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Will Plastic-Eating Bacteria Shift Towards Sustaining and Improving Our Environment?

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Abstract

Plastic pollution is a significant problem globally, which contaminates oceans and surrounding environments, posing huge risks to agricultural communities, ecosystems, and their inhabitants. The collective impact of this pollution also has negative consequences for human health. Climate change is also impacted by plastic pollution, with 3.4% of greenhouse gas emissions generated from the carbon footprint throughout the entire life cycle of plastic production to waste. In this article, a short review of plastic-eating bacterial species is discussed, and the underlying benefits and ethical implications that may arise from their introduction into our ecosystems. However, it should be noted that the quantity of plastic waste in comparison to the enormous quantities of bacteria needed to degrade all plastic waste produced is not viable and may be a significant limitation. The risks of releasing such large quantities of bacteria into the environment mean that the use of these bacteria should only be used under controlled conditions, i.e., not released into the environment freely, and in conjunction with other plastic waste reduction methods such as education, change in manufacturing materials and methods.

Sustainability within a growing population presents significant challenges, especially amongst waste that is generated in our communities. Each year it is estimated that around 250 billion plastic bottles alone are not recycled, with over 29 million tonnes of plastic waste contaminating oceans[7,8]. This magnitude of waste is increasing each year, meaning that we must aim to minimise the use of plastic and be very conscious of how our waste is disposed of. Ethical issues arise with plastic waste such as the extreme environmental damage observed in countries such as China and Malaysia amongst others. It has been reported that recycling from the UK is often shipped abroad and recycling standards are not upheld, meaning that significant proportions could end up in landfills unnecessarily[5].

The sheer quantity of our waste poses substantial threats to marine wildlife and their habitats, with up to 700 species impacted, for example, seabirds, whales, and dolphins[1]. The highest cause of death within marine wildlife involves entanglement and starvation because of plastic contamination. It is noteworthy that ecological disruption may impact food production and climate change.

In 2016, *Ideonella sakaiensis* was identified as a candidate bacterium for plastic-eating bacterial research[13]. *I. sakaiensis* are aerobic gram-negative rod-shaped bacteria with structural capabilities that enable resistance and degrade polyethylene terephthalate (PET), commonly found in plastic bottles. Plastic-eating bacteria provide a variety of benefits such as degrading plastic waste and converting polyethylene terephthalate into adipic acid, which is useful in pharmaceuticals, the food industry along with others[12].

Research has also found other species such as strain-specific *Escherichia coli*, which has been genetically modified in vitro to amplify enzyme synthesis thus, more effectively breaking down PET into adipic acid[12].

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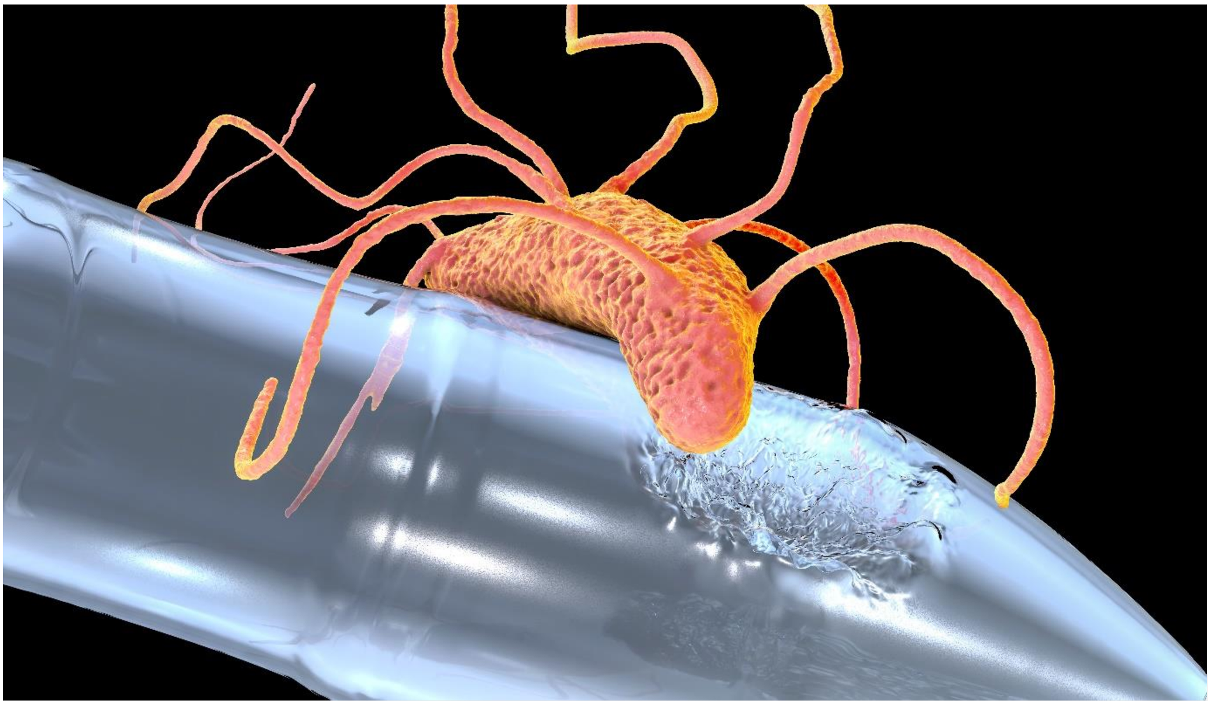

Figure 1. *E. coli* degrading polyethylene terephthalate illustration[3].

Several bacterial candidates for genetic engineering to enhance plastic breakdown have been identified. However, there are currently limitations exhibited in plastics with characteristics such as longer polymer chains, and additives such as heat stabilisers affecting the rate of breakdown[2]. Other microorganisms have also been identified that bio deteriorate heated, or UV-treated polypropylene (PP), such as the soil-based fungi *Aspergillus terreus* and *Engyodontium album*[9]. PP plastic has only a 1% rate of recycling and has been observed as the highest proportion of plastic pollutants (see Figure 2). It is also evident that different bacterial species are affected by physicochemical influences such as such as specific temperatures that do not occur naturally in the environment, and each type of plastic has different structural properties which means that not all plastics can be broken down by one type of bacteria, presenting further complexity[6].

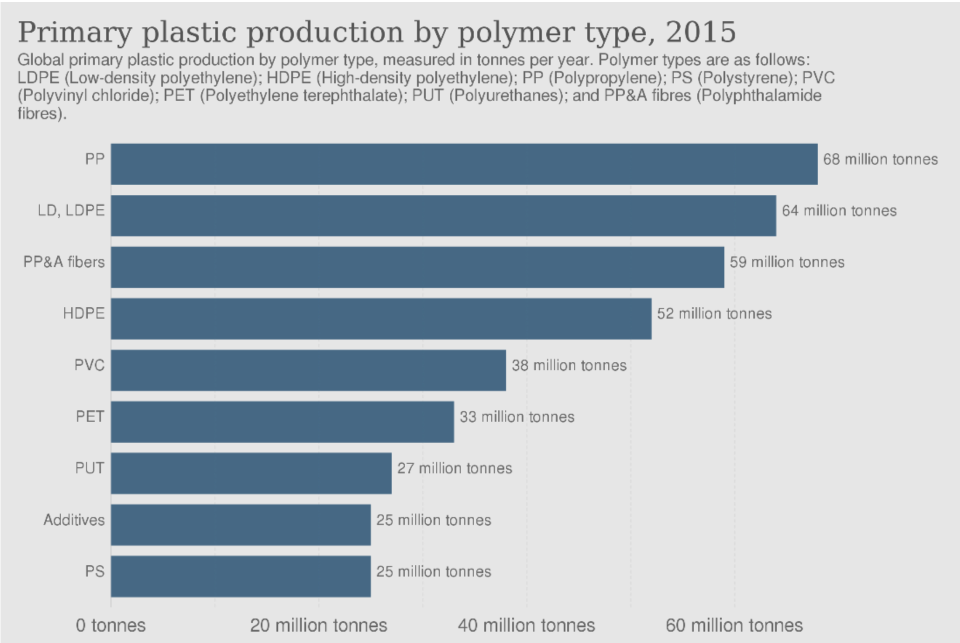

Figure 2. Plastic pollution per type of plastic[4].

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Genetic engineering poses a wide array of ethical implications and poses challenges such as unpredicted ecological impact and questions around biodiversity amongst existing bacterial species in our ecosystems. With genetic engineering careful consideration of environmental impacts, biological diversity, and societal impacts they present. For example, if imbalances were to occur within the environment where the genetically engineered bacteria had been released, this may pose a threat to other bacterial species in the same environment in terms of competition and survival, in turn affecting plant life. Another example may be that some genetically engineered organisms may pose potential threats to human health.

Another challenge is the proportion of bacteria compared to the amount of plastic waste. Thus, will there be enough quantity of bacteria to sustainably breakdown all our plastic waste?

Lack of funding may also be a potential drawback of generating and deploying plastic-eating bacterial species, which may also disproportionally impact lower socio-economic countries. Currently in the UK BBSRC (Biotechnology and Biological Sciences Research Council) and NC3Rs (National Centre for the Replacement, Refinement and Reduction of Animals in Research) is funding approximately £4.7 million into research alongside biome bioplastics[10]. NERC (Natural Environment Research Council) has funded £3 million in research from 2020-2023 in Southeast Asia due to the concerns of this region producing the highest plastic pollution globally[11]. With the funding currently being spent on research, more is needed to combat the scale of the problem.

To conclude, plastic-eating bacteria provide significant potential in degrading a variety of plastics. However, more research is needed to determine the complexities behind additional challenges presented in the deployment of these species into our environment. As beneficial as these species may be, additional measures must also be used in conjunction such as education on recycling schemes, waste reduction methods, change in packaging manufacturing processes, and environmental clean-up volunteering.

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