***Systematic Review***

**Microplastic Contamination in Agricultural Soils Across India: A Systematic Review of Studies and Research Gaps**

**Abstract**

Microplastic contamination in India has been extensively studied in aquatic ecosystems, yet its implications for agricultural soils remain insufficiently addressed. This research paper bridges this gap by analyzing data from 73 studies published between 2020 and 2024, synthesizing findings on microplastic contamination across diverse ecosystems in India and assessing their potential impact on agricultural land. While most studies focus on microplastics in beaches, rivers, lakes, and ponds, only a limited number directly investigate agricultural soils, highlighting a significant research gap.

Key contamination sources identified include irrigation with polluted water, atmospheric deposition, industrial discharge, inadequate waste management, and agricultural practices such as plastic mulch use. In Northern India, extensive irrigation networks sourcing water from the Ganga, Yamuna, and Sutlej rivers pose significant risks of microplastic infiltration into farmland. Western India experiences high contamination due to industrial effluents, urban plastic waste, and irrigation practices. In Southern and Eastern India, coastal agricultural regions face risks from marine and estuarine microplastic pollution, potentially affecting soil and crop health. Additionally, Northeastern India shows potential threats due to microplastic-laden water bodies and atmospheric deposition near agricultural lands.

The review underscores the urgent need for standardized methodologies, comprehensive soil sampling, and targeted research on microplastic contamination pathways in agricultural ecosystems. By identifying high-risk zones and knowledge gaps, this study provides a foundation for future research aimed at mitigating the growing threat of microplastic pollution in India’s agricultural sector. Addressing these challenges is crucial for ensuring soil health, food security, and environmental sustainability.

**Keywords**: Microplastic contamination, agricultural soils, India, pollution sources, soil health, environmental impact, research gaps.

**Introduction**

Microplastics, defined as plastic particles smaller than 5 mm, have become widespread environmental pollutants with significant ecological and human health risks. 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 (Rillig, 2012). Agricultural soils, in particular, face contamination risks due to direct plastic inputs, irrigation with polluted water, and atmospheric deposition, raising concerns about long-term soil degradation and food safety (Wright & Kelly, 2017).

India, with its vast agricultural landscape, rapid urbanization, and high plastic consumption, is particularly vulnerable to soil microplastic contamination. Major sources include urban runoff, industrial discharge, plastic-based agricultural practices, improper waste disposal, and irrigation with polluted water (Kumar et al., 2020). Studies have reported microplastic contamination in agricultural soils across multiple states, including Himachal Pradesh, Haryana, Maharashtra, and Tamil Nadu, emphasizing the urgent need for systematic research and mitigation strategies.

Microplastics in soil can negatively impact plant growth, alter soil microbial communities, and reduce fertility, potentially leading to lower agricultural productivity (Boots et al., 2019). 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 (Rochman et al., 2013). Given these risks, understanding the extent and sources of microplastic pollution in agricultural soils is essential for developing effective mitigation strategies.

This review synthesizes findings from existing studies to provide a comprehensive statewise analysis of microplastic contamination in Indian agricultural soils. By identifying key sources, contamination levels, and research gaps, this study aims to inform future research directions to mitigate the growing threat of microplastic pollution in India’s agricultural sector.

**Methodology**

**Study Design :** This systematic review assessed microplastic contamination in agricultural soils across India by synthesizing findings from recent peer-reviewed studies. The primary objective was to evaluate contamination levels, sources, and regional distribution while identifying research gaps. The review focused on both direct contamination, where studies explicitly analyzed soil samples, and inferred contamination, where pollution sources such as irrigation water, atmospheric deposition, and agricultural runoff were examined.

**Data Collection :** A comprehensive literature search was conducted using Google Scholar, PubMed, Scopus, and Web of Science to identify relevant studies. The search included the keywords “microplastics,” “India,” “soil contamination,” and “agriculture” to ensure a broad yet targeted selection. To incorporate the most recent data, the review considered studies published between 2020 and August 2024. The initial search retrieved 157 studies, which were screened based on predefined inclusion and exclusion criteria. After removing duplicates and assessing methodological quality, 104 studies were shortlisted. Following further evaluation, 73 studies met all inclusion criteria and were selected for final analysis.

Studies were included if they investigated microplastic contamination in agricultural soils or examined land-based sources contributing to contamination, even if direct soil sampling was not performed. Research employing standardized microplastic identification and quantification techniques, such as Fourier-transform infrared spectroscopy (FTIR) or Raman spectroscopy, was prioritized. Only studies providing region-specific data on microplastic concentrations, sources, and potential impacts were considered. Exclusion criteria included studies focused exclusively on marine environments, where microplastic sources were primarily oceanic, and research lacking quantitative data on microplastic concentrations or employing unreliable methodologies.

**Analysis Framework :** The 73 selected studies were systematically analyzed to identify contamination patterns, sources, and research gaps. The studies were categorized based on geographic regions, including Northern, Southern, Eastern, Western, and Northeastern India, to assess spatial trends in microplastic contamination. Sources of contamination were evaluated with particular emphasis on urban runoff, industrial discharge, plastic mulch use in agriculture, irrigation with contaminated water, and inadequate waste management. The compiled data included concentration levels, microplastic morphotypes such as fibers, fragments, and films, and polymer composition, including polyethylene and polypropylene. These findings were structured into a comparative database.

To assess microplastic contamination in agricultural soils, the studies were classified into three categories: confirmed contamination, where studies directly reported microplastic presence in agricultural land; potential contamination, where contamination was inferred based on irrigation with polluted water, atmospheric deposition, or proximity to pollution sources; and insufficient evidence, where data on microplastic contamination in agricultural soils was limited or unavailable. Additionally, research gaps were identified by documenting regions where microplastic contamination in soil remains unassessed. These findings highlight areas requiring further study to improve understanding of contamination pathways and risks.

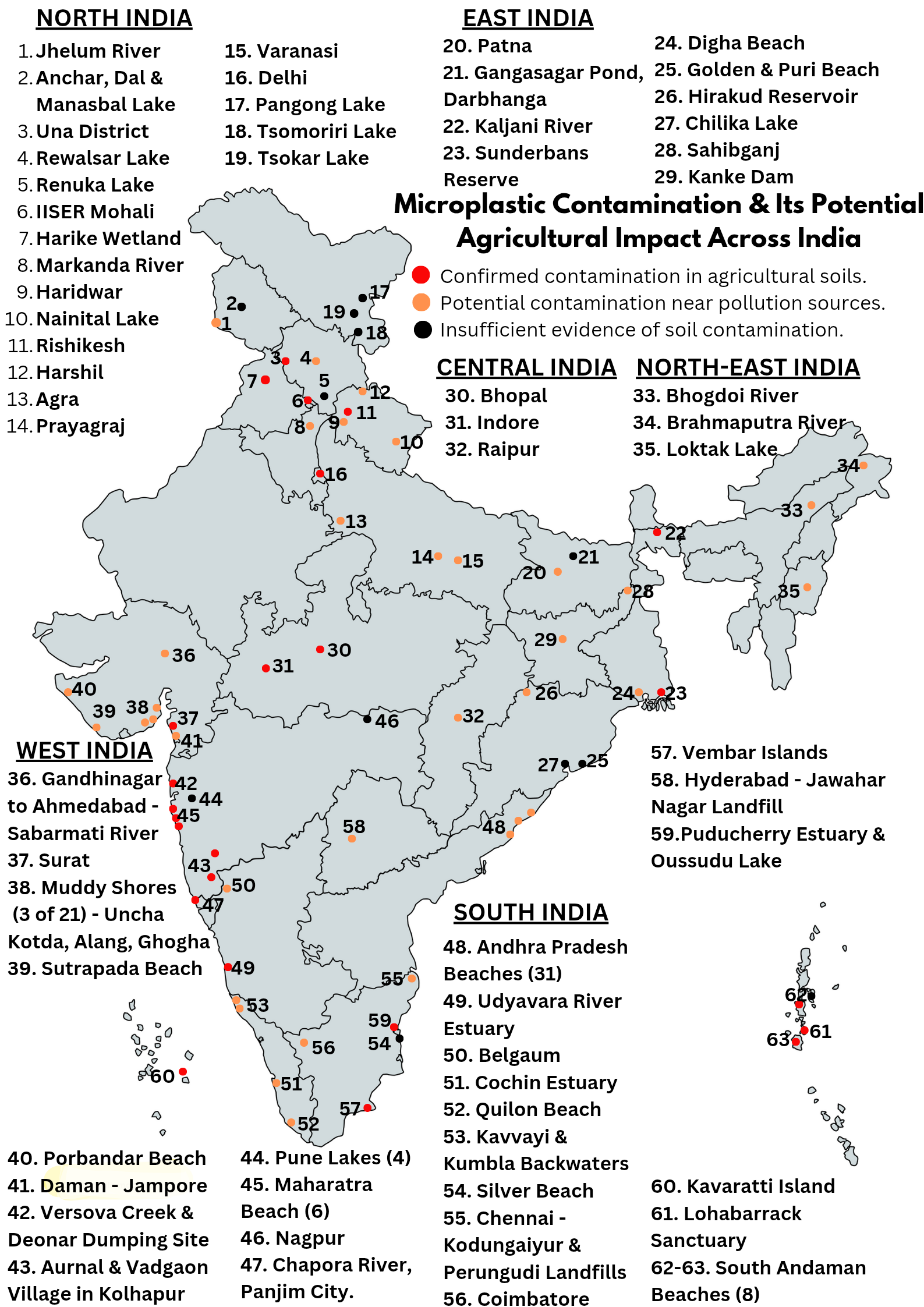
**Data Visualization and Documentation :** To enhance clarity, findings were organized into a structured table summarizing study locations, microplastic concentrations, polymer types, and pollution sources. This table is provided in **Annexure 1 (Supplementary Material)** for reference. A geospatial map was developed to illustrate the distribution of microplastic contamination across India. Locations were categorized using a dot-based classification system: red dots indicate confirmed contamination in agricultural lands, orange dots represent inferred contamination based on irrigation with polluted water, and black dots mark areas with insufficient data or the absence of agricultural activity. The geospatial map is presented in **Figure 1** at the beginning of the **Results section** to provide an overview of the contamination distribution across India.

**Limitations :** This review relies on published data, and in cases where explicit information on agricultural soil contamination was unavailable, inferences were drawn from irrigation practices, proximity to polluted water bodies, and other contamination pathways. While this approach provides valuable insights, it introduces a level of uncertainty, emphasizing the need for direct soil sampling studies in under-researched regions.

**Results**

This study analyzed data from 73 peer-reviewed studies to assess microplastic contamination in agricultural soils across India. Contamination was classified as **confirmed**, **inferred**, or **uncertain**, based on direct soil sampling, irrigation sources, and proximity to pollution. A **detailed dataset** summarizing contamination levels and sources is provided in **Annexure 1 (Supplementary Material)**.

The **spatial distribution of contamination** is shown in **Figure 1**, highlighting key hotspots and regions requiring further investigation.



**Figure 1.** *Geospatial distribution of microplastic contamination in agricultural soils across India. Red dots indicate confirmed contamination, orange dots represent inferred contamination, and black dots mark regions with insufficient data.*

The map shows regional variations, with high contamination near polluted rivers and industrial zones. Some areas lack sufficient data, emphasizing the need for further research. The following sections provide a regional breakdown, summarizing contamination levels, sources, and key findings.

**North India** : In Jammu & Kashmir, agricultural lands irrigated by the Jhelum River are likely contaminated with microplastics (MPs) due to extensive irrigation and pollution from municipal solid waste disposal and plastic debris along the riverbanks (Farooq et al., 2023). Contamination of agricultural areas near Dal Lake is unlikely, as the lake's water is not used for irrigation, and no direct pathways for MP transfer to farmland were identified (Firdous et al., 2020). Agricultural lands near Manasbal Lake are contaminated with MPs, as agricultural runoff is both a source and recipient of MP pollution in the lake (Kumar et al., 2025). For Anchar Lake, contamination of surrounding agricultural lands cannot be determined due to insufficient data on irrigation use or MP transfer to soil (Neelavannan et al., 2022). In Ladakh, agricultural lands irrigated by the Indus River are likely contaminated with microplastics (MPs) due to extensive irrigation and pollution from tourism, improper waste disposal, and long-range plastic transport (Tsering et al., 2021). Contamination of agricultural areas near high-altitude lakes such as Pangong, Tsomoriri, and Tsokar is unlikely, as these lakes' water is not typically used for irrigation, and no direct pathways for MP transfer to farmland were identified (Tsering et al., 2022). In Himachal Pradesh, agricultural lands in Amb, Gagret, Mubarikpur, Una, and Tahliwal are contaminated with microplastics (MPs) due to industrial, urban, and agricultural plastic pollution (Dhiman et al., 2024). Agricultural lands irrigated by the Markanda River are also likely contaminated, as the river is a major irrigation source and receives MPs from domestic, industrial, and agricultural activities (Kumar et al., 2024b). Contamination of farmland near Rewalsar Lake remains uncertain but may be possible due to runoff from polluted areas (Bulbul et al., 2023). In contrast, Renuka Lake's surrounding agricultural lands are unlikely to be contaminated, as its water is not used for irrigation, and pollution sources are unrelated to land-based activities (Ajay et al., 2021). In Punjab, agricultural fields in Kharar and Derabassi are likely contaminated with atmospheric microplastics due to deposition from urban, industrial, and agricultural sources transported by westerly winds (Ankit et al., 2024). Additionally, farmlands in Amritsar and Tarn Taran are contaminated with microplastics, as they are irrigated with water from Harike Canal, which carries MP pollution from mismanaged plastic waste and industrial activities (Manzoor & Singh, 2022). In Haryana, agricultural lands irrigated by the Markanda River are likely contaminated with microplastics due to pollution from domestic, industrial, and urban runoff, along with potential heavy metal contamination in downstream regions (Kumar et al., 2024b). In Uttarakhand, agricultural lands irrigated by the Alaknanda River in areas like Rudraprayag and Rishikesh are likely contaminated with microplastics due to the presence of fibers and threads in the river’s water and sediment (Chauhan et al., 2021). Similarly, farmlands relying on the Ganga River, particularly in Haridwar, Rishikesh, and Harsil, face significant contamination risks due to high levels of fiber-based microplastics from urban waste, industrial discharge, and atmospheric deposition (Gupta et al., 2024; Napper et al., 2023). Agricultural lands around Nainital Lake may also be affected by microplastic runoff from tourism and domestic waste, though the risk is lower than in irrigation-dependent regions (Jain et al., 2024). In Delhi, agricultural lands downstream of the Najafgarh Drain and Shahdara Drain are at significant risk of microplastic (MP) contamination due to industrial wastewater, domestic discharges, and urban runoff (Vaid et al., 2022). Moderate contamination is likely in agricultural areas near the Old Yamuna Iron Bridge, ITO Barrage, and Nizamuddin Bridge, where MPs from urban activities, transportation, and solid waste may enter irrigation water. However, the impact on agricultural land near Wazirabad Barrage is minimal, as MP pollution is less concentrated and diluted downstream (Vaid et al., 2022). In Uttar Pradesh, agricultural lands along the Yamuna River in Agra and at the confluence of the Ganges and Yamuna in Prayagraj are likely contaminated with microplastics (MPs) due to irrigation water sourced from polluted rivers (Gupta et al., 2024). Agricultural fields near the Ganges River in Anupshahr, Kannauj, and Varanasi face MP contamination from floodwaters and irrigation, primarily carrying fiber-shaped MPs from wastewater and garment washing (Napper et al., 2023). Additionally, airborne MPs from urban pollution in Varanasi may be depositing onto nearby farmlands, increasing contamination risks (Pandey et al., 2022).

**East India** : In Bihar, agricultural lands irrigated by the Ganges River in Patna and Sahibganj are likely contaminated with microplastics due to pollution from urban waste, drainage systems, and industrial discharge (Gupta et al., 2024; Napper et al., 2023; Singh et al., 2022). Floodwaters may further transport microplastics to farmlands in these areas. Atmospheric deposition from vehicular emissions, construction activities, and waste mismanagement contributes to microplastic contamination in peri-urban agricultural lands of Patna (Parashar et al., 2023). Downstream sediment in the Ganges near Patna shows higher microplastic concentrations, increasing the risk of agricultural contamination (Singh et al., 2022). While Gangasagar Pond in Darbhanga contains microplastics from domestic and medical waste, its impact on surrounding agricultural land remains undetermined (Kumari, 2024). In Jharkhand, agricultural lands irrigated by Kanke Lake in Ranchi are likely contaminated with microplastics due to pollution from urban waste, improper plastic disposal, and industrial activities affecting the lake’s water quality (Singh et al., 2021b). In Odisha, agricultural lands downstream of the Hirakud Reservoir, particularly in Cuttack and Khurda, may be contaminated with microplastics due to irrigation with Mahanadi River water, which is impacted by tourism, aquaculture, fishing gear, and solid waste runoff (Patra & Baitharu, 2024). However, microplastic contamination of agricultural land near Chilika Lake could not be determined, as the lake's water is not typically used for irrigation (Kumar et al., 2024a). Similarly, contamination near Puri Beach and Golden Beach was not assessed, as there is no agricultural land in these areas (Patidar et al., 2024; Singh et al., 2021a). In West Bengal, agricultural land near the Hooghly River may be contaminated with microplastics due to irrigation, particularly in urban and industrial zones affected by sewage discharge, industrial runoff, and urban pollution (Ghosh et al., 2021). The Ganga-Brahmaputra Delta and Sundarbans Biosphere Reserve are also impacted, with agricultural land contamination confirmed due to microplastics from industrial discharge, municipal waste, tourism, and agricultural activities (Neelavannan et al., 2023). Tea garden soil in Alipurduar has been found to contain microplastics, highlighting the impact of waste mismanagement in the region (Goswami & Bhadury, 2024). However, microplastic contamination near Digha Beach was not assessed, as there is no agricultural land in the area (Patidar et al., 2024).

**North East India** : In Assam, agricultural lands near the Brahmaputra River are at risk of microplastic contamination due to irrigation with polluted river water, which contains microplastics from industrial waste, urban runoff, and fishing activities (Tsering et al., 2021). Similarly, upstream pollution in Jorhat may affect agricultural fields downstream, including those in Majuli, as microplastics from urban runoff, industrial discharge, and agricultural practices have been detected in fish from the Bhogdoi River (Ahmed et al., 2023). In Manipur, agricultural lands in Bishnupur district may be contaminated with microplastics from Loktak Wetland, raising concerns about their transfer into soils and food chains (Borah et al., 2024b). In Arunachal Pradesh, agricultural lands irrigated by the Brahmaputra River may be contaminated with microplastics, posing risks to soil health and crop safety (Tsering et al., 2021).

**Central India** : In Madhya Pradesh, agricultural lands near Bhopal may be contaminated with microplastics due to tourism, improper waste management, and commercial activities (Singh et al., 2023). In Indore, microplastics in agricultural soil suggest contamination from textile industry emissions and improper plastic waste disposal (Singh et al., 2024). In Chhattisgarh, runoff from urban areas in Raipur City may introduce microplastics into nearby agricultural lands, potentially affecting soil health and crop productivity (Upadhyay & Bajpai, 2023).

**West India** : In Gujarat, agricultural lands in Surat Taluka, Palsana, Dumas, and Magdalla may be contaminated via irrigation water from the Tapi River, potentially affecting crop yield and food safety (Bhavsar et al., 2024). Similarly, irrigation using Sabarmati River water could introduce microplastics into farmlands (Patel et al., 2020). Additionally, runoff from polluted coastal areas and sandy beaches may contribute to microplastic contamination in agricultural soils (Rabari et al., 2022, 2023). Furthermore, coastal runoff and seafood-related pollution could impact farmland near fishing harbors (Rabari et al., 2024). In Maharashtra, agricultural lands near Dapoli Village, Anjarle, Karde, Murud, and Harnai may be contaminated with microplastics (MPs) from beach pollution, affecting crops such as coconut, cashew nuts, rice, vegetables, and fruits (Borah et al., 2024a). Aurnol and Badgaon agricultural soils are already contaminated with MPs from plastic mulch degradation and wastewater irrigation, posing risks to groundwater and pesticide transport (Mahesh et al., 2022). Landfill leachate runoff from Pune and Mumbai may also introduce MPs into nearby agricultural lands (Verma et al., 2024). Studies in Nagpur (Patil et al., 2022) and Pune (Sapkale et al., 2024) do not confirm MP contamination in surrounding farmlands, while Versova Creek has no agricultural impact (Yousuf et al., 2023). In Goa, agricultural lands near the Chapora River may be contaminated with microplastics due to runoff and irrigation practices (Kalangutkar et al., 2024). In Panjim City, improper wastewater disposal may increase the risk of microplastic contamination in agricultural soils through irrigation or groundwater infiltration, though direct contamination is uncertain (Rathore et al., 2024).

**South India** : In Karnataka, agricultural lands in Khanapur and Hukkeri are contaminated with microplastics due to plastic mulch degradation, sludge application, and wastewater irrigation, posing risks to soil health and groundwater (Mahesh et al., 2022). In the Chandragiri River region, microplastic contamination may affect agricultural land since estuary water is used for irrigation (Radhakrishnan et al., 2024). Similarly, in the Udyavara River Estuary, monsoonal runoff may transport microplastics to nearby agricultural lands (Unnikrishnan et al., 2023). In Telangana, agricultural land near the Jawahar Nagar landfill in Hyderabad may be contaminated with microplastics due to landfill leachate infiltration into underground water, which can enter irrigation systems (Sekar & Sundaram, 2023b). In Andhra Pradesh, agricultural land near the Godavari River may be contaminated with microplastics, as river water is used for irrigation (Sekar & Sundaram, 2023a). In Northern Andhra Pradesh, microplastics from beach sediments may enter agricultural land through runoff and atmospheric deposition, though direct contamination is uncertain (Shaji et al., 2024). In Puducherry, agricultural areas near Ousudu Lake, including Ossudu and Kurumbapet, are contaminated with microplastics due to plastic mulch usage in nearby fields (D et al., 2021). In the Ariyankuppam, Panithittu, and Chunnambar estuaries, microplastics from estuarine waters may contaminate surrounding agricultural lands through watershed runoff, though direct evidence is uncertain (Dowarah et al., 2020). In Tamil Nadu, agricultural land near the Noyyal River may be contaminated with microplastics, as river water is used for irrigation (Ayyamperumal et al., 2022). Groundwater contamination near the Vellalore Dump Yard may impact farmlands in Podanur, Malumichampatti, and Chettipalayam due to irrigation use (Bharath et al., 2024). Similarly, groundwater contamination near the Perungudi and Kodungaiyur landfills may affect nearby agricultural lands (K. et al., 2021). Microplastics from the Uppanar and Gadilam estuaries may contaminate farmland through irrigation with groundwater linked to estuarine pollution (Nithin et al., 2023). In Muttukadu Backwater Estuary and along the Chennai coast, estuary water used for irrigation may contribute to microplastic contamination in agricultural land (Ramakrishnan & Sathiyamoorthy, 2024; Somasundaram & Ramesh, 2023). Agricultural soils in Coimbatore are already contaminated with microplastics due to irrigation, fertilizers, pesticides, and plastic mulch (Sangilidurai et al., 2024). For the Cooum River, high microplastic levels in water and sediments suggest a potential risk to agricultural land, particularly in irrigated or flood-affected areas, though direct contamination remains undetermined (Ganapathy et al., 2021). In the Gulf of Mannar and Silver Beach, no determination of agricultural contamination was made due to the absence of nearby farmland (Pradhap et al., 2023; Vidyasakar et al., 2020). In Lakshadweep, no determination of agricultural land contamination was made due to the absence of nearby farmland (Ragesh et al., 2024). In Kerala, agricultural lands near Quilon Beach may be contaminated with microplastics (MPs) due to sewage effluents, landfill leachates, and airborne plastic particles (Gopakumar et al., 2024). Agricultural areas near Kavvayi and Kumbla Backwaters are also at risk, as agricultural runoff contributes to MP contamination in these water bodies (Padmachandran et al., 2022). Estuarine irrigation raises concerns about MP contamination in farmlands near the Cochin Estuary (Praved et al., 2023), Chandragiri River (Radhakrishnan et al., 2024), and Azhikkal Estuary (Sunil et al., 2024). Similarly, the Paravoor Mangrove Ecosystem may introduce MPs into agricultural soil through urban runoff and irrigation sources (Vijayan et al., 2024). In the Andaman and Nicobar Islands, microplastic contamination in agricultural land remains uncertain. While coastal agricultural areas near the North and Middle Andaman Islands & Nicobar Islands may be at risk due to marine currents carrying plastic debris inland (Krishnakumar et al., 2020), no direct evidence of contamination was found in South Andaman Beaches, as no agricultural activities exist in the study areas (Patchaiyappan et al., 2020). Similarly, no agricultural land is present around the Lohabarrack Salt Water Crocodile Sanctuary, making contamination assessment irrelevant (Jaini & Namboothri, 2023).

**Research Gaps & Future Research Recommendation**

**North India**, a major agricultural hub of the country, has received little attention regarding microplastic (MP) contamination in its farmlands despite extensive plastic use in irrigation systems, packaging, and agricultural inputs. The region is home to the Indo-Gangetic Plain, which supports high agricultural productivity in states like Punjab, Haryana, Uttar Pradesh, and Uttarakhand. However, there is a lack of research on MP accumulation in soils irrigated by river systems such as the Ganga, Yamuna, Sutlej, and Ghaggar, which are already known to carry high loads of plastic waste. Given the extensive use of canal and tube well irrigation, studies should assess whether microplastics from water sources enter farmland soils and affect crop quality. Punjab and Haryana, known for intensive farming and high fertilizer and pesticide usage, also rely on plastic mulch films and polyvinyl chloride (PVC) pipes for irrigation. Despite this, no systematic research has quantified MP contamination from these sources in the soil or assessed its impact on soil health and microbial diversity. Similarly, in the wheat and paddy-dominated fields of Uttar Pradesh and Bihar, where plastic usage in seed packaging, fertilizers, and pesticides is widespread, there is little understanding of how MPs accumulate over time and whether they affect crop yields. Furthermore, North India's rapid urbanization has led to increased plastic pollution in peri-urban agricultural zones, where wastewater irrigation is common. Cities like Delhi, Lucknow, Kanpur, and Chandigarh discharge untreated or partially treated sewage containing microplastics into nearby water bodies, which are then used for irrigation. However, no studies have quantified MP deposition in agricultural lands irrigated with such contaminated water sources. Similarly, floodplain farming along the Ganga and Yamuna river basins remains unexplored regarding MP accumulation from floodwaters carrying urban and industrial plastic waste. Another critical research gap is the impact of seasonal climatic variations, such as extreme summer temperatures, heavy monsoon rainfall, and winter stubble burning, on MP breakdown and soil retention. Stubble burning, a widespread practice in Punjab and Haryana, could potentially release microplastics into the atmosphere, leading to their deposition in nearby farmlands, yet no studies have examined this possibility. Additionally, the effect of MPs on soil fertility, microbial composition, and nutrient cycling in different soil types prevalent in the region remains unknown. Given the region's role as the "food bowl" of India, addressing these research gaps is crucial to ensuring food safety and soil sustainability. Future studies must focus on identifying MP sources, quantifying their presence in soil and crops, and assessing their potential impact on food production and human health.

**East India**, comprising states like West Bengal, Bihar, Odisha, and Jharkhand, has vast agricultural lands nourished by major river systems such as the Ganga, Brahmaputra, Mahanadi, and their tributaries. Despite being a region with high agricultural dependence and significant plastic usage, microplastic (MP) contamination in its farmlands remains an underexplored area of research. The prevalence of river-fed irrigation, plastic-based agricultural inputs, and rapid urbanization raises concerns about MP accumulation in soil, yet limited studies have assessed the extent of contamination and its potential impact on agriculture. In West Bengal, the extensive use of plastic in packaging fertilizers, pesticides, and seeds, along with the dominance of plastic mulch in vegetable farming, raises the likelihood of MP deposition in farmlands. Additionally, the Sundarbans delta, where saltwater intrusion and tidal irrigation are common, may be exposed to marine microplastics entering agricultural lands. However, no studies have analyzed MP contamination in soil from these unique agro-ecological conditions. Similarly, in Bihar, where floodplain farming along the Ganga and its tributaries is widespread, there is little understanding of how seasonal flooding contributes to MP accumulation in agricultural soils. The use of wastewater for irrigation in urban agricultural zones, such as around Patna, Bhagalpur, and Muzaffarpur, further raises concerns, but no data exists on the extent of MP contamination from such sources. Odisha’s coastal farmlands, heavily influenced by cyclonic storms and tidal surges, may receive microplastics transported from marine sources, yet research on this phenomenon is absent. Additionally, rice-dominated agriculture in Odisha and Jharkhand relies on plastic-based irrigation infrastructure such as polythene-lined canals and plastic drip systems, which may contribute to microplastic deposition in soil. However, there has been no systematic effort to measure the breakdown of these materials and their impact on soil health. In tribal-dominated regions of Jharkhand, where traditional farming methods coexist with modern plastic-based agricultural inputs, research is needed to determine whether the introduction of plastic materials affects soil biodiversity and fertility. Another significant research gap in East India is the effect of MPs on soil-water interactions, given the region’s high rainfall and frequent flooding. Heavy monsoons may mobilize microplastics, leading to their redistribution across agricultural landscapes, yet no studies have examined how MPs behave under such hydrological conditions. Additionally, the impact of MPs on soil microbial communities, particularly in wetland paddy ecosystems, remains unexplored. Overall, despite East India’s critical role in food production, especially in rice, vegetables, and cash crops, research on MP contamination in agricultural lands is almost nonexistent. Future studies should focus on identifying MP sources, analyzing their long-term accumulation in soil and crops, and assessing their potential impact on food safety, soil fertility, and water resources.

Despite the ecological significance of **Northeast India**, there is a glaring lack of research on microplastic (MP) contamination in agricultural soils. The region is highly dependent on river systems like the Brahmaputra, Barak, and their tributaries for irrigation, yet no studies have assessed MP accumulation in farmlands irrigated by these water sources. Given the increasing plastic pollution in major urban centers such as Guwahati, Imphal, and Shillong, there is a strong possibility of MP infiltration into agricultural lands through wastewater, runoff, and floodwaters. Additionally, shifting cultivation (Jhum farming) is widely practiced in states like Arunachal Pradesh, Nagaland, and Mizoram, but its role in microplastic distribution remains unexplored. Plastic mulch and packaging waste from tea plantations in Assam and Tripura could also contribute to MP contamination, yet no studies have assessed the extent of this pollution. The region's high rainfall and frequent floods may facilitate MP transport from urban areas to rural farmlands, but no data exists on how extreme weather events influence MP deposition in soil. Furthermore, the impact of MPs on soil fertility, microbial communities, and crop productivity in the Northeast remains unstudied. Research is needed to quantify MP presence in irrigation water, soil, and staple crops such as rice, maize, and tea, which are major agricultural products of the region. Given the region’s reliance on traditional and organic farming practices, understanding MP contamination is crucial for sustainable agriculture and food safety.

**Central India,** encompassing Madhya Pradesh and Chhattisgarh, has a predominantly agrarian economy with diverse agricultural practices ranging from traditional rain-fed farming to modern intensive cultivation. The region is known for its extensive use of chemical fertilizers, pesticides, and irrigation systems, many of which involve plastic-based applications such as mulch films, polyhouse farming, and plastic pipes. However, research on microplastic (MP) contamination in agricultural soils in Central India remains significantly limited, leaving a crucial knowledge gap regarding its sources, dispersion, and ecological consequences. Madhya Pradesh, the largest state in the region, has vast agricultural lands where crops like wheat, soybean, pulses, and horticultural products are grown. The state’s increasing adoption of plasticulture, especially in horticulture and floriculture, raises concerns about the potential accumulation of MPs in soil. However, there is no available research assessing the degradation of plastic mulches, irrigation pipes, and greenhouse materials in the region’s varied climatic conditions. Additionally, MP contamination through wastewater irrigation is an unexplored area, despite the presence of urban farming near cities like Bhopal, Indore, and Jabalpur, where treated and untreated sewage water is often used for irrigation. Chhattisgarh, a major rice-producing state, relies heavily on canal and groundwater irrigation, with plastic pipes and linings commonly used in water management. The possible leaching of MPs from these sources into paddy fields is yet to be investigated. Furthermore, the state’s industrial presence, particularly in cities like Raipur and Bhilai, raises concerns about industrial MP emissions that could settle on farmlands through atmospheric deposition or wastewater discharge. Despite this, no studies have explored the correlation between industrial activities and MP contamination in agricultural soil. Another major research gap in Central India is the role of river systems in MP transport. Rivers like the Narmada, Chambal, and Mahanadi flow through agricultural belts, often carrying plastic waste from urban centers. The potential deposition of MPs onto farmlands during irrigation or flooding events has not been examined. The impact of seasonal changes, such as monsoons, on MP transport and accumulation in soil is also an unaddressed area. Furthermore, there is no data on the interaction between MPs and the region’s black and red soil types, which have different compositions and water retention capacities. Understanding how MPs degrade and persist in these soils is crucial for evaluating their long-term impact on soil health and crop productivity. Given that Central India is a major contributor to India’s food production, research on MP contamination is essential for assessing potential risks to food safety and human health. Overall, the lack of studies on MP contamination in Central India’s agricultural lands highlights the need for systematic research to identify sources, transport mechanisms, and environmental impacts. Future studies should focus on assessing MP accumulation in different soil types, understanding their interaction with fertilizers and pesticides, and evaluating their effects on crop growth and soil microbiota.

**West India**, comprising states like Rajasthan, Gujarat, Maharashtra, and Goa, exhibits diverse agro-climatic conditions ranging from arid and semi-arid zones to coastal and high-rainfall areas. Agriculture in this region heavily depends on plastic-based inputs such as mulch films, greenhouse coverings, drip irrigation pipes, and plastic-lined reservoirs. However, research on microplastic (MP) contamination in agricultural lands across West India is significantly lacking. Given the region’s intensive farming practices, industrial hubs, and coastal influence, there is an urgent need to assess the extent and impact of MPs in soil. In Rajasthan, where water scarcity is a major challenge, plastic-based irrigation systems such as drip and sprinkler irrigation are widely adopted to conserve water. However, no studies have examined whether degradation of these plastic components contributes to MP accumulation in soil. Additionally, Rajasthan's desert farming relies on plastic mulch to retain soil moisture, but the long-term impact of plastic degradation in arid conditions remains unknown. Research is needed to determine how high temperatures and strong winds influence the breakdown and transport of MPs in desert soils. Gujarat, a major industrial and agricultural state, presents another critical research gap. Being home to numerous plastic manufacturing units, there is a risk of industrial MP contamination in agricultural fields through atmospheric deposition and wastewater irrigation. Moreover, the extensive use of plasticulture techniques, such as greenhouse farming in Kutch and Saurashtra, may contribute to soil MP pollution, yet there is no data on MP accumulation in these agricultural zones. The coastal farming regions of Gujarat, especially those practicing aquaculture and salt farming, may also be exposed to marine MPs, but studies investigating their potential entry into farmland are lacking. Maharashtra, with its highly diversified agricultural landscape, faces potential MP contamination from multiple sources. The state has a strong presence of polyhouse and greenhouse farming, particularly in regions like Pune and Nashik, where plastic coverings and grow bags are extensively used. However, the contribution of these plastic materials to MP accumulation in soil has not been assessed. Additionally, urban farming near cities like Mumbai and Nagpur often relies on sewage-irrigated lands, where microplastics from untreated municipal wastewater may be deposited. Despite this, no systematic research has been conducted to quantify MP presence in such farmlands. The sugarcane belt of western Maharashtra, which uses plastic-lined irrigation canals and fertigation systems, may also be prone to microplastic leaching, but this remains an unexplored area of study. Goa, with its unique blend of coastal agriculture and tourism-driven plastic pollution, represents another significant research gap. While studies have identified MPs in Goa’s beaches and marine ecosystems, no research has explored their potential impact on adjacent agricultural lands. Traditional paddy fields and cashew plantations in the region may be receiving MPs through irrigation water and atmospheric fallout, yet there is no data to confirm this. Another critical knowledge gap in West India is the role of climatic factors such as monsoons, high temperatures, and wind patterns in MP dispersion. Maharashtra and Gujarat, both experiencing heavy rainfall, may face MP runoff from urban and industrial areas into agricultural lands, but no studies have quantified this phenomenon. Similarly, Rajasthan’s desert regions may experience airborne MP deposition from plastic waste degradation, but research in this aspect is completely absent. Overall, despite West India’s economic and agricultural importance, the issue of MP contamination in farmland remains largely unaddressed. Future research should focus on identifying MP sources, understanding their transport and accumulation mechanisms in different soil types, and assessing their potential impact on soil fertility, crop growth, and food safety.

**South India**, comprising states like Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, and Telangana, has a diverse agricultural landscape that includes intensive cash crop farming, plantation agriculture, and high-tech farming practices. The region is characterized by widespread use of plastic-based farming techniques such as drip irrigation, plastic mulching, greenhouse cultivation, and plastic-lined reservoirs. Despite this, research on microplastic (MP) contamination in South Indian agricultural soils remains significantly limited, creating major gaps in understanding the sources, distribution, and long-term environmental consequences of MPs in the region’s farmlands. One of the major research gaps is in plasticulture-associated microplastic pollution. States like Tamil Nadu and Karnataka have large-scale horticultural production, especially in crops like tomatoes, chilies, bananas, and grapes, which rely heavily on plastic mulching and drip irrigation systems. While these practices enhance productivity, the degradation and fragmentation of plastic materials over time could lead to significant MP accumulation in the soil. However, no detailed studies have assessed the rate of plastic degradation in South India’s tropical climate or its contribution to MP pollution in farmlands. The role of wastewater irrigation in MP contamination is another unexplored area. Cities like Chennai, Bengaluru, and Hyderabad generate vast amounts of municipal wastewater, a portion of which is used for peri-urban agriculture. Studies in other regions of India have highlighted wastewater as a significant source of MPs in agricultural fields, but similar research is lacking in South India. Given the prevalence of treated and untreated sewage irrigation in regions like Andhra Pradesh and Telangana, there is an urgent need to analyze the extent of MP contamination in these farmlands and its potential uptake by crops. The impact of marine microplastic pollution on coastal farmlands is also an unstudied aspect. Kerala and Tamil Nadu have significant agricultural zones near the coast, where tidal floods, storm surges, and seawater intrusion could introduce MPs into the soil. With South India being one of the primary sources of plastic leakage into the Indian Ocean, there is a possibility that marine MPs are making their way into coastal farmlands through irrigation or atmospheric deposition. However, no systematic studies have been conducted to determine the extent of this phenomenon or its effects on soil and plant health. South India’s industrial and urban MP emissions are another potential contributor to agricultural contamination. The region hosts major industrial hubs such as Chennai, Bengaluru, Coimbatore, and Visakhapatnam, which generate plastic waste that could be transported to nearby agricultural lands via wind and water runoff. The impact of such emissions on soil MP levels remains unexplored. Additionally, there is no research on how major river systems such as the Godavari, Krishna, and Kaveri might be transporting MPs to agricultural lands through irrigation networks. Another major research gap is the interaction between microplastics and South India’s soil types. The region has diverse soil categories, including red laterite soils, black cotton soils, and alluvial coastal soils, each with different water retention and organic matter content. Understanding how MPs behave in these soils—whether they bind to clay particles, leach into groundwater, or persist in the upper soil layers—is crucial for assessing their long-term environmental impact. However, there is no research on how South India’s specific soil characteristics influence MP degradation and accumulation. Additionally, there is no data on MP uptake by key crops grown in South India, such as rice, millets, pulses, coconut, coffee, and spices like pepper and cardamom. Since MPs can enter the food chain through plant roots and edible parts, assessing their presence in South Indian staple crops is critical for evaluating food safety risks. However, no studies have been conducted to measure MP contamination levels in crops grown in plastic-intensive farming regions. Overall, the lack of research on microplastic contamination in South Indian agricultural lands presents significant challenges in assessing the long-term risks to soil health, crop productivity, and food safety. Future studies should focus on quantifying MP accumulation in farmlands, analyzing its interaction with soil and crops, and developing sustainable alternatives to plastic-based agricultural practices.

**Conclusion**

Microplastic contamination in agricultural soils across India is an emerging environmental concern with significant implications for soil health, crop productivity, and food safety. This review synthesizes findings from 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. While contamination levels vary geographically, major agricultural hubs near rivers, industrial zones, and coastal areas exhibit a higher risk of microplastic infiltration into farmlands.

The findings underscore the urgent need for more comprehensive and standardized research on microplastic contamination in Indian agricultural soils. Many regions, particularly in North and Central India, remain underexplored, with limited direct soil sampling studies available. Additionally, the long-term impact of microplastic accumulation on soil properties, plant uptake, and microbial communities remains poorly understood.

Addressing these research gaps is crucial for a better understanding of microplastic dynamics in soil ecosystems. Future studies should focus on assessing contamination levels using advanced detection methods, evaluating microplastic interactions with soil nutrients and organisms, and exploring potential mitigation strategies. As microplastics continue to infiltrate agricultural landscapes, ensuring sustainable soil management practices will be essential to safeguarding both environmental and food security in India.

**Reference**

Ahmed, M., Phukan, B., Talukdar, A., Ahmed, I., Sarma, J., Ali, A., Gogoi, R., Borah, K., & Xavier, M. (2023). Assessment of microplastic contamination in the gastrointestinal tracts of indigenous fishes from north eastern hill regions of Bhogdoi, a tributary of River Brahmaputra, India. *Environmental Science and Pollution Research*, 30(57), 121124–121137. <https://doi.org/10.1007/s11356-023-30821-0>

Ajay, K., Behera, D., Bhattacharya, S., Mishra, P. K., Ankit, Y., & Anoop, A. (2021). Distribution and characteristics of microplastics and phthalate esters from a freshwater lake system in Lesser Himalayas. *Chemosphere*, *283*, 131132. <https://doi.org/10.1016/j.chemosphere.2021.131132>

Ankit, Y., Ajay, K., Nischal, S., Kaushal, S., Kataria, V., Dietze, E., & Anoop, A. (2024). Atmospheric deposition of microplastics in an urban conglomerate near to the foothills of Indian Himalayas: investigating the quantity, chemical character, possible sources and transport mechanisms. *Environmental Pollution*, 124629.<https://doi.org/10.1016/j.envpol.2024.124629>.

Ayyamperumal, R., et al. (2022). Investigation of microplastic contamination in the sediments of Noyyal River- Southern India. *Journal of Hazardous Materials Advances*, 8, 100198.<https://doi.org/10.1016/j.hazadv.2022.100198>.

Bharath, K. M., Ruthra, R., Kasinath, A., & Natesan, U. (2024). A review of landfill leachate with environmental impacts: Sustainable waste management and treatment methods of Vellalore dump yard, Coimbatore Corporation. In *A review of landfill leachate* (pp. 1-15). *Springer Nature Switzerland.*<https://doi.org/10.1007/978-3-031-55513-8_5>

Bhavsar, P. S., Chovatiya, B. V., Kamble, S. B., & Gore, A. H. (2024). Extraction and analysis of microplastics in the soil of Diamond City, Surat (Gujarat, India): Ecological risk, pollution indices, and greenness evaluation. *ACS Agricultural Science & Technology*, 4(5), 614-625. <https://doi.org/10.1021/acsagscitech.4c00140>

Boots, B., Russell, C. W., & Green, D. S. (2019). Effects of microplastics in soil ecosystems: above and below ground. *Environmental Science & Technology*, *53*(19), 11496–11506. <https://doi.org/10.1021/acs.est.9b03304>

Borah, A., Hande, O. M., Jayakumar, S., & Devipriya, S. P. (2024a). Microplastic pollution in beach sediments in the Dapoli coast, Maharashtra, the western peninsular region of India. *Regional Studies in Marine Science,* 103640. <https://doi.org/10.1016/j.rsma.2024.103640>

Borah, P., Kshiar, N., Reang, D., Nath, A. J., & Baruah, K. K. (2024b). Incidence of microplastic contamination in fishes of the Ramsar Wetland, Loktak – The world’s only floating lake from the Indian Himalayan region. *Journal of Environmental Management*, 358, 120928. <https://doi.org/10.1016/j.jenvman.2024.120928>

Bulbul, M., Kumar, S., Ajay, K., & Anoop, A. (2023). Spatial distribution and characteristics of microplastics and associated contaminants from mid-altitude lake in NW Himalaya. *Chemosphere*, 326, 138415.<https://doi.org/10.1016/j.chemosphere.2023.138415>

Chauhan, J. S., Semwal, D., Nainwal, M., Badola, N., & Thapliyal, P. (2021). Investigation of microplastic pollution in river Alaknanda stretch of Uttarakhand. *Environment Development and Sustainability, 23*(11), 16819–16833.<https://doi.org/10.1007/s10668-021-01388-y>.

D, S. V., K, R., & K, S. (2021). A preliminary study on microplastic occurrences in surface waters of Ousudu Lake, Pondicherry, India. *International Journal of Civil Environmental and Agricultural Engineering*, 35–48. <https://doi.org/10.34256/10.34256/ijceae2113>

Dhiman, S., Sharma, D., Kotia, N., & Sinha, R. (2024). Estimation of microplastics distribution in soil sample from District Una, Himachal Pradesh, India. *Journal of Toxicological Studies*, 2(1), 527.<https://doi.org/10.59400/jts.v2i1.527>

Dowarah, K., Patchaiyappan, A., Thirunavukkarasu, C., Jayakumar, S., & Devipriya, S. P. (2020). Quantification of microplastics using Nile Red in two bivalve species *Perna viridis* and *Meretrix meretrix* from three estuaries in Pondicherry, India and microplastic uptake by local communities through bivalve diet. *Marine Pollution Bulletin*, 153, 110982.<https://doi.org/10.1016/j.marpolbul.2020.110982>

Farooq, M., Nisa, F. U., Manzoor, Z., Tripathi, S., Thulasiraman, A. V., Khan, M. I., Khan, M. Y. A., & Gani, K. M. (2023). Abundance and characteristics of microplastics in a freshwater river in northwestern Himalayas, India - Scenario of riverbank solid waste disposal sites. *The Science of the Total Environment*, 886, 164027.<https://doi.org/10.1016/j.scitotenv.2023.164027>

Firdous, J., Mathur, Y. K., Jeelani, M., Aziz, A., Azmat, S., & Mudasir, S. (2020). Preliminary studies on the microplastic pollution in Dal lake, Kashmir (first report). *Advances in Environmental Research*, 9(4), 275–284.<https://doi.org/10.12989/AER.2020.9.4.275>

Ganapathy, V. S., Radhakrishnan, K., & Prakasheswar, P. (2021). A baseline study on the occurrence and distribution of microplastics in the highly polluted Metropolitan River Cooum, Chennai, India. *Research Square*.<https://doi.org/10.21203/rs.3.rs-720731/v1>

Ghosh, S., Das, R., Bakshi, M., & others. (2021). Potentially toxic element and microplastic contamination in the river Hooghly: Implications to better water quality management. *Journal of Earth System Science*, 130(236). <https://doi.org/10.1007/s12040-021-01733-9>

Gopakumar, G., Nathan, D. S., Harikrishnan, S., Sridharan, M., & Jilsha, V. (2024). An investigation on the presence and risk assessment of microplastics in Quilon Beach, south west coast of India. *Environmental Pollution and Management*.<https://doi.org/10.1016/j.epm.2024.08.002>

Goswami, P., & Bhadury, P. (2024). Characteristics of microplastics in tributaries of the upper Brahmaputra River along the Himalayan foothills, India. *Environmental Research Communications*. <https://doi.org/10.1088/2515-7620/ad54a2>

Gupta, P., Saha, M., Naik, A., Kumar, M. M., Rathore, C., Vashishth, S., Maitra, S. P., Bhardwaj, K., & Thukral, H. (2024). A comprehensive assessment of macro and microplastics from Rivers Ganga and Yamuna: Unveiling the seasonal, spatial and risk factors. *Journal of Hazardous Materials, 469*, 133926.<https://doi.org/10.1016/j.jhazmat.2024.133926>.

Jain, Y., Govindasamy, H., Kaur, G., Ajith, N., Ramasamy, K., RS, R., & Ramachandran, P. (2024). Microplastic pollution in high-altitude Nainital lake, Uttarakhand, India. *Environmental Pollution, 346*, 123598.<https://doi.org/10.1016/j.envpol.2024.123598>.

Jaini, M., & Namboothri, N. (2023). Boat paint and epoxy fragments - Leading contributors of microplastic pollution in surface waters of a protected Andaman bay. *Chemosphere, 312*, 137183.<https://doi.org/10.1016/j.chemosphere.2022.137183>

K, M. B., Natesan, U., R, V., R, P. K., R, R., & S, S. (2021). Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater. *Chemosphere*, 277, 130263.<https://doi.org/10.1016/j.chemosphere.2021.130263>

Kalangutkar, N., Mhapsekar, S., Redkar, P., Valsan, G., & Warrier, A. K. (2024). Microplastic pollution in the Chapora River, Goa, Southwest India: spatial distribution and risk assessment. *Environmental Monitoring and Assessment*, *196*(5). <https://doi.org/10.1007/s10661-024-12587-1>

Krishnakumar, S., Anbalagan, S., Kasilingam, K., Smrithi, P., Anbazhagi, S., & Srinivasalu, S. (2020). Baseline assessment of plastic debris in remote islands of the Andaman and Nicobar Archipelago, India. *Marine Pollution Bulletin*, 151, 110841.<https://doi.org/10.1016/j.marpolbul.2019.110841>

Kumar, M., Naik, D. K., Maharana, D., Das, M., Jaiswal, E., Naik, A. S., & Kumari, N. (2024a). Sediment-associated microplastics in Chilika lake, India: Highlighting their prevalence, polymer types, possible sources, and ecological risks. *The Science of the Total Environment*, *914*, 169707. <https://doi.org/10.1016/j.scitotenv.2023.169707>

Kumar, M., Xiong, X., He, M., Tsang, D. C., Gupta, J., Khan, E., Harrad, S., Hou, D., Ok, Y. S., & Bolan, N. S. (2020). Microplastics as pollutants in agricultural soils. *Environmental Pollution*, *265*, 114980. <https://doi.org/10.1016/j.envpol.2020.114980>

Kumar, S., Ajay, K., Behera, D., Yaseen, A., Karthick, B., Prasad, S., Bhat, S. U., Jehangir, A., & Anoop, A. (2025). Co-occurrence of microplastics and heavy metals in a freshwater lake system in Indian Himalaya: Distribution and influencing factors. *Emerging Contaminants*, 11(1), 100394.<https://doi.org/10.1016/j.emcon.2024.100394>

Kumar, S., Behera, D., Ajay, K., Karthick, B., Dharia, C., & Anoop, A. (2024b). Microplastics and heavy metal contamination along a land-use gradient in a Himalayan foothill river: Prevalence and controlling factors. *Journal of Contaminant Hydrology*, 104411.<https://doi.org/10.1016/j.jconhyd.2024.104411>

Kumari, R. (2024). Chronic Toxicity of Microplastics on Fish (*Labeo rohita*) and Their Impact on the Freshwater Ecosystem: A Case Study of Gangasagar Pond, Darbhanga, India. *Uttar Pradesh Journal of Zoology*, 45(10), 135-143. <https://doi.org/10.56557/UPJOZ/2024/v45i104057>

Mahesh, P., Priti, M., Chauhan, A., & Warrier, A. (2022). Plastic mulching; Microplastics in agricultural soil. *ResearchGate*. <https://doi.org/10.13140/RG.2.2.29673.16480>

Manzoor, S., & Singh, R. (2022). Spatiotemporal microplastic occurrence study of Harike wetland, A Ramsar wetland of India. *Research Square*.<https://doi.org/10.21203/rs.3.rs-1892051/v1>.

Napper, I. E., Baroth, A., Barrett, A. C., Bhola, S., Chowdhury, G. W., Davies, B. F., Duncan, E. M., Kumar, S., Nelms, S. E., Niloy, M. N. H., Nishat, B., Maddalene, T., Smith, N., Thompson, R. C., & Koldewey, H. (2023). The distribution and characterisation of microplastics in air, surface water and sediment within a major river system. *The Science of the Total Environment, 901*, 166640.<https://doi.org/10.1016/j.scitotenv.2023.166640>.

Neelavannan, K., Sen, I. S., Lone, A. M., & Gopinath, K. (2022). Microplastics in the high-altitude Himalayas: Assessment of microplastic contamination in freshwater lake sediments, Northwest Himalaya (India). *Chemosphere*, 290, 133354.<https://doi.org/10.1016/j.chemosphere.2021.133354>

Neelavannan, K., Sen, I. S., Sinha, N., Thakur, A. K., & Misra, S. (2023). Microplastics in the Ganga-Brahmaputra delta: Sources and Pathways to the Sundarbans Biosphere Reserve - an UNESCO World Heritage Centre. *Environmental Advances*, 11, 100350. <https://doi.org/10.1016/j.envadv.2023.100350>

Nithin, A., Sundaramanickam, A., Saha, M., Hassanshahian, M., Thangaraj, M., & Rathore, C. (2023). Risk assessments of microplastics accumulated in estuarine sediments at Cuddalore, Tamil Nadu, southeast coast of India. *Environmental Monitoring and Assessment*, 195(7), 890.<https://doi.org/10.1007/s10661-023-11434-z>

Padmachandran, A. V., Sree, N., Nasrin, F., Muthuchamy, M., & Muthukumar, A. (2022). Presence of Microplastics in Estuarine Environment- A Case Study from Kavvayi and Kumbla Backwaters of Malabar Coast, Kerala, India. *Research Square*.<https://doi.org/10.21203/rs.3.rs-2095097/v1>

Pandey, D., Banerjee, T., Badola, N., & Chauhan, J. S. (2022). Evidences of microplastic in air and street dust: a case study of Varanasi City, India. *Research Square*.<https://doi.org/10.21203/rs.3.rs-1151250/v1>.

Parashar, N., & Hait, S. (2023). Plastic rain—Atmospheric microplastics deposition in urban and peri-urban areas of Patna City, Bihar, India: Distribution, characteristics, transport, and source analysis. *Journal of Hazardous Materials*, 458, 131883.<https://doi.org/10.1016/j.jhazmat.2023.131883>

Patchaiyappan, A., Ahmed, S. Z., Dowarah, K., Jayakumar, S., & Devipriya, S. P. (2020). Occurrence, distribution and composition of microplastics in the sediments of South Andaman beaches. *Marine Pollution Bulletin, 156*, 111227.<https://doi.org/10.1016/j.marpolbul.2020.111227>

Patel, A., Bhagat, C., Taki, K., & Kumar, M. (2020). Microplastic vulnerability in the sediments of the Sabarmati River of India. In *Environmental Pollution* (pp. 127-138). Springer. <https://doi.org/10.1007/978-981-15-4668-6_7>

Patidar, K., Ambade, B., & Alshehri, M. (2024). Microplastics and associated polycyclic aromatic hydrocarbons in surface water and sediment of the Bay of Bengal coastal area, India: sources, pathway and ecological risk. *Environmental Geochemistry and Health*, *46*(5). <https://doi.org/10.1007/s10653-024-01926-3>

Patil, S., Kamdi, P., Chakraborty, S., Das, S., Bafana, A., Krishnamurthi, K., & Sivanesan, S. (2022). Characterization and removal of microplastics in a sewage treatment plant from urban Nagpur, India. *Environmental Monitoring and Assessment*, 195(1). <https://doi.org/10.1007/s10661-022-10680-x>

Patra, K. B., & Baitharu, I. (2024). Assessment of microplastics and associated ecological risk in the Hirakud Reservoir, Odisha, India. *Journal of water and health*, 22(6), 1017–1032. <https://doi.org/10.2166/wh.2024.393>

Pradhap, D., et al. (2023). Distribution and characterization of microplastic from reef associated surface sediments of Vembar group of Islands, Gulf of Mannar, India. *Total Environment Research Themes*, 5, 100024.<https://doi.org/10.1016/j.totert.2023.100024>.

Praved, P., Hari, K. V., Neethu, K. V., Aravind, E. H., & Bijoy Nandan, S. (2023). Evaluation of microplastic pollution in Cnidaria and Ctenophora in the Cochin estuary. *ResearchGate*.<https://doi.org/10.13140/RG.2.2.18940.76164>

Rabari, V., Patel, H., Patel, K., Patel, A., Bagtharia, S., & Trivedi, J. (2023). Quantitative assessment of microplastic contamination in muddy shores of Gulf of Khambhat, India. *Marine Pollution Bulletin*, 192, 115131. <https://doi.org/10.1016/j.marpolbul.2023.115131>

Rabari, V., Patel, K., Patel, H., & Trivedi, J. (2022). Quantitative assessment of microplastic in sandy beaches of Gujarat state, India. *Marine Pollution Bulletin*, 181, 113925. <https://doi.org/10.1016/j.marpolbul.2022.113925>

Rabari, V., Rakib, M. R. J., Patel, H., Idris, A. M., Malafaia, G., & Trivedi, J. (2024). Microplastic prevalence in epipelagic layer: Evidence from epipelagic inhabiting prawns of north-west Arabian Sea. *Marine Pollution Bulletin, 200*, 116137.<https://doi.org/10.1016/j.marpolbul.2024.116137>

Radhakrishnan, N. K. K., Sangeetha, J., Alabhai, J. M., & Jayasree, P. (2024). Accumulation of microplastics in bivalves within the Chandragiri River in South-Western India. *Anthropocene Coasts*, 7(1). <https://doi.org/10.1007/s44218-024-00038-w>.

Ragesh, S., Jaleel, K. U. A., Nikki, R., Razaque, M. A. A., Ashraf, P. M., Ravikumar, C. N., Abdulaziz, A., & Kumar, P. K. D. (2024). Environmental and ecological risk of microplastics in the surface waters and gastrointestinal tract of skipjack tuna (Katsuwonus pelamis) around the Lakshadweep Islands, India. *Environmental Science and Pollution Research*, 31(15), 22715–22735.<https://doi.org/10.1007/s11356-024-32564-y>

Ramakrishnan, D., & Sathiyamoorthy, M. (2024). Seasonal Distribution, Source Apportionment and Risk Exposure of Microplastic Contaminants along the Muttukadu Backwater Estuary, Tamil Nadu, India. *Results in Engineering*, 102776.<https://doi.org/10.1016/j.rineng.2024.102776>.

Rathore, C., Saha, M., De Boer, J., Desai, A., Gupta, P., Naik, A., & Subha, H. Y. (2024). Unraveling the land-based discharge of microplastics from sewers to oceans – A comprehensive study and risk assessment in wastewaters of Goa, India. *The Science of the Total Environment, 913*, 169621.<https://doi.org/10.1016/j.scitotenv.2023.169621>

Rillig, M. C. (2012). Microplastic in terrestrial ecosystems and the soil? *Environmental Science & Technology*, *46*(12), 6453–6454. <https://doi.org/10.1021/es302011r>

Rochman, C. M., Hoh, E., Kurobe, T., & Teh, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports*, *3*(1). <https://doi.org/10.1038/srep03263>

Sangilidurai, K., Karuppusamy, S., Periyasamy, D., Krishnaraj, R. S., Narayanasamy, C., Arunachalam, L., & Kamalam, D. G. (2024). Ecological risk assessment of microplastics in agricultural soils of Coimbatore region, India. *Natural Resources for Human Health*, *4*(2), 152–159. <https://doi.org/10.53365/nrfhh/184013>

Sapkale, D., Banot, P., & Pandit, S. (2024). Qualitative and Quantitative Analysis of Microplastics in the Surface Waters and Freshwater Fish from Four Important Lakes in Pune, India. *Water Air & Soil Pollution*, 235(8). <https://doi.org/10.1007/s11270-024-07292-1>

Sekar, V., & Sundaram, B. (2023a). Occurrence, quantification and characterisation of microplastics in Godavari River, India. *Case Studies in Chemical and Environmental Engineering, 8*, 100542.<https://doi.org/10.1016/j.cscee.2023.100542>

Sekar, V., & Sundaram, B. (2023b). Preliminary evidence of microplastics in landfill leachate, Hyderabad, India. *Process Safety and Environmental Protection,* 175, 369–376. <https://doi.org/10.1016/j.psep.2023.05.070>

Shaji, S., Vannarath, A., Rao, Y. S., & Sundaram, B. (2024). Distribution, Characteristics and Ecological Risk of Microplastics in beach sediments along the Northern Coast of Andhra Pradesh, India. *Regional Studies in Marine Science*, 103716.<https://doi.org/10.1016/j.rsma.2024.103716>

Singh, R., Kumar, R., & Sharma, P. (2022). Microplastic in the subsurface system: Extraction and characterization from sediments of River Ganga near Patna, Bihar. In Elsevier eBooks (pp. 191–217).<https://doi.org/10.1016/b978-0-12-823830-1.00013-4>

Singh, S., Chakma, S., Alawa, B., Kalyanasundaram, M., & Diwan, V. (2023). Identification, characterization, and implications of microplastics in soil – A case study of Bhopal, central India. *Journal of Hazardous Materials Advances*, 9, 100225. <https://doi.org/10.1016/j.hazadv.2022.100225>

Singh, S., Chakma, S., Alawa, B., Kalyanasundaram, M., & Diwan, V. (2024). Microplastic pollution in terrestrial environment: Identification, characterization, and risk assessment in Indore, Central India. *Soil Use and Management*, 40(2). <https://doi.org/10.1111/sum.13053>

Singh, V., Chakraborty, S., & Chaudhuri, P. (2021a). Quantification and polymer characterization of sediment microplastics along the Golden Beach, Puri, India. *Indian Journal of Geo-Marine Sciences, 50,* 1–11.

Singh, V., & Chakraborty, S. (2021b). Quantification and characterization of microplastics in Kanke Lake, a freshwater system of Ranchi, Jharkhand, India. In *Lecture notes in civil engineering* (pp. 271–281). <https://doi.org/10.1007/978-981-15-9805-0_23>

Somasundaram, R., & Nagalakshmi, R. (2023). Impact due to microplastics pollution in coastal environment along Chennai Coast. *Chelonian Research Foundation*, 18(2), 361–375.

Sunil, M., Mithun, N., Kalthur, G., Nair, M. P., Gopinath, A., Chidangil, S., Kumar, S., & Lukose, J. (2024). Analysis of microplastics in the estuary lying along the coastal belt of the Arabian Sea. *Case Studies in Chemical and Environmental Engineering*, 100804. <https://doi.org/10.1016/j.cscee.2024.100804>.

Tsering, T., Sillanpää, M., Viitala, M., & Reinikainen, S. (2021). Microplastics pollution in the Brahmaputra River and the Indus River of the Indian Himalaya. *The Science of the Total Environment*, *789*, 147968. <https://doi.org/10.1016/j.scitotenv.2021.147968>

Tsering, T., Sillanpää, M., Viitala, M., & Reinikainen, S. (2022). Variation of microplastics in the shore sediment of high-altitude lakes of the Indian Himalaya using different pretreatment methods. *The Science of the Total Environment*, 849, 157870.<https://doi.org/10.1016/j.scitotenv.2022.157870>

Unnikrishnan, V., Valsan, G., Amrutha, K., Sebastian, J. G., Rangel-Buitrago, N., Khaleel, R., Chandran, T., Reshma, S., & Warrier, A. K. (2023). A baseline study of microplastic pollution in a Southern Indian Estuary. *Marine Pollution Bulletin, 186*, 114468.<https://doi.org/10.1016/j.marpolbul.2022.114468>

Upadhyay, K., & Bajpai, S. (2023). Urban tropical freshwater ponds as microplastics hotspots—insight on abundance and characteristics using an improved sampling technique. *Environmental Monitoring and Assessment,* 196(1). <https://doi.org/10.1007/s10661-023-12188-4>

Vaid, M., Mehra, K., Sarma, K., & Gupta, A. (2022). Investigations on the co-occurrence of microplastics and other pollutants in the River Yamuna, Delhi. *Water Science & Technology Water Supply*, 22(12), 8767–8777.<https://doi.org/10.2166/ws.2022.408>

Verma, M., Singh, P., & Dhanorkar, M. (2024). Exploring the abundance of microplastics in Indian landfill leachate: An analytical study. *Journal of Environmental Management*, 360, 121181. <https://doi.org/10.1016/j.jenvman.2024.121181>

Vidyasakar, A., Krishnakumar, S., Kasilingam, K., Neelavannan, K., Bharathi, V. A., Godson, P. S., Prabha, K., & Magesh, N. S. (2020). Characterization and distribution of microplastics and plastic debris along Silver Beach, Southern India. *Marine Pollution Bulletin*, 158, 111421.<https://doi.org/10.1016/j.marpolbul.2020.111421>

Vijayan, R., Suresh, A. S., & Mathew, S. (2024). Analysis of physico-chemical properties in the mangrove ecosystem of Paravoor, Kollam District, Kerala, South India. *Journal of Chemical Health Risks*, 14(3), 54-69.

Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: a micro issue? *Environmental Science & Technology*, *51*(12), 6634–6647. <https://doi.org/10.1021/acs.est.7b00423>

Yousuf Dar, J., Saha, M., Taghizade, Z., Kantharajan, G., & Valappil Rajendran, K. (2023). Microplastics contamination in the gastropod, Telescopium telescopium, from the mangrove area of Versova Creek, Mumbai, India: Microplastics in the gastropod. *International Journal of Aquatic Biology*, 11(5), 417–430.