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The Role of Biochar in Modifying Polyethylene Microplastic-contaminated Soil Properties

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Introduction

The global environmental crisis caused by plastic pollution has escalated with the increasing accumulation of microplastics in soil, oceans, and ecosystems. Among the various types of plastic, Polyethylene (PE) is one of the most commonly used polymers in the world, and it is also a significant contributor to microplastic contamination. The persistence of polyethylene in the environment, particularly in soils, has become a major concern due to its long-lasting and non-biodegradable nature. As these microplastics accumulate in the soil, they pose potential risks to soil health, fertility, and the functioning of various ecosystems.

In response to these growing challenges, biochar— a highly porous, carbon-rich material produced from the pyrolysis of organic biomass— has gained attention as a potential solution for mitigating plastic pollution. Biochar has been widely researched for its ability to improve soil properties and enhance soil health, particularly in relation to soil fertility, water retention, and microbial activity. Its application in microplastic-contaminated soils, specifically polyethylene micro plastics, has also shown promising potential for modifying soil properties and mitigating the adverse effects of plastic contamination. This article explores the role of biochar in modifying polyethylene microplastic-contaminated soil properties, with a particular focus on its impact on soil physical, chemical, and biological characteristics.

Description

Polyethylene microplastics, often defined as plastic particles smaller than 5 millimeters, are pervasive in the environment, including in agricultural soils. The widespread use of polyethylene products, such as plastic bags, packaging, and agricultural films, has contributed to the accumulation of microplastics in soils through direct deposition, fragmentation of larger plastic debris, and the breakdown of plastic waste materials. These microplastics are resistant to natural degradation processes due to their chemical structure, which makes them persist in the environment for hundreds of years. Polyethylene microplastics pose several threats to soil health, including physical and chemical alterations to soil structure, disruption of nutrient cycles, and negative impacts on soil microbial communities. These changes can lead to reduced soil fertility, impaired water retention, and decreased overall soil health. Additionally, microplastics may interact with soil organisms, leading to potential bioaccumulation of toxic substances, which can then enter the food chain. As a result, the management of microplastic contamination in soils has become a priority in environmental research [1].

Polyethylene microplastics can adversely affect the physical structure of soils, leading to decreased porosity, reduced water retention, and impaired root growth. The accumulation of microplastics may also alter the aggregation of soil particles, making it more difficult for water and air to penetrate the soil. This disruption in soil structure can lead to poor soil aeration and reduced root access to nutrients, ultimately affecting plant health. Biochar, with its high porosity and large surface area, can help mitigate these physical alterations caused by polyethylene microplastics. When added to microplastic-contaminated soil, biochar enhances soil aggregation by improving the soil's physical structure. The porous nature of biochar improves soil porosity, allowing for better air and water infiltration. Additionally, biochar helps retain moisture in the soil, improving the overall water-holding capacity of the soil and making it more resilient to drought conditions. Moreover, biochar's ability to stabilize soil aggregates helps reduce the negative effects of microplastic contamination on soil structure. By improving soil aggregation, biochar promotes a healthier root environment, which is essential for maintaining plant growth and agricultural productivity [2].

Polyethylene microplastics can alter the chemical properties of soils, including nutrient availability, pH levels, and soil toxicity. Microplastics may leach chemical additives, such as plasticizers, stabilizers, and flame retardants, which can contaminate the soil and affect its chemical balance. These substances can disrupt nutrient cycles, inhibit microbial activity, and negatively impact plant growth. Biochar can help mitigate these effects by improving the chemical properties of microplastic-contaminated soils. The alkaline pH of many biochar types can help neutralize acidic soils, creating a more favorable environment for plant growth. Furthermore, biochar's high Cation Exchange Capacity (CEC) enables it to retain and slowly release nutrients, such as nitrogen, phosphorus, and potassium, which are essential for plant health. This nutrient retention can be particularly important in microplastic-contaminated soils, where nutrient leaching may be a concern due to the physical disruption of the soil structure by the microplastics. Additionally, biochar can act as a sorbent for toxic chemicals leached from polyethylene microplastics, helping to immobilize these harmful substances and reduce their bioavailability in the soil. This immobilization reduces the risk of bioaccumulation in plants and soil organisms, preventing the spread of toxins through the food chain [3].

Soil microorganisms play a vital role in maintaining soil health by breaking down organic matter, recycling nutrients, and promoting plant growth. Polyethylene microplastics can disrupt soil microbial communities by physically obstructing microbial activity, reducing microbial diversity, and introducing toxic substances that affect microbial growth. The introduction of biochar into microplastic-contaminated soils can support soil microbial communities by providing a habitat for microorganisms. The porous structure of biochar offers a protective microenvironment for beneficial soil organisms, allowing them to thrive even in the presence of microplastics. Biochar also serves as a carbon source for soil microbes, promoting microbial growth and activity. Biochar's large surface area and adsorptive properties enable it to capture and immobilize polyethylene microplastics in the soil. When polyethylene microplastics come into contact with biochar, they may adhere to its surface, preventing them from moving through the soil profile and reducing their potential to impact soil organisms and plant roots. This adsorption mechanism is particularly important for mitigating the long-term effects of microplastic contamination, as it helps contain microplastics within the soil and reduces their potential for migration into groundwater or surface water systems. Furthermore, biochar can enhance the biodegradation of polyethylene microplastics by providing a surface for microbial colonization. Microorganisms may break down microplastics over time, and biochar can act as a substrate for these microbial communities, promoting the natural degradation of polyethylene in the soil. While polyethylene is known to be highly resistant to degradation, biochar may

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help accelerate the biodegradation process by fostering microbial activity that can slowly break down the polymer [4,5].

Conclusion

The application of biochar to polyethylene microplastic-contaminated soils offers a promising solution to mitigate the negative effects of microplastic pollution on soil properties. Biochar's ability to improve soil physical, chemical, and biological characteristics, along with its potential to adsorb and immobilize microplastics, makes it a valuable tool for restoring soil health and promoting sustainable land management practices. As research continues to explore the full potential of biochar in addressing plastic contamination, it is clear that biochar-based strategies could play a critical role in combating the growing environmental challenge posed by microplastics in soils.

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Conflict of Interest

There is no conflict of interest by author.

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