



BB-REG-NET

Addressing Persistent Plastic Pollution

The Case for Biodegradable Solutions



Addressing Persistent Plastic Pollution

The Case for Biodegradable Solutions

Circular Bioeconomy Working Group

Report Reference: Microplastics

Date: October 2025

Version: 1.8

Classification: Public

Lead Author: Gail Shuttleworth*

Contributing Authors: Adrian Higson*, Polly-Ann Hanson*, Jen Vanderhoven**

Organisation: Alder BioInsights*, BBIA**

Contents

Contents	3
Executive Summary	4
Introduction	7
Background: definitions and sources of microplastics in the open environment	9
What are microplastics?	9
What are nanoplastics?	9
How do microplastics get into the environment?	9
How plastics break down in the environment	11
How biodegradable plastics break down in the environment	12
Factors that impact on biodegradation of biodegradable materials	12
Direct placement of plastics in the environment – agricultural mulch films and tree guards	14
Agricultural mulch films	14
. EN 17033:2018 biodegradable mulch films for use in agriculture and horticulture	15
. Fate of mulch films made from biodegradable materials	16
Tree guards	17
Indirect placement of microplastics in the environment via organics recycling	20
Composting	20
. EN 13432:2000 Requirements for packaging recoverable through composting and biodegradation	21
. Detection of microplastics in composts	22
. Industrial composting studies	23
. Home composting	26
. Impact on soil health	28
. Fate of microplastics from composts in soil	29
. Fate of microplastics in marine environments	29
Digestate from anaerobic digestion	30
Conclusions	31
Moving forward	32
Key actions and recommendations	33
Annexes	34
Annex 1: Bio-Barometer Survey	34
Annex 2: Methodology	35

Executive Summary

In 2021, the UK Governments summary of responses to the call for evidence on 'Standards for bio-based, biodegradable, and compostable plastics, highlighted that 'bio-based, biodegradable, and compostable plastics are of increasing interest as a potential solution to some of the issues caused by plastic waste. However, the government is concerned, that without robust standards or certification criteria, claims about the benefits that such materials may bring cannot be verified and uncertainty about unintended consequences will remain'. It concluded that 'more research, is required to fully understand whether in practise biodegradable plastics do not simply accelerate the fragmentation of plastic into microplastic.'

In response to this, and through the BB-REG-NET project, Alder BioInsights have undertaken a literature review of the evidence around the presence, impact and persistence of microplastics in the open environment due to the use of biodegradable materials (see Annex1: Bio-Barometer Survey and Annex 2: Methodology). To incorporate real-world insights, interviews were conducted with key stakeholders to understand industry perspectives.

This report documents evidence from case studies in agriculture, forestry, and composting, and shows that, with proper use and supportive regulatory frameworks, biodegradable plastics can mitigate the long-term environmental impacts of conventional plastics.

Microplastics - plastic particles less than five millimetres in diameter - have emerged as a widespread environmental concern, drawing attention through the media such as the BBC's 'Blue Planet'. They are found across marine, freshwater, terrestrial, and atmospheric systems, originating both from intentionally manufactured sources and the fragmentation of larger plastic items. Due to their durability and microscopic size, microplastics tend to accumulate in ecosystems, from soils and waterways to the food chain, where their removal becomes exceedingly difficult. Scientific research has linked microplastics to disruptions in soil health, reduced water retention, impaired plant growth, and adverse impacts on aquatic environments. They can also carry hazardous chemicals like heavy metals and persistent organic pollutants, potentially amplifying the toxicological impact when ingested by wildlife or humans.

Biodegradable plastics have been developed as an alternative to conventional polymers, with the specific aim of mitigating their long-term environmental persistence. These materials are engineered to undergo microbial biodegradation, yielding end products such as carbon dioxide, water, biomass, and under anaerobic conditions, methane. Although the fragmentation of biodegradable plastics does generate microplastic particles as part of the biodegradation process, their fate differs fundamentally from that of conventional (non-biodegradable) plastics. In biodegradable systems, microplastic formation represents an intermediate stage in a dynamic biodegradation pathway, with subsequent microbial colonisation and enzymatic activity, driving further breakdown and eventual mineralisation into naturally occurring compounds.

Plastics enter the environment intentionally or unintentionally during their life cycle. If they cause adverse changes to ecosystems or organisms outside their intended function or are expected to cause such effects, they may be regarded as pollutants to the environment.

This report presents three case studies exploring the role of biodegradable plastics in open environments, where they are intentionally used – with and without regulatory oversight – through their application in agricultural mulch films, tree guards, and compostable materials.

Biodegradable Mulch Films

Biodegradable mulch films are increasingly used in agriculture to suppress weeds, conserve moisture, and protect crops. They offer a more sustainable alternative to conventional plastic mulch film, which contributes significantly to long-term soil pollution. Unlike traditional films that require labour-intensive retrieval and disposal, biodegradable films are designed to be ploughed directly into the soil after use where they gradually break down and biodegrade due to microorganism activity.

European Standard EN 17033:2018 was established to ensure consistency, environmental security and performance of these films. It requires that at least 90% of the organic carbon in the film be converted to carbon dioxide within 24 months under controlled aerobic conditions (20–28°C). Whilst real-world field conditions (such as fluctuating temperatures and exposure to UV radiation) can slow this process, studies show that biodegradable films continue to degrade and an equilibrium develops between application rates and the accumulation of plastic fragments. This suggests that full mineralisation is achievable with proper use and adequate time, offering a more sustainable long-term solution compared to conventional materials. Furthermore, the EU Fertilising Products Regulation (Regulation (EU) 1009/2019) defined the criteria for certified biodegradable mulch films to be traded as fertilisers. It specifies a set of biodegradability criteria that the films must satisfy in both soil and water and demonstrates the benefit of use of these materials in agricultural settings.

Biodegradable Tree Guards

Tree guards are essential for protecting saplings during early growth stages. Conventional plastic guards, however, can become environmental liabilities when weathering, entanglement, or geographical isolation prevents their retrieval. Further, UK forestry guidelines recommend minimising plastic use and mandate the removal and appropriate disposal of redundant guards. Aligned to this, biodegradable tree guards, engineered to decompose gradually in natural conditions, are increasingly being adopted, promoting sustainable land management. Although mineralisation may take longer than in controlled environments, their environmental impact is significantly reduced compared to traditional plastics that can persist for decades. As tree planting initiatives expand globally to address climate change, biodegradable guards represent a practical step in forestry practices.

Compostable Plastics

Compostable plastics are specifically designed to break down under industrial composting conditions, characterised by high temperatures, active microbial populations, and controlled aeration. Compostable materials can degrade rapidly and thoroughly under these optimal conditions. According to European Standard EN 13432:2000, compostable plastics must disintegrate into particles smaller than 2 mm within 12 weeks and achieve at least 90% mineralisation within six months.

All certified compostable plastics meet the EN 13432:2000 criteria. Compostability rates will vary depending on operational conditions in facilities, including content of feedstock and facility layout. To enhance composting rates, it is important that compostable materials are properly treated (composted) within the organic waste flow. Despite that, some microplastic residues may remain if composting cycles are incomplete or faster than the compostability kinetics of compostable materials. However, these residues continue to biodegrade (in soil, or cold environment), unlike conventional plastics, which will persist indefinitely. Although thicker or multi-layered compostable items may exhibit slower degradation rates, ongoing advances in material design and formulation are improving both the efficiency and reliability of compostable plastics.

Conclusion

Evidence from case studies in agriculture, forestry, and composting shows that, with proper use and supportive regulatory frameworks, biodegradable plastics can mitigate long-term environmental impacts.

Biodegradable plastics offer a pathway toward reducing plastic pollution and addressing the presence of microplastics, and the use of certified compostable and biodegradable materials will reduce long term accumulation of microplastics. Although real-world biodegradation may occur more slowly than in laboratory conditions, a dynamic balance often emerges between the rate that materials are placed in the open environment and their subsequent biodegradation, indicating that biodegradable microplastics are transient and steadily processed by natural systems. Furthermore, certified biodegradable plastics have undergone biodegradation and ecotoxicological testing as part of the certification process, which conventional plastics do not. For fair comparison to be made, both biodegradable and conventional plastics should be subject to the same scrutiny.

As standards and technologies continue to evolve, biodegradable plastics will play an increasingly important role in building a more circular and sustainable bioeconomy. Many of these materials are bio-based and offer a lower environmental impact than their fossil-derived counterparts.

The key is to deploy them thoughtfully and robustly balancing economic and performance requirements with environmental objectives. Achieving this will require close collaboration between policymakers, regulators, researchers, and industry, drawing on the substantial knowledge and data already available.

Key actions and recommendations

To support sustainable innovation in the biodegradable materials sector, the following integrated recommendations are proposed:

1. Closer collaboration between policymakers, regulators and industry
2. Establish application-specific biodegradation standards
3. Support research into acceptable timeframes for mineralisation
4. Fund long-term environmental fate studies
5. Monitor soil accumulation for applications not covered by a standard
6. Develop a global monitoring framework for microplastics
7. Standardise detection and reporting methods
8. Clarify communication around biodegradability claims

Introduction

Plastics have a relatively short history compared with other material groups, yet their accumulation in the environment is already substantial, appearing both as discarded items (macroplastics) and as smaller fragments or particles (microplastics)¹. The presence of microplastics in the open environment is the subject of widespread public concern, particularly following high profile popular science reporting such as the BBC's 'Blue Planet'.

Microplastics, defined as plastic particles less than five millimetres in diameter, are increasingly recognised as a pervasive and multifaceted environmental problem with significant implications for ecological integrity, human health, and regulatory policy. Their presence in marine, freshwater, terrestrial, and atmospheric systems, combined with their capacity to act as vectors for toxic substances, has prompted scientific and policy attention.

Microplastics can either be intentionally manufactured or form through fragmentation of larger plastic pieces. They are nearly impossible to remove from the environment and, if persistent, lead to accumulation in soils, waterways, and the food chain². Recent studies have suggested that microplastics disrupt soil structure, reduce water retention, and impair plant growth by interfering with root systems and photosynthesis, with resulting impacts on crop yields and food security³. In aquatic systems, microplastics are ingested by a wide range of organisms, from plankton to fish and shellfish. Further, emerging evidence suggests microplastics may pose direct risks to human health as well as adsorb and transport hazardous chemicals (e.g. heavy metals, persistent organic pollutants), amplifying their toxicological impact when ingested by organisms or humans. As scientific understanding evolves, policy frameworks need to address both intentionally and unintentionally generated microplastics, ensuring protection of ecosystems and public health in line with global sustainability goals.

Recent regulatory actions - particularly in the EU - reflect a desire to mitigate microplastic pollution from plastic production and waste management, through both targeted restrictions and systemic changes. The EU's Commission Regulation (EU) 2023/2055, effective from October 2023, is one of the most comprehensive regulatory efforts to date and restricts the use of synthetic polymer microparticles intentionally added to products. The regulation aligns with the European Green Deal's Zero Pollution Action Plan targeting a 30% reduction in microplastic emissions. Whilst the UK is not directly bound by new EU regulations, the UK government is actively monitoring EU developments and has commissioned research to inform further domestic action on intentionally added microplastics, which is expected to report in 2025⁴. While the EU's REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) restrictions set phased bans on microplastics in various products through to 2035, the UK's current approach is more targeted, focusing on high-profile sources such as microbeads and microfibres, but leaving broader restrictions under review pending further evidence and consultation. The UK government has indicated that, in practice, many industries are already moving away from intentionally added microplastics, and any immediate regulatory impact is expected to be limited.

The UK has implemented several measures to address microplastics such as the 2018 ban on the manufacture and sale of rinse-off cosmetics and personal care products containing plastic microbeads⁵. This ban, supported across all UK administrations, was one of the earliest and most comprehensive regulatory interventions targeting intentionally added microplastics in consumer

¹ Bertling (2025) [Plastic Emissions: From Sources to a Plastic Pollution Equivalent](#) In: *Springer Handbook of Circular Plastics Economy*

² World Economic Forum (2025) [Microplastics: are we facing a new health crisis – and what can be done about it?](#)

³ SCI (2025) [Microplastic pollution is growing: What's the impact?](#)

⁴ Defra (2024) [Explanatory memorandum for European Union Legislation within the scope of the UK/EU withdrawal agreement and the Windsor framework](#) : C(2023)6419 Final + Annex: Commission regulation (EU) / Amending Annex XVII to regulation (EC) No 1907/2006 of the European Parliament and of the council as regards synthetic polymer microparticles

⁵ Defra (2017) [Implementation of the Environmental Protection \(Microbeads\) \(England\) Regulations 2017](#)

products. It drove the formation of the All-Party Parliamentary Group on Microplastics in 2020, which works to raise awareness of the effect microplastics have on the environment. The group works cross-party with interested stakeholders to discuss potential policy solutions to the problem of microplastics and microfibres.

In addition, recommendations from the Marine Conservation Society and parliamentary reports⁶ called for all new domestic and commercial washing machines to be fitted with microfibre filters by 2025, and for the introduction of Extended Producer Responsibility (EPR) schemes for textiles. The European Union leads with mandatory EPR schemes in France, Sweden and the Netherlands, while Germany and Italy are set to introduce similar systems. The UK is developing its own framework, and the US sees fragmented state-level efforts, with California and New York drafting EPR laws⁷.

While these interventions target intentionally added microplastics, concerns remain that the adoption of biodegradable materials could inadvertently contribute to environmental microplastics through three potential pathways:

1. The use of biodegradable plastics in products intended for use in the open environment e.g. agricultural mulch films or use of tree guards.
2. In products improperly disposed of e.g. litter (which is the focus of a separate report⁸).
3. As microplastics generated during organic recycling processes and subsequent transfer to the open environment e.g. through composting.

These considerations were observed indirectly by the inaugural BB-REG-NET 'BioBarometer' Survey⁹ (see Annex 1: Bio-Barometer Survey) which indicated that industry members are aware that their stakeholders have concerns over deployment of products made from biodegradable materials citing concerns over end-of-life management and contamination of recycling streams, with a third referring to microplastic formation.

In addition, the UK government is cautious about promoting biodegradable plastics because of the potential that these materials will fragment into microplastics which then persist in the environment due to incomplete microbial breakdown and incomplete microbial assimilation

As such, the UK government has highlighted that, without robust and verifiable standards confirming full biodegradation across various natural settings, that they view claims about the environmental benefits of biodegradable materials as remaining unproven¹⁰. Their 2021 consultation concluded that the UK Government 'welcomes further research on the full environmental impacts of using bio-based plastics ... We also welcome further evidence on the development and application of robust standards for biodegradability which are proven to apply outside of laboratory conditions'.

Through the BB-REG-NET project, Alder BioInsights have undertaken a literature review of the evidence around the presence, impact and persistence of microplastics in the open environment due to the use of biodegradable materials (see Annex1: Bio-Barometer Survey and Annex 2: Methodology). To incorporate real-world insights, interviews were conducted with a wide range of key stakeholders to understand industry perspectives.

⁶ APPG on Microplastics (2021) [Microplastics Policies for the Government](#)

⁷ [Mapping Global EPR schemes for Textiles | EU Textiles Ecosystem Platform](#)

⁸ This BBRegNet report demonstrated that biodegradable materials are not littered more than any other packaging materials: Hanson et al (2025) [Do Biodegradable Plastics Encourage Littering?](#)

⁹ BBRegNet (2025) [Shaping the future of sustainable materials in the UK](#)

¹⁰ HM Government (2021) [Standards for bio-based, biodegradable, and compostable plastics: summary of responses to the call for evidence and Government response](#)

Background: definitions and sources of microplastics in the open environment

What are microplastics?

Microplastics are solid plastic particles composed of mixtures of polymers and functional additives. They can be directly used in a wide variety of products - including cosmetics, detergents, agricultural settings, medical devices and paints - however, the vast majority of microplastics in the environment are due to the weathering of plastic.

Currently there is no internationally agreed definition of a microplastic – with a microplastic being defined as being between 100 nm and 5 mm in size^{11, 12, 13, 14}. The lower boundary size is considered to be 1 µm below which particles are usually referred to as nanoplastics, showing some overlap. The European Chemicals Agency (ECHA) further specifies that microplastic fibres are defined as having a length of 3 nm to 15 mm and a length-to-diameter ratio greater than 3.

The European Union issued legislation in 2023 to regulate synthetic polymer microparticles under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (Annex XVII amendment)¹⁵. Whilst this legislation refers to intentionally manufactured microplastics that are placed on the market in their own right, it defines microplastics as either having all dimensions as less than 5 mm or that the length of the particles is equal to or less than 15 mm and their length to diameter ratio is greater than 3. This definition does not distinguish between microplastics and nanoplastics

What are nanoplastics?

There is no universally agreed regulatory definition for nanoplastics, although they are considered as particles between 1 nm and 100 nm¹⁶. Nanoplastics are often considered under the broader framework of nanomaterials, which are defined by particle size and specific physicochemical properties. The European Commission defines a nanomaterial as: ‘a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm’^{17 18}.

How do microplastics get into the environment?

Microplastics (and nanoplastics) enter the environment via a range of avenues (see Figure 1 for indication of source of microplastics found in the world’s oceans).

¹¹ Defra (2024) [Explanatory memorandum for European Union Legislation within the scope of the UK/EU withdrawal agreement and the Windsor framework](#) : C(2023)6419 Final + Annex: Commission regulation (EU) / Amending Annex XVII to regulation (EC) No 1907/2006 of the European Parliament and of the council as regards synthetic polymer microparticles

¹² FSA Committee on Toxicology [Sub-statement on the potential risk\(s\) from exposure to microplastics: Inhalation route](#) (2024)

¹³ European Commission – Environment Topics [Microplastics](#)

¹⁴ For intentionally manufactured microplastics, the definition specifically excludes natural polymers that have not been chemically modified (other than by hydrolysis) and (bio)degradable polymers

¹⁵ Regulation (EU) 2023/2055 of September 25, 2023, [amending Annex XVII of REACH to Regulation \(EC\) No. 1907/2006](#) Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles’

¹⁶ Abdolapur Monikh et al (2022) [Can current regulations account for intentionally produced nanoplastics?](#) *Environmental Science Technology* 56(7), 3836-3839

¹⁷ European Union Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. Off. J. Eur. Union. 2011, L304/18.

¹⁸ Allan et al (2021) [Regulatory landscape of nanotechnology and nanoplastics from a global perspective](#) *Regulatory Toxicology and Pharmacology* 122, 104885

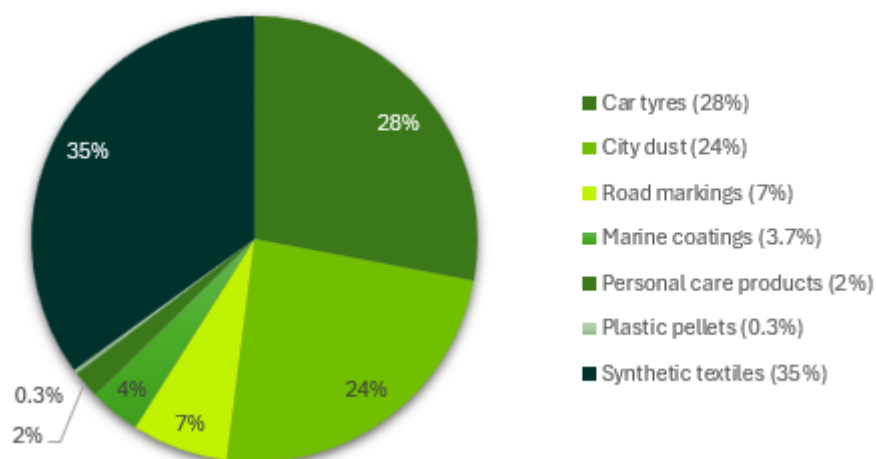


Figure 1: Estimated source of microplastics in the oceans (IUCN, 2017)¹⁹

Microplastics can be intentionally manufactured for a specific purpose and as such are considered primary microplastics (e.g. cosmetics, as drug vectors, or for air blasting: see Table 2). They can also be generated through breakdown of larger plastics into smaller fragments, which are referred to as secondary microplastics (see Table 2). Secondary microplastics result from physical breakdown of macroplastics followed by further subsequent degradation through mechanical, chemical (photooxidation, temperature, corrosion), and biological activities.

Microplastic Type	Source
Primary (purposefully manufactured)	- Primary microplastic for targeted industrial applications e.g. seed coatings, paints, construction materials, blasting - Primary microplastic lost through consumption e.g. cosmetic beads, toothpastes, drug delivery
Secondary (generated through degradation pathways)	- Uncollected plastic waste e.g. mismanaged packaging, fishing nets - Mechanical stress creating hotspots of high release e.g. tyre wear, textile washing - Plastics used in agriculture ('plasticulture') e.g. uncollected mulch films - Accidents and transport losses of industrial intermediates e.g. plastic pellets ('nurdles')

Table 1: Primary and secondary sources of microplastics in the environment (derived from) Primary and secondary sources of microplastics in the environment (derived from ²⁰)

Secondary sources can be further expanded into the following groups ^{21 22 23}:

- **Synthetic textiles** and fibres released during washing and drying, contributing significantly to microplastic pollution in aquatic and terrestrial ecosystems.
- **Vehicle tyre²⁴ wear** and road abrasions, which shed microplastics into air and water systems.
- **Artificial turfs, paints, and rubber roads** which release microplastics through wear and tear.

¹⁹ <https://www.statista.com/chart/17957/where-the-oceans-microplastics-come-from/>

²⁰ Mitrano & Wohleben (2020) [Microplastic regulation should be more precise to incentivize both innovation and environmental safety](#) *Nature Communications* 11: 5324

²¹ Amobonye et al (2021) [Environmental Impacts of microplastics and nanoplastics: a current overview](#) *Frontiers in Microbiology* 15(12): 768297

²² Yang, Chen & Wang (2021) [Microplastics in the marine environment: sources, fates, impacts and microbial degradation](#) *Toxics* 9(2): 41

²³ European Environment Agency (2022) [Microplastics from textiles: towards a circular economy for textiles in Europe](#)

²⁴ Noting that rubber is not a plastic *per se*. Although rubber and plastic are polymers, rubber is an elastomer and can return to its original shape after being stretched. Plastics can be moulded and shaped.

- **Degradation of larger plastic debris** due to physical, chemical, and biological weathering processes, producing secondary microplastics over time.
- **Plastic waste in municipal and agricultural settings**, including plastic bags, fishing gear, and farming films, which break down into microplastics.
- **Marine and riverine transport** of terrestrial plastics, with rivers acting as major pathways for microplastics from land to oceans.
- **Loss of fishing and aquaculture equipment**, contributing to marine microplastic pollution.

How plastics break down in the environment

A key question about plastic pollution is: how long will it last? Persistence refers to a material's resistance to degradation and removal by natural processes. However, definitions and thresholds vary, with no universal standard.

Plastics degrade in the environment through a combination of physical, chemical, and biological processes²⁵. The process is initiated by surface weathering which causes the plastic to become brittle and fragment into microplastics. This also increases the surface area susceptible to further degradation and leaching of dust and additives in the material. While some polymers, such as polyesters, are more susceptible to hydrolysis and microbial action, others (particularly polymers with a carbon backbone) are more resistant and complete mineralisation is rare in natural environments. Key steps are illustrated in Figure 2 and include:

1. **Fragmentation:** Environmental factors such as sunlight (UV radiation), heat, and mechanical abrasion cause larger plastic items to break down into smaller pieces.
2. **Abiotic (physical and/or chemical) degradation:** Initial breakdown is driven by abiotic processes (photooxidation, mechanical abrasion, hydrolysis, and thermal degradation) which reduce the polymer's molecular weight.
3. **Microplastic formation:** Steps 1 and 2 produce microplastics.
4. **Microbial degradation:** This involves **microbial colonisation** and **enzymatic depolymerisation**. Microorganisms (bacteria, fungi, some algae) colonise the surface of microplastics, form biofilms and secrete extracellular enzymes (e.g. depolymerases and hydrolases), breaking polymers into smaller oligomers and monomers^{20 26 27}. The presence of heteroatoms (such as oxygen, nitrogen, or sulphur) in the polymer structure provides sites for hydrolytic enzymatic attacks, facilitating breakdown. As the polymer chains are broken, the plastic physically fragments into smaller microplastics and nanoplastics.

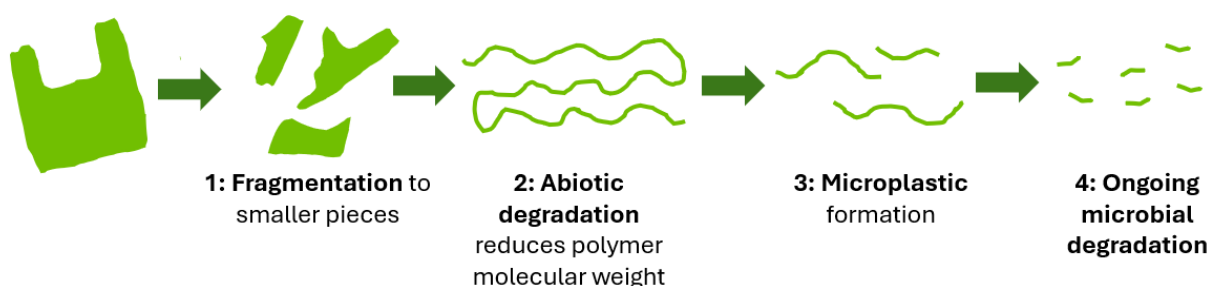


Figure 2: Simplified process of plastic degradation

²⁵ Webb et al (2013) [Plastic degradation and its environmental implications with special reference to poly\(ethylene terephthalate\)](#) *Polymers* 5(1): 1-18

²⁶ Cai et al (2023) [Biological degradation of plastics and microplastics: a recent perspective on associated mechanisms and influencing factors](#) *Microorganisms* 11(7): 1661

²⁷ Choi et al (2024) [Recent advances in microbial and enzymatic engineering for the biodegradation of micro- and nanoplastics](#) *RSC Advances* 14(14): 9943

How biodegradable plastics break down in the environment

As with conventional plastics, biodegradable materials degrade in the environment through a combination of physical, chemical, and biological processes^{28, 29, 30}. Steps 1 to 4 detailed in the previous section occur, but it is the additional mineralisation and assimilation that differentiates biodegradable materials with further degradation (see Figure 3).

1. **Assimilation of microplastics:** If environmental conditions are suitable (adequate temperature, moisture, oxygen, and active microbial communities), biodegradable microplastics are transient: they progressively reduce in number and size and are eventually transported into microbial cells and assimilated.
2. **Mineralisation:** Further intracellular enzymatic processes convert these smaller molecules into metabolic intermediates. Ultimately, under aerobic conditions, these intermediates are mineralised into CO₂ and H₂O; under anaerobic conditions, into CO₂, H₂O, and CH₄, with some carbon assimilated into microbial biomass.

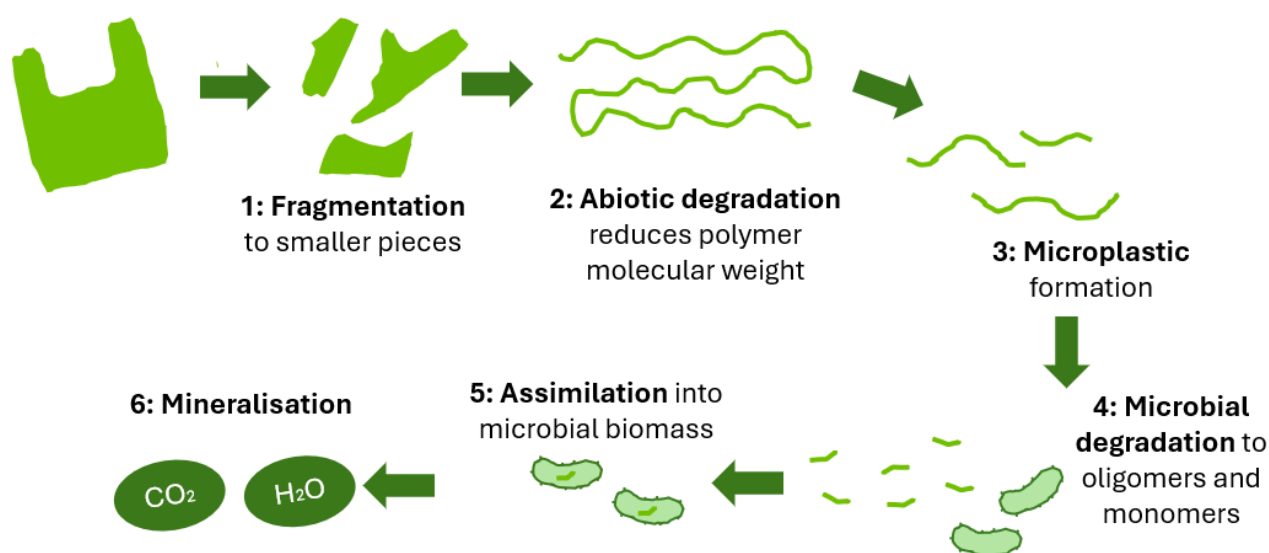


Figure 3: Simplified process of biodegradable plastic degradation

The end state of biodegradable materials is not as smaller numbers of microplastic particles, but as assimilation into microbes and production of carbon dioxide, water, and biomass. However, it should be noted that if environmental conditions are sub-optimal, this may result in slow subsequent biodegradation^{31 32}.

Factors that impact on biodegradation of biodegradable materials

While biodegradation is often proposed as a solution, expectations of rapid breakdown are unrealistic, since plastics are designed to resist decay during use. In some applications, however, such as mulch films, seed coatings, or tree guards, biodegradability is a desired function. Yet predicting degradation in open environments is complex, as rates depend on both material

²⁸ Alleman et al (2024) [Rapid biodegradation of microplastics generated from bio-based thermoplastic polyurethane](#) *Nature Scientific Reports* 14: 6036

²⁹ Chamas et al (2020) [Degradation rates of plastics in the environment](#) *ACS Sustainable Chemistry and Engineering* 8(9)

³⁰ Zumstein et al (2018) [Biodegradation of synthetic polymers in soils: Tracking carbon into CO₂ and microbial biomass](#) *Science Advances* 4:7

³¹ Islam et al (2024) [Impact of bioplastics on environment from its production to end-of-life](#) *Process Safety and Environmental Protection* 188: 151

³² Reay et al (2025) [Microbial degradation of bioplastic \(PHBV\) is limited by nutrient availability at high microplastic loadings](#) *Environmental Science: Advances* (4): 133

properties and environmental conditions. Thus, claims of “biodegradability in the environment” must always specify the context in which they apply.

The rate and completeness of biodegradable microplastic degradation is highly dependent on several factors^{20, 24, 33 34 47}:

- The **chemistry of the polymer** itself including the presence of specific functional groups and the degree of branching as well as associated crystallinity (amorphous regions degrade faster).
- **Environmental conditions** such as temperature, moisture, pH, nutrient availability.
- The presence and diversity of **microorganisms** capable of contributing to the biodegradation of plastics³⁵.
- **Physical size** with smaller microplastics generally degrading faster due to higher surface area.
- Greater **adherence of microorganisms** to biodegradable materials and biofilm formation which leads to faster rates of breakdown. This is due to being chemically less inert than conventional plastics, having accessible functional groups, and being a nutritional substrate to promote attachment and colonisation through biofilm formation.

Microbial enzymes break down biodegradable plastics into microplastics by targeting and hydrolysing the chemical bonds in the polymer backbone. This produces progressively smaller fragments that can be further assimilated and mineralised by microorganisms, and which are more susceptible to further microbial degradation and assimilation than conventional plastic microplastics^{24,25,36}. It is likely that enzymatic cleavage occurs not only after the material has fragmented into small pieces, but also concurrently with the physical breakdown process, meaning that polymer-level degradation and fragmentation may overlap during the pathway to complete biodegradation.

Biodegradable plastics will form microplastics, that is a factor of the degradation process. However the rate of biodegradation and subsequent assimilation is dependent on specific conditions, and the resultant effect if these are not met. To examine this further, we looked at three biodegradable material applications: the direct use of agricultural mulches and tree guards on the land, as well as two other indirect avenues for microplastics to enter the environment (as a result of composting, or via digestate derived from anaerobic digestion which is then spread on the land).

³³ Reay et al (2025) [Microbial degradation of bioplastic \(PHBV\) is limited by nutrient availability at high microplastic loadings](#) *Environmental Science : Advances* 4: 133

³⁴ Fan et al (2022) [A review on the occurrence and influence of biodegradable microplastics in soil ecosystems: Are biodegradable plastics substitute or threat?](#) *Environment International* 163:107244

³⁵ Degli-Innocenti et al [Microorganisms that produce enzymes active on biodegradable polyesters are ubiquitous](#) *Biodegradation* 34: 489

³⁶ De Jesus & Alkendi (2023) [A minireview on the bioremediative potential of microbial enzymes as solution to emerging microplastic pollution](#) *Frontiers in Microbiology* 13: 2022

Direct placement of plastics in the environment – agricultural mulch films and tree guards

Two case studies were considered which reflect active and passive management approaches when biodegradable materials are deployed directly in the environment. One focused on agricultural mulch films which are actively managed on-farm and ploughed into the soil at the end of use, and has associated standards. A second considered tree guards, which are more passively managed at end of use. There are currently no standards associated with tree guards.

Agricultural mulch films

Mulch films are used in agriculture to cover soil and protect crops from environmental impacts as well as preserving soil moisture and controlling soil temperature, suppressing weed growth and therefore reducing the need for herbicides, and improving soil microbial levels and activity (Figure 4). They can be organic or inorganic – including straws, compost, wood chips and plastics – and can be used in commercial agriculture and home gardening.



Figure 4: Carrots growing under agricultural mulch film (Gail Shuttleworth)

Polyethylene mulching films were first introduced in the 1950's, with oxo-degradable and photo-degradable versions appearing in the 1980's in an attempt to address microplastic formation in soils³⁷. Oxodegradable plastics are conventional plastics with additives that cause them to fragment into microplastics when exposed to oxygen, in comparison to biodegradable plastics which are designed to be broken down by microorganisms into water, carbon dioxide, and biomass. In 2021 the UK Government concluded that they are 'minded to introduce a ban on oxo-degradable plastics, subject to further evidence and a public consultation'¹⁰. To date, polyethylene is still the most used mulch film due to its mechanical properties and low cost.

At the end of a growing season, used films will also have plant and soil material associated with them which makes collection on-farm hard, and contributes to the challenges in subsequent recycling by collectors. In 2021, around 70-75% was collected across Europe and only a quarter of that was recycled^{38, 39}, the remainder usually being landfilled or incinerated. Inevitably, some of the

³⁷ Mansoor et al (2022) [Polymers use as mulch films in agriculture – a review of history, problems and current trends](#) *Polymers* 14:23: 5062

³⁸ <https://minagris.eu/where-farm-plastics-recycling-goes-wrong-the-perspective-from-irish-farmers/>

³⁹ Hann et al (2021) [Relevance of conventional and biodegradable plastics in agriculture](#) (EUNOMIA final report for DG Environment of the European Commission)

film is left on the farm land due to tearing and degradation, making its retrieval unviable. As a result, if not responsibly managed at the end of life, mulch films can be a source of microplastic pollution that accumulates in the soil and thereafter, water run-off.

Studies have shown that continuous use of plastic mulch films can lead to significant microplastic accumulation in agricultural soils, potentially up to 0.67% w/w by 2122⁴⁰. In one study, soil samples from fields continuously mulched with polyethylene plastic film (which is not biodegradable) for 30 years showed high levels of microplastics (40.35 mg/kg). This study showed that the concentration of larger plastic particles increased from 91.2 mg/kg after 5 years to 308.5 mg/kg after 30 years⁴¹.

The first biodegradable mulch films were commercialised in 2006³⁷ with the aim that these could be ploughed into the soil at end of use, and subsequently biodegrade whilst still retaining mechanical and operational properties to protect growing plants. Since it was known that the rate of biodegradation could vary depending on environmental conditions, it was recognised that an industry standard needed to be developed. By 2018 an agreed standard was published, and in 2021 the UN Food and Agriculture Organisation recommended that certified biodegradable polymers be used for mulching⁴².

EN 17033:2018 biodegradable mulch films for use in agriculture and horticulture

EN 17033:2018 is the European standard for biodegradable mulch films used in agriculture. The EU standard for conventional mulch films (EN 13655:2002) was revised in 2018 as two end-of-life options for mulch films became clear and two separate standards were needed to account for this⁴³. As a result, EN 13655:2018 provided updated specifications for recoverable mulch films which are removed and then disposed of, and EN 17033:2018 was developed which covers biodegradable mulch films, which can be ploughed into the soil at end of use. This standard specifies test methodology and evaluation on biodegradation, ecotoxicity, film properties and composition of biodegradable mulch films. The core biodegradation criterion is that at least 90% of the organic carbon in the mulch film must be converted to CO₂ within 24 months under controlled aerobic conditions in a standardised soil at 20-28°C, using methods such as ISO 17556⁴⁴.

Tests associated with EN 17033:2018 are completed in a laboratory environment at ambient temperature (typically 25°C) and do not directly consider environmental factors such as differing temperatures, weathering, and UV degradation. Whilst field trials are not part of the certification process, the standard makes allowances for the variations on environmental factors of real agricultural environments – such as soil type, climate, and weather – which can affect degradation rates. This is specifically addressed through two Annexes: G and H. Annex G gives guidelines on field performance including expected service life and provides guidance on the classification of films by crop cycle, degradation in the field, and defines excessive deterioration (e.g. loss of more than 10% of surface area during a season: if this is triggered then the standard prescribes additional laboratory tests). Annex H offers recommendations for best practices in field use – soil preparation, film deployment, irrigation, and storage – to ensure optimal performance and minimise premature degradation⁴⁵.

⁴⁰ Meizoso-Regueira et al (2024) [Prediction of future microplastic accumulation in agricultural soils](#) *Environmental Pollution* 359: 124587

⁴¹ Li et al (2020) Microplastics in agricultural soils: [Extraction and characterization after different periods of polythene film mulching in an arid region](#) *The Science of the Total Environment* 749:141420

⁴² Food and Agriculture Organization of the United Nations (2021) [Assessment of agricultural plastics and their sustainability: a call for action](#)

⁴³ European Bioplastics (2018) [New EU standard for biodegradable mulch films in agriculture published](#)

⁴⁴ It is highly likely that the remaining 10% will continue to exponentially degrade further and then be assimilated and mineralised.

⁴⁵ Hayes and Flury (2018) [Summary and assessment of EN 17033:2018, a new standard for biodegradable plastic mulch films](#)

Furthermore, the EU Fertilising Products Regulation (Regulation (EU) 1009/2019) defined the criteria for certified biodegradable mulch films to be traded as fertilisers (from November 2024)⁴⁶⁴⁷. This is seen as a positive progression from EN 17033:2018, particularly as the Regulation has higher requirements on biodegradability (in soil and water) and ecotoxicity compared to existing standards and demonstrates the benefit of use of these materials in agricultural settings.

Fate of mulch films made from biodegradable materials

Biodegradation of biodegradable mulch films are intrinsically linked to temperature and dominated by thermodynamic effects across the 15-28°C range (which biodegradation tests are most usually carried out)⁴⁸. This is important when considering the environmental fate of biodegradable mulch films in the open environment. Mater-Bi®⁴⁹ is one example of a biodegradable mulch film. Studies have shown that at room temperature (20-25°C), white Mater-Bi® biodegradable mulch residues showed up to 69.15% degradation after 6 months⁵⁰. At 30°C, the same biodegradable mulch achieved up to 88.90% degradation. In comparison, polyethylene mulch films showed little to no degradation over the same time periods.

However, field soil temperatures rarely exceed 20°C and are not constant, leading to slower biodegradation in real environmental conditions when compared to laboratory-based tests under controlled conditions⁵¹. In a 5 year field trial in a Mediterranean-type climate, mulches were applied and ploughed in annually, but the number of visible fragments recovered remained constant. This indicates that the mulch degraded at the same rate it was added, with no buildup of visible fragments over time. Modelling indicated that degradation in-field could take from around 21 months up to 58 months. It is noted that this timeframe is longer than the time requirements specified under the experimental conditions of EN 17033:2018 (90% biodegradation within 24 months). However, there was better correlation between in-field and laboratory degradation rates observed when analysis is completed using principles of thermal time. Indeed, the biodegradable mulches tested reached 90% degradation using this methodology.

Furthermore, studies under Nordic conditions also showed that the biodegradable mulches reach an equilibrium between the film degradation and application of new film and suggest that subsequent applications would need to reflect this time lag if films are to be entirely degraded⁵².

Biodegradation takes longer during field degradation studies than in regulated, controlled laboratory tests.

Research on mulch films, as discussed above, has suggested that the use of 'thermal time' based on degree days⁵³ would address issues associated with differences in temperature in field (which is lower and inconsistent over the 2 month degradation time) than in the lab⁵¹. Identification of an appropriate 'base temperature' would be needed, which is the temperature where a process begins

⁴⁶ European Bioplastics Association (2024) [Bioplastics in Agriculture](#)

⁴⁷ Dominguez-Solera et al (2025) [The biodegradability of plastic products for agricultural application: European regulations and technical criteria](#) *Clean Technologies* 5(1)

⁴⁸ Pischedda et al (2019) [Biodegradation of plastics in soil: the effect of temperature](#) *Polymer Degradation and Stability* 170: 109017

⁴⁹ <https://materbi.com/en/applications/mulching-film/>

⁵⁰ Romano et al (2024) [Changes in soil microbial communities induced by biodegradable and polyethylene mulch residues under three different temperatures](#) *Microbial Ecology* 87:101

⁵¹ Griffen-LaHue (2022) [In-field degradation of soil-biodegradable plastic mulch films in a Mediterranean climate](#) *Science of the Total Environment* 806:150238 Available at:

⁵² de Sadeleer (2024) [Environmental impact of biodegradable and non-biodegradable agricultural mulch film: a case study for Nordic conditions](#) *LCA for Agriculture* 29:275-290

⁵³ Thermal days and degree days both quantify the effect of temperature over time but are used in different contexts; thermal days enable accelerated laboratory testing at fixed high temperatures, while degree days quantify natural environmental heat exposure relative to a biologically or operationally relevant base temperature

or ends. For instance, agricultural growing degree days will have a base value of around 10°C whereas plastics degradation modelling could have a base temperature around ambient environmental temperature (e.g. 20°C).

A lab-based study compared microplastic generation from different mulch films – biodegradable, oxo-degradable, black polyethylene, and white polyethylene – under simulated UV exposure for up to 70 days⁵⁴. It found that biodegradable mulch films produced microplastics much faster (indicating greater biodegradation), mostly between 20 µm and 100 µm in size, with 475 particles/cm². In comparison, oxo-degradable films produced 266 particles/cm², white polyethylene 163 particles/cm², and black polyethylene 147 particles/cm².

Furthermore, an integrated biodegradation model assessed and compared how different polymers used in agricultural mulch films could contribute to microplastic accumulation in soil⁵⁵. The model used experimentally determined CO₂ evolution curves to estimate the concentration and residence time of microplastics. The model predicted that biodegradable plastics would cause short-lived spikes in microplastic concentration which were higher than for other plastics examined. Importantly, these spikes quickly diminished, while the other conventional plastic films were predicted to cause persistent and accumulating microplastics in the soil over time. The findings suggest that using mulch films with high biodegradation rates can prevent long-term microplastic accumulation, resulting in a stable, steady-state concentration in the soil.

The studies above demonstrate that an equilibrium is established between application rates and levels of fragments and microplastics in the soil. As more mulch film is applied, the levels remain constant implying that there is an ongoing degradation and exit from the levels of fragmentation and microplastics present. The inference is that the mulch will fully biodegrade.

Field trials show that there is no long-term accumulation of plastic in soil when using biodegradable mulches. An equilibrium concentration would result from continued biodegradable mulch film application with the biodegradation rate of prior biodegradable mulch film applications.

Tree guards

Biodegradable tree guards (also referred to as tree shelters or tree guides) have been introduced as an alternative to durable plastic versions and are used to protect sapling and young trees in the early 7-10 years of establishment⁵⁶ (Figure 5). Unlike mulch films, which are actively ploughed into the soil at the end of use facilitating initial breakdown, tree guards are not actively dug into the ground (as this could disrupt the saplings root systems) and are generally left *in situ* until removed.

The UK Forestry Standard (2024) is the technical standard for sustainable forest management across the UK and applies to all woodlands. It stipulates that: ‘the use of plastics, whether made from oil or bio-based polymers, should be avoided or reduced as much as possible’, and redundant products should be removed and recycled^{57 58}. In Scotland, the Forestry Grant Scheme (FGS) states that all tree shelters must be removed and reused, recycled or disposed of appropriately.

⁵⁴ Yang et al (2022) [Kinetics of microplastic generation from different types of mulch films in agricultural soil](#) *Science of the Total Environment* 814:152572

⁵⁵ Brouwer et al (2024) [A predictive model to assess the accumulation of microplastics in the natural environment](#) *Science of the Total Environment* 957:177503

⁵⁶ <https://forestrycommission.blog.gov.uk/2024/04/22/tackling-plastics-in-woodland-creation/>

⁵⁷ Forestry Commission (2023) [The UK Forestry Standard: the governments approach to sustainable forest management](#) (page 24)

⁵⁸ Harden Scott (2023) [Focus on forest plastics: reducing single-use plastics in forestry](#) *Scottish Forestry* 77:3

Currently, the use and removal of conventional plastic guards is cheaper than use of biodegradable plastics⁵⁹. Furthermore, prior to the update to the FGS in 2022, removal of forest plastics (and associated labour and costs) was not necessarily considered when planting. Following the update and specific reference to removal of tree guards, applicants are encouraged to plan for removal. However, the effect of this will not be seen for several years as the recommendation came into effect in 2022, and guards are usually deployed for 5-10 years. Currently removal rates are not available from authorities, although industry estimates it at 5-10%.



Figure 5: Tree guards supporting new tree growth and protecting from damage due to animal browse (Gail Shuttleworth)

Nevertheless, at the end of their useful life, tree guards are difficult to collect, particularly at scale. They might not be in a condition to reuse or recycle due to animal damage or having broken down either completely or partially due to weathering and photodegradation, which makes the guard brittle. Further, the presence of compacted grass and biomass entwined in the guard can make physical removal without damaging the sapling difficult. Reports suggest that most tree guards start to degrade after 10 years exposure to sunlight⁶⁰ and that only 30-40% may be reusable⁵⁸. In addition, estimations indicate that it can cost the equivalent of £1 per tree guard removed when considering labour and travel⁶¹. As a result, the mass planting of trees as part of efforts to meet net-zero targets⁶² could result in significant levels of tree guards being left unrecovered in the environment. To meet current planting targets, this would result in an estimated 30,000 tonnes of plastic used a year, with ~90% not being collected⁶³.

Biodegradable tree guards are predominantly produced from paper and cardboard, natural materials (wool, jute, bamboo) or polylactic acid (PLA) which is a bio-based and biodegradable material. PLA can biodegrade efficiently into CO₂ and water with a half-life of around 60 days in industrial composting conditions with a temperature above 60°C⁶⁴. Outside of this process, breakdown can take much longer. A tree guard needs to be environmentally robust – withstanding weather and animal damage for at least 5 years. However, it has been suggested that the degradation process might take up to 200 years to fully break down the tree guard⁶⁵.

⁵⁹ Forestry Scotland (personal communication)

⁶⁰ Defra Farming Blog (2025) : [maintaining new tree planting](#)

⁶¹ Personal communication – Richard Walker, Wool Innovation International Group Ltd.

⁶² UK Government (2023) [Government tree planting meets less than half its annual targets, despite the growing demands on UK woodland for net zero](#)

⁶³ Carpenter (2022) [Biodegradable Tree Guards Phase 1 Final Report](#)

⁶⁴ Iovino et al (2008) [Biodegradation of poly\(lactic acid\)/starch/coir biocomposites under controlled composting conditions](#) *Polymer Degradation and Stability* 93(1) 147-157

⁶⁵ <https://nhsforest.org/blog/tree-guards-how-can-we-promote-reforestation-and-reduce-plastic-waste/>

Tree guards made from polylactic acid will take less time to degrade in the environment than polyethylene alternatives but might still take hundreds of years.

When considering environmental degradation rates of plastics in the environment, land trials showed that PLA degrades completely approximately 20 times faster than polyethylene⁶⁶. Polyethylene bottles have a half-life of 250 years when buried, increasing to 5,000 years for thicker pipes. This infers a degradation rate of approximately 15 years for PLA at the same thickness of a bottle, which is a reasonable approximation to the thickness of a tree guard.

Unlike conventional plastics, PLA can be hydrolysed in water and fragment further. As a result, fragment sizes will decrease until chains are short and become soluble in water, profoundly affecting degradation rates: it can take around 2.5 years (at 25°C) to 27 years (at 4°C) for complete biodegradation in water⁶⁷. The dynamics of complete mineralisation in different and mixed environments are not known and may range from several months to several decades or more⁶⁸.

The challenge is whether biodegradable plastics will give rise to more microplastics over a specified timeframe when compared to unrecovered conventional plastic tree guard. As a result, further investigation is needed to understand and agree what is an appropriate rate to minimise microplastics in the environment. Conventional PLA might not present a clear alternative, but work is ongoing on other materials and material blends. For example, current trials are focused on a novel bio-based and biodegradable tree guard which has been designed to protect trees for 5-7 years, and subsequently breakdown over 2 years⁶⁹. This would be in line with current UK government advice which indicates that tree guards should be used to protect trees within the first 5 years of planting, and that damaged guards be replaced during this time⁷⁰.

Debate on slowly biodegrading polymers is still in its early stages, with no international standards to assess their behaviour in the open environment. Testing is difficult due to long timescales, low degradation rates, and varying environmental conditions, making predictions of lifetimes highly uncertain. Establishing rates and extents of biodegradation across environments is therefore urgent to guide policy and innovation. A proposed classification - fast (weeks–months), medium (months–years), and slow (years–decades) - has entered EU policy⁷¹, though its value remains debated, alongside the broader question of what timeframes for degradation are acceptable.

What is clear is that a standard is needed relating to the durability of biodegradable tree guards and subsequent fate in the environment.

⁶⁶ Chamas et al (2020) [Degradation rates of plastics in the environment](#) *ACS Sustainable Chemistry and Engineering* 8(9)

⁶⁷ Colwell et al (2023) [Hazardous state lifetimes of biodegradable plastics in natural environments](#) *Science of the Total Environment* 894: 165025

⁶⁸ Lott et al PeToPLA [A meta-study on the persistence and toxicity of PLA, and the formation of microplastics in various environments](#)

⁶⁹ <https://biomebioplastics.com/tree-shelter/>

⁷⁰ Defra farming blog (2025) [Maintain new tree planting](#)

⁷¹ Science Advice for Policy by European Academies (SAPEA), European Commission (2020) [Biodegradability of Plastics in the Open Environment](#)

Indirect placement of microplastics in the environment via organics recycling

Microplastics from any origin can enter the environment following end-of-life treatment. Examples include via composting (including though incomplete composting of compostable plastics) or through inadvertent presence in feedstocks used for anaerobic digestion and subsequent presence in digestate⁷². Since compost and digestate are both deliberately spread onto land to condition and improve soil quality and growing conditions, any contamination will also enter soils.

Composting

Composting is an aerobic process characterised by microbial breakdown of materials in the presence of oxygen to produce carbon dioxide, water, and biomass. If a biodegradable material can be composted, and has been certified as such, then this is an alternative end of life option to the material otherwise ending up in landfill or being incinerated.

Compostable materials are designed for disintegration and then mineralisation through the composting process, with industrial composting facilities providing optimal conditions for biodegradation, both in terms of the process conditions (temperature, intensive aeration) and the metabolic activity of the associated microbial communities. Whilst larger pieces of materials that have not fully disintegrated are often reprocessed, those that pass through the final sieving will be present in the final product. If mineralisation is incomplete under these circumstances, the remaining material will be released into the environment, where it may persist as the conditions are not necessarily conducive to further breakdown. However, the standard for a certified compostable material (EN 13432:2000 Requirements for packaging recoverable through composting and biodegradation.) recognises that it is not necessary for the complete biodegradation of packaging material to be fully completed in technical facilities as the process can continue during the application and use of the compost produced

There are two main industrial composting methods.

Windrow Composting – Where organic waste is arranged in long rows approximately 1.5–2.0 m high and around 4.5 m wide. These rows are turned regularly to maintain optimal oxygen, moisture, and temperature conditions for efficient decomposition.

In-Vessel Composting (IVC) – Where organic material is shredded, mixed, and placed in an enclosed commercial composting unit. These systems carefully regulate temperature, oxygen, and moisture, while mechanical rotation ensures uniform breakdown. During the process, the material reaches temperatures above 60 °C, effectively accelerating decomposition and destroying.

In addition, other less used industrial processes include vermicomposting which is similar to domestic composting and which is difficult to manage, and static pile composting where organic material is mixed with dry material (e.g. shredded paper or wood chips) which allows aeration without the need for turning.

Although a certified biodegradable product can be broken down by microorganisms, this does not necessarily mean that the resultant compost will be good quality compost. Compostability is heavily dependent on the operational composting process and the environment it creates e.g. temperature, humidity and microbial community. Biodegradation is much faster under controlled composting conditions than in natural environments, with the rate and extent of biodegradation

⁷² Regulation (EU) 2023/2055 of September 25, 2023, [amending Annex XVII of REACH to Regulation \(EC\) No. 1907/2006](#) Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles'

dependent on the presence and diversity of microbial communities capable of degrading the specific plastic polymer²². This means that plastics which are biodegradable in an industrial composting plant are not always biodegradable in water or soil, or home composting.

Compostable materials are suitable for microbial treatment at end-of-life in a composting environment, whether industrially or at home, however, to do this it is important that materials meet specific requirements and parameters, such as defined in a standard: products or materials that pass the required standard for microbial treatment in these environments can be verified as compostable.

. **EN 13432:2000 Requirements for packaging recoverable through composting and biodegradation.**

EN 13432:2000 (Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging) is a European standard that defines the criteria and testing procedures for assessing the industrial compostability of packaging materials and products. This standard specifies the requirements and procedures for determining whether packaging and packaging materials are compostable and biodegradable, including the necessary test schemes and evaluation criteria acceptance. Meeting the requirements of EN 13432:2000 allows a product to be certified as compostable and be issued a certificate and a registration number and grants the right to use a compostability mark and registration number. This applies to certified products, materials, intermediates, or additives.

To achieve this, materials must demonstrate the following key characteristics:

- **Disintegration:** After 12 weeks in an industrial composting process, at least 90% of the material fragments must be smaller than 2 mm, ensuring the material physically breaks down and is no longer distinguishable in the compost.
- **Biodegradability:** At least 90% of the material must be converted to carbon dioxide when compared to a control within six months under action by microorganisms.
- **No negative effects on composting process**
- **No adverse impact on compost quality:** The resulting compost must not contain heavy metals above specified limits and must not be toxic to plants, as demonstrated by ecotoxicity and plant growth tests. The material must also meet strict limits for volatile matter and heavy metals to prevent contamination of the compost. Finally, the material must not adversely affect parameters in the final product such as bulk density, pH, salinity, and volatile solids, as well as total nitrogen, total phosphorus, total magnesium, total potassium and ammonium nitrogen characteristics.

EN 13432:2000 specifies that compostable plastic packaging disintegrates into fragments smaller than 2 mm so that after 12 weeks of composting, less than 10% of the original mass remains visible in the compost. At least 90% of the material must be completely mineralised within 6 months.

There are several standards for home composting, which are detailed in a later section.

. Detection of microplastics in composts

There are very few research papers focusing on the presence of microplastics in compost⁷³. Often, studies examine microplastics in general, with compostable plastics briefly mentioned, or one of the types of material tested. Microplastics can be found in compost at all production stages (post-shredding, turning and post-screening) with higher concentrations found in the screening stages of the composting process suggesting that the composting process may cause macroplastics to fragment⁷⁴.

Although a considerable body of evidence exists on the occurrence of large plastic debris, the data on microplastics are still scarce due to the difficulties associated with their separation and analysis⁷³. However, microplastics have been found in industrially produced compost samples. Whilst the most common polymers found were conventional non-biodegradable polymers - polypropylene, polyethylene and polymethyl methacrylate - some biodegradable polymers (PLA and PBAT) were detected when using μ -FTIR (which detects particles $\geq 18 \mu\text{m}$, within the lower end of the microplastic range). However, there was no quantification of the proportion of biodegradable plastic that was present in the feedstock prior to composting, and that which is still present in the final product.

According to a position paper from the European Compost Network (ECN), the average contamination of plastics in compost from selected EU countries ranges between 0.01% and 0.2% dry matter and generally refers to fragments larger than 2mm. This 0.01% dry matter figure is consistent with strict regimes and clean feedstocks (especially in Austria, Germany, and the Netherlands) while higher levels are observed where input is more contaminated or less well regulated^{75,76}. However, direct cross-country comparison is challenging due to differences in measurement methods and regulatory thresholds. Most regulations focus on particles larger than 1-2 mm, and so smaller microplastics are not consistently regulated or measured and could therefore be under reported. In addition, regulations generally look at the mass of plastic within a compost, whereas research studies examine the counts of plastic particles which increase with time due to fragmentation and degradation.

A long-term field study looked at microplastics in farm soils that received compost from three different urban sources (municipal solid waste, biowaste, and a mix of sewage sludge and green waste) every two years for 21 years. The results showed that the number of larger microplastics (2–5 mm) were found in the soil at levels determined in the original compost⁷⁷, with that from green waste and sewage sludge having the lowest microplastic counts. However, when comparing the total mass of microplastics in the soil to that expected based on compost inputs, the measured mass was lower than estimated. This suggests that microplastics continued to break down into smaller pieces by weathering and other natural processes and may also have been moved by soil organisms or water flow to other areas. This could include previously uncontaminated areas or waterways.

⁷³ Ruffell et al (2025) [Quantification of microplastics in biowastes including biosolids, compost, and vermicompost destined for land application](#) *Water Emerging Contaminants & Nanoplastics* 4(1)

⁷⁴ Zapata et al (2023) [Microplastic emissions via air and compost from an industrial composting facility in England](#) *Environmental Pollutants and Bioavailability* 36: 2296046

⁷⁵ Foster, Breton & Bird (2024) [Identifying the source and scale of plastic in compost derived from household and commercial food waste](#) *Environmental Protection Agency Research Report* (2021-GCE-1035)

⁷⁶ ECN (2021) [Position Paper: plastics, microplastics in compost and digestate](#)

⁷⁷ Columbine et al (2024) [Coarse microplastic accumulation patterns in agricultural soils during two decades of different urban composts application](#) *Environmental Pollution* 1 (15): 125076

Industrial composting studies

Reviews and surveys of compost from municipal solid waste (MSW) and other biowastes have repeatedly reported microplastic contamination in finished compost, regardless of the waste stream origin. Concentrations reported range from 0.012 to 62 microplastic particles per gram of compost, with most being fragments, films, and fibres. Both conventional and some biodegradable polymers have been detected in mature compost, indicating incomplete degradation during industrial processing^{73,105}. In addition, fragments of biodegradable plastics have been detected in finished composts alongside conventional plastic residues, although finished composts typically contain fewer and smaller fragments than pre-composts. The final sieving process removes larger plastic fragments (>5 mm), resulting in contamination levels of less than 0.1% by weight for fragments over 2 mm, which aligns with regulatory and industry standards for compost purity.

However, recent academic and industry research demonstrates that certified compostable plastics effectively disintegrated within 22 days^{49,50,78}: In full-scale industrial composting trials, various compostable plastic products – including organic waste bags, plant pots, and tea bags – showed degradation rates comparable to or faster than conventional biowaste, with some items such as PLA plant pots fully disintegrating in just 11 days (summarised in Table 2):

- A **Dutch study** examined the fate of 9 different compostable packaging products in a full scale organic waste treatment facility focussing on products (organic waste collection bags, PLA plant pots, tea bags, coffee pads, coffee capsules, and fruit labels) that fulfil the requirements for compostable packaging (EN 13432:2000)⁷⁹. They showed that all the products broke down within 22 days, with PLA plant pots disintegrating within 11 days, faster than most organic materials. Visually, no compostable plastics were identified.
- A **Spanish study** collected samples from five different composting facilities (four composting plants and one using anaerobic digestion followed by composting)⁸⁰. The majority of microplastics were conventional polymers such as polyethylene, polystyrene, polyester, polypropylene, and polyvinyl chloride. Microplastics amounted to 10-30 particles/g of dry weight, mostly fragments and fibres smaller than 5 mm. About 30% of these particles were under 1 mm. Smaller plants, with door-to-door collection (as opposed to bigger facilities fed from street bin collections) produce compost which had lower microplastic contamination. No debris from compostable plastics were found.
- An **Italian study** investigated composting plant plastic impurities on collected biowaste using a waste flow analysis to quantify and compare the amount of conventional plastic and compostable plastic before and after industrial composting. The percentage of conventional plastics remained nearly constant, whereas the amount of compostable plastic ‘almost disappeared’ in the composted waste fraction from 4.8% of the total waste fraction to 0.63% of the composted fraction⁸¹.
- Full-scale trials by Envar Composting Ltd as part of a **Composting Coalition UK** project in the UK demonstrated that compostable packaging and materials, when managed correctly in industrial composting processes, broke down effectively. The finished, screened compost met compost quality standards (PAS 100) and showed no detectable compostable plastic

⁷⁸ Gastaldi et al (2024) [Degradation and environmental assessment of compostable packaging mixed with biowaste in full-scale industrial composting conditions](#) *Bioresource Technology* 400:130670

⁷⁹ Van der Zee (2020) [The fate of \(compostable\) plastic products in a full scale industrial organic waste treatment facility](#)

⁸⁰ Edo et al (2022) [Microplastics identification and quantification in the composted organic fraction of municipal solid waste](#) *Science of the Total Environment* 813:151902

⁸¹ Bottausci (2024) [Plastic impurities in biowaste treatment: environmental and economic life cycle assessment of a composting plant](#) *Environmental Science and Pollution Research* 33:9964

microplastics⁸². It also found that materials with larger surface areas break down faster, e.g. coffee pods, and pre-treatment methods like shredding can enhance breakdown efficiency.

- A recent **New Zealand** study examined the presence of microplastics in various organic waste products destined for land application, including biosolids, vermicompost, bulk compost, and bagged compost. Microplastics were detected in every sample tested, with concentrations in compost ranging from 1.1 to 1.94 particles per gram. Both conventional and biodegradable forms were present, indicating that the industrial composting processes used did not always fully break down all compostable polymers under the conditions studied. However, the report did not provide details about the specific composition of the feedstock materials used⁷³.

⁸² REA (2025) [Envar's report on degradation of compostables in full-scale composting trials](#)

Study/Country	Biodegradable Materials Detected	Composting Conditions	Number of Fragments/Microplastics Detected	Time Parameters/Degradation Rate
Dutch Study	Compostable packaging: organic waste bags, PLA plant pots, tea bags, coffee pads, coffee capsules, fruit labels	Full-scale organic waste treatment facility (industrial composting, EN 13432:2000 standard)	No compostable plastics visually identified in finished compost	All products broke down within 22 days: PLA pots within 11 days (faster than most organic materials)
Spanish Study	Majority were conventional polymers; no compostable plastic debris found	Five facilities: 4 composting plants, 1 anaerobic digestion + composting	Microplastics: 10–30 particles/g dry weight (mostly fragments/fibres <5 mm); ~30% <1 mm; no compostable plastic debris	Not specified (focus on microplastic contamination, not degradation time)
Italian Study	Conventional plastics, compostable plastics	Industrial composting plant	Compostable plastic reduced from 4.8% (input) to 0.63% (output); nearly disappeared	Not specified (focus on before/after impurity levels)
UK (Envar Composting)	Compostable packaging and materials (not specified)	Full-scale industrial composting; PAS 100 quality standard	No detectable compostable plastic microplastics in finished compost	Not specified; larger surface area and shredding increase breakdown speed
New Zealand Study	Both conventional and biodegradable microplastics	Industrial composting (biosolids, vermicompost, bulk and bagged compost)	Microplastics in compost: 1.1–1.94 particles/g; both conventional and biodegradable types found	Not specified; not all biodegradable polymers fully degraded

Table 2: synthesis of recent composting trials detailing test materials, composting conditions, detection rates, and degradation rates

Biodegradation rates of compostable plastics in industrial composting facilities vary significantly due to differences in operational conditions such as temperature profiles, composting duration, waste composition, and process management. While certified compostable products (produced from PLA for example) can fully disintegrate within 2–3 weeks in some facilities (below the 12 week EN 13432:2000 benchmark) other studies have reported much slower degradation, particularly for thicker or more rigid products, with some items showing limited mass loss after several weeks⁸³. For example, a 1 mm thick PLA-based blend for rigid packaging retained 97.2% of its mass after 3 weeks in an industrial plant, compared to higher disintegration in controlled lab tests, highlighting the impact of real-world variability. Across multiple European facilities, average degradation rates for biodegradable plastics have ranged from 95–98% mass loss after a standard 3–4 month composting cycle, but incomplete degradation is observed if composting times are shorter or if the plastics are particularly thick or formulated with additives that slow breakdown⁸⁴. Whilst this study did not state if these plastics comply with EN 13432:2000, findings underscore that actual biodegradation rates are highly dependent on specific facility practices and conditions.

Finally, and with caution, there is the risk of contamination of industrial sources from sources other than the feedstock. A UK-based study of a green waste composting facility quantified and characterised microplastics in both air and compost – including from PVA, which is considered biodegradable⁸⁵. This showed that airborne microplastics were found not only onsite but also up- and down-wind from the composting site. Whilst this shows the composting facility could be a point of entry of microplastics into the wider environment, it cannot be entirely ruled out that contamination could also enter the site from other sources. Furthermore, research has shown that additional sources, such as irrigation water, can further contribute to microplastic content in the final product⁸⁶.

Certified compostable plastics degrade in industrial composting facilities. However, studies show biodegradable microplastics can remain and will be transferred to soils.

Industrial trials across multiple regions and waste streams consistently show that finished compost products contain microplastics, primarily from conventional plastics but also, in some cases, from biodegradable polymers that did not fully biodegrade. These findings highlight the need for better source control, improved processing, and ongoing monitoring.

When compost containing microplastics is applied to soil, research indicates that microplastics from a wide range of conventional and biodegradable plastics can accumulate with repeated applications^{87 73}. Ruffell *et al* (2025) demonstrated that the most frequently detected polymer types were polypropylene and polyethylene. They also showed that biodegradable polymers including PLA and PBAT (polybutylene adipate terephthalate) were detected for the first time in mature compost and are likely to persist in soils⁷³.

Home composting

⁸³ Chong *et al* (2024) [Lab-scale and full-scale industrial composting of biodegradable plastic blends for packaging](#) *Open Research Europe* 22 (2):101

⁸⁴ Gastaldi *et al* (2024) [Degradation and environmental assessment of compostable packaging mixed with biowaste in full-scale industrial composting conditions](#) *Bioresource Technology* 400: 130670

⁸⁵ Zapata *et al* (2023) [Microplastic emissions via air and compost from an industrial composting facility in England](#) *Environmental Pollutants and Bioavailability* 36 (1)

⁸⁶ Peneva *et al* (2025) [Plastic input and dynamics in industrial composting](#) *Waste management* 193: 283-292

⁸⁷ Braun *et al* (2023) [Microplastic contamination of soil: Are input pathways by compost overridden by littering?](#) *Science of the Total Environment* 855:158889

There are some important differences between industrial composting and home composting. Industrial facilities control conditions (including temperature, moisture content and availability of oxygen among others) to optimise the process. In contrast, home composting typically takes place at lower temperature, over a longer period, and with no temperature control. As a result, much less is known about how compostable plastics behave in home composting conditions.

Some countries have developed standards for home composting, including:

- AS 5810-2010 Biodegradable plastics – Biodegradable plastics suitable for home composting (Australia)⁸⁸
- NF T 51-800 (2015) Plastics – Specifications for plastics suitable for home composting (France)
- EN 17427:2020 Packaging – Requirements and test scheme for carrier bags suitable for treatment in well-managed home composting installations.

Both standards describe biodegradable plastics suitable for home composting, with biodegradation tests that are longer and at lower temperatures than required for industrial composting. They specify at least 90% biodegradation within 12 months at ambient temperatures (around 25°C), with no more than 10% of the original dry weight remaining as fragments larger than 2 mm after 180 days. The Australian Standard has a slightly higher test temperature range (25-30°C) and requires an earthworm toxicity test (*Eisenia fetida*) to ensure no adverse effects on soil fauna, as well as specifying that any remaining material must not be visually distinguishable from compost at a distance of 500 mm⁸⁹. There are also some private certification schemes in operation including TUV OK compost. While not a standard, this scheme served as the basis for development of AS 5810-2010, NF T 51-800 (2015) and EN 17427:2020.

In the UK, EN 13432:2000 defines the criteria that must be met for a material to be suitable for industrial composting, but the only standard relevant to home composting conditions is BS EN 17427: 2022 Packaging: Requirements and test scheme for carrier bags suitable for treatment in well-managed home composting installations.

Based on the French standard [NF T 51-800 (2015)], EN 17427:2022 specifies requirements and a testing scheme for carrier bags to be designated as suitable for home composting. It requires at least 90% disintegration into fragments smaller than 2 mm in a 'well managed' home composting cycle, specified as being ambient temperatures over 12 months.

Outside of EN 17427 – which focusses on home composting of plastic bags – there is no general UK standard for home composting. International standards from Australia (AS 5810-2010) and France (NF T 51-800) specify 90% biodegradation within 12 months at ambient temperatures (around 25°C)

As an example, a recent study demonstrated that microplastics generated from a bio-based, biodegradable thermoplastic polyurethane (TPU-FC1) rapidly decreased in number during home composting, with 97% reduction over 200 days, with the remaining carbon was largely converted to CO₂ confirming mineralisation and assimilation by microbes⁹⁰. In contrast, ethyl vinyl acetate – a non-biodegradable conventional plastic – persisted as microplastics, showing little to no reduction in count or mineralisation.

⁸⁸ Australian Standard AS 5810-2010 [Biodegradable plastic – biodegradable plastics suitable for home composting](#)

⁸⁹ REAL (2023) [Home compostable products scheme rules](#)

⁹⁰ Allemann et al (2024) [Rapid biodegradation of microplastics generated from bio-based thermoplastic polyurethane](#) *Nature Scientific Reports* 6036

Impact on soil health

Some long-term field studies suggest that current concentrations of microplastics in many agricultural fields remain below thresholds likely to cause acute negative effects⁹³, including significant disruption of soil structure, soil organisms, microbial communities, or plant growth^{91,93,94}. However, the potential risks associated with chronic exposure and accumulation are increasingly recognised. As microplastic inputs continue to rise, concerns persist regarding their long-term impact on soil productivity and environmental health⁹¹.

Microplastics can alter key soil physicochemical properties, including soil aggregation, bulk density, and water retention, which may reduce soil fertility and limit the soil's capacity to support healthy plant growth. Furthermore, microplastics have been shown to negatively affect plant growth and crop quality⁹¹ by limiting root development, hindering nutrient uptake, and potentially accumulating within plant tissues⁹².

Particles can also be ingested by soil organisms such as earthworms⁹³, potentially disrupting soil fauna health and biodiversity. Further, whilst the composition and abundance of microarthropod and nematode communities also reduced, there were variations across species (e.g. larger omnivorous and predatory nematode populations decreased whereas there was little change in fungal- and bacterial-feeding nematodes). An in-field microplastic addition experiment examining polyethylene fragments (<400µm) showed that the microbial community was not affected although activity increased⁹⁴.

Counter to the above arguments, the use of sewage sludge and composted household waste in a Danish trial showed improved soil health compared to unfertilised and NPK fertilised soil and found no indications of unwanted effects of microplastics. Those authors also undertook a meta-analysis of the effects of microplastics on soil health and found that of the 32 published studies that observed effects, these were seen at exposure concentrations higher than environmentally realistic⁹⁵.

However, plastics made from biodegradable materials might behave differently in the soil, particularly as degradation progresses beyond fragmentation to assimilation and mineralisation. Indeed, adding biodegradable plastics to the soil results introduces carbon to the system and, in specific soil types (loamy and sandy), demonstrated higher growth of microbial biomass, increased carbon mineralisation⁹⁶. Whilst generating microplastics more rapidly, fragments generated from certified soil-biodegradable plastics are subsequently biodegraded by microbes, unlike microplastics from non-biodegradable materials which accumulated in the environment⁹⁷. The initial rate of degradation into microplastics is one part of the degradation pathway for biodegradable materials, and it is the ability and time taken to progress through to assimilation and mineralisation that is challenging to identify.

⁹¹ Cusworth et al (2024) [Agricultural fertilisers contribute substantially to microplastic concentrations in UK soils](#) *Communications Earth & Environment* 5(7)

⁹² Jia et al (2023) [Microplastic stress in plants: effects on plant growth and their remediations](#) *Frontiers in Plant Science* 14

⁹³ Sakali et al (2024) [Analysis of microplastics in the reuse of compost in three agricultural sites \(Cádiz, Spain\) as a circular economy strategy: detection of micropollutants and incidence of plastic ingestion levels by annelids](#) *Environmental Science and Pollution Research* 31(39): 51747

⁹⁴ Lin et al (2020) [Microplastics negatively affect soil fauna but stimulate microbial activity: insights from a field-based microplastic addition experiment](#) *Proceedings of the Royal Society B* 287 (1934)

⁹⁵ Liengaard Johansen et al (2024) [Extent and effects of microplastic pollution in soil with focus on recycling of sewage sludge and composted household waste and experiences from the long-term field experiment CRUCIAL](#) *Trends in Analytical Chemistry* 171: 117574

⁹⁶ Mazzon et al (2022) [Biodegradable plastics: Effects on functionality and fertility of two different soils](#) *Applied Soil Ecology* 169:104216

⁹⁷ Degli-Innocenti et al (2022) [Analysis of the microplastic emission potential of a starch-based biodegradable plastic material](#) *Polymer Degradation and Stability* 199:109934

Fate of microplastics from composts in soil

Recent studies indicate that biodegradable microplastics like polylactic acid (PLA), when introduced to soil via composts, undergo further biodegradation driven by soil microbial activity, environmental conditions, and the chemical characteristics of the polymer. A 2024 meta study focussed on PLA indicated that biodegradable microplastics continue to break down in soil environments primarily through hydrolysis, which prevents the accumulation of persistent PLA microplastics in the environment⁹⁸. Once in the soil, they are subject to further microbial activity and environmental conditions that promote continued degradation, ultimately leading to their mineralisation into carbon dioxide, water, and biomass, rather than persisting as microplastic fragments. The technical summary of the PeToPLA meta-study underscores that, unlike conventional plastics, compostable bioplastics do not form persistent microplastic residues in soil.

PLA microplastics are a carbon source for soil microorganisms, influencing microbial community structure and function, and can contribute to increases in soil organic carbon and dissolved organic carbon, which may improve soil structure and nutrient retention⁹⁹. However, the rate and completeness of PLA biodegradation in soil varies depending on factors such as particle size, concentration, soil type, and microbial diversity¹⁰⁰. While some studies report that realistic concentrations of PLA microplastics (e.g. 0.2% by weight) have minimal effects on soil properties and plant growth over several months, higher concentrations or the presence of weathered particles could negatively impact plant biomass and alter nitrogen cycling potentially due to influxes of carbon and changes in soil microbiome dynamics¹⁰¹. Additionally, incomplete degradation could lead to the temporary presence of PLA fragments, although these are ultimately mineralised to carbon dioxide, water, and biomass.

Nonetheless, the actual rate and completeness of biodegradation in field conditions can vary depending on factors such as polymer type, soil characteristics, and microbial community composition, highlighting the need for ongoing monitoring and optimization of composting and land application practices.

Fate of microplastics in marine environments

Microplastics present in soil will be present in rivers and the sea because of wash off. Biodegradable plastics will degrade more slowly in the marine environment than in soil due to lower temperatures, less microbial diversity, and lower nutrient levels^{102,103}. PLA and PBS degradation studies in marine environments found that biodegradable plastics behaved like conventional plastics in cold deep water due to low temperature and light exposure. As photodegradation is a key process in the sea, research has shown that PLA may release fewer microplastics than conventional plastics when exposed to sunlight and seawater, implying a lower fragmentation rate¹⁰⁴.

⁹⁸ Lott et al (2024) [PeToPLA A meta-study on the persistence and toxicity of PLA, and the formation of microplastics in various environments](#) (prepared for Holland Bioplastics, Total Energies, Corbion, Natureworks and Futerro)

⁹⁹ Withana et al (2025) [Biodegradable plastics in soils: sources, degradation, and effects](#) *Environmental Science: Processes and Impacts* (advance article)

¹⁰⁰ Hajilou et al (2025) [A comparative review on biodegradation of poly\(lactic acid\) in soil, compost, water, and wastewater environments: incorporating mathematical modelling perspectives](#) *Applied Chemistry* 5(1) 1

¹⁰¹ Malafeev et al (2023) [Understanding the impact of biodegradable microplastics on living organisms entering the food chain: a review](#) *Polymers* 6: 15(18) 3680

¹⁰² Zhao et al (2022) [Photodegradation of biobased polymer blends in seawater: A major source of microplastics in the marine environment](#) *Frontiers in Marine Science* 9

¹⁰³ Weinstein et al (2020) [Degradation of bio-based and biodegradable plastics in a salt marsh habitat: Another potential source of microplastics in coastal waters](#) *Marine Pollution Bulletin* 160: 111518

¹⁰⁴ Niu et al (2024) [Accelerated fragmentation of two thermoplastics \(polylactic acid and polypropylene\) into microplastics after UV radiation and seawater immersion](#) *Ecotoxicology and Environmental Safety* 271: 115981

Polymer blends, however, are less resistant to UV and mechanical stress in seawater than neat polymers. Many biodegradable polymers are blended to give different properties, and this often enhances the breakdown under ambient conditions. Indeed, research showed that blends were fragmented more readily and produce a higher proportion of small microplastic particles after photodegradation in seawater than neat polymers. Some biodegradable polymer blends (particularly those with thermoplastic starch) release more and smaller microplastic particles than conventional plastics due to their poorer mechanical properties with low miscibility between the starch granules and the surrounding polymer matrix¹⁰². This is due to starch granules migrating out of the matrix, creating a porous structure that further promotes fragmentation and alterations such as cracks, holes, and pits on the plastic surface. This facilitates deeper UV penetration and acceleration of further oxidation and fragmentation, so that the particles are more likely to fragment and release microplastics. The process breaks polymer chains, reducing the molecular weight and durability of the material and further facilitating fragmentation.

Digestate from anaerobic digestion

Anaerobic digestion (AD) is widely used to produce biogas from organic wastes such as food waste and sewage sludge. Whilst compostable plastics should not be deliberately subjected to AD, there is the inadvertent potential of residual plastics being present in the resulting digestate. Recent research has consistently reported the presence of microplastics in AD digestate, with typical concentrations ranging from 1,000 to 1,500 particles per kilogram of dry digestate (approximately 1g/kg dry weight)^{105 106}. Further, AD does not significantly reduce microplastic abundance¹⁰⁷. However, these studies focussed on microplastics as a whole and made no discrimination between conventional and biodegradable materials. In practice, studies have not reported significant quantities of biodegradable plastic derived microplastics in digestate, potentially due to biodegradable plastics partially degrading under AD conditions¹⁰⁸, or the proportion of biodegradable plastics in AD feedstock is low compared to conventional plastics, or studies have not specifically targeted biodegradable plastics. Whilst Raman spectroscopic analyses could, in principle, distinguish between polymers from biodegradable plastics from fossil-based plastics, the risk is that this would also misidentify naturally occurring polymers as microplastics⁶⁰.

¹⁰⁵ Porterfield et al (2023) [Microplastics in composts, digestates, and food wastes: A review](#) *Journal of Environmental Quality* 52(2): 225

¹⁰⁶ Akaniro et al (2024) [Exploring the potential of hydrothermal treatment for microplastics removal in digestate](#) *ACS Sustainable Chemical Engineering* 12 (38): 14187

¹⁰⁷ Belone et al (2025) [Microplastics in an anaerobic digester treating sewage sludge: Occurrence and factors affecting their identification with Raman spectroscopy](#) *Journal of Hazardous Materials* 491: 138015

¹⁰⁸ The operating temperature range for anaerobic digestion can vary depending on the specific application and the types of microorganisms involved. However, most AD bioreactors operate in the mesophilic temperature range (15-40°C) and can also be used under thermophilic conditions (45-65°C).

Conclusions

Biodegradable materials can help reduce plastic accumulation, particularly in applications where plastics are used in the natural environment. While biodegradable plastics may have similar short-term microplastic impacts as conventional ones, they do not persist indefinitely, lowering long-term accumulation.

Biodegradable plastics are increasingly recognised as a suitable alternative to conventional plastics, particularly in applications where direct exposure in the open environment is expected such as agriculture and composting, and where recycling or recovery from the environment is unlikely. While concerns have been raised about their potential to contribute to microplastic pollution, emerging evidence suggests that their environmental behaviour differs significantly from that of conventional plastics, offering a more manageable and ultimately less persistent impact.

All plastics, whether conventional or biodegradable, can break down into microplastics. However, this does not mean they pose equal environmental risks. Unlike conventional microplastics, which can persist for decades or longer, those derived from biodegradable materials are transient and will be further broken down and mineralised by naturally occurring microorganisms - provided suitable environmental conditions exist that meet the conditions and timeframe they have been designed for. This biodegradation involves multiple steps, including fragmentation, microbial colonisation, enzymatic depolymerisation, uptake of monomers, and conversion into water, carbon dioxide and microbial biomass.

Importantly, biodegradable materials tend to fragment and biodegrade more rapidly than fossil-based counterparts. Field studies suggest that over time, an equilibrium is reached between the rate at which microplastics are introduced into the environment and the rate at which they are broken down. This dynamic equilibrium contrasts with conventional plastics, which continue to accumulate. The key question becomes not whether biodegradable plastics form microplastics - they do - but how long those microplastics persist and whether they are ultimately assimilated by natural systems.

Environmental conditions influence degradation rates. For example, biodegradation can take longer in cooler or drier conditions. However, this challenge is not unique to biodegradable plastics as it applies to all biological processes. What's critical is setting realistic expectations around degradation timeframes and defining what constitutes acceptable persistence in specific applications. For instance, a material that takes 100 years to mineralise may not be appropriate in some contexts, but biodegradable plastics often degrade on much shorter timescales, especially in microbially active environments.

Biodegradable plastics are already being applied in a variety of beneficial ways. In agriculture, biodegradable mulch films (certified under standards such as EN 17033:2018) support crop productivity and reduce the need for manual removal. These films must convert at least 90% of their organic carbon to CO₂ within 24 months under controlled lab conditions. While real-world soil conditions can slow this process, field data show that over time, a plateau in microplastic levels is achieved, reflecting ongoing mineralisation. In contrast, conventional mulch films would continue to accumulate in the soil.

Tree guards, another useful application given the extensive deployment with the increases in tree planting, currently lack a defined biodegradation standard. These products remain visible for longer periods as they are not ploughed into the soil. However, new guidelines around removal and recycling, combined with growing demand for low-maintenance, environmentally friendly alternatives, are driving innovation in biodegradable formulations and designs. This will likely

accelerate the development and adoption of biodegradable tree guards that break down naturally after serving their purpose.

While more consensus is needed around definitions of ‘persistence’, there is growing agreement that biodegradable microplastics behave differently from conventional ones, especially in microbially-rich and -diverse settings like compost or soil. Studies across varied climates, from the Mediterranean to Nordic regions, confirm that biodegradation is feasible under a range of conditions.

In composting systems, compostable plastics are subject to standards such as EN 13432:2000, which require 90% biodegradation within six months, and less than 10% visible residue after 12 weeks. While some microplastics may initially be present, further processing steps - including mechanical separation and biological treatment - significantly reduce contamination. Composters are also commercially motivated to exceed these standards, as consumers demand clean, plastic-free compost. Data show that when optimal composting conditions are met, compostable plastics do not contribute significantly to microplastic loads.

Current regulatory frameworks like PAS 100 in the UK also set limits on visible contamination, but do not address microplastics smaller than 2 mm (noting that Resource Frameworks for compost quality exist and are currently under review: it is anticipated that the allowance is expected to be halved). However, the industry is advancing methods to remove even smaller fragments through sieving and source control. Once compost is applied to land, degradation of residual biodegradable material continues, contributing to a stable microplastic plateau rather than a growing burden. This is particularly important as compost expands as a sustainable alternative to peat-based growing media.

Home composting poses unique challenges, as conditions are highly variable. Laboratory standards simulate ideal conditions, but these may not reflect real-life home environments. Nevertheless, the concept of ‘thermal time’ (accumulated temperature over time) offers a promising approach to predict degradation more accurately across diverse settings. Public engagement will depend on clear labelling, achievable standards, and continued transparency about what biodegradable means in practice.

Moving forward

While biodegradable plastics are not a panacea for microplastic pollution, they offer a fundamentally different and more positive trajectory than conventional plastics. With appropriate product design, use, and regulatory oversight, biodegradable and compostable materials can significantly reduce the long-term persistence of microplastics in the environment. The key lies in promoting robust, science-backed standards, ongoing monitoring, and continuous improvements in both materials and waste management practices. The alternative of continued reliance on conventional plastics will lead to increasing accumulation and long-term environmental impact. In contrast, biodegradable plastics, when used judiciously and managed responsibly, represent a meaningful step toward more sustainable materials and healthier ecosystems.

To prevent unintended environmental harm and ensure the credibility of biodegradable plastics, the UK government must establish clearer regulatory frameworks, invest in long-term environmental research, and set transparent testing and performance standards. In addition, the government should consider mandating specific uses - as has occurred in the EU under the Packaging and Packaging Waste Regulation - where a small number of packaging items (such as tea and coffee bags, sticky labels for fruit and vegetables, and very lightweight plastic bags) must be made from

certified compostable materials¹⁰⁹. Without such measures, the potential for microplastic pollution and other ecological risks remains significant, even from materials intended to be sustainable.

Key actions and recommendations

To support sustainable innovation in the biodegradable materials sector, the following integrated recommendations are proposed:

1. Closer collaboration between policymakers, regulators and industry

This will allow government to actively benefit from the considerable knowledge and research data has been generated by companies working in this area for many years.

2. Establish application-specific biodegradation standards

Current standards do not cover the diverse environmental conditions where biodegradable plastics are used. Government should consider adopting European standards under harmonisation protocols, such as with EU 17033:2018. However, where standards do not exist, government should lead the development of robust, verifiable biodegradation requirements tailored to specific applications and natural environments where appropriate.

3. Support research into acceptable timeframes for mineralisation

The expectation of rapid degradation is unrealistic in many natural settings and decomposition may take decades. Government should fund work to determine what constitutes an acceptable timeframe for full mineralisation under different environmental conditions, developing predictive models that mimic the various possible conditions and recognising this variation in future standards and policies.

4. Fund long-term environmental fate studies

Understanding the behaviour of transient, biodegradable micro- and nano-plastics in real-world conditions is crucial. Government should support extended studies across various climates and ecosystems to assess how these materials behave, not just in controlled laboratory settings, and compare results with conventional plastic behaviour.

5. Monitor soil accumulation for applications not covered by a standard

Biodegradable microplastics can accumulate over time, although they are transient and less durable than conventional plastics. This potential buildup warrants targeted monitoring and long-term studies, including assessing conventional microplastics. This is particularly the case for those materials that will not have undergone ecological testing whereas those biodegradable materials that meet standards (such as EN 13432:2000) will have.

6. Develop a global monitoring framework for microplastics

A comprehensive understanding of microplastic distribution from both conventional and biodegradable sources is needed. Government should contribute to - or initiate - global monitoring initiatives to build reliable datasets on microplastics in soil, water and air.

7. Standardise detection and reporting methods

Inconsistent testing and reporting methods hinder scientific comparability. Harmonised detection techniques and reporting units (e.g. size thresholds, mass concentrations) would enable meaningful cross-study comparisons and support the creation of quality standards.

8. Clarify communication around biodegradability claims

Evidence to support claims of biodegradability in natural settings should be substantiated where possible by conformation to an agreed standard. Policymakers should require clear labelling, substantiated claims, and possibly restrict marketing of 'biodegradable' products unless supported by evidence and certification.

¹⁰⁹ [Regulation \(EU\) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste](#)

Annexes

Annex 1: Bio-Barometer Survey

BB-REG-NET launched its Bio-Barometer Survey in Spring 2025¹¹⁰. The survey aims to capture data on what limits the uptake of biobased and biodegradable materials. A specific question relates to uptake of biobased materials:

Q10: 'When talking to stakeholders, which of the following, if any, are coming up as concerns for Bio-based and Biodegradable products?'

Whilst the results are yet to be published, the survey had 91 responses, predominantly from professionals in the material and chemical industries, academia or industry support services. The options and the percentage chosen as an answer are given in

Table 2 below.

Table 2 Results from Bio-barometer survey Q10: When talking to stakeholders, which of the following, if any, are coming up as concerns for Bio-based and Biodegradable products?

Those answers relevant to the current report are highlighted.

Answer	Result
Life Cycle Analysis	52
Concerns over best use of biomass	44
Issues with end-of-life management	43
Unintended consequences (e.g. detrimental land use changes, increased water consumption etc.)	42
Contamination of recycling streams	40
Insufficient standards and certification schemes	37
Formation of microplastics	30
Opinion that products are 'single-use'	29
Increased risk of littering	15
None of the above	7

¹¹⁰ BBIA Newsletter (February 2025) Available at: https://bbia.org.uk/wp-content/uploads/2025/02/BBIA-newsletter_Feb-2025.pdf

Annex 2: Methodology

A comprehensive literature review focused on the link between microplastics and compostable or biodegradable material was conducted between November 2024 and February 2025. The challenge in designing appropriate search strings soon became apparent due to the confusing terminology when referring to 'biodegradable' and 'bioplastics'.

Several options were assessed and reviewed with the final strings being as in Table 1. The terms were examined in six search engines (Google scholar, RefSeek, SpringerLink, WorldCat, Science.gov, and BASE), with the time frame restricted to 2005-2025 and the first two pages of results reviewed. Relevance was established by confirmation of search terms appearing in the title, abstract, and introduction. If absent, then the item was excluded. Where not clear, relevance was determined by expert opinion.

Table 1 Search strings employed

Search Strings
microplastics AND compostable
microplastics AND biodegradable
microplastics AND bioplastic
(agriculture OR horticulture OR forestry) AND microplastics AND compostable
(agriculture OR horticulture OR forestry) AND microplastics AND biodegradable AND mulch
(tree OR sapling) AND (guard OR shelter OR guide) AND microplastics AND biodegradable

Stakeholder engagement and feedback for further research

A self-selecting Working Group of 61 participants was established via a request for participants via the BB-REG-NET mailing list. This was open to anyone who has an interest in the circular economy within the context of the regulation of biobased and biodegradable materials and was not subject to any screening.

The Working Group met first in January 2025 to validate approach and initial results, as well as recruit additional relevant material. The Group agreed with the approach discussed and the initial three search strings employed, with additional sources shared. The BB-REG-NET Advisory Board were also separately consulted.