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Biotechnology advances for dealing with environmental pollution by micro(nano)plastics: Lessons on theory and practices

Ana B. Silva[1], Monica F. Costa[2] and Armando C. Duarte[1,3]

Abstract

Plastic pollution has become a global problem and a threat for environmental and human health. The management of plastic pollution has been mainly focused on macroplastics, involving several strategies such as legislation and waste management. Education and awareness are increasingly used for controlling the demand of disposable plastic items, for the increase of the recycling effectiveness and for raising consciousness regarding plastic pollution impacts on the environment. Biotechnology tools, as discussed in this review, are currently under development for the remediation of plastics, and particularly, micro(nano)plastics, and demonstrated to be promising in facilitating degradation and subsidizing research on a new generation of biodegradable plastics.

Addresses

[1] Departamento de Química, Universidade de Aveiro, 3810-193 Aveiro, Portugal

[2] Laboratório de Ecologia e Gerenciamento de Ecossistemas Costeiros e Estuarinos, Departamento de Oceanografia da Universidade Federal de Pernambuco, CEP 50740-550 Recife, Pernambuco, Brazil

[3] Centro de Estudos do Ambiente e do Mar (CESAM), 3810-193 Aveiro, Portugal

Corresponding author: Silva, Ana B (abls@ua.pt)

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Introduction

Micro(nano)plastics size confers unique features that are not shared with larger items found at sea, rendering these a potential route for bioaccumulation and bioamplification of chemicals through the food webs.

When released in the environment, most plastic items are not readily degradable, since these are intrinsically resistant and often contain additives conferring additional durability [1]. As a result, the degradation rate does not make up for the inputs of plastics, leading to their accumulation in the environment. However, the prolonged exposure of large plastic items to the environmental settings yields progressively micro(nano) plastics [2].

Microplastics consist of plastic particles with less than 5 mm in diameter and can be intentionally produced for the manufacture of plastic products (resin pellets), used in cosmetics (microbeads) and as industrial abrasives (powders) [2]. Dust resulting from tyre wear is also a source of microplastics and microfibres can be released from textiles during washing [3]. Nanoplastics (<1 μm) are ever increasingly employed, for example in electronics and medicine, leading to a consequent increase in their production and also in the likelihood of release [4]. One way or another these particles find their way to the environment, and can be transported through the atmosphere, watercourses and ocean, aided by wind, rain and biological vectors, which makes them untraceable to the source [2,5]. Consequently, these particles have invaded every environmental compartment [2,6–8].

Micro(nano)plastics pollution is expected to rise, even if the release of larger plastics become relatively more under control, because of degradation of plastic litter already in the environment. Due to their small size, these particles can easily be ingested and accumulated in a diverse range of organisms, leading to physical and chemical harm [7]. Moreover, they may leach adsorbed organic pollutants and metals to the organisms, eventually leading to their bioaccumulation and bioamplification through the food webs [7–9]. Nanoplastics' impacts on organisms are more complex and not yet fully understood. These particles can penetrate cell membranes and the adsorbed chemicals can directly interfere in metabolic pathways, possibly leading to disruption of cell function [2,8].

Public health may also be affected by micro(nano)plastics, either by the exposure to contaminated seafood or to water contaminated with pathogens transported by these particles ("microbial hitchhikers") [2,10]. Furthermore, economic activities like fishing, aquaculture and tourism are also negatively impacted [2,3].

Perceiving the multiple impacts of these pollutants is of great importance to establish efficient strategies to reduce their inputs and passives in the environment [11,12*]. Fig. 1 evidences the role of regulatory entities, science, plastic producers and consumers influencing the environmental micro(nano)plastics pollution, as well as the potential actions towards its mitigation.

According to Rochman (2016) [13], plastics pollution mitigation strategies are more effective when based on scientific evidence. However, this pollution has been managed mainly regarding macroplastics [14]: there is a large number of instruments that include regulations, action plans and guidelines that have been adopted at regional, national and international levels aiming at the management of macroplastic pollution [12*,15]. But since micro(nano)plastics are a central marine pollution issue, they were also included in national and international policies regarding pollution control, food security and nature conservation [12*,14–16]. The development of prevention and mitigation tools (legislation, technologies and capacities) is an integral part of the strategies designed to solve problem [17], as the insufficiency of current policies has demonstrated the need for multidisciplinary strategies [12*].

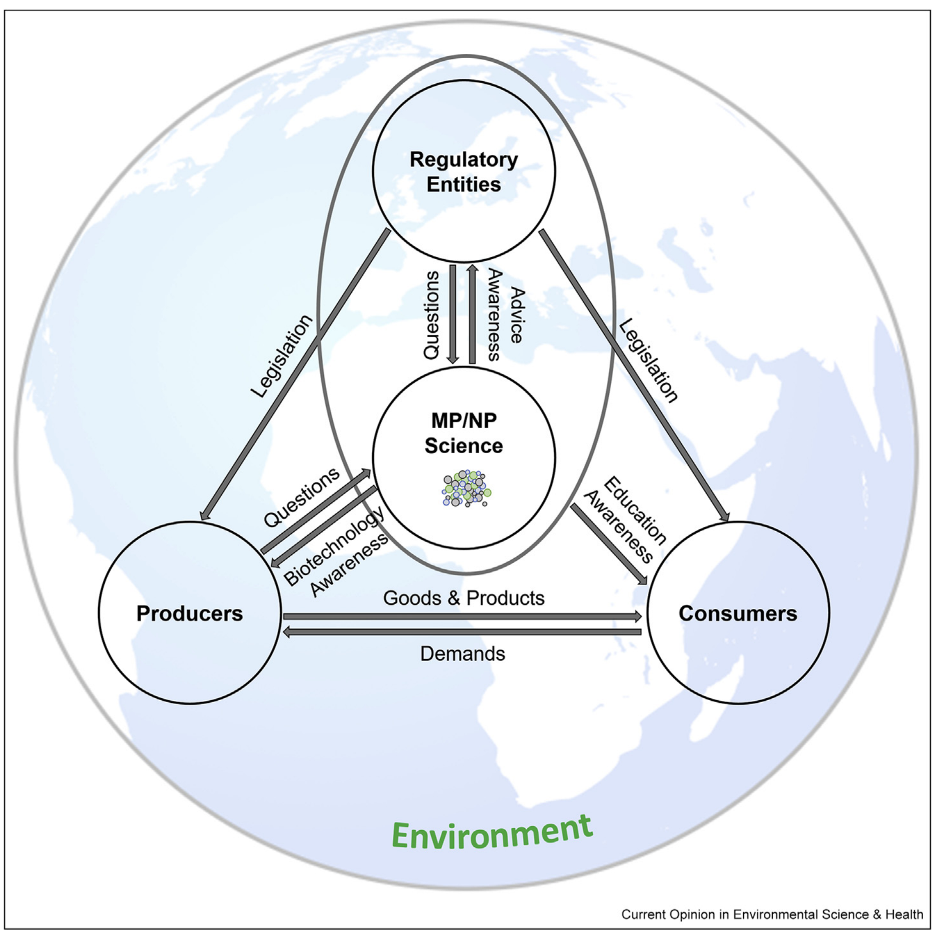
Even though preventive measures are the most effective for dealing with the bulk of micro(nano)plastics pollution [5,12*], bio-based strategies are increasingly sought after and may be integrated in mitigation procedures. In this context, the aim of this review is to briefly address the current biotechnological developments for mitigation of micro(nano)plastics, as well as to evidence the role of these tools in the context of a multidisciplinary approach.

Biotechnological tools

Currently, biotechnology has been presenting itself very promising, namely concerning the mitigation of plastic pollution, providing primarily two bio-based strategies:

- production of biodegradable plastics;
- use of organisms capable of degrading plastics.

Fig. 1



Potential approaches for dealing with mitigation of micro(nano)plastics pollution in the environment. Each sector (regulatory entities, science, plastic producers and consumers) influences the environmental pollution by micro(nano)plastics and has the potential to act towards its mitigation. MP – microplastics; NP – nanoplastics.

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