impacts [97-112]. Plant based thin biodegradable films plays an important role in food storage and packaging industries [97-112]. In the following section, the causes of microplastic contamination of soil, source of contamination, extraction and detection methods have been discussed and updated.

2. Main causes and source of microplastic pollution

Microplastics, defined as plastic particles smaller than 5 mm, have become widespread environmental pollutants with significant ecological and human health risks [1-60-90,113-116]. Experts are of the opinion that agriculture methods, input from irrigation and fertilizer, and atmospheric deposition are the main causes for the microplastic pollution of agricultural soil [1-60-90, 113-116]. Microplastics are fragmented and degraded in agricultural soils by photo-oxidation, mechanical abrasion, and UV irradiation dominating the early phases of the process [1-60-90]. In agriculture, plastic in fields has many sources they can be due to washout water from landfills reaching the field during rain or mulches or fertilizers used [1-60-90]. Because of the nature of the soil, agricultural practices, and the qualities of the microplastics, microplastics may also move through soil systems in physical and biological ways [1-60-90]. Through direct consumption or accumulation by organisms as well as indirect changes to soil characteristics or the soil microbial population, microplastics have a variety of effects on agricultural soils [1-60-90, 113-116]. Initially recognized as a marine pollution issue, microplastics are now documented in terrestrial environments, particularly in soils, where they can alter soil structure, reduce fertility, and disrupt microbial communities [1-60-90]. Arya and Kumar (2025) [4] are of the opinion that waste water from industries like textile, sugar, and cosmetics or effluent of wastewater treatment plants being released into agriculture fields or runoff water from landfill areas usually reaches fields during the rainy season, such water contains a high amount of microplastic usually in the shape of microfibers and polyester [4]. The microplastic from tire abrasion, agriculture vehicles or construction site- released waste can get deposited in soil because of atmospheric deposition, and airborne micro plastics from sources like household or textile industry dust can settle down in the field or on the plant leaves [4]. In agricultural fields, plastic mulching is widely used across the world to boost yields, improve fruit quality, and improve water usage efficiency [1-60-90]. Furthermore, due to their specific optical and material properties, plastic mulches are employed globally [4]. Besides this, the use of organic fertilizers and films made up of plastic in agricultural operations is the primary cause of microplastics build up in farms [1-60-90]. Microplastics accumulate more in terrestrial soil than in aquatic habitats [1-4, 13]. Recent research has discovered a considerable amount of filamentous and fragmented microplastics in soils all around the world [1-4-25]. Microplastics accumulated in the soil can be easily taken up by plants and transferred through the food chain [1-3-70]. Microplastics have been shown to harm soil health and function as well as in marine environments [1-60-90]. The plastics gradually accumulate in the soil, contaminating the soil with microplastics fragments [3-80]. Furthermore, the recent increase in the number of waste sites has made soil huge microplastics sink [1-60-90]. Contamination has resulted in inadvertent microplastics ingestion by soil fauna. Worms, including earthworms and ringworms, have been shown to consume microplastics, with the rate increasing substantially as the amount of microplastics rises [1-60-90].

According to Solanki et al., (2024) [3] mulch film, which is made of polyvinyl chloride and polyethylene, has become a popular technique in worldwide agriculture because of its numerous economic benefits, including increased harvest, enhanced quality of fruits, and water use efficiency [3-50]. The excessive growth of plastics and unplanned or poor management procedures have increased the presence of a large variety and range of microplastics waste in the soil [3-60]. The twine composed of polypropylene (PP) is used for various agricultural uses [3-50]. Twine helps to secure plants to stakes for significant crops, including tomatoes, crucifers, and sweet peppers [3, 4]. It is utilized in the cultivation of bananas to connect plants and keep them from toppling [3-50]. Solanki et al., (2024) [3] reported that during harvesting, the twine is cut and frequently dumped carelessly in the fields only, where it ends up in the form of microplastics in the soil [3-50]. There are initiatives to promote the use of biodegradable twine, which may be gathered along with plant leftovers and composted [3]. Plastic films, along with non-woven textiles made of plastic, such as those utilized in greenhouses, polytunnels, shade nets, and also as wind barriers, enhance the presence of microplastics in soil samples [3]. Plastic waste management in agricultural regions is a major problem, which can be ascribed in part to inappropriate plastic storage on farms [1-3, 4]. Sludge from sewage and wastewater treatment plants causes microplastics contamination, and microplastics can build in soil with repeated sludge use [3-60]. Compost soil addition can potentially provide a conduit for microplastics to enter the soil [4]. Organic waste is often placed in fields as nutrients after it has been composted and fermented for reuse nutrients, minerals, trace elements, and humus [3-45]. Solanki et al., (2024) [3] indicated that the presence of microplastics in agricultural irrigation water resources has been widely verified [2, 3, 4]. Rivers, lakes, reservoirs, and ponds are the primary irrigation water sources worldwide [2, 3-50]. Sewage is also utilized for irrigation in some locations when water resources are restricted [2, 3, 4]. Microplastics contained within water reservoirs will be transported to the soil by irrigation, creating a pedigree of microplastics in the soil [3]. Solanki et al., (2024) reported that street runoff and floods, in addition to purposeful irrigation, are key channels for the transfer and accumulation of microplastics into the soil [2, 3-60]. Street runoff and floods can introduce unmanaged rubbish dumping near roadways, as well as rubber tire abrasion into soils [3]. Some of them already constitute microplastics, while others are progressively changed into microplastics as a result of numerous environmental encounters [3-70]. Atmospheric transmission is a significant mode of microplastics deposition to land [4]. Migration, which includes horizontal and vertical movement as well as biological and non-biological transportation, is a critical link for extending the effect of microplastics in soil [2, 3-40]. Solanki et al., (2024) [3] confirmed that external pressures such as biological disturbance by the fauna and flora and agricultural operations cause bigger microplastics to move in the soil [3-50]. Furthermore, the bio-duration of plant roots in soil may influence microplastics translocation through root growth and movement [3, 4]. Soil fauna may help to move microplastics vertically and horizontally in the soil [2,3, 4-40].

3. Microplastic Types

According to the literature survey the microplastics may be divided into numerous shapes, including pellets, fragments, foam, fiber, and film [1- 3-50, 113-116]. Microplastic sources are classified into two types either primary or secondary [1- 3-50]. Primary microplastics are designed with specific applications in mind, such as cosmetic harsh chemicals, drug vectors, and engineering-related uses such as air blasting [1- 3-50]. Microplastics are difficult to eliminate utilizing sewage disposal systems, and once they enter the wastewater, they eventually accumulate in the environment [1- 3-50]. Secondary microplastics are formed when bigger plastics are gradually shattered into smaller bits by a variety of complicated environmental factors, including wave action, temperature of wind, and UV radiation [1- 3-50]. Repeated usage of products made of plastics can induce fragmentation and the development of additional microplastics [1- 3-50]. Furthermore, plastic emissions from vehicle transportation, such as wearing and tearing of tires, brakes, and road markings, are major contributors to microplastics in the natural environment [1- 3-50]. Plastic is a flexible, long-lasting, and cost-effective material used in a variety of important industries such as packaging, electronics, agricultural production [1-4-25]. However, the widespread use of these synthetic materials increased manufacturing, resulting in a huge amount of plastic litter in the environment [1-60-90]. Unfortunately, the fragmentation process does not entirely disintegrate the plastic waste but instead transforms it into a plethora of fine-sized plastic particles, encompassing microplastics defined as 5 mm in diameter [1-60-90]. The toxic chemicals, polyethylene, polypropylene, polyvinyl chloride, polyamide, polystyrene, and polyester are the most prevalent polymers found in soil [1-4-20]. Polyethylene and polypropylene are the most commonly found in soil [1- 3-50].

4. Microplastics influencing Soil health

Microplastics change soil properties such as soil structure and functioning as well as the diversity of microbes, which may have implications for plant and animal health and pose possible risks for the safety and quality of food, ultimately jeopardizing human health [1- 3-50]. Microplastics pollution has damaged the structure and fertility of soil [1- 3-50]. The presence of substantial residual plastic films in soil has been found to reduce soil-saturated hydraulic conductivity and influence soil microbial activity and abundance, thereby influencing soil fertility [1- 3-50]. Microplastics have also been demonstrated to influence soil permeability and water retention, which affects the evaporation of water [1- 3-50]. Solanki et al., (2024), [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13] reported that the growing prominence of microplastics as an ecosystem stressor impacts not only soil health and function but also soil biophysical characteristics, resulting in complicated changes in the environmental behavior of other soil contaminants [1- 3-50].

The presence of microplastics would alter the physical and chemical properties of the soil, which will alter the root system and the vegetative phase and thus impair plant growth [1- 3-50]. The direct absorption of microplastics from soils through apo plastic and simplistic routes, and by distribution to the plant as a whole through the vascular system, is well documented to affect the development of agriculturally important plants [1- 3-50]

There are a number of factors that contribute to the effects of microplastics on agricultural soil systems [1- 3-50-90]. According to a number of studies, ingesting microplastics may slow down earthworm growth and induce weight loss, reduce nematode survival and body length, and slow down collembolan growth [1- 3-50-90]. The potential causes may be attributed to digestive tract obstructions created by microplastics in faunal guts that reduced food intake and nutrient absorption, or even injuries to the skin and digestive system brought on by some sharp microplastics [1- 3-50-90]. While other studies have reported a variety of effects of microplastics on soil fauna, the results have shown a decrease in nematode reproduction rates, an increase in the diversity of gut bacteria in collembolan, and no appreciable effects on the reproduction of epigenic earthworms [1- 3-50-90]. Although the causes of these variations have not yet been determined, it has been hypothesized that they may be linked to animal dietary preferences as well as the characteristics and microplastic exposure concentration. Additionally, researchers have provided evidence that microplastics may migrate along with a terrestrial food chain, going from soil through earthworm casts and chicken faces (with increased microplastic concentration [1- 3-50-90]. Recent studies have documented how microplastics affect terrestrial plants in addition to soil animals [1- 3-50-90]. Wheat plants have reportedly experienced severe detrimental impacts from microplastic PE residues both throughout the vegetative and reproductive growth phases [1- 3-50-90]. Additionally, PS microplastics of various sizes could reduce the photosynthetic rate while increasing the weight of Chinese cabbage by changing the microbial metabolism and the relationships between microorganisms [1- 3-50-90]. Spring onion leaves and overall plant biomass may grow substantially more quickly when PA microbeads are used [1- 3-50-90]. Additionally, microplastics may build up by the roots of wheat and lettuce plants before moving to the shoots and leaves and in the roots of cucumber plants before moving to the leaves, flowers, and fruits [1- 3-50-90]. The consequences of microplastics varied depending on the plant species and degree of contamination, and they included changes to soil structure, water holding capacity, nutritional content, and microbial population [1- 3-50-90].

Solanki et al., (2024), [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13] reported that microplastics can alter soil parameters, such as soil bulk density, soil aggregate size fraction, and evapotranspiration, in addition to their direct effects on soil animals and crops [1- 3-50-90]. These changes can then have an indirect impact on plant performance. By expanding the routes for water movement, microplastics may hasten soil water evaporation and alter the soil microbial population, especially with regard to root colonization microorganisms [1- 3-50-90]. Additionally, microplastics have been shown to lessen the detrimental effects of sulfamethazine on plant growth by modifying microbial populations [1- 3-50-90]. Microplastics interact with other pollutants such polycyclic aromatic hydrocarbons, organochlorine insecticides, and heavy metals (Cd, Zn, and Pb) in agricultural soil due to their large specific surface area, which in turn affects their environmental consequences [1- 3-50-90]. Microplastics may cause the adsorption and attachment of sorbed organic contaminants as they move vertically through the soil profile via bioturbation, surface runoff, and water penetration, or through irrigation canals, overland runoff, and even into the atmosphere [1- 3-50-90, 113-116]. Microplastics and their co-existing contaminants provide significant environmental dangers in agricultural soil systems and act as vectors for other contaminants [1- 3-50-90].

5. Chemical degradation of microplastics

The chemical degradation caused by ultraviolet (UV) radiation is the most important and frequently predominates the early degradation processes of plastic waste among these three forms of transformation [1- 3-50-90, 113-116]. Due to UV exposure at an appropriate temperature and oxygen usage, microplastics in topsoil undergo photo transformation [2, 3, 4, 13-90]. Chemical reactions such chain scission, cross-linking, the creation of functional groups containing oxygen, and even mineralization into CO2 are all involved in the photo transformation of microplastics [1- 3-50-90]. Smaller microplastics and even nano plastics may be produced during these processes [1- 3-50-90]. Additionally, the fragmentation of microplastics is accelerated by the combined impacts of UV radiation and mechanical abrasion caused by the turbulence of agricultural operations and soil organisms [1- 3-50-90]. Microplastics tend to aggregate with soil particles by electrostatic forces, which were facilitated by root exudates in the rhizosphere or during feeding and excretion by soil animals, in contrast to the way that microplastics break down into smaller particles [1- 3-50-90]. Aggregates may contain microplastics that are resistant to UV radiation and other types of mechanical abrasion [1- 3-50-90]. Microplastics in soil may not completely degrade, which could lead to an accumulation of plastic at the submicron scale and unknown environmental concerns [1- 3-50-90]. Nano plastics are much easier to uptake as compared to microplastic which can adhere to the surface of leaves, making the penetration easier lead to a higher rate of uptake by plants [1- 3-50-90]. The rate of accumulation of neoplastic is much higher than microplastic, they exhibit greater mobility which leads them to being transported throughout the plant parts [1- 3-50-90, 113-116]. They are potential bio accumulators of plastic disrupting the germination rate, causing physiological changes, and hindering the metabolism of plants making them potentially more harmful for the plants [1- 3-50-90].

6. Microplastics contamination in India

According to Anand and Sheel (2025) [2] microplastic contamination in India has been extensively studied in aquatic ecosystems, yet its implications for agricultural soils remain insufficiently addressed [2, 3, 4, 13, 113-116]. While most studies focus on microplastics in beaches, rivers, lakes, and ponds, only a limited number of studies directly investigated agricultural soils, highlighting a significant research gap [2, 3, 4, 13-90]. Key contamination sources identified include irrigation with polluted water, atmospheric deposition, industrial discharge, inadequate waste management, and agricultural practices such as plastic mulch use [2, 3, 4, 13-90]. In Northern India, extensive irrigation networks sourcing water from the Ganga, Yamuna, and Sutlej rivers pose significant risks of microplastic infiltration into farmland [2, 3, 4, 13-90, 113-116]. Western India experiences high contamination due to industrial effluents, urban plastic waste, and irrigation practices [2, 3, 4, 13-90, 113-116]. In Southern and Eastern India, coastal agricultural regions face risks from marine and microplastic pollution, potentially affecting soil and crop health [2, 3, 4, 13-90]. Additionally, Northeastern India showed potential threats due to microplastic-laden water bodies and atmospheric deposition near agricultural lands [2, 3, 4, 13-90]. Anand and Sheel (2025) [2] are of the opinion that addressing these challenges is crucial for ensuring soil health, food security, and environmental sustainability [2, 3, 4, 13-90]. India, with its vast agricultural landscape, rapid urbanization, and high plastic consumption, is particularly vulnerable to soil microplastic contamination [2, 3, 4, 13-90, 113-116]. Major sources include urban runoff, industrial discharge, plastic-based agricultural practices, contaminated rain water entering farm lands and rivers, improper waste disposal, and irrigation with polluted water [2, 3, 4, 13-90, 113-116]. Studies have reported microplastic contamination in agricultural soils across multiple states, including Himachal Pradesh, Haryana, Punjab, Karnataka, Kerala, Maharashtra, and Tamil Nadu, emphasizing the urgent need for systematic research and mitigation strategies [2, 3, 4, 13-90]. Microplastics in soil can negatively impact plant growth, alter soil microbial communities, and reduce fertility, potentially leading to lower agricultural productivity [1, 2, 3, 4, 13-90, 113-116]. Additionally, their presence in soil raises food safety concerns, as microplastics can be absorbed by crops and enter the food chain, leading to bioaccumulation and potential health hazards [2, 3, 4, 13-90, 96]. Given these risks, understanding the extent and sources of microplastic pollution in agricultural soils is essential for developing effective mitigation strategies [2, 3, 4, 13-90, 113-116].

Microplastic contamination in agricultural soils across India is an emerging environmental concern with significant implications for soil health, crop productivity, and food safety [2, 3, 4, 13-90, 113-116]. According to the literature survey of multiple studies, highlighting widespread microplastic pollution across different regions, driven by sources such as irrigation with polluted water, plastic mulch degradation, industrial discharge, urban runoff, and improper waste disposal [2, 3, 4, 13-90]. While contamination levels vary geographically, major agricultural hubs near rivers, industrial zones, and coastal areas exhibit a higher risk of microplastic infiltration into farmlands [2, 3, 4, 13-90].

Plastic products were widely used in agricultural techniques, such as cultivation, fertilization, and plastic mulching, as modern agricultural systems developed [2, 3, 4, 13-90]. These polymers provided a significant amount of microplastics to soils and even accumulated in crops when they degraded in agricultural soils [2, 3, 4, 13-90]. Plastic mulch films make up a significant fraction of those sources and are frequently utilized in arid and cold climates to maintain the proper temperature and increase crop output [2, 3, 4, 13-90]. They broke up into microplastics after being exposed to light and mechanical forces like tillage procedures, and they then migrated into agricultural soils, especially in regions with a poor rate of mulch film recovery [2, 3, 4, 13-90]. Consumption of mulching films and microplastic concentrations are positively correlated [2, 3, 4, 13-90]. The fallout of microplastics from the atmosphere to soil systems may be considerably influenced by precipitation and snowfall, as described in earlier research, and wind/atmosphere circulation significantly influenced the remote transport to various places [2, 3, 4, 13-90]. The microplastics in sludge and wastewater are primarily obtained from the effluent of residential washing machines and discharged from personal care items, synthetic textile fibers, and microbeads, in contrast to the input from plastic usage inside agricultural systems [2, 3, 4, 13-90]. Due to the varying compositions, characteristics, and additions of these microplastics, there may be a variety of ecological threats to both agricultural soils and human life [2, 3, 4, 13-90]. Compost is also frequently used to increase soil fertility, in addition to mulch films [2, 3, 4, 13-90]. A significant channel for microplastics entering agricultural soils was suggested by the high proportion of plastics found in the compost [2, 3, 4, 13-90]. The rapid fragmentation of larger plastics into smaller pieces and the microbial activity that occurs during the composting processes accelerate the concentration of microplastics added to agricultural soils [2, 3, 4, 13-90]. Additionally, microplastics have been discovered in a variety of commercial bio wastes from household, energy crops, mature compost, and non-matured fertilizer [2, 3, 4, 13-90]. The degradation, transport, and consequent ecological consequences of these microplastics from various sources are directly influenced by their form, type, and additive content in agricultural soils [2, 3, 4, 13-90, 113-116].

7. Microplastics: Influencing Plant Health

On the basis of literature survey, sludge from sewage and wastewater treatment plants has been discovered to contain microplastics [2, 3, 4, 13-90]. According to reports, around 50% of sewage sludge in developed countries was eventually applied to farmlands as commercial fertilizers, resulting in up to 870 tons of microplastics per million inhabitants entering European agricultural soils [1, 2, 3, 4, 13-90]. When agricultural plastic films are used for mulching, microplastics are released into the soil when the films disintegrate [1, 2, 3, 4, 13-90, 113-116]. There is currently very few research on the effects of microplastics on crops. According to one study, fluorescent polystyrene nanobeads (100 nm) entered tobacco cells via endocytosis. Another study revealed that crop tissue cultures can ingest and store polystyrene microplastics (0.2 m), implying that the microplastics could be transferred to humans via the food chain [1, 2, 3, 4, 13-90]. Moving beyond the cellular level, it has been found that biodegradable and polyethylene microplastics can interfere with wheat growth, with biodegradable microplastics having a greater negative impact [2, 3, 4, 13-90]. The presence of earthworms partially mitigated the harmful effects of biodegradable microplastics on fruit biomass, according to the study [2, 3, 4, 13-90, 113-116]. This study raised a new worry about biodegradable polymers, which have been promoted as a replacement for conventional plastics in order to reduce environmental microplastics [2, 3, 4, 13-90].

According to the review of literature by Solanki et al., (2024) [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13], microplastics modify soil biophysical properties, researchers hypothesized that by lowering soil bulk density, microplastics could promote plant root penetration, soil aeration, and root growth [1, 2, 3, 4, 13-90]. On the other hand, experimentally added plastic film pieces to soil created channels that promoted water movement, evaporation, and resulting in water loss from soil that could impact plant health [2, 3, 4, 13-90]. Plant health is also influenced by changes in soil microbial populations caused by microplastics, and the impact is likely to be detrimental if root symbionts like mycorrhiza and nitrogen fixers are harmed [2, 3, 4, 13-90]. The slow breakdown of microplastics has been connected to microbial immobilization, while empirical proof for immobilization is currently lacking [2, 3, 4, 13-90]. Furthermore, microplastics may act as a medium for the introduction of phytotoxic chemicals into soil, thereby damaging plant roots and health [2, 3, 4, 13-90]. According to the review of literature by Solanki et al., (2024) [3], Anand and Sheel (2025) [2], Arya and Kumar (2025) [4], Ranveer et al., (2025) [13], higher concentrations of micro/nano plastic can intensely harm the soil- plant interaction and ecosystem as well as marine ecosystem as they can easily penetrate through the gills of fish and create blockages in their organs by traveling through their blood circulation system, it harmful to all the poultry as well as fish farming practices [2, 3, 4, 13-90]. High concentrations of microplastics and nano plastics increases the stress responses in plants, affecting their ability to uptake and utilize nutrients effectively [2, 3, 4, 13-90]. When microplastics and nano plastics are present in the soil, they get attached to plant roots and they hinder their absorption capacity as they create blockage, creating difficulties for plants in absorbing water and other essential nutrients [2, 3, 4, 13-90]. This change in root structure can impede plants' uptake of vital nutrients [2, 3, 4, 13-90]. Mangroves are vital ecosystems that provide numerous ecological benefits, including shoreline protection, carbon sequestration, and habitat for diverse flora and fauna. However, these ecosystems are facing a severe threat from microplastic pollution, as highlighted in a recent study conducted in Mangala Vanam, Kerala, India. The study, led by a team of researchers from Cochin University of Science and Technology, aimed to assess the impact of microplastic pollution on urban mangrove ecosystems [2, 3, 4, 13-90, 113-116]. One of the studies has raised concerns about the potential impact of microplastics on food safety and environmental sustainability [2, 3, 4, 13-90, 113-116]. The accumulation of microplastics in agricultural soils could lead to contamination of crops, affecting human health throughout the food chain [2, 3, 4, 13-90, 96]. Moreover, the long- term presence of microplastics in soils may harm soil quality and ecosystem health [2, 3, 4, 13-90]. Furthermore, varying levels of microplastic abundance in the soil samples, with higher concentrations observed in soils cultivated with watermelons compared to canning tomatoes [2, 3, 4, 13-90, 113-116]. Microplastic/ neoplastic impact does not only impact the productivity and health of crops but also affected other sectors such as livestock, fisheries, and aquaculture [2, 3, 4, 13-90].

8. Microplastics: Separation and Identification Methods

According to Arya and Kumar (2025) [4], centrifugation is a method used to remove microplastic by using a solution with a specific density, mainly a solution of CaCl2 solution with a density of 1.4g/cm3 is used to separate microplastic from soil [4]. Centrifugation separates the microplastics from the soil matrix based on density differences. The microplastics, being less dense than the soil particles, will move to the top of the centrifuge tube during centrifugation. The separated microplastics are stained with Nile Red, a fluorescent dye that binds to hydrophobic substances, including certain types of plastics. This staining process helps to visualize and identify the microplastics under fluorescence microscopy. According to Arya and Kumar (2025) [4], leachate, which is the liquid that drains or "leaches" from a landfill. This liquid typically contains various contaminants, such as micro/nano plastics, that can pose environmental risks if not properly managed. The leachate treatment system aims to remove pollutants and contaminants from the leachate before it is released into the environment. As, this results in one of the major causes of soil and water pollution [4]. Furthermore, dynamic membrane technology is a very innovative approach process that is used in wastewater treatment processes, including urban wastewater treatment, surface water treatment, industrial wastewater treatment, and sludge treatment [4].

On the basis of literature survey by Solanki et al., (2024) [3] the technique of density separation is one of the most often used techniques for separating soil microplastics [2, 3, 4, 13-90]. To ensure every particle in the bulk sample sinks or floats, the soil is first treated with ultrasonics [3]. Sodium chloride is a low-cost, ecologically friendly salt that is commonly used in suspension solutions [3]. Plastics are not electrically conductive, unlike soil minerals and other particles [1-3-50]. An external electric field can also be used to separate the two because of the difference in electrostatic characteristics [1-3-50]. Electrostatic separation is a dry processing technology that uses electric forces working on charged particles to separate main and secondary raw materials [1-3-50]. In another development, the lipophilic characteristics of microplastics are used as an alternative to density-based oil recovery technologies in a new, cost-effective oil extraction process [1-3-50]. Froth flotation takes the use of the material's density and the hydrophilic nature of its surface. It is widely employed in the recycling sector. Froth preferentially binds to hydrophobic particles and lifts them upward, segregating them from hydrophilic molecules [1-3-50]. To remove plastics from dirt, this approach employs various hydrophilic properties [1-3-50]. Plastic flotation techniques include gamma flotation, reagent adsorption, and surface modification have been applied [1-3-50]. In a magnetic plastic extraction technique in which magnetized hydrophobic iron nanoparticles are bonded to plastic particles [1-3-50]. Identification and quantification of microplastics from the ambient matrix are required after separation and purification [1-3-50]. The common strategy is to first identify obvious/possible microplastics using a microscope, followed by confirmation using spectroscopy and thermodynamic methods such as Fourier Transform infrared spectroscopy (FTIR) or Raman spectroscopies, and pyrolysis gas chromatography-mass spectrometry [1-3-50]. Optical microscopes, particularly stereomicroscopes, are essential tools for documenting the physical features of microplastics [1-3-50].

9. Conclusion

Microplastics have created a major problem to agriculture productivity by ultimately altering the soil's physical properties, transforming soil density, nutrient cycle mechanism, water retention quality, soil aeration, aggregation, intoxicating soil with heavy metals, other toxicants which are likely to stick to the plant roots absorbed by the plant. Furthermore, microplastics also interfere with the number of soil microorganisms by introducing invasive species leading to the extinction of natural species or by bioaccumulation. The high concentration of micro/nano plastic gets build in tissues of organisms over time disrupting their physiological process, killing them and weakening the whole soil ecosystem. Plastic films utilized in agriculture, like mulching films, play a role in the prevalence of films as a common form of microplastic pollution in fields. Although less common than fibers, fragments, and films, granules, and foams are also detected in atmospheric deposition samples in urban areas. Plastics are transformed in the environment by chemical, physical, and biological processes, including fragmentation and degradation. These smaller plastic fragments, categorized as primary and secondary micro/nano plastic, pose a greater threat to the environment due to their ability to carry harmful substances and disrupt ecosystems. However, microplastic detection technology for soil is not yet fully developed and there are many problems. Therefore, experts are of the opinion that collaborative efforts among researchers, policymakers, and industries are essential to developing effective strategies for detecting, mitigating, and preventing further plastic pollution.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclsoed.

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