European Commission

Scientific Advice Mechanism (SAM)

Biodegradability of Plastics
in the Open Environment

Group of Chief Scientific Advisors
Scientific Opinion No.10, December 2020

Independent Expert Report

Research and Innovation

Biodegradability of Plastics in the Open Environment

Group of Chief Scientific Advisors

European Commission
Directorate-General for Research and Innovation
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Manuscript completed in December 2020.

Print	ISBN 978-92-76-23785-3	doi:10.2777/284409	KI-02-20-895-EN-C
PDF	ISBN 978-92-76-23786-0	doi:10.2777/690248	KI-02-20-895-EN-N

Luxembourg: Publications Office of the European Union, 2021

EUROPEAN COMMISSION

Chief Scientific Advisors – SAM, EGE
INDEPENDENT SCIENTIFIC ADVICE FOR POLICY MAKING

Biodegradability of Plastics
in the Open Environment

Group of Chief Scientific Advisors
Scientific Opinion No.10, December 2020
(Informed by SAPEA Evidence Review Report No. 8)

Brussels, 14 December 2020

2020 Directorate-General for Research and Innovation

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ACKNOWLEDGMENTS

The Scientific Opinion on the Biodegradability of Plastics in the Open Environment was adopted by the Group of Chief Scientific advisors at the request of former Commissioner for Environment, Maritime Affairs and Fisheries Karmenu Vella during the mandate of the Junker Commission, delivered to his successor in the Von der Leyen Commission, Commissioner Virginijus Sinkevičius.

The Scientific Advisors in charge of preparing this Opinion were Nicole Grobert (lead and Chair of the Group) and Rolf Heuer (former Chair). Pearl Dykstra (former Deputy Chair) and Elvira Fortunato served as Scientific Advisors until November 2020. The Scientific Advisors wish to acknowledge cooperation on this topic with Canada's Chief Science Advisor Mona Nemer, as part of an ongoing cooperation which started in 2019 with the Scientific Opinion on 'Environmental and Health Risks of Microplastic Pollution'.

The Scientific Advisors would like to thank the many contributors for their support and input in the preparation of this Scientific Opinion:

- The Science Advice for Policy by European Academies (SAPEA) consortium which provided an Evidence Review Report (ERR) prepared under the leadership of the SAPEA Working Group Chair Ann-Christine Albertsson, aided by the SAPEA staff Louise Edwards and with the support of the SAPEA Board member Ole Pedersen;

- European Commission Directorate-General Environment (Silvia Forni and Werner Bosmans) and Joint Research Centre (Birgit Sokull-Klüttgen)

- European Commission support team of Unit RTD.03 (SAM Unit) (Alessandro Allegra, Blagovesta Cholova, Jacques Verraes, Ingrid Zegers, Annabelle Ascher, Daniel Braakman and Dulce Boavida) and other SAM Unit staff

- All of the experts listed in Annex 3 who were consulted or contributed in one way or another in the course of the work.

EXECUTIVE SUMMARY

The Opinion on the *'Biodegradability of Plastics in the Open Environment'* is provided in support of the European Commission Directorate-General for Environment. This Opinion intends to contribute to informing the forthcoming Commission's policy framework related to bio-based, biodegradable and compostable plastics, and help define the main challenges and policy actions needed in this area. It builds on some of the recommendations of the Scientific Opinion on *'Environmental and Health Risks of Microplastic Pollution'* published in 2019.

The 2018 EU Plastics Strategy sets out a cautious approach for the use of biodegradable plastics (BDP). While it acknowledges that targeted BDP applications have shown some benefits, it also identifies several challenges and points out that *"It is important to ensure that consumers are provided with clear and correct information, and to make sure that biodegradable plastics are not put forward as a solution to littering".* Moreover, *"Applications with clear environmental benefits (and criteria for such applications) should be identified, and in those cases the Commission will consider measures to stimulate innovation and drive market developments in the right direction".*

The mandate outlined in the scoping paper requests the Group of Chief Scientific Advisors to investigate the following question: '*from a scientific point-of-view and an end-of-life perspective, and applying to plastics that biodegrade either in the terrestrial, riverine or marine environments, and considering the waste hierarchy and circular economy approach: What are the criteria and corresponding applications of such plastics that are beneficial to the environment, compared with non-biodegradable plastics?'*

The recommendations below are informed by an extensive review of scientific literature and evidence carried out by the consortium of European Academies under the Horizon 2020 funded SAPEA grant agreement. In the context of this Opinion, biodegradation of plastic is understood as the microbial conversion of all its organic constituents to carbon dioxide (CO_2) (or carbon dioxide and methane in conditions where oxygen is not present), new microbial biomass and mineral salts, within a timescale short enough not to lead to lasting harm or accumulation in the open environment. Here, the term '*open environment*' (as opposed to a controlled environment) denotes any environment, including agricultural and urban environments, with no or only minimal control over conditions that influence biodegradation. It excludes managed waste systems, such as industrial composting facilities.

Recommendation 0:

Adopt a definition of biodegradability as a system property which takes into account material properties and specific environmental conditions

Recommendation 1:

Limit the use of BDPs in the open environment to specific applications for which reduction, reuse, and recycling are not feasible

1.1 Prioritize reduction, reuse and recycling of plastics before considering biodegradation

1.2 Limit use of BDP in the open environment to specific applications where collection from the open environment is not feasible

1.3 Do not consider BDPs as solution for inappropriate waste management or littering

Recommendation 2:

Support the development of coherent testing and certification standards for biodegradation of plastic in the open environment

2.1 Support the development of testing and certification schemes evaluating *actual* biodegradation of BDP *in the context of their application* in a specific receiving open environment

2.2 Require testing of biodegradation of BDP applications under laboratory and simulated environmental conditions

2.3 Require assessment of biodegradation and environmental risk of BDP under the conditions of specific open environments

2.4 Support the development of a materials catalogue and their relative biodegradation rates in a range of environments

Recommendation 3:

Promote the supply of accurate information on the properties, appropriate use and disposal, and limitations of BDPs to relevant user groups

3.1 Initiate and support information campaigns to address current misconceptions and confusion related to bio-based, compostable and biodegradable plastics

3.2 Support the development of standards for clear, effective European labelling for a) end-users and consumers to ensure proper use and disposal of BDP applications in the open environment; and b) manufacturers and vendors to ensure accurate information transfer along the value chain

1. INTRODUCTION AND BACKGROUND

1.1. Background to the opinion

This Opinion intends to support policy development by the Directorate-General for Environment and to contribute to informing the forthcoming European Commission's policy framework related to bio-based, biodegradable and compostable plastics by helping to define the main challenges and policy actions needed in this area. The Commission endorsed the approach we proposed in the Scoping paper published in December 2019 (see Annex 1).

The focus of this Opinion is on biodegradable plastics (BDP) applications ***in the open environment***. Plastics intended for composting under controlled conditions are therefore outside its scope. For the purpose of this opinion, '*open environment*' (as opposed to a controlled environment) denotes any environment, including agricultural and urban environments, with no or only minimal control on conditions that influence biodegradation. It excludes managed waste systems, such as industrial composting facilities.

The main input to the Opinion is the SAPEA review (SAPEA 2020) which contains a systematic and independent synthesis of relevant state-of-the-art scientific evidence and knowledge regarding the biodegradability of plastics in the open environment. The review draws on the natural, social and behavioural sciences. Further literature on specific aspects related to BDPs in the open environment, and relevant policy and grey literature have been consulted to complement the SAPEA review. The scientific evidence on a) testing and certification of BDP applications in the open environment, b) assessment of current and potential applications, and c) the attitudes and behaviour of users is still scarce and partial. We therefore stress the need for further evidence and research to support the development of policies for BDP applications in the recommendations of this scientific opinion.

1.2. Plastic pollution and BDPs

The global demand for very durable, lightweight and versatile materials, such as plastic materials, is growing and with it the amount of related plastic waste in the open environment is increasing, causing harm and pollution in land and marine ecosystems (SAPEA, 2020, p. 18). For example, recent studies showed that the mass of plastic has reached 8 billion tonnes globally in 2020 and is now double that of living biomass (Elhacham, 2020, p. 3).

Plastic can reach an open environment for a variety of reasons. For most plastic applications, the intended end-of-life scenario is disposal in a managed waste stream, where they can be recycled or composted, if applicable. However, plastics destined for managed waste systems at the end of their life can escape from such systems or reach the open environment as a result of improper disposal or littering.

Some plastic applications on the other hand, *e.g.,* those used in agriculture to protect crops, are specifically intended to be used in the open environment. Loss may also be intrinsic to use, for example dolly rope abrading to protect fishing gears or fireworks generating fragments after use in the open. Finally, there are applications, such as fishing gear, where (partial) loss is considered unavoidable during normal use in the open environment. Although recovery from the environment for reuse or recycling would be preferable, for some of these applications it is either impossible or disproportionally expensive (see 2.1.2).

BDPs have been proposed as part of a potential solution to plastic pollution. However, their environmental benefits over conventional plastics need to be carefully assessed. In 2019, the global production capacity of BDPs was reported to be 1.174 million tonnes, which corresponds to only about 0.3% of the total plastic production capacity of about 360 million tonnes (PlasticsEurope, 2019). The production of BDP is expected to increase in the upcoming years, continuing the trend observed in recent years.

1.3. Policy context

The need for better plastic waste management to avoid pollution of land- and marine ecosystems has been recognised globally. In particular, it was acknowledged that plastic litter in marine environments poses a global problem that needs to be addressed through education, waste removal and research (G7 Summit, 2015, p. 19). Similarly, in 2015, the UN published a list of Sustainable Development Goals emphasising the need for improved waste management and recycling (United Nations, 2015, p. 13). The role of biodegradable- and compostable plastics is yet to be specified in this global context, but the European Commission stated in the Communication on the European Green Deal of December 2019 that *"it will develop a regulatory framework for biodegradable and bio-based plastics"* (COM 2019/640, p. 8). This commitment was preceded by several documents assessing the challenges and risks involved with the implementation of biodegradable plastics, as described below.

1.3.1 Green Paper on a European Strategy on Plastic Waste in the Environment (2013)

In 2013, the European Commission published a Green Paper '*On a European Strategy on Plastic Waste in the Environment'*, concentrating on proper waste management and recycling (COM 2013/123). Whilst the Green Paper does not bring forward specific policies for biodegradable plastics, it does point out the knowledge gaps and risks future policies would need to address. The Green Paper also acknowledges that the term 'biodegradable' needs further explanation, as it may give rise to the false assumption that biodegradable plastics can be composted at home or littered into natural environments (ibid, p. 16).

Since most of these plastics only biodegrade in industrial composting facilities under sufficiently high temperatures and humidity, the Green Paper stresses that clear labelling is necessary to distinguish industrially-compostable from home-compostable plastics. Furthermore, the paper points out that claims of biodegradability need to be scrutinised, and end-of-life scenarios properly understood, before promoting BDPs as a solution to problems associated with conventional plastics. It also notes that biodegradable plastics may contain additives that can be harmful to the environment.

Another issue brought forward by the Green Paper is the possible confusion between 'bio-based' and 'biodegradable' plastics. Although plastics can be made from renewable sources and therefore considered 'bio-based', this does not necessarily imply that they will degrade in natural environments. Consumers will need to be informed about these differences in order to ensure correct disposal.

1.3.2 European Strategy for Plastics in a Circular Economy (2018)

Consequently, a *European Strategy for Plastics in a Circular Economy* has been laid out in 2018. In this strategy, the EC proposed to put in place "a smart, innovative and sustainable plastics industry, where design and production fully respect the concept of reuse, repair, and recycling, brings growth and jobs to Europe, and helps cut Europe's greenhouse gas emissions and dependence on imported fossil fuels." (COM 2018/28, p. 2).

In this context, the EC proposes to: a) recycle half of the annually generated plastic waste by 2030, and b) stop the export of poorly sorted plastic waste to non-EU countries. Consumers should be properly informed of the benefits of recycled plastics and market incentives should be created to increase business opportunities in the recycling sector (ibid, p. 6).

With regard to BDPs, the European 2018 Strategy for Plastics follows-up on the 2013 Green Paper and emphasises the need to establish regulatory frameworks for plastics with biodegradable and compostable properties. Many of the BDPs, currently on the market, only biodegrade under specific conditions which are often not met in the open environment. Furthermore, it is acknowledged that specific labelling is needed to distinguish recyclable plastics from compostable, conventional and BDPs, as they may negatively affect the quality of recycled products and increase littering (ibid, p. 12). Given the lack of "clear labelling or marking" and "adequate waste collection and treatment" schemes for BDP, the EC currently advises caution against the use of BDPs not to aggravate the problem of littering (ibid, p. 4).

Whilst the 2018 European Plastics Strategy identified these challenges, it also acknowledged that targeted applications of BDPs have shown positive results. Going forward, it will therefore be necessary "to ensure that consumers are provided with clear and correct information and to make sure that biodegradable plastics are not put forward as a solution to littering" (ibid, p. 12). For this reason, the European

Strategy proposes to introduce harmonised rules and testing schemes that take the life cycles of biodegradable and compostable plastics into account and help to identify false claims of biodegradability. It requires the identification of applications with clear environmental benefits and appropriate stimuli to drive market developments. The Directorate for Research and Innovation of the European Commission also published an updated version of the Bio-economy Strategy in 2018, suggesting to promote Research and Innovation into alternatives and substitutes to conventional, fossil-fuel based plastics (DG RTD, 2018).

1.3.3 Report on a Circular Economy for Plastics (2019)

Another report from the Directorate for Research and Innovation from 2019, titled *A Circular Economy for Plastics* further details how the Commission should avoid false claims of biodegradability in the future and facilitate the development of plastics that actually biodegrade in their receiving environment (DG RTD, 2019, pp. 177). It recommends to:

a) develop a legal framework where timeframe and environment in which BDPs degrade are specified and appropriately communicated to consumers and businesses
b) provide directions to policymakers across Europe on how to support R&I and infrastructure for BDPs
c) expand appropriate infrastructure to ensure biological waste collection and treatment capacities for larger volumes of organic waste
d) develop a methodology to compare the environmental, social and economic impacts of different materials and applications and implement regulatory measures accordingly
e) develop and harmonise standards that take into account material and product categories, as well as anaerobic digestion and the various environments that waste will end up in

1.3.4 Report on the implementation of the Circular Economy Action Plan (2019)

The 2019 *Report on the implementation of the Circular Economy Action Plan* underlined once again the need to increase recycling and reuse of plastics (COM 2019/190). However, it also reminded the Commission of its commitment *"to develop a framework on the biodegradability of plastics to ensure that the development and use of such plastic products is only encouraged when it is beneficial to the environment and does not interfere with waste management systems nor compromise food safety"* (ibid, p. 7).

1.3.5 Directive on 'The reduction of the impact of certain plastic products on the environment' (2019)

In June 2019, the European Parliament and European Council published the Directive on '*The reduction of the impact of certain plastic products on the environment* (Directive 2019/904) with the goal to prevent and reduce the negative effects of plastics on the environment, while facilitating the transition to a circular economy. In the context of this Directive, a ban on the use of oxo-degradable plastics is envisioned by mid-2021 as they do not fully decompose into CO_2, biomass and water, but rather fragment into microplastics. Furthermore, the directive established a definition of plastics that does not distinguish between conventional, non-biodegradable plastics and BDPs (see 1.4.1). Bans on certain single-use plastic products will therefore apply irrespective of the materials used. Nevertheless, an evaluation of the directive is envisioned by July 2027, including an *"assessment of the scientific and technological progress concerning criteria or a standard for biodegradability in the marine environment applicable to single-use plastic products within the scope of this Directive and their single-use substitutes which ensure full decomposition into carbon dioxide (CO_2), biomass and water within a timescale short enough for the plastics not to be harmful to marine life and not to lead to an accumulation of plastics in the environment."* (Directive 2019/904, art 15).

1.4. Scientific context

Conflicting claims exist around bioplastics in general and BDPs in particular. The term 'bioplastics' is often used as umbrella description for a range of materials with very different properties. Typically, bioplastic includes materials that are either bio-based, biodegradable, or both. Therefore, a clear definition of "plastic", "biodegradable" and the biodegradation process is crucial to tackle this confusion and to set the ground for a clear distinction between the different types of plastics and their biodegradability in the open environment.

1.4.1 Definition of plastic

The EU 2019 Directive on the reduction of the impact of certain plastic products on the environment defines plastic as *"a material consisting of a polymer […], to which additives or other substances may have been added, and which can function as a main structural component of final products."* (Directive 2019/904, p. 8). The Directive explicitly excludes natural polymers, such as cellulose, which have not been chemically modified. The Directive refers to the EC Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) definition of a polymer as – *"a substance consisting of molecules characterised by the sequence of one or more types of monomer units."* (REGULATION (EC) No 1907/2006, p. 54).

As recognised in the definition above, beyond the polymer molecules, plastic materials often contain additives such as stabilisers, plasticisers, fillers, reinforcing agents, colorants and fire retardants to bestow desired properties to the material. These additives can influence the biodegradation behaviour of plastic and should therefore be taken into account when assessing its biodegradability.

For the purpose of this Opinion, the definition of the EU 2019 *Directive on the reduction of the impact of certain plastic products on the environment* will be adopted. An encompassing definition of plastic such as the one above, comprising all the elements which constitute the material, is important not only to avoid confusion about the material itself, but also to determine how biodegradability should be tested, certified and communicated to users.

1.4.2 Biodegradable and bio-based plastics

Confusion often exists among consumers between *bio-based* and *biodegradable* plastics and the polymers they are composed of, which are sometimes conflated under the term *bioplastics* (SAPEA, 2020, p. 152). Bio-based polymers (or biopolymers) such as cellulose, starch, and lignin are composed of carbon derived from renewable biological sources such as plants, in contrast to fossil-based polymers. The fact that these plastics are bio-based, however, does not necessarily mean they are biodegradable, and both bio-based and fossil-based polymers can be either biodegradable or non-biodegradable. The distinction is important because the prefix 'bio' is often a source of confusion, as shown in the figure below.

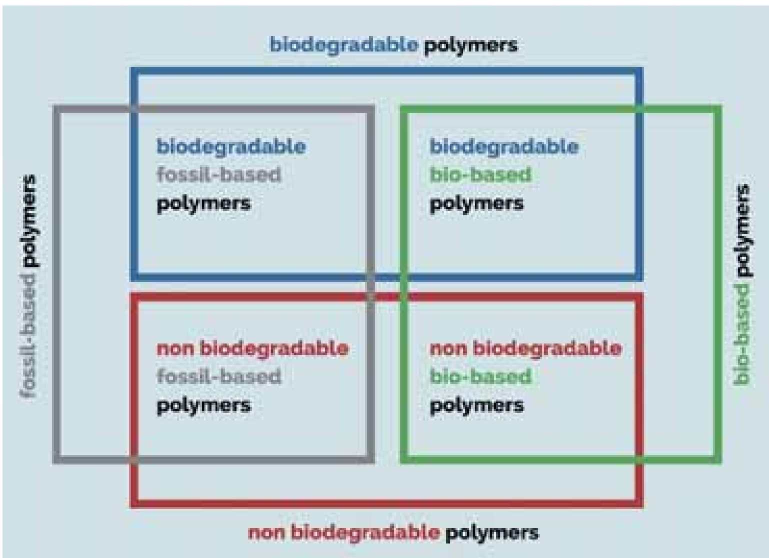

Figure 1 – Overview of Plastic Materials including Biodegradable and bio-based polymers and how they are related (SAPEA, 2020, p. 31)

This Opinion focuses on the impact of biodegradable plastics in the open environment, irrespectively of whether they are composed of bio-based or fossil-based polymers. The origin of the polymer also has important environmental implications and should be taken into account for a full assessment of the overall environmental impact of plastics compared to alternative materials.

1.4.3 Plastic biodegradation

The biodegradation of plastic is a complex process that results in extensive reworking of the carbon-containing compounds in the plastic by living organisms. We herein define plastic biodegradation as: "*the microbial conversion of all its organic constituents to carbon dioxide (CO_2), new microbial biomass and mineral salts under oxic conditions* [in the presence of oxygen] *or to carbon dioxide (CO_2), methane (CH_4), new microbial biomass and mineral salts under anoxic conditions* [in the absence of oxygen]." (SAPEA, 2020, p. 34)

This definition of plastic biodegradation applies only to the organic component of the plastic material, i.e., those compounds that contain carbon-hydrogen bonds, which include the organic polymer(s) itself and any organic additives in plastics. A plastic composed entirely of inorganic polymers cannot be considered biodegradable under this definition. Inorganic additives can affect the biodegradation process and require dedicated assessment (see 2.2.1). For regulatory purposes, the definition of plastic biodegradation needs to be complemented by specification of the requested extent of biodegradation over a pre-defined timeframe, and of the specific (open) environment(s) in which biodegradation is being considered. The timeframe needs to be a timescale short enough not to be as harmful to the environment as conventional plastics and not to lead to a harmful or lasting accumulation in the open environment.

In this context, biodegradation is a different process than *biodeterioration*. Biodeterioration refers more broadly to the impact of microorganisms on the properties of plastic, without the chemical transformation of the carbon-containing compounds in the plastic as per definition of biodegradation. This clarification of the definition of biodegradation is important because it determines the requirements for testing of biodegradable plastics materials and the related standards (see 2.2.1).

For a plastic to biodegrade according to the definition above it must undergo two key steps:

Step 1: The polymer molecules (hydrocarbon chains) need to break down into smaller components of low molecular weight through enzymatic action. This first step depends to a large extent on the material properties of the BDP itself and the environment in which is located. In the open environment this breakdown process typically needs weeks, months, or years to occur. (SAPEA, 2020, p. 41).

Step 2: These smaller components must then be converted into CO_2 (or CO_2 and CH_4 under anoxic conditions) and new microbial biomass (SAPEA, 2020, p. 41), which is done by microorganisms. This second step is particularly dependent on the specific environmental conditions (see 1.4.4), and in the open environment occurs typically within hours or weeks (SAPEA, 2020, p. 43). It is therefore necessary that claims of plastic biodegradability demonstrate the successful completion of the second step, which requires that testing conditions reproduce as closely as possible those of the open environment in which the plastic it is most likely to enter, and ideally should be done in the real environment where feasible (see 2.2.1).

The definition of plastic biodegradation adopted in this Opinion is therefore more specific and restrictive than the generic definition of [plastic] biodegradation given by IUPAC: *'Breakdown of a substance [plastic] catalysed by enzymes in vitro or in vivo'* (Vert et al., 2012).

1.4.4 Enabling factors for biodegradation

There are two main groups of factors that affect the biodegradation process:

1.4.4.1 Factors depending on the structure of the polymer: chemical bonds, crystallinity, surface-to-volume-ratio, and additives

Chemical bonds: The backbone of polymeric molecules is made from chains of small molecules (i.e. monomers) that are linked by chemical reactions forming covalent bonds. These chains can consist of carbon-carbon-bonds only, or contain non-carbon atoms (heteroatoms) like nitrogen, oxygen or phosphorus besides hydrogen atoms. The carbon-carbon covalent bond is the strongest chemical bond known. Carbon-carbon bonds cannot easily be broken, neither abiotically nor enzymatically. Therefore, polymers with only carbon-carbon backbone bond will undergo the breakdown process (described in Step 1) extremely slowly in the open environment, thus hindering the conversion to CO_2, CH_4 and new microbial biomass (Step 2). Polymers that contain heteroatoms are often more readily broken down, e.g.by hydrolysing enzymes (SAPEA, 2020, Box 2.1, p. 29).

The crystallinity of a material has an effect on how stable the material is. This fact also holds true for BDPs. For example, biodegradable polyesters can contain both amorphous and microcrystalline regions. Whilst the polymer chains are less entangled in the amorphous regions and can break down more easily, they are tightly packed in the microcrystalline parts and require high temperatures (which are not common in the open environment) to break down (SAPEA, 2020, pp. 46-47).

Surface-to-volume ratio: Enzymatic processes take place only at the surface of the polymer ('surface erosion') and therefore will depend on the surface to volume ratio: smaller/thinner objects will be more easily eroded than items with larger/thicker objects. This aspect is important when it comes to testing. Biodegradation is often tested on plastic powders, which can lead to a bias in the results as the powder will have higher biodegradation rate than the actual object (SAPEA, 2020, p. 48). Fragmentation into micro and nano-particles increases the surface-to volume ratio, thus potentially enhancing enzymatic breakdown.

Additives: Many plastic products contain additives such as stabilisers, which impede the breakdown of the polymer chains and subsequently the biodegradation process. Moreover, there are additives claimed to transform non-biodegradable plastics into biodegradable. They may range from oxoadditives to new technologies with a biological enhancer, enzyme or other.

1.4.4.2 Factors depending on the environment: temperature, presence of microbial degraders

Temperature: With increasing temperatures most abiotic and biotic reactions also increase, leading to faster biodegradation processes (Deroine et al., 2014; Dilkes-Hoffman et al., 2019; Volova et al., 2007). Higher temperature will enhance biodegradation processes provided it does not alter other conditions (e.g., increase humidity or provoke thermal inactivation of enzymes). However, further research is needed in order to demonstrate and measure the direct effect of temperature change on biodegradation for different types of polymers.

Presence of microbial degraders: Temperature also determines the specific microorganisms that develop under these specific conditions. Their presence and activity could catalyse the breakdown of plastics. All environmental factors that influence the activity of these microorganisms will therefore have an impact on the biodegradation process: temperature, moisture, availability of essential nutrients and electron acceptors, pH and salinity (Ahmed et al., 2018; Bonifer et al., 2019; Deroine et al., 2015; Dilkes-Hoffman et al., 2019; Ho & Pometto, 1999; Pischedda et al., 2019; Volova et al., 2007; SAPEA, 2020, p. 50).

1.4.5 The open environment

Given that temperature and presence of microbial degraders vary significantly across open environments, the specific environment in which biodegradation occurs plays a critical role in the process. Unlike industrial composting facilities, where the biodegradation process is happening under controlled conditions. The open environment comprises a broad range of environments across soil and water (both sea and river), with very different conditions and substantial variations in terms of organisms, temperature and chemical composition. The open environment comprises a variety of ecosystems which cover a range of abiotic and biotic conditions that largely affect the plastic breakdown and microbial conversion necessary to achieve biodegradation. It is therefore crucial that discussion and assessment of plastic biodegradation always makes clear reference to the specific (recipient) environment(s). The variations in open environments need to be taken into consideration not only during the process of testing and certification (see 2.2.1), but also needs to be clearly stated on the label of each product to ensure correct disposal (see 2.3.2). Defining the specific environment in which a BDP application actually *biodegrades* is therefore crucial to limit plastic pollution and avoid unjustified claims of biodegradation based solely on testing certain forms of biodegradable polymers under controlled conditions.

In this Opinion, ‘beneficial to the environment’ means the material fully decomposes into carbon dioxide (CO_2) (or carbon dioxide and methane in anoxic conditions), biomass and mineral salts within a timescale short enough not to lead to lasting harm or accumulation in the open environment.

2. RECOMMENDATIONS

2.0 Adopt a definition of biodegradability as a system property which takes into account material properties and specific environmental conditions

As discussed above, whether or not a plastic item biodegrades depends not only on the properties of the material itself, but also on the specific conditions of the receiving environment in which biodegradation takes place. From the SAPEA evidence review it emerges that treating plastic biodegradability merely as a material property neglects the importance of environmental conditions affecting plastic biodegradation, as well as the large variations in rates and extents of biodegradation of a specific plastic across different receiving systems in the open environment (SAPEA, 2020, p. 33).

Biodegradability should therefore be defined as a ***system property*** that describes the interplay of the specific material properties of the plastic and the conditions of the specific receiving environment where biodegradation takes place. For instance, food stored in a fridge lasts longer than food stored at higher temperatures, e.g., on a kitchen counter. Similarly, many BDPs biodegrade slower at colder temperatures.

2.1 Limit the use of BDPs in the open environment to specific applications for which reduction, reuse, and recycling are not feasible

The assessment of potential environmental benefits of BDP applications over their alternatives in the open environment requires a systems' approach which takes into account their societal benefits and place in the waste hierarchy, their likely end-of-life scenarios, and the impact of both the biodegradable polymer itself and the BDP product on the specific receiving environment(s). This approach should also be applied to alternative non-biodegradable material systems in order to assess the eventual relative benefits BDPs may bring. We therefore recommend that BDPs are only considered for a narrow range of specific applications for which the potential environmental benefits are clear. These include applications for which collection from the environment is challenging and applications where separation of the plastic from other waste presents a challenge. For some applications currently using BDPs where the environmental benefits are less clear, other strategies should be considered instead.

2.1.1 Prioritize reduction, reuse and recycling of plastics before considering biodegradation

The 2018 EU Plastics Strategy lays the foundation for a new circular plastics economy, where materials are kept in use for as long as possible. Within a 'waste hierarchy' approach, the first priority is to reduce the use of plastic, followed by reusing and recycling plastic items whenever possible (i.e., overcoming the circularity gap in our economy). If products can be disposed of whilst ensuring a circular economy, alternative after-use options such as biodegradation in the open environment, should not be considered as the primary option. BDPs should therefore be considered as part of a waste hierarchy in which reduction, recycling and reuse are the preferred options.

The societal benefits of plastic applications should be considered as a central part of their assessment. Some plastic applications, e.g., in agriculture and fishing, have clear benefits in terms of contributing to food production. Others, such as single-use carrier bags, may have little added value and often only short-lived benefits, yet they have a long end-of-life persistence. Specifically, before considering BDPs for certain applications, it is important to consider whether the application should exist in the first place, or if alternatives materials could be employed instead. For single-use items whose benefits are short-lived, and/or those with limited benefit for society, a reduction strategy is more appropriate.

2.1.2 Limit use of BDPs in the open environment to specific applications where collection from the open environment is not feasible

Applications of BDPs will bring maximum environmental benefits over conventional plastics if the product is used in, or ends its service life in, an environment appropriate for complete biodegradation. For the assessment of applications that could benefit from the use of BDPs it is important to consider the degree of control over the item ending up and remaining in the specific receiving environment. Therefore, both the likelihood of the product reaching the end-of-life scenario for which it was designed, tested, and certified, and the risk of the product or fragments of the product reaching the wrong environment in which it cannot sufficiently biodegrade, must be considered. The risk of a BDP product to escape and accumulate in an open environment other than the environment for which it has been demonstrated to biodegrade, either through inappropriate use or disposal, or transfer between environments, must also be considered. Important assessment criteria include also the accumulation rate in cases where BDPs enter an environment at a higher rate than they biodegrade, and the severity of any ecological impacts associated with accumulation. Current environmental risk assessment methods for plastics, including BDPs, are inadequate and must be further developed (see 2.2.3).

Based on these considerations, we recommend that BDPs are only considered for specific applications for which the potential environmental benefits are clear. For applications where release in the open environment is intended or unavoidable, and recovery and reuse or recycling are not logistically and/or economically feasible, BDPs could offer some environmental benefits over conventional plastics. Examples include thin agricultural mulch films or applications where conventional plastics would generate persistent irretrievable fragments or microplastics during use (e.g., dolly rope or fireworks). For these applications BDPs may be an option if they reach a receiving environment for which they have been shown to biodegrade within appropriate timescales and without adverse environmental effects. Applications, such as fruit stickers and bags for compostable food waste, in which plastics and organic waste unavoidably mix and cannot be easily separated, could benefit from using plastic that biodegrades under conditions of the managed composting system, to prevent contamination of the waste stream. However, if the risk of escape to the open environment is high, then the biodegradation of these BDP applications must also be assessed against a range of potential receiving environments.

2.1.3 Do not consider BDPs as solution for inappropriate waste management or littering

For some applications, the potential benefits of using biodegradable plastics are less clear. Packaging for example, which is mostly single-use accounts for *ca.* 40% of the conventional plastic production (PlasticsEurope, 2019), is an application for which BDPs are sometimes used. However, for products such as carrier bags and single use packaging not intended for use in the open environment, and for which the open environment is not the intended end-of-life scenario (according to the criteria above) the benefits of BDPs are less clear. For such products, transfer into open environment is typically caused by improper waste management or littering, which cannot be controlled. This lack of control implies a high risk of the products entering inappropriate receiving environments in which biodegradation is limited or cannot occur, thus increasing the probability of environmental accumulation. Moreover, there is a risk that using BDPs for such applications could have the unintended effects of encouraging littering, compromising proper disposal and recycling of conventional plastics, and further confusing consumers. Although it is sometimes proposed that BDPs could play a role in reducing the negative environmental impacts of littering, their use must be very carefully weighed against the potential negative impacts it can have on the collection and recycling of conventional plastics, as well as the risk of increased littering and accumulation. Given the relatively low societal value of such applications and the existing reusable alternatives, reduction should be the primary strategy, and littering should be addressed through better consumer education and appropriate waste management.

2.2 Support the development of coherent testing and certification standards for biodegradation of plastic in the open environment

Applications consisting of BDPs can deliver environmental benefits only if biodegradability can be verified and certified appropriately. The assessment of biodegradation in open environments has already been subject of specific standards, but at present the difficulty of replicating open environment conditions still persists and the need to develop such standards has been recognised by environment protection agencies: *"Standards for the 'open environment' must take up the* *conditions of the place of interest"* (EPA Network, 2019). The EU can further support international processes for standardisation, in consultation with stakeholders.

In the absence of suitable testing and certification regimes, there is a risk of the term 'biodegradability' being abused or misunderstood. Moreover, environmental risks cannot be fully assessed without suitable and unambiguous data from biodegradation tests. Appropriate testing and certification schemes are therefore a prerequisite to realise potential benefits outlined above. Moreover, testing and certification schemes are necessary to validate and contextualise statements of biodegradability, and to underpin labelling and user information efforts. These schemes need to cover applications in which plastics are intentionally brought into the open environment (e.g., mulch films), those with a high-risk of unintended and intended loss (e.g., from fireworks to fishing devices), and those in which loss is intrinsic to use (e.g., dolly rope).

2.2.1 Support the development of testing and certification schemes evaluating actual biodegradation of BDP in the context of their application in specific open receiving environments

The difference between 'biodegradability' in the laboratory and actual 'biodegradation' in the environment must be carefully taken into consideration during testing of the polymer and overall assessment of a BDP application. Biodegradability is the predisposition of the polymer to biodegrade under specific conditions. The actual biodegradation of a BDP in the likely receiving environment(s) must be tested and observed as a process under the specific conditions of that environment. The testing of actual biodegradation is essential to verify any biodegradability claim of a BDP in the context of its application.

Biodegradation of a BDP must be tested and measured in the context of its application in the real environment, rather than only for the material in a laboratory setting. Additives and other chemical products such as adhesives, pigments, inks, prints, coatings, which fall under the definition of plastics discussed above (see 1.3.1), can affect the biodegradation process and their effect needs to be assessed. Even if all components of a BDP application biodegrade individually, their biodegradation must also be assessed for the final product in order to confirm biodegradability of specific applications under specific environments reliably, including non-accumulation and non-toxicity. For plastics containing non-biodegradable (inorganic) additives it is important to establish that they pose no harm to the environment.

The testing and certification of the biodegradation rate of BDP applications need to take into consideration variations in conditions that affect biodegradation across the open environment and requires testing conditions that match as closely as possible those in which biodegradation will occur. This requires assessment of the specific conditions of the likely receiving environments, whether intended or not. Because of the multiple effects of temperature change on the biodegradation process (see 1.3.4), testing methods need to take into consideration potential variations and test the final product biodegradation under different temperatures, instead of extrapolating temperature effects after testing in laboratory conditions (SAPEA, 2020, p. 35). The specific environment for which biodegradation has been tested need to be referred to on the label.

2.2.2 Require testing of biodegradation of BDP applications under laboratory and simulated environmental conditions

The assessment of biodegradation must follow a multi-step approach. Initial assessments include laboratory testing of the BDPs alone, to determine their biodegradability properties, and subsequent tests under simulated conditions of the open environment. Laboratory testing should preferably occur by applying a direct test of the biodegradation of all constituents of the BDP in an application. Confirming the biodegradability of a product should always be seen in the context of a specific receiving environment in which it is supposed to biodegrade. The matrices of this environment (soil, water, aquatic sediment) must be taken into consideration in the testing phase of the product. Testing in laboratory should be complemented by tank tests (mesocosm testing) that simulate conditions in the open environment in a controlled setting, and where available by open environment testing.

2.2.3 Require assessment of biodegradation and environmental risk of BDP under the conditions of specific open environments

Knowing the timeframe of the BDP persistence in an environment is crucially important for its life cycle analysis and the environmental impact assessment. Under laboratory conditions, the CO_2 release is a clear indicator of the biodegradation of a BDP. In the open environment the CO_2 release cannot be captured and measured, therefore, disintegration of the BDP could constitute a proxy measure for biodegradation in the open environment if biodegradation under laboratory and mesocosm conditions have been demonstrated. More accurate assessment and testing methods should be developed. The measure of disintegration can be mass loss or erosion rate, which could then be used to model a complete biodegradation process (lifetime). Modelling of the ‘lifetime/persistence in the receiving environments of interest’ (e.g., soil, freshwater, marine systems) should be conducted in support of the real condition testing.

The relative effects and impact of BDPs on the environment, in comparison with conventional plastics and other materials should be addressed at organism and ecosystem level, using risk assessments, life cycle analysis (LCA), and life cycle impact analysis (LCIA), assessing residence time, recovery time, and intensity of the effects etc. These impacts should be compared with those of the material the BDP would replace to assess the relative benefits. Classical toxicity tests can assess the effects at organism level, but assessment of toxicity at ecosystem level is not yet available and the development of such methods, although challenging, could be considered for both conventional and biodegradable plastics. Given that not all plastic items can be tested under all environmental conditions, the SAPEA working group has developed a proposed flowchart to guide assessment (SAPEA, 2020, pp. 111-114). For open environment applications it is necessary to demonstrate that the inorganic constituents and polymers eventually present in a BDP do not have negative ecotoxicological impacts and, for the inorganic polymers, do not persist in the environment but instead readily react to form low molecular weight inorganic compounds and salts.

2.2.4 Support the development of a catalogue of the biodegradation rates of different materials in a range of environments

To inform risk assessment, life cycle assessment, and life cycle impact assessment, further research is needed to determine biodegradation rates for different materials in a range of environments. As identified by SAPEA (2020), several knowledge gaps exist, such as systematic benchmarking studies comparing the biodegradation of a consistent set of polymers across a range of environments remain missing. This data is needed in order to compare biodegradation rates and extents across environments. Given the great variability, the development and maintenance of a comprehensive catalogue of such rates for different materials in a range of environmental conditions would be useful for testing, certification and regulatory purposes.

2.3 Promote the supply of accurate information on the properties, appropriate use, and limitations of BDP and to relevant user groups

For the potential environmental benefits of BDPs applications to be realised it is necessary that they are used in, or ends their service life in, an environment appropriate for biodegradation. User behaviour is often important in determining the end-of-life scenario of applications. For example, if a BDP application is likely to be employed by a specific group of end-users who benefit from its biodegradation (e.g., farmers employing BDP mulch films) then the chances of the BDP application to be disposed of correctly is likely to be higher compared to applications used by a wide range of users who do not directly benefit from its biodegradation.

2.3.1 Initiate and support information campaigns to address current confusion related to bioplastics

At present, there is still widespread confusion among end-users/consumers about the meaning of bio-based, biodegradable plastics and compostable plastics. These misperceptions combined with the lack of clear standards in both testing and labelling for BDPs applications in open environment can lead to incorrect disposal. Clear information about what BDPs are, and the difference between bio-based, biodegradable and compostable plastics, need to be conveyed to consumers and end users both through labelling and with information and education campaigns. Industry has a key role to play in this, as labelling products as biodegradable or using related terms is often used to promote their "green" credentials.

2.3.2 Support the development of standards for clear, effective European labelling for a) end-users and consumers to ensure proper use and disposal of BDP applications in the open environment; and b) manufacturers and vendors to ensure accurate information transfer along the value chain

For some BDPs applications, it is necessary that end-users apply and dispose of them correctly in order for them to reach the environment(s) for which they have been designed and in which they have been tested for biodegradation. Labelling is important in enabling end-users and consumers to make informed decisions relating to the nature, origin and impacts of BDPs, and how they should be disposed of. Crucially, as biodegradability can only be certified for a particular use, environment, and disposal, this information must be conveyed to the user in an accessible and straightforward manner. Labelling should cover the environment for intended use, clear disposal instructions, the specific BDP used, and the timescale and conditions for full biodegradation, to avoid the misperception among consumers that biodegradability is a universal quality and would occur in every type of environment. The proliferation of different forms of labelling could add to the confusion and hinder behavioural change because consumers might tend to ignore labels.

We recommend the development of clear European labelling standards for BDP applications, with the potential for setting the bar for international standards. The effectiveness of labelling schemes in conveying suitable and clear guidance must be carefully evaluated. This requires assessing whether relevant information is accurately conveyed to the target user group, and whether they are likely to follow it. Member States have different levels of development and performance of their waste management systems and most evidence on how consumers react to labelling has been gathered within Western Europe and the US, where consumers have already experience with sorting waste and different disposal and collection schemes.

Annex 1 – Methodology

Following their earlier work – specifically on “Food from the oceans”[1] and “Environmental and health risks of microplastics pollution”[2] the Group of Chief Scientific Advisors (the ‘Scientific Advisors’) intended to provide scientific advice on applications of biodegradable plastics.

The scoping of the question included a (grey) literature search and was aided by consultations with scientific experts and expert practitioners, a limited web search and a scoping workshop. On this basis a Scoping Paper (Annex 1) was prepared, in consultation with the College of Commissioners, setting out the request for advice. The Scientific Advisors agreed to take up the work as detailed in the Scoping Paper (December 2019). Two members of the group, Nicole Grobert and Rolf-Dieter Heuer, led the development of the Scientific Opinion on behalf of the Group of Chief Scientific Advisors.

The Scientific Advisors were aided by SAPEA[3] which supplied the supporting evidence underpinning the Scientific Opinion. For this, it formed an expert Working Group that gathered and synthesised the scientific evidence, including expert knowledge, in the form of a peer-reviewed Evidence Review Report. Evidence from the SAPEA Evidence Review Report and further academic and ‘grey’ literature was supplemented with expert elicitation, covering academic experts, policy experts and expert practitioners (see Annex 3). SAPEA also organised an expert workshop with independent scientific experts.

The SAM Secretariat helped the Scientific Advisors in organising a discussion with policy experts of the European Commission on the scientific evidence and policy relevance and an expert ‘sounding board meeting’ on the draft Scientific Opinion.

Finally, the SAM Secretariat aided the Scientific Advisors in organising a stakeholder meeting, where the preliminary outputs of the SAPEA Evidence Review Report and the areas under consideration for the Scientific Opinion were presented by the SAPEA Working Group members and the Scientific Advisors, respectively.

This Scientific Opinion was thus informed by various sources of evidence, notably:

1. Scoping paper ‘Biodegradability of plastics in the open environment’ (SAM, 2019)

[1] https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/food-oceans_en
[2] https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/environmental-and-health-risks-microplastic-pollution_en
[3] https://www.sapea.info/

2. Scoping workshop ‘Biodegradability of plastics in the open environment’ (SAM, 2019)
3. Review of the scientific literature by SAPEA - “Biodegradability of plastics in the open environment” (SAPEA, 2020), referred to as the SAPEA review.
4. SAPEA Expert workshop – September 2020;
5. Sounding Board Meeting – November 2020
6. Stakeholders Meeting – November 2020

Meeting reports or summarising notes are published online.

Annex 2 – Scoping paper

European Commission

Scientific Advice Mechanism
Group of Chief Scientific Advisors

Scoping paper

Biodegradability of plastics in the open environment

11 December, 2019

Research and Innovation

1. Issues at stake

In today's linear plastics economy[1], omnipresent and persistent plastic pollution is a major problem that leads to degradation of the environment and economic costs for society. The 2018 EU Plastics Strategy[2] lays the foundation to a new circular plastics economy, where materials are kept in the loop for as long as possible, by promoting reuse and repair, remanufacturing, recycling and the prevention of plastic waste[3]. Therefore, whenever materials can be disposed of in a way that ensures a circular economy, there is no reason to justify alternative after-use options, i.e. options other than those that ensure a circular economy.

Some plastic products, however, may be either difficult or not possible to collect after their use, due to their nature or circumstances in which they are employed. As a result there is a high risk of these products ending up in the environment. In those specific cases, biodegradability could be investigated as a possible remediation measure.

Biodegradable polymers and additives have been proposed by some as part of the solution to the problem of plastic pollution. Others warn that biodegradable polymers may lead to higher energy or resource-consuming manufacturing routes, and the resulting materials may have unintended consequences.

To avoid any unintended consequences as a result of widely applied biodegradable plastics, further insights are needed including insights for the situation in developing countries, in order to inform society, consumers, businesses and policy makers of possible risks and ways to prevent them.

There are clear differences between biodegradation under:

- controlled conditions i.e. industrial composting;
- somewhat controlled conditions i.e. home composting;
- in uncontrolled conditions i.e. the open environment (land, fresh and brackish water, marine, deep sea).

The environmental impacts of biodegradable plastics under different conditions remain to be assessed, including uncontrolled environmental conditions. Biodegradability can contribute to the remediation of 'unavoidable' littering, but it does not solve the littering problem as such. According to some, it can even aggravate the problem, since labelling a product as 'biodegradable' might result in a greater inclination to litter by consumers

[1] By 'plastics', it should be intended a material consisting of a polymer as defined in point 5 of Article 3 of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified (see Article 3(1) of Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. OJ L 155, 12.6.2019, p. 1–19.)

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN See in particular section on "Establishing a clear regulatory framework for plastics with biodegradable properties".

[3] This is in line with the waste hierarchy as defined in EU legislation and policy, in particular Article 4 of Directive (EU) 2008/98 of the European Parliament and of the Council of 19 November 2008 on waste (Framework Waste Directive). OJ L 312, 22.11.2008, p.3 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN - (a) prevention;(b) preparing for re-use;(c) recycling;(d) other recovery, e.g. energy recovery; and (e) disposal.

(consumer behaviour), possibly even more when there is no indication of the conditions nor the time under which it actually degrades[4].

Whilst EU packaging standards for compostable packaging in industry (also applicable to plastic packaging) exist, there is no European standard covering home-compostable plastics. Similarly, there is no general standard for the biodegradability of plastics in the open environment. In some cases, this has led to some confusion. For instance, in some cases national legislation prohibits biodegradable packaging, but permits compostable packaging, including materials for home-composting by the consumer.

The correct disposal of plastics can cause confusion for consumers potentially causing cross-contamination of waste streams. Such cross-contamination can occur when biodegradable plastic, which typically is difficult to recycle[5], is mixed with non-biodegradable and recyclable plastics. It is difficult if not impossible for the consumer to assess the type of plastic and therefore normal plastic can also end up in the bio-waste stream.

In light of the above, the role of biodegradable plastics within the portfolio of solutions must be considered application by application. For example, agricultural mulch films that would biodegrade in the soil, following a European Standard, because collection of recyclable plastic films is not possible nor affordable. In this case, soil quality as well as the potential wash-off of the biodegradable plastic into rivers by rain would need to be taken into account.

2. EU policy background

The 2018 EU Plastics Strategy[6] sets out a cautious approach for the use of biodegradable plastics. While it acknowledges that targeted applications have shown positive results, it also identifies a number of challenges: "*It is important to ensure that consumers are provided with clear and correct information, and to make sure that biodegradable plastics are not put forward as a solution to littering*". Further, "*Applications with clear environmental benefits (and criteria for such applications) should be identified, and in those cases the Commission will consider measures to stimulate innovation and drive market developments in the right direction*".

The 2019 Report on the implementation of the Circular Economy Action Plan[7] confirms such an approach. In particular, it recalls that "*the Commission committed to develop a framework on biodegradability of plastics to ensure that the development and use of such plastic products is only encouraged when it is beneficial to the environment and does not interfere with waste management systems nor compromise food safety*".

The 2019 European Commission Report on "A Circular Economy for plastics"[8] made the following policy recommendation:

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[4] See UNEP report and Commission's Staff Working Document accompanying the EU Plastics Strategy (see footnote 2).
[5] While there are polymers with inherent properties that make them both biodegradable and recyclable, real-life conditions and cost-effectiveness need to be taken into account.
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN See in particular section on "Establishing a clear regulatory framework for plastics with biodegradable properties".
[7] https://ec.europa.eu/commission/sites/beta-political/files/report_implementation_circular_economy_action_plan.pdf See in particular section on "A systemic approach: the EU Strategy for Plastics in a Circular Economy".
[8] https://publications.europa.eu/en/publication-detail/-/publication/33251cf9-3b0b-11e9-8d04-01aa75ed71a1/language-en/format-PDF/source-87705298

Develop a legal framework for communication about compostability and biodegradability, and provide clear information and business guidance on the different after-use pathways, and their complementarity.

Claims of a product being biodegradable can be misused, as they do not specify whether something is fully biodegradable within a given timeframe or only partly, and which specific environment they are intended for. Therefore, according to the same report, *claims should be made sufficiently specific e.g. including a reference to the specific environmental habitat, and based on the appropriate information validated by a third party i.e. certification*. In summary, biodegradability alone is not sufficient as a solution, and should always be linked to overall environmental safety.

It should be noted also that the Directive on single use plastics and fishing gear ('SUP Directive')[9] does not make a distinction between conventional, non-biodegradable plastics and biodegradable plastics nor does other relevant legislation, such as the 'Plastic Bags' Directive[10] amending the Packaging and Packaging Waste Directive[11]. The bans on certain single-use plastic products apply irrespective of the plastic characteristics. The evaluation of the SUP Directive (to be carried out by 2027) will include "*an assessment of the scientific and technical progress concerning criteria or a standard for biodegradability in the marine environment applicable to single-use plastic products within the scope of this Directive and their single-use substitutes which ensure full decomposition into carbon dioxide (CO_2), biomass and water within a timescale short enough for the plastics not to be harmful to marine life and not to lead to an accumulation of plastics in the environment*". The SUP Directive does also ban all oxo-degradable plastics[12].

The Packaging and Packaging Waste Directive requires the adoption of an implementing act on marking of compostable and biodegradable plastic carrier bags, to provide consumers with the correct information. Related to that, a separate standard for home-compostable plastic carrier bags is envisaged.

The updated Bio-economy Strategy[13] promotes Research & Innovation, and a specific action is dedicated to the development of substitutes to fossil-based plastics that are bio-based, recyclable and marine biodegradable. It supports activities contributing to the elaboration of CEN[14] standards for biodegradability in the marine environment.

Concerning microplastics, at the request of the Commission, ECHA published its REACH restriction dossier on 30 January 2019[15] stating that the health and environmental risks posed by intentionally added microplastics justify an EU-wide restriction. ECHA's Scientific Committees will now review the dossier; if agreed, an EU-wide restriction could be in place by mid-2021. Where available, biodegradable alternatives would be exempted by the

[9] Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. OJ L 155, 12.6.2019, p. 1–19.
[10] Directive (EU) 2015/720 of the European Parliament and of the Council of 29 April 2015 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags (Text with EEA relevance). OJ L 115, 6.5.2015, p. 11–15.
[11] Directive 94/62/EC of the European Parliament and Council of 20 December 1994 on packaging and packaging waste. OJ L 365 31.12.1994, p. 10.
[12] See the Report from the Commission to the European Parliament and to the Council on the impact of the use of oxo-degradable plastic, including oxo-degradable plastic carrier bags, on the environment, of 16.1.2018 COM(2018) 35 final.
[13] https://ec.europa.eu/knowledge4policy/publication/updated-bioeconomy-strategy-2018_en
[14] European Committee for Standardization (CEN, French: Comité Européen de Normalisation)
[15] https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18244cd73

restriction[16]. Therefore, with the file already in progress, such microplastics intentionally added to products are out of the scope of this present request. However, the microplastics from unintentional sources (e.g. abrasion of tyres, textiles) are within the scope of this request, as well as those resulting from the fragmentation of macroplastics.

3. Request to the EC Group of Chief Scientific Advisors

In this context, the European Commission's Group of Chief Scientific Advisors is asked to provide by end October 2020 a scientific opinion to support the preparation of a framework i.e. set of general rules for biodegradability of plastics.

In the open environment, the objective is to determine for which applications, if any, biodegradable plastics can be beneficial to the environment, compared to non-biodegradable plastics and considering the waste hierarchy[17] and circular economy approach. By 'beneficial to the environment' it should be intended that the material fully decomposes into carbon dioxide (CO_2), biomass and water within a timescale short enough not to be harmful to the environment and not to lead to an accumulation of (micro) plastics in the environment[18].

With no prejudice to the work of the Chief Scientific Advisors, beneficial applications could include products that, due to their nature (litter prone), or specific use scenario (e.g. agricultural mulch films), might be hard to collect at their end of life. This would lead to a high risk of them ending up in the environment, therefore suggesting a focus on biodegradability in the open environment as a remediation measure.

Yet, even when applications are identified and criteria for such applications are developed, the use of biodegradable plastics in real-life conditions remains challenging, because real-life conditions significantly vary from one habitat to another (e.g. for marine biodegradability, Baltic vs Mediterranean Sea, or beach vs surface vs deep water vs sea floor).

Home composting, which is not standardised to the same degree as industrial composting and presents real life environmental conditions closer to the open environment, should be included in the analysis. Industrial composting does not fall under the scope of the present analysis.

Consequently, the main question to be answered by the Group of Chief Scientific Advisors is:

> *From a scientific point-of-view and an end-of-life perspective, and applying to plastics that biodegrade either in the terrestrial, riverine or marine environments, and considering the waste hierarchy and circular economy approach:*
>
> *What are the criteria and corresponding applications of such plastics that are beneficial to the environment, compared with non-biodegradable plastics?*

[16] https://echa.europa.eu/documents/10162/0724031f-e356-ed1d-2c7c-346ab7adb59b . The biodegradability criteria are discussed in paragraph 2.2.1.6 of the Annex XV dossier for restriction.
[17] See footnote 3
[18] Article 15 of Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (see footnote 9).

Annex 3 – List of experts and stakeholder representatives consulted

Almeida	Felipe	CEFIC - European Chemical Industry Council - Cefic aisb	*
Alvarez	Helena	Oceana	*
Bergmann	Melanie	Alfred Wegener Institute	
Bonten	Christian	University of Stuttgart	
De Los Llanos	Carlos	CITEO	
De Wilde	Bruno	OWS	
Degli Innocenti	Francesco	European Bioplastics	*
Farmer	Andrew	Institute for European Environmental Policy (IEEP)	*
Grefenstein	Achim	EU Plastics Converters (EuPC)	*
Hauschild	Michael Zwicky	Technical University of Denmark	
Haut	Gaëlle	Surfrider	*
Malinconico	Mario	Assobioplastiche	*
Marshall	Shawn	Departmental Science Advisor from Environment and Climate Change Canada	
Mukherjee	Anindya	PHA Platform (GoPHA)	*
Narancic	Tanja	University College Dublin	

Navazas	Alejandro	European Recycling Industries' Confederation (EURIC)	*
Nemer	Mona	Chief Science Advisor Canada	
Newman	David	Bio-based and biodegradable Industries association	*
Nony	Jean-Marc	CEN TC 261 SC4	*
Sander	Michael	ETH Zurich	
Schlegel	Katharina	Plastics Europe	*
Shawn	Marshall	Departmental Science Advisor from Environment and Climate Change Canada	
Simon	Jordi	Asobiocom	*
Simpson	Peter	European Chemicals Agency (ECHA)	*
Thompson	Richard	Plymouth University	
Tonin	Elisabetta	European Federation of Waste Management and Environmental Services (FEAD)	*
Van Der Zee	Maarten	Wageningen University	

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This scientific opinion examines the conditions and criteria under which biodegradable plastic applications can be beneficial for the environment, and provides advice to inform decisions by society, consumers, businesses and policy makers. A growing global use of plastics has led to an increased amount of plastic waste in the environment, polluting and harming in land and marine ecosystems. Biodegradable plastics could be part of the solution to this problem, but they also present challenges. Biodegradability depends not only on the properties of the plastic material itself, but also on the environmental conditions. Many biodegradable plastic products only actually biodegrade in certain specific environments, or only in industrial composting facilities, rather than in the open environment more generally.

The opinion recommends limiting the use of biodegradable plastics in the open environment to specific applications for which reduction, reuse, and recycling are not feasible, rather than as a solution for inappropriate waste management or littering. To realize the potential environmental benefits over conventional plastics, it recommends supporting the development of coherent testing and certification standards. It also identifies a need to promote the supply of accurate information on the properties, appropriate use and disposal, and limitations of biodegradable plastics and their applications to relevant user groups.

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