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Microplastics: A Boon or a Bane?

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The global demand for plastic has rapidly grown, leading to an annual production exceeding 359 million tons of synthetic polymers. This widespread use of plastics has become an integral part of our daily lives [1]. Microplastics (MPs), debris smaller than 5 mm in size, pose potential harm and obnoxious contamination [2]. It is predicted that by 2050, the production of plastic waste will increase to 12,000 million tons. Despite considerable efforts in recycling, repurposing, or incinerating plastic, 32% of all plastic waste continues to enter the natural environment. Terrestrially derived plastic waste contributes to approximately 80% of marine plastic pollution, and it is within terrestrial ecosystems, particularly in the biosphere, where the highest concentrations are frequently observed. This accumulation of plastic in terrestrial ecosystems serves as a long-term reservoir, potentially impacting freshwater and marine ecosystems for decades[1, 3].

The floatable and persistent nature of MPs contributes to their widespread dispersion in aquatic environments through ocean currents, acting as carriers for pollutants [4]. MPs with their large surface areas and hydrophobic properties, adsorb diverse toxic substances such as antibiotics and fungicides, leading to a reduction in their concentrations in water [5]. Yet, the adsorption of toxic substances onto MPs increases the long-range transport in aquatic environments, potentially resulting in ingestion by aquatic organisms. This, in turn, triggers food web transfer and bioaccumulation, intensifying the ecological risks associated with these contaminants [5, 6].

MPs and toxic substances in aquatic ecosystems are influenced by multiple factors. Following exposure, the hydrophobic surfaces and coated conditioning layers of MPs provide a suitable environment for microbial colonization, fostering biofilm formation. In natural settings, around 6% of total plastic particles are linked to biofilms [7]. The presence of biofilms on MPs provides an enhancement in their adsorption capacity for lead, copper, and xenobiotic compounds. Evidence suggests that biofilms attached to MPs have the potential to alter the transport and fate of toxic substances, affecting both adsorption and degradation processes [8, 9].

MPs, as emerging contaminants, pose a potential threat to global terrestrial ecosystems, including agroecosystems. Interestingly, they can also be viewed as having positive effects on agricultural

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soil fertility and quality. MPs have been associated with positive outcomes, including increased soil enzyme activity, soil cation exchange capacity, and organic carbon content. Conversely, they have been linked to decreasing soil bulk density, affecting overall soil quality [10].

MPs possess the ability to affect the soil properties by altering their physical structures, owing to the distinctive characteristics of soil.

MPs can affect essential soil biogeochemical processes by altering soil properties, forming specific microbial hotspots, and affecting microbial activities and functions. The diverse characteristics of MPs, including polymer type, shape, and size variations, result in distinct effects on soil organic matter decomposition, nutrient cycling, and greenhouse gas production. The notable rise in bioavailable carbon, stemming from the decomposition of biodegradable MPs, amplifies microbial and enzymatic activities. This has the potential to accelerate soil organic matter mineralization, thereby intensifying nutrient competition between plants and microbes. Consequently, biodegradable MPs may pose a greater risk to plant growth compared to petroleum-based MPs. Despite potential benefits in agroecosystems, such as enhanced soil structure and aeration, these advantages are believed to be outweighed by potential drawbacks [1, 10].

Overall, MPs are both boon and bane. Although they have beneficial uses, they will have harmful impacts on nature. MPs pose a global environmental challenge, prompting widespread concern regarding their potential ecological risks. Given the limited understanding of plastic behavior in the environment, making informed decisions about future policies for safe use in ecosystems is currently unattainable. It is imperative to conduct systematic investigations on the safety of MPs in ecosystems to address this knowledge gap. For sustainable development and reduction in the future, it is required to implement principles of reducing, reusing, and recycling of plastics.

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