ENVIRONMENTAL INVESTIGATION AGENCY

Ocean

Unpacking non-conventional plastics

Introduction

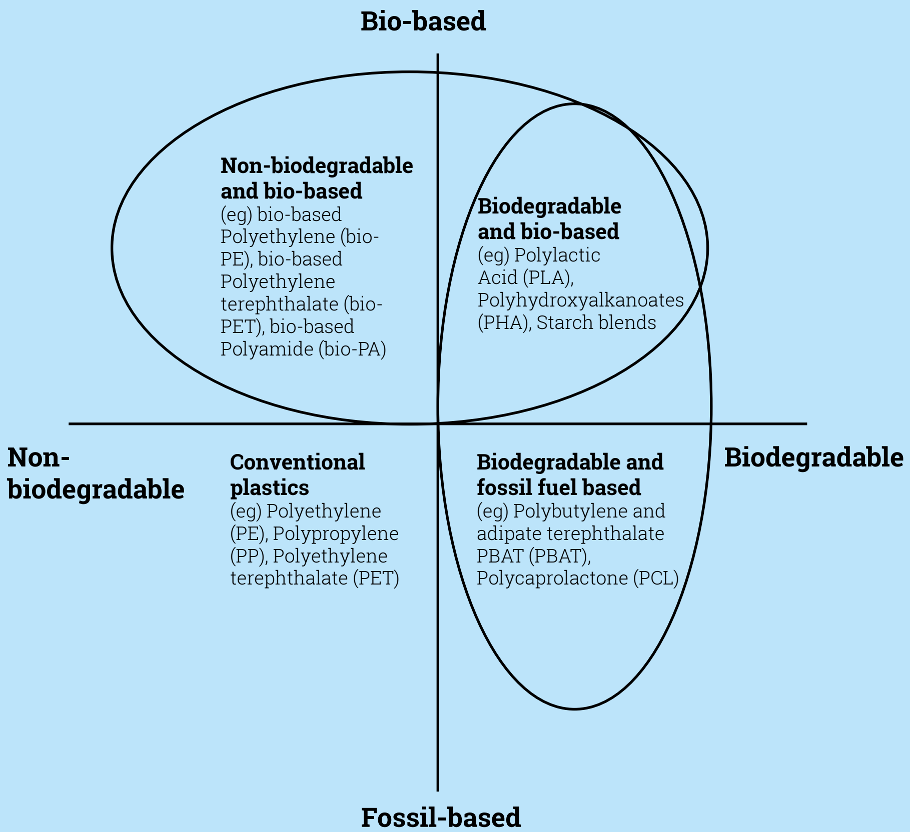
As the debate on plastics heats up, non-conventional plastics including biodegradable, bio-based, compostable and oxo-degradable are sometimes promoted as sustainable alternatives as companies and policy-makers look to shift away from polymers derived from fossil fuels.

This briefing gives an overview of four commonly considered non-conventional plastics. Information is presented in a table providing background details and assessing how far they present a sustainable solution.

Given that no finished product has yet been proven to be marine biodegradable, all alternatives will continue to pose a risk to marine life if they leak into the natural environment. Furthermore, their widescale adoption could present additional problems such as putting undue pressure on natural resources; complicating waste collection and recycling systems, and causing microplastic pollution if the conditions required for full biodegradation are not met.

While there may be a limited role for some non-conventional plastics, they are not a silver bullet solution to the plastics crisis, which requires a more comprehensive strategy emphasising reduction, reuse, redesign and recycling.

What you mean by bio-plastics?



Summary of non-conventional plastics

- **Bioplastics:** 'Bioplastics' is an ambiguous term used to describe materials and products which are bio-based, biodegradable or both.[1] Bio-based plastics are those at least partially constituted of organic materials, while biodegradable plastics are those which break down into natural elements under certain conditions. Biodegradable plastics can be manufactured from both fossil fuels and biomass.
- **Biodegradable:** Biodegradable plastics break down under certain conditions through the actions of naturally occurring micro-organisms, within a timeframe specified by industry standards. Conditions required for rapid and full degradation are rarely met in the natural environment, thus the plastics will pose a hazard to marine life if they leak into the ocean or persist as micro- and nano-plastic fragments.[2] If incorrectly sorted, they can contaminate recycling systems.[3]
- **Bio-based:** These are derived, at least in part, from organic matter, predominantly from agro-based feedstock such as corn but they can also be produced from waste or by-products.[4] To meet current plastics demand with bio-based feedstocks would divert land from agriculture or require conversion of natural habitats, neither of which are desirable. They do not necessarily break down any faster than conventional plastics and, like biodegradable plastics, will pose threats if they leak into the ocean. Given the interest in bio-based products, there is an urgent need to fully assess the potential impacts of growth in their use.
- **Compostable:** Compostable plastics break down through biological processes, yielding CO_2, water, inorganic compounds and biomass.[5] Depending on the polymer, they are treatable through home or industrial composting systems. Conditions required for industrial composting are not be found in the natural environment, thus these plastics do not provide a solution to plastic pollution. If they are not separately collected and sorted, they could also contaminate recycling streams.[6]
- **Oxo-degradable:** These are conventional polymers with chemicals added to speed up degradation. However, significant evidence suggests oxo-degradable plastics do not fully biodegrade but fragment into small pieces, contributing to microplastics pollution.[7] They can contaminate conventional recycling streams.[8] Experts have provided evidence that oxo-degradable plastics are not suited for effective long-term reuse, recycling at scale or composting.[9]
- **Marine-biodegradability:** There is no international or European standard for biodegradability. A conformity mark has been developed for products described as biodegradable in seawater by Vinçotte, known as 'OK Biodegradable MARINE'. The biodegradability component of this certificate is based on the now-withdrawn international standard ASTM D7081-05 and such products should therefore not be considered as safe for the marine environment. The test procedures involved do not address the impacts on multispecies communities and biogeochemical processes, and the toxicity assays required by the OK Biodegradable MARINE label do not account for the ability of microplastic particles to adversely affect aquatic organisms.[10]

	Biodegradable plastics	Bio-based plastics	Compostable plastics	Oxo-degradable plastics
Definition and relevant standard	Biodegradable plastics break down through the actions of microorganisms.[11] Complete biodegradation occurs when none of the original polymer remains. The main standards used to demonstrate plastic biodegradability under industrial conditions are EN 13432:2000 and ASTM 6400-12. Both require the test material to yield 90 per cent of its organic fraction within 180 days. Other criteria cover the material's disintegration under test conditions and its potential toxicity. Currently, there is no standard providing pass/fail criteria for marine bio-degradation.[12] US legislation ASTM D7081 defined marine degradable plastics as materials that, besides full biodegradation in a composting test, reach 20 per cent biodegradation in a marine test within six months, and at least 70 per cent disintegration within three months. This was withdrawn without replacement.[13]	Bio-based plastics are derived (at least partially) from organic materials such as starch, cellulose, oils (e.g. rapeseed oil), wood and proteins.[14] Most European bio-based plastics (~80%) are starch-based, from maize, potatoes and cassava.[15] Bio-based plastics can also be derived from waste feedstock materials, and from microalgae.[16] Bio-plastics can indicate 'bio-based carbon content', measured by EU standard CEN/TS 16137 and US standard ASTM 6866.[17] The European Committee for Standardisation is currently developing measures for the indication of bio-based content.	Compostable plastic breaks down through biological processes, yielding CO_2, water, inorganic compounds and biomass.[18] They are manufactured from either fossil-based or bio-based materials and, depending on the polymer, can be recovered through home or industrial composting systems. EU standard EN 13432 defines industrial compostability[19]: • Biodegradation: It biodegrades at least 90 per cent within six months under controlled composting conditions (58 +/- 2°C). • Chemical characteristics: It contains at least 50 per cent organic matter, not exceeding a given concentration of heavy metals. • Disintegration: It fragments into pieces smaller than 2mm under controlled composting conditions within 12 weeks. • Ecotoxicity: Compost obtained does not cause negative effects (e.g. on plant germination). There are no current standards for home compostable plastics.	Oxo-degradable plastics are conventional polymers with chemicals added to accelerate fragmentation under UV light and/or heat, and oxygen.[20] Oxo-degradable plastics do not fulfil the requirements of relevant standards for composting, such as ISO 18606, EN 13432, ASTM D6400, AS 4736 or GreenPla, as their biodegradation takes too long, and plastic fragments can remain in the compost.[21]
Example polymers	PBS, PCL, PBAT, PVOH, bio-PVOH, bio-PBS, PHA	Bio-PET, bio-PE, PEF, bio-PP, bio-PA, bio-PVOH, PHA	PLA, ecovio®, starch-based polymers, cellulose-based polymers	Oxo-degradables are made from polymers such as PE, PP, and PS containing extra ingredients (metal salts)
Conditions for degradation	EN 13432 and EN 14995 require at least 90 per cent disintegration after 12 weeks and 90 per cent biodegradation after six months, with tests on ecotoxicity and heavy metal content.[22] Conditions required for rapid biodegradation are rarely met in the natural environment. For example, some need prolonged exposure to temperatures of 50°C+.[23] No finished product has been approved as marine biodegradable.[24] There is a disparity between the timescale specifying 180 days for 90 per cent biodegradation of plastics, and the typical UK industrial composting process, which rarely runs beyond three months.[25] Furthermore, infrastructure for composting bio-plastics is not widely available.	Some bio-based plastics are also biodegradable (PHA, bio-PBS, bio-PVOH), but biodegradability is not a necessary criterion.[26] Many will take as long as conventional plastics to break-down.	Composting is divided into two stages: active composting (minimum 21 days), followed by curing.[27] Industrial composting facilities range between 50°C and 60°C. For hygiene purposes, temperatures need to remain above 60°C for a week. Many compostable plastics take around 60-90 days to compost industrially, but some facilities operate on shorter cycles (i.e. 30 days).[28] Home compostable products must be treatable at ambient temperatures. The timeframes for biodegradation and disintegration can be longer. Parameters such as moisture content, aeration, pH, and carbon to nitrogen ratio do not need controlling.	Oxidation enables faster fragmentation. In theory, this accelerates biodegradation. This process depends on multiple criteria that vary significantly in practice, including fragment size, quantity of additives, and environmental conditions (e.g. temperature, biotic factors).[29] Studies show that the entire process varies and often takes (much) longer than claimed – with approximately 98 per cent of material remaining after 40 weeks under a test rig.[30]
Impact on marine species	Even under the most optimistic biodegradation time horizons, biodegradable plastics could cause death and injury to marine life through entanglement and ingestion. A study found that once ingested by sea turtles, biodegradable plastic mass reduced by just 4.5-8.5 per cent over 49 days.[31] Existing biodegradability standards and test methods for aquatic environments do not involve toxicity testing, or account for the potentially adverse impacts of polymer degradation or microscopic plastic particles arising from fragmentation.[32] A UNEP report concluded that biodegradables *"will not bring about a significant decrease either in the quantity of plastic entering the ocean or the risk of physical and chemical impacts on the marine environment"*.[33]	Bio-based plastics, including those commonly considered biodegradable, will pose threats to marine species if they leak into the ocean.. For example, over 600 days, PLA weight loss of just 2.5 per cent was observed in a stimulated marine environment.[34] UNEP notes that increasing use of biopolymers will not reduce the amount of plastic waste reaching the ocean or landfill.[35]	Given that the conditions required for industrial (and even home) composting are unlikely to be met in the marine environment, these plastics will pose a threat if they leak into the ocean. While they may fragment, there is little information on their biodegradation in aquatic environments and further research is required to understand if problems will arise from fragmentation into microplastics.[36]	As with other alternatives, oxo-degradable plastics still pose threats to marine life through entanglement and ingestion as well as through the creation of microplastic fragments.[37]

	Biodegradable plastics	Bio-based plastics	Compostable plastics	Oxo-degradable plastics
Carbon footprint and natural resource impacts	Under the anaerobic conditions likely to be found in landfills, anaerobic microbes decompose biodegradable polymers into methane and carbon dioxide.[38] Methane is among the strongest greenhouse gases (GHGs) contributing to climate change. There is some evidence to suggest that labelling a product 'biodegradable' will result in a greater inclination to litter, although this theory is not widely tested.[39]	Most bio-based plastics are produced from agro-based feedstock[40], requiring an estimated 600,000 hectares to produce 1.6 million tonnes of plastics in 2013 – a fraction of the total demand for plastics (< 0.5 per cent of 2015 total).[41] Increasing land-use could bring about competition with agriculture, cause biodiversity loss and raise land rights concerns.[42] Emissions associated with land use change (i.e. deforestation) could release 9-170 times more CO_2 than the annual GHG savings bio-based plastics provide, and put pressure on other natural resources such as water.[43] With growing interest in bio-based plastics, there is a need to fully assess the potential impacts. Bio-based feedstocks are generally grown using methods of industrial agricultural production and therefore significant amounts of toxic pesticides are used, which can pollute water and soil, and impact wildlife habitats. When processing bio-based feedstocks to produce plastics, significant amounts of energy and water are used, as well as hazardous chemicals/additives.[44] There is scope to increase the use of agricultural and horticultural waste as a raw material for biopolymer production.[45]	If disposed to landfill with compostable plastics, they are likely to decompose anaerobically and produce methane, a strong greenhouse gas.[46]	While comprehensive research has not been undertaken, it seems likely that oxo-degradable plastics will have a similar carbon and resource footprint to conventional plastics.
Recycling challenges	While biodegradable plastics can be recycled, they need separating from other polymers, requiring investment in sorting technologies. According to UNEP, their promotion as a greener alternative is unjustified in the absence of effective provision of industrial composting or anaerobic digestion facilities.[47] There are also concerns that novel additives used to promote biodegradation may pose a challenge to the recycling sector.[48]	Bio-based plastics generally require recycling in separate streams to fossil-based plastics and failure to separate them from other polymers could cause contamination.[49] There are technological challenges associated with separation.[50] If sorting and processing cannot be done economically because of low volumes, bio-based plastics will most likely be incinerated or sent to land fill.[51]	Use of compostable plastics in packaging formats that have established recycling systems (e.g. bottles) could result in contamination of recovered plastics, particularly if consumers cannot readily tell the difference between compostable and non-compostable plastics.[52] Scientists report a "serve incompatibility" of PLA with PET recycling streams given the different behaviour of PLA at higher temperatures – with contamination occurring at levels of two per cent PLA.[53]	While producers claim oxo-degradable plastics are recyclable, others in the plastic industry report that they negatively affect the quality and economic value of plastic recyclates.[54] They reported that oxo-degradable plastic packaging cannot be detected by current technology at sufficient scale to be sorted from conventional plastics. Oxo-degradable plastics fragment over time, damaging medium- and long-life products such as those used in construction. Producers say stabilisers can be added to offset the oxo-degradable effect, but concerns then arise regarding the quantity of stabiliser required and how it affects recycling.[55]
Other challenges	*Cost.* Biodegradable polymers tend to be significantly more expensive.[56] *Life-cycle impacts* Biodegradable plastics have environmental and occupational health impacts throughout their life cycles.[57]	*Waste feedstock complications.* The economic viability of using waste feedstocks to produce bio-based plastics will depend on the volume, quality and cost of transportation of feedstocks to reprocessing facilities. Seasonal changes affect the availability of certain feedstocks. Many processes for converting waste feedstocks depend on enzymes that can be very resource intensive to produce.[58]	*Disposal challenges.* Not all households have composting facilities or access to kerbside compostable waste collections; even when they do, it is possible that home-based composting will fail to achieve the heat or moisture levels required to trigger biodegradation.[59] No data could be found on the nationwide availability of local authority collections of compostable waste or municipal industrial composting infrastructure in the UK.	*Heavy metal pollution.* Concerns have been raised about the release of 'heavy metals' from the oxo-degradable additives into the soil. Additive producers respond to this by saying that the metals used are transition metals (iron, nickel, cobalt and manganese) and are not 'heavy' metals.[60]

Recommendations for retailers

Non-conventional plastics are not a miracle solution to the plastic crisis, with all the proposed alternatives posing risks to biodiversity if they leak into the ocean or other natural environments. In line with the waste hierarchy, reduction should come as the first option rather than replacing conventional plastics with other single-use items and packaging. There may be a limited role for the adoption of certain non-conventional plastics for well-suited purposes (e.g. bags for compost collections) - particularly those produced from waste feedstocks that might otherwise be sent to landfill or incinerated - but the availability of suitable end-of-life collection and treatment infrastructure must be the foremost consideration.

While there remains a need for further analysis to fully understand the potential environmental, social, health and economic impacts of increasing the production of non-conventional plastics, there is already enough evidence to suggest that a precautionary approach should be employed. Retailers can:

- support an holistic approach to addressing plastic pollution in line with the waste hierarchy, with an emphasis on reduction and re-use where possible
- commit to eliminate all non-conventional plastics for single-use items and packaging, and engage with brand suppliers about setting similar targets
- publish a policy stating their position and usage of different non-conventional plastics, engaging with policy-makers about sustainability concerns and promoting the precautionary principle
- promote clear labelling of materials and discourage use of the term biodegradable without further clarification of the conditions under which biodegradation will occur
- support research to better understand the social and environmental implications of increased consumption of non-conventional plastics, including full lifecycle analysis of different polymer types
- ensure products are adequately labelled so that users and consumers are provided with clear, comprehensible information about use and disposal.

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ENVIRONMENTAL INVESTIGATION AGENCY

ABOUT EIA

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EIA UK
62-63 Upper Street,
London N1 0NY UK
T: +44 (0) 20 7354 7960
E: sarahbaulch@eia-international.org
eia-international.org