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Review

Algae: a frontline photosynthetic organism in the microplastic catastrophe

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Recalcitrancy in microplastics (MPs) contributes to white pollution. Bioremediation can remove MPs and facilitate environmental sustainability. Although recent studies have been conducted on the interaction of algae and MPs, the role of algae in MP removal with the simultaneous implementation of 'omics studies has not yet been discussed. Here, we review the adverse effects of MPs on the environment and possible approaches to remove them from the aquatic environment by using algae. We highlight the mechanism of MP biodegradation, the algal species that have been used, and how these are affected by MPs. We propose that algomics, characterization of biodegrading enzymes, and genetic engineering could be effective strategies for optimizing MP degradation.

Highlights

Microplastics (MPs) pollution is a challenge to both environmental and human health.

Recent studies on the interaction of algae and MPs have contributed to the understanding of algal responses to the effects of MPs.

Aggregation of algae and MPs is a key for MP removal approaches.

Application of algae with 'omics and genetic engineering could be an effective strategy for enhancing MP biodegradation.

Fate and diversity of microplastics

The production of plastic products has expanded exponentially due to the economic feasibility and availability of plastic commodities in many aspects of everyday life [1]. The world's plastic production reached 360 million tons (Mts) in 2018 compared with 348 Mts in 2017 [2]. Polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyamide (PA), and polyurethane (PUR) are plastics that account for 90% of global plastic production [3]. These **polymers** (see Glossary) comprise various elements (such as carbon, hydrogen, oxygen, nitrogen, silicon, and chloride) and other chemical additives are applied to obtain the desired properties [4].

Plastic pollution includes **MPs**, which has catastrophic impacts on the environment and contributes to the top-ten emerging pollutants in the world [5]. Globally, floatable MPs, >100 μm in size, in marine environments are on the order of 12.5–125 trillion particles [6]. The main types of MPs, according to their origin, are primary and secondary MPs. Primary MPs are plastic pieces designed to be small and are generated as nurdles (including glitter and microbeads) used in personal care products or cosmetics [2]. Secondary MPs are plastic particles (such as road wear, tire abrasion, and films) derived through mechanical fragmentation and photooxidative processes of large plastics [7]. Of the total MPs released into aquatic ecosystems annually, 21% comprises primary MPs, whereas secondary MPs account for the remaining 79% [8]. The interactions of MPs with the soil–plant system is one of the important issues closely related to food pollution and human health [9].

MPs have garnered attention because of their hydrophobicity, large specific surface area, and propensity to accumulate inorganic and organic contaminants and harmful microorganisms [10]. MPs hold and carry toxic substances and, thus, have adverse effects on life once ingested by organisms [11]. MP removal is challenging because they cannot be collected for recycling or removed after entering freshwater or marine ecosystems [12]. Therefore, the development of techniques to facilitate plastic degradation has sparked increasing research attention. It has

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