Journal of Scientific Research and Reports

Volume 30, Issue 6, Page 412-419, 2024; Article no.JSRR.116904
ISSN: 2320-0227

Micro Plastic Pollution in Soil Environment: A Comprehensive Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2024/v30i62057

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/116904

Review Article

Received: 02/03/2024
Accepted: 07/05/2024
Published: 11/05/2024

ABSTRACT

Plastic is a substance that is fundamental to current human existence. However, the issue of plastic trash polluting the environment has emerged due to the rapidly growing demand for plastic use. Even though some used plastics are recycled or burned for energy, a significant amount of plastic

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waste is landfilled or released into marine and terrestrial habitats worldwide. Particularly, trash made of microplastics smaller than 5 mm is regarded as a rising global problem for contamination. Nonetheless, the majority of studies on the effects of microplastic pollution conducted in the previous ten years have been on the marine ecosystem, with relatively few on the terrestrial ecology. One may argue that soil serves as both a significant source of microplastic pollution and a conduit for it into the aquatic ecosystem. The majority of microplastic sources in soil settings enter through a variety of openings, fragment, and spread both vertically and horizontally to the surrounding surroundings. Additionally, there are detrimental effects on the soil biota, which could influence the food web and raise questions about human health. This overview of microplastics' properties, research trends, analytical techniques, migration and degradation processes, impacts on soil biogeochemistry, and interactions with soil organisms highlights the significance of continuing studies on the effects of microplastics on terrestrial ecosystems.

Keywords: Cluster mapping; ecotoxicological effects; risk assessment models; soil microplastics; analytical techniques.

1. INTRODUCTION

Due to their potent adsorption [2] and capacity to continuously pollute the environment with compounds [3], microplastics, a term used to describe plastic trash and particles smaller than 5 mm [1], have garnered significant attention. Microplastics have recently been found in the ocean [4], the atmosphere [8], soil [9, 10], food [6, 7], surface rivers and lakes [5], and even in the seldom visited polar areas [11] and deserts [12]. This demonstrates how the gradual emergence of microplastic contamination as a serious threat to human health and the environment is evident. When it comes to the environmental media, the study of microplastics begins with water bodies and moves on to soil and atmospheric systems, although research on microplastics in water remains at the forefront. The term "microplastics" was first used in a 2004, research on plastic trash in marine water and sediments by British scientist Thompson [13], which was published in the journal Science. Later, microplastic residues were discovered in the Yangtze River Basin [17], the South China Sea [16], the North Pacific [15], the North Atlantic Ocean [15], and the Mediterranean Sea [14].

The first study of microplastics in soil was by German scientist Rilling [18], who published the paper "Microplastic in Terrestrial Ecosystems and the Soil" in the journal Environmental Science and Technology in 2012. Following that, food and the atmosphere were found to contain micro (nano)plastics in increasing amounts. The focus of microplastics research has shifted throughout time, moving from the detection of microplastics in environmental media [19, 20] to the assessment of their toxicity [21, 22] and finally to the current study of their behavior in the environment [23]. The field of study on microplastics in soil is still in its early stages of rapid expansion, in contrast to aquatic bodies. The majority of studies concentrate on the level of pollution caused by microplastics in soil [24] and the fastest and most effective ways to detect and remove microplastics from soil [25, 26]. There is currently no appropriate approach that can handle the examination of smaller microplastics, according to a review of known techniques for the study of microplastics in soil matrices [27]. Therefore, more research is required to determine how to set up a consistent microplastic analysis procedure for soil matrices. According to other research, microplastics are made of carbon and other components [28]. This shows that microplastics can significantly affect plant development, soil structure, and most likely the stability of soil aggregates, which can change the rate of erosion. Nevertheless, there is still a lack of systematic research on the mechanisms underlying microplastic activity in soil, particularly with regard to the need to further categorize and summarize microplastic migratory behavior. This will encourage the study of soil microplastic systems by making it easier to index and search pertinent research material.

2. PLASTICS IN SOILS IN ABUNDANCE

The manufacturing of plastics has expanded significantly worldwide, according to multiple studies, which has led to an unprecedented level of "plastic pollution" [14,15,16]. At the start of the twenty-first century, there were more than 450,000 hectares of greenhouses in use worldwide [17].

There are several types of greenhouses. These homes can have raspa or feint, be flat or vinetype, located in a tunnel or semi-cylinder, in a chapel with one or two water features, asymmetrical or symmetrical, etc. depending on the forms and materials employed [18,19, 20]. According to estimates by [2], 3.5 Mt of bio-based polymers were produced globally in 2018, 3.8 Mt in 2019, and 4.2 Mt in 2020. According to Plastics Europe [21], 367 Mt were manufactured globally in 2021. According to Microplastics in Fisheries and Aquaculture [22], out of all plastics, MPs—plastic fragment particles with diameters ranging from 5 mm to 1 µm or from 5 mm to 0.1 µm—have multiplied the greatest. These findings are supported by He et al. and Bläsing and Amelung [23,24]. A sizable body of research [25,26,27] examined the categorization of plastics according to their size: macroplastics (>5 mm), microplastics (MP, 5000–1 µm), or nanoplastics (<1 µm).

Plastic covers are used for intensive agriculture within the greenhouses. Given that Europe is home to more than 43% of the world's greenhouse area, this is particularly pertinent there. A European Union (EU) research [28] states that 175,000 ha of the 405,000 hectares of greenhouses that have been detected globally are found in Europe. The countries with the most importance are Spain, France, Greece, Italy, and the Netherlands; with 71,783 hectares of protected agriculture, Spain has the largest area.

Spain, the US, China, and Italy are the nations that have made the greatest contributions to our understanding of biodegradable mulch [29]. On the other hand, some parts of Spanish land have not received much research attention since they are devoted to plastic-free agricultural cultivation; in fact, greenhouses are not given priority. Castilla y León (CYL) is one such area where the usage of plastics in agriculture is progressively growing [30-32].

Many agricultural practices, including the roofing of greenhouses and contemporary methods for storing and preserving food, involve the usage of plastics. When plastics were initially introduced into usage in the middle of the 20th century, they were seen to offer a number of benefits and were therefore highly appreciated. This original theory, however, has undergone a significant shift in light of the fact that certain plastic types continue to exist in the environment as non-biodegradable micro- and nanoparticles, as noted by [33,34].

Plastics output has grown 20-fold globally since the 1960s and surpassed 300 Mt in 2015. The EIP-AGRI Focus Group [36] and Plastics Europe [21] anticipate that production of plastics will double over the next 20 years. It is now crucial to research and comprehend the effects that this rise in plastics will have on the ecology. The effects of plastic pollution on aquatic ecosystems have been the subject of numerous research [37], while the effects on terrestrial habitats have received less attention to date [5,38].

Understanding the presence and distribution of MPs in soils is crucial nowadays. As a result, it is imperative that the plastics problem in agriculture be addressed as soon as feasible. To ascertain the effects of MPs on soil characteristics, subsidiary agricultural quality, and crop productivity, this work reviews the literature on plastic in general and MPs in specifically in the agro-environmental soils of CYL. Therefore, this study's primary goal is to assess the current status of research on MPs in CYL's agricultural soils. This review's overall goal is to draw attention to the most urgent research gaps in the body of literature while highlighting the prospects for the future of historically agricultural regions that are embracing modern agriculture by utilizing microplastics that wind up in the soil.

3. PLASTICS' IMPACT ON AGRICULTURAL SOILS' PHYSICOCHEMICAL PROPERTIES

Generally speaking, there are many advantages to using plastic nets, including fewer insects and vermin. Furthermore, plastic nets have shown promise in managing pests like Philaenus spumarius and Xylella fastidiosa, which are prevalent in olive tree nurseries and orchards [17]. They also serve to establish a distinct microclimate [18].

In the literature, there are conflicting claims made by certain writers [19, 10, 11] and others [12, 13, 47] on the sometimes beneficial impacts of plastics on the physicochemical characteristics of soil, soil microbiota, and invertebrates. Micro (nano) plastic is thought to be a physical soil contaminant that can decrease soil bulk density; possibly lessen root penetration resistance; and increase soil aeration, soil water movement, and water evaporation. However, the extent of soil plastic pollution and its short- and long-term effects are largely unknown. It has the ability to alter the way soil aggregates and discharge harmful plastic seepage into soils [14]. Numerous processes that may cause microplastics to seep into soils include irrigation, plastic mulching, soil amendments, flooding, and diffuse and urban runoff [3,6,8,13,43,17,10,15,16]. A significant portion of the literature covers these factors. According to [27,17], the breakdown of microplastics in soil aggregates can change the physicochemical properties of soil, including its pH, bulk density, water-holding capacity, and structural makeup. The previously mentioned authors [27,17] and [28] claim that the presence of microplastics in terrestrial ecosystems may have a negative impact on soil properties, microbial activity, and plant performance.

4. RESEARCH GAPS, PROSPECTS, AND CONCLUSIONS

This work marks a turning point in the widespread usage of plastics in CYL agriculture, which can result in significant trash production. Plastic contamination of soil is currently occurring as a result of numerous agricultural techniques and additions. There's more and more proof that these plastics cause pollution in the soil. In fact, crop rotation and mechanical tillage are two agricultural practices that might quicken MNP fractionation [54], implying their release into the soil. MNPs cause soil contamination through two distinct processes: first, they release their hazardous substances [57], and second, they serve as carriers of other pollutants [58]. Every day, more plastic is being used in CYL agriculture, which suggests that there will be an increase in agricultural output. However, improper usage of plastics during agricultural operations can result in plastic waste and subsequent plastic debris contamination of the environment. It's clear that soil systems serve as a reservoir for microplastics after more than 20 years of microplastic addition to soils. Reducing the amount of plastic used in agriculture is a problem in order to preserve the fertility of soils that have historically been particularly productive. To the best of our knowledge, there hasn't been much research done on how MPs affect CYL agricultural soils. On this subject, there are very few experimental research.

Thus, research on the impact of MPs on soil fauna, vegetation growth, microbes, and bio-geophysical and chemical qualities should be started, even though data for this kind of study are essentially restricted to the beginning of the last ten years. Based on the fieldwork conducted in CYL for this study, it was determined that the application of organic fertilizer, wastewater irrigation, and plastic mulching film were the main possible sources of MPs. In any event, the FAO has identified protecting the soil ecology from excessive plastic pollution as one of its specific priorities when faced with this situation. When microplastics are present, the behavior of the soils under analysis varies significantly. Because the deep mollic horizon provides protection in Calcixeroll, the addition of plastic fibers won't have a negative effect on the aggregates, preventing increased runoff and erosion. Water infiltration and runoff, however, will be adversely affected in Dystroxerept [58].

A few actions need to be performed in CYL. Initially, a study should be carried out to identify the zones or locations that are now heavily impacted by the usage of plastics in agriculture. Second, research should be done to establish standardized procedures for gathering, removing, identifying, and measuring MNPs in agricultural soils while taking into account the characteristics of the various types of soils.

5. WE SUGGEST THE FOLLOWING ACTIONS

Avoiding the use of plastics by using more environmentally friendly farming methods, such that it is vital to make an effort to stop using plastics that are harmful or useless; replacing needless plastics and greenhouse films with safer, ecological materials and more robust substitutes like polycarbonate or glass; substituting reusable items for disposable, one-time use ones, such as robust, stackable harvesting crates in place of flexible bags, and biodegradable polymers for traditional, non-biodegradable polymers. The review conducted leads to the conclusion that knowledge on plastics in agricultural soils has truly exploded, especially in the last 20 years [60-68].

Maybe because of this, the topic is still not completely understood, necessitating the need for impact evaluations in soils to be the main focus of future study. Remember that over a partially semi-arid region, true climate change will bring greater temperatures, more solar radiation, and less precipitation. These factors will accelerate the physical weathering, aging, and quality degradation of plastic films. This article highlights potential environmental degradation by providing an overview of regional microplastic concentrations and marking a turning point in the unchecked and escalating production of plastic in CYL soil agriculture [50,-59].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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