European Commission

Science for Environment Policy

Biodegradable plastics: testing can help inform most appropriate end-of-life options, but also reveals environmental concerns

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Scientists have tested the behaviour of biodegradable plastics in managed composting and anaerobic conditions, as well as under simulated environmental conditions, such as in seawater or soil. This study found that blending different types of biodegradable plastics may open up new opportunities in relation to their end-of-life treatment — notably the potential to make one of the world's best-selling biodegradable plastics, polyactic acid (PLA), home-compostable by blending it with another polymer (polycaprolactone — PCL). However, the researchers were also concerned that most materials tested could still cause plastic pollution as they failed to biodegrade sufficiently — and, in some cases, not at all, in particular, in soil and the marine environment.

Biodegradable plastics are often promoted as an environmentally friendly alternative to conventional plastics. However, most of the time it is not clear how efficiently they degrade — either under managed conditions, such as composting facilities — or in the natural environment. This lack of clarity is compounded by the fact that biodegradable plastics are often blended, to create a stronger or more flexible material. This study found all mixtures of plastics tested reached the biodegradation standard under industrial composting conditions.

The results of this EU-financed study[1] suggest that biodegradable plastics can generate biogas as they biodegrade which, in the context of an anaerobic digestion plant, can serve to produce electricity. However, their post-consumer management needs careful consideration, as does the design of products made from these materials.

The researchers investigated the fate of six different types of biodegradable plastics used, for example, in packaging and medical applications: polylactic acid (PLA), polyhydroxybutyrate (PHB), polyhydroxyoctanoate (PHO), poly(butylene succinate) (PBS), thermoplastic starch (TPS) and polycaprolactone (PCL). They also tested nine different blends of these materials, which were mixed in different ratios to achieve certain characteristics such as flexibility or increased strength.

Samples of these materials were studied in the lab under various simulated conditions. Three of the lab conditions mimicked managed end-of-life options: industrial composting, home composting and anaerobic (airless) digestion. Another four simulated environmental conditions: soil, seawater, freshwater and anaerobic sludge.

The scientists explored whether the materials met international standards for biodegradation set by the ISO and ASTM, under these lab conditions. For instance, plastics must biodegrade within one year at a temperature of 28°C to meet the home composting standards of the International Organization for Standardization (ISO) 14855.

TPS and PHB were the only bioplastics to degrade according to the standards across all seven of the tested environments. The least degradable materials were PBS and PHO, which only biodegraded in the industrial composting environment.

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1. EU Horizon 2020 project P4SB - From Plastic Waste to Plastic Value Using Pseudomonas putida Synthetic Biology

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These results are of concern, as they suggest that, if improperly managed at end-of-life, biodegradable plastics still contribute to plastic pollution. They are likely to degrade even more slowly in the real world, where temperatures are cooler, than for test conditions (e.g. 25 °C for soil tests and 30 °C for marine tests). More generally, the researchers recognise that the temperatures used in international tests applied in this study are higher than temperatures in the unmanaged environments that tests mimic — an aspect to be carefully considered when shaping plastic waste policies and plastic product design.

However, there were also positive results. Surprisingly, PLA met the ISO criteria for home composting when it was blended with PCL at a 80/20 ratio. After 259 days at a temperature of 28°C, the PLA-PCL blend was shown to be as degradable as cellulose (plant fibre), which the study used as a comparison. On its own, PLA is not home-compostable as it needs temperatures of over 50°C to biodegrade.

It is important to note that, while the clear majority of biodegradable plastics appear to degrade under anaerobic digestion conditions, their degradation time is three to six times longer than the retention time in industrial anaerobic digestion plants.

Furthermore, when bioplastics break down under anaerobic conditions, as found in landfill, they release CO_2 and methane and contribute to climate change, suggesting it is imperative that biodegradable plastic are managed and directed to the appropriate organic stream in collection, the researchers note. They argue, however, that under controlled anaerobic conditions, the emissions could be harnessed as a form of renewable energy. Methane can be used as biogas, which can be used to produce electricity. Plastics in this study could potentially produce 265–600 litres (L) of methane per kilogram (kg) of bioplastics, compared with 200–529 L/kg for food waste.

The researchers comment that biodegradable plastics should not be perceived as an undesirable contaminant in waste streams. It is more important for waste management to adapt to evolving compositions of waste, they suggest.

A better understanding of the behaviour of biodegradable plastics and their blends could also help inform product design; for example, plastic that biodegrades well in seawater could be prioritised for marine products, which have a higher chance of being unintentionally released into the sea. In this study, only PHB and TPS biodegraded in seawater, under laboratory conditions with a temperature of 30 °C ± 1.