Regulatory and Mitigation Strategies to Combat Microplastic Pollution in Agricultural Ecosystems

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Abstract Microplastic contamination is a growing concern that affects environment and human health. Agriculture has been identified as a major source of microplastics (MPs) released into the environment, hence mitigating it will require a big paradigm shift across numerous sectors. The most recent research on the origins of MPs in agricultural ecosystems and the dangers they bring is reviewed in this study. Research gaps and future trends are reviewed, along with the regulatory, mitigation, and intervention methods needed to combat plastic pollution of agricultural ecosystems. In conclusion, there is currently a dearth of information regarding the origins and migration routes of MP in agricultural ecosystems, and further study is needed in a variety of farming environments with varying soil and climate conditions.

Keywords: Microplastic Pollution, Agriculture, Mitigation Strategies

1. Introduction

Plastic waste output continues to rise, placing enormous pressure on waste management systems and the environment. The fragmentation of larger plastic items, synthetic textile fibers, and agricultural practices such as the use of plastic mulch films, results in secondary MPs (MPs) (Qi, R et al., 2020). MPs are defined as plastic particles smaller than 5 millimeters, with significant implications for agricultural ecosystems and human health. To mitigate plastic pollution, countries following directives of the European Commission (EC), have started to regulate the production, consumption, and circulation of plastics. However, plastic is an invaluable, versatile, and lightweight material whose excellent mechanical properties, low specific weight, chemical inertness, and the economy in natural resources have established it as the most popular class of material for consumer and construction uses (dua, **S** et al., 2023).

Agricultural ecosystems are complex systems characterized by vital interactions between atmosphere, soil, water and biodiversity. Any disturbance of the balance of the system can bring about irreversible changes, significantly reducing crop survival and the growth of healthy plants. Regulating plastic pollution and mitigating the effects in soil health is of great priority to safeguard the foundation for food production, supporting human and animal life, while maintaining terrestrial biodiversity.

2. Methodology

Literature review was conducted in July 2024 using the “title, abstract, keyword” option with the following search string: “microplastics” AND "agricultural ecosystems" OR "agricultural soil" OR "policy regulation". The search string was designed to capture the scope of this research, regarding the presence and impact of MPs in agricultural systems and the on-going discussed regulatory frameworks related to the issue. The search resulted in 527 articles with the distribution of these articles over the years. The first reference is o noted in 2016 with only 2 articles, followed by a rising trend that reached 168 articles in 2023.

3. Microplastics in Agriculture

Agricultural plastic pollution poses a major environmental challenge, with over 12.5 million tons used annually—40–50% of which are plastic films (FAO,2024). Exposure to environmental conditions like UV radiation, mechanical stress, and microbial activity cause these films to breakdown into smaller particles over time, considerably contributing to MP contamination in agricultural soils. Continuous application of manure and other soil amendments, significantly increases the concentration of MPs into the soil upon application, as they have been found to contain MPs (Zhang, B et al., 2020). Irrigation water is another major source of pollution, containing high levels of fibers from synthetic textiles (64%) and polypropylene (40%) MPs originating from from wastewater, road dust, and runoff. (Zhang, B et al., 2020). The source of MPs in agriculture extends beyond direct agricultural activities by the farmer, as they also originate from roads, buildings and other activities at close distances, accumulating in agricultural soils after being transported by air and water runoff (secondary source) (Zhang, B et al., 2020).

The sequestration of MPs inside soil aggregates may have the potential to change the soil physical characteristics, including the texture, bulk density, porosity, water holding capacity and depth whereas the biological properties concern the soil organic carbon, microbial community, aggregate stability nutrient exchange as well as soil enzyme activity and biota (Qiu, Y. et al., 2018).

Polyacrylic fibers, polyamide beads, polyester fibers, and polyethylene fragments have been found to decrease soil bulk density and microbial activity and potentially increase the water holding capacity (de Souza Machado et al., 2018). Any decrease is the bulk density can positively affect soil aeration, root penetration and growth, but as the MPs accumulate, they can increase water evaporation, creating harsher conditions for plant growth (Hanif, M.N et al., 2024). While in another study, Wan et al. discovered that MPs derived from polyethylene films could speed up soil water evaporation by facilitating desiccation cracking on the soil's surface and forming channels for water movement. Although MPs increase the soil's surface area, their microscopic particles can also make the soil more hydrophobic restricting water flow and concentrating toxins harmful to plant roots. (Wan, Y et al., 2018).

MPs can have a major impact on nutrient cycles and the carbon cycle by increasing the dissolved organic matter by up to 324%, impacting the mobilization and availability of nutrients, as well as organic matter content. The action of several enzymes involved in the N-cycle, such as urease and acid phosphatase, has been found to be inhibited by the presence of MPs, thus reducing the availability of N for plants (Li, Z et al.,2023).

4. Mitigation strategies to overcome microplastic contamination

Mitigating MP pollution necessitates a diverse approach that includes strategies ranging from source reduction to end-of-life management. Mitigation could be accomplished by enacting legislation and regulations that promote the use of alternative materials, such as biodegradable plastics, or by encouraging people to use reusable things. Other environmentally beneficial techniques that businesses might take include reducing packaging and designing things in circular patterns (Fadeeva, Z.; Van Berkel, R,2021). Similarly, upgrading wastewater treatment facilities to sophisticated treatment methods can dramatically reduce the quantity of MP released into the environment (Xu,Z et al., 2021). Furthermore, consumer education on the effects of MP pollution can induce behavior change and reduce plastic waste production.

5. Conclusions & Outlook

MP pollution is a global environmental problem that threatens soil health, plant growth, and human health. In summary, the article emphasizes the importance of addressing MP pollution through a comprehensive and integrated approach that includes research, policy, and technology solutions, as well as interdisciplinary cooperation across many sectors.

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