BPA RESPONSE TO HSAC 2025 REVIEW

1. Purpose, Regulatory Intent, and Audience

This document sets out the response of the **Biodegradable Plastics Association (BPA)** www.biodeg.org to the October 2025 HSAC review entitled *"Updated review of the science relating to pro-oxidant additive-containing plastic (PAC plastics)."* HSAC is a Committee of the Department of the Environment and Rural Affairs (DEFRA) of the UK government. This Response is addressed to **HSAC,** and to **DEFRA** in its capacity as regulator.

What BPA is asking DEFRA to do:

- Distinguish commercially-available oxo-biodegradable PE/PP from experimental and other biodegradable plastic materials.

- Treat specific testing by ISO 17025-accredited test-houses according to ASTM D6954 (or the British equivalent BS 8472) as the primary evidential framework for oxo biodegradable plastics, instead of general academic papers and literature reviews.

- Re-evaluate the HSAC Report because it has:
    - failed to consider the results of the four-year Oxomar interdisciplinary study, which is the most important study on this specific subject in recent years.
    - failed to consider specific testing by Intertek which proves complete biodegradation and absence of microplastics.
    - attached weight to specific academic papers which are irrelevant and/or mistaken

- Make a statement to Parliament that DEFRA is not considering a ban on any oxo-biodegradable plastic certified by an ISO 17025-accredited test-house as successfully tested according to ASTM D6954. DEFRA's current position is adversely affecting employment and British exports. This response demonstrates that oxo-biodegradable plastic does provide measurable environmental benefits, but even if it did not, absence of demonstrated benefit is not a lawful or rational basis for any prohibition.

A ban would be **disproportionate; based on inadequate evidence; and counter-productive** to environmental objectives. Instead DEFRA should encourage the use of oxo-biodegradable PE and PP as a **harm-reduction measure** for single-use plastic items that are statistically most likely to escape collection and end up in the open environment.

This submission does not seek to displace recycling, reuse, or waste-management policy. It seeks to ensure that **avoidable environmental persistence** of single-use plastics is reduced through **deployment of existing technology rather than prohibition**.

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2. Executive Summary

The key point to remember is that oxo-biodegradable technology does not cause the plastic to break up into small pieces of plastic – it converts the plastic into non-toxic biodegradable materials, which are bio-assimilated by naturally-occurring microbes in the environment. It requires no special conditions – only oxygen. The process is initiated by sunlight and will then continue even in the dark. If collected during its useful life it can be recycled with ordinary plastic without the need for separation.

Oxo-biodegradable technology was invented fifty years ago, not by marketeers or salesmen, but by the scientists who had themselves created plastics, and who realised that the durability which they had achieved could be a problem. Foremost among these scientists were Professor Gerald Scott, Professor of Chemistry at Aston University, UK; Professor Jacques LeMair of Clermont-Ferrand, France; Professor Emo Chiellini of the University of Pisa, Italy; and Professor Ignacy Jakubowicz of Gothenburg, Sweden.

Professor Scott was the holder of several patents for the technology and was later the Chief Scientific Adviser to the BPA. He published the results of his work in many scientific publications including "Polymers & the Environment" (ISBN 9780854045785); "Degradable Polymers; Principles & Applications" (ISBN 1-4020-0790-6). See also "Programmed-Life Plastics from Polyolefins: A New Look at Sustainability" http://www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf

Oxo biodegradable technology has been successfully deployed at national scale for nearly a decade in the UAE and Saudi Arabia, after due diligence and technical evaluation. Its use is compulsory for a wide range of products likely to be littered, and the national standards in both jurisdictions are based on ASTM D6954. Compliance with those standards is required for products placed on the market, and this demonstrates that ASTM D6954 is not merely an industry reference but a standard with regulatory effect already adopted and enforced by governments.

The Saudi and UAE example has been followed in other countries, most recently the Dominican Republic. In Colombia the law says "The use of biodegradable raw materials under natural environmental conditions shall be authorised, **as shall the use of additives that accelerate biodegradation under natural environmental conditions**."
It has also been used on a voluntary basis for at least 15 years in many other countries, and there are official Standards for it in France; Sweden; Saudi Arabia; UAE; Jordan; Jamaica; Mexico; Dominican Republic; Ecuador; and the Russian Federation.

The sustained use of this technology without evidence of environmental harm, is inconsistent with claims that oxo biodegradable plastics are unproven, unsafe, or unsuitable for regulatory acceptance.

The BPA agreed with the HSAC 2019 Report that “Many of the advantages, conveniences and indeed environmental benefits of modern life brought to us over the past 70 years has been thanks to the employment of plastics. .... Plastic films and packaging have provided health and safety benefits, reduced food waste and lowered the costs of transportation.”

Life-cycle assessments consistently show that plastics often outperform alternative materials, including paper, in overall environmental impact. https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/ and https://www.biodeg.org/subjects-of-interest/paper-bags/ However, plastic waste that escapes collection remains a persistent and well-documented environmental challenge.

HSAC correctly recognises that mismanaged plastic persists in the environment, but while the review is rigorous in tone, it does not constitute a complete or balanced assessment of oxo-biodegradable technologies, nor does it adequately reflect the current state of the science.

The BPA’s central concerns with the HSAC 2025 review are:

1. **Aggregation of materials**: HSAC evaluates a wide range of fundamentally different materials as a single category (“PAC plastics”), without distinguishing between commercially available oxo-biodegradable plastic (which is made from PE and PP) and other types of plastic. **It is not therefore clear what is being reviewed**.
2. **Choice of evidence**: The review relies predominantly on selected peer-reviewed literature, while giving little or no weight to ISO 17025 -accredited data from tests performed according to internationally recognised standards specifically developed for regulatory and industry decision-making. **They should have relied upon specific tests by ISO 17025 accredited test houses, such as the series of tests in 2025 by Intertek which showed biodegradation and absence of microplastics. These were not even mentioned, and instead HSAC relied upon general academic publications and literature-reviews; - many of which are shown to be irrelevant and/or to contain fundamental errors.** See p11 below.
3. **Omission of key public research**: The review does not engage with the French government-sponsored **Oxomar** project, https://anr.fr/Project-ANR-16-CE34-0007 the most comprehensive real-world study of oxo-biodegradable plastics in marine environments.
4. **Terminological inconsistency**: Non-standard and imprecise terminology (“oxo-degradable”) is used in ways that conflate fragmentation with biodegradation, leading to flawed methodological conclusions. Also, as mentioned above, the application of the term “PAC Plastics” to so many fundamentally different materials renders that term, and for that reason much of

the HSAC report, meaningless. The BPA is concerned only with commercially available oxo-biodegradable masterbatches for use in PE and PP.

5. The BPA does **not** argue that oxo-biodegradable plastics are a substitute for waste management, recycling, redesign, or reduction; nor does it maintain that oxo-biodegradable plastics are designed to be discarded into the environment or into a composting facility. Rather, they are a **harm-reduction technology** designed to address the **inevitable leakage** of PE and PP plastics into the open environment.

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3. The Policy Context

There is no single solution to plastic leakage into the environment. Even in countries with advanced waste-management systems, significant quantities of single-use plastic enter the open environment each year. Waste management in Switzerland is among the most efficient in the world, but the Swiss Federal Office for the Environment https://www.bafu.admin.ch/bafu/en/home/topics/waste/waste-policy-and-measures/plastics-in-the-environment.html says:

"Plastics have no place in the environment. Nevertheless, around 14,000 tonnes of plastics end up in Switzerland's soil and waters every year – primarily due to the abrasion and decomposition of plastic products and improper disposal of plastic waste. Plastics then accumulate in the environment because they only degrade very slowly."

This is the reason why oxo-biodegradable plastic was invented, for use in a wide variety of packaging and other products made from polyethylene or polypropylene, which are among those most likely to be littered. It is also very useful in agriculture See https://www.biodeg.org/agricultural-plastic-products-2/ It tackles the problem at the molecular level by **ensuring that the plastic does not just break up into smaller pieces. It dismantles the molecular chains *within* the polymer so that it ceases to be a plastic and becomes a biodegradable material which is consumed by bacteria and fungi and cleaned out of the eco-system by them.**

Oxo-biodegradable PE and PP are designed to perform identically to conventional plastics during manufacture, use, reuse, and recycling, with degradation ocurring only if the material enters unmanaged environments.

As to recycling, for the reasons explained in detail at https://www.biodeg.org/subjects-of-interest/recycling-2/ oxo-biodegradable plastics are compatible with recycling without the need for separation, but the **type of plastic marketed as "compostable" is not.** DEFRA has expressed no intention of banning that type of plastic on that or any other ground.

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4. Terminology and Material Classification

4.1 Oxo-degradable vs oxo-biodegradable

The HSAC review frequently uses the term "oxo-degradable." This usage is inconsistent with international standards and introduces a significant scientific error.

- **Oxo-degradation** refers to oxidative chain scission which occurs in conventional plastics, resulting in persistent microplastics.
- **Oxo-biodegradation**, is a two-stage process defined by CEN in TR15351 as oxidation followed by biological (cell-mediated) assimilation of the resulting low-molecular-weight material.

HSAC say that the terms "oxo-degradable" and "oxo-biodegradable" are often used interchangeably." This is true but it is careless use of terminology by HSAC and others, which causes confusion. The scientists who invented the technology called it "oxo-biodegradable" because it oxidises and then biodegrades. "Oxo-degradable plastic" is a term commonly used in media; NGO reports, policy summaries, and some academic literature, but it should not be used.

Using the term "oxo-degradable" mistakenly (and perhaps intentionally in some cases) implies fragmentation without biodegradation, and a design-intent limited to physical breakdown into microplastics. That is not how manufacturers describe their products, and it is not how the related standards frame the technology. Nobody includes a pro-oxidant masterbatch into plastic and markets it as "oxo-degradable," nor do they claim that oxidation is the endpoint. They claim oxo-biodegradation — i.e. conversion by oxidation to a biodegradable molecular-weight range followed by biological assimilation — and they test against standards written explicitly for that process (e.g. ASTM D6954, BS 8472 etc), NOT against Standards such as EN13432 or ASTM D6400, or ISO17088 designed for an entirely different technology.

Commercially-available oxo-biodegradable plastics are explicitly designed, marketed, and tested for oxo-biodegradation. Excluding the biological phase from the definition leads to inappropriate testing regimes and policymaking.

Another **misuse of terminology by HAC is "PAC plastics are thus distinct from biodegradable polymers which are meant to break down purely biotically."** The bio-based plastic manufacturers like to reserve the term "biodegradable polymers" for their products, but "biodegradable polymers" describes both oxo-biodegradable and hydro-biodegradable polymers.

4.2 Aggregation of PAC plastics

HSAC evaluates "PAC plastics" as a single category despite substantial differences between:

- Experimental or fragmentable materials described only in patents;
- Blends containing starch or other biodegradable fillers;
- Plastics such as polystyrene or polyester;

- Commercially-available oxo-biodegradable PE and PP systems (e.g. d2w®), which do not contain starch and are engineered for controlled degradation kinetics.

This aggregation obscures performance differences and undermines meaningful regulatory assessment.

Commercially-available oxo-biodegradable plastics do not include the following materials aggregated by HSAC: polystyrene, PVC, PLA, PBAT; photo-initiators such as benzophenone, benzoin or TiO2 nanomaterials, or extracted chlorophyll. Nor plastics containing vegetable fillers, pectin, chitosan, cellulose diacetate and starch, or microcrystalline cellulose. Nor do they include plastics containing a combination of dyes and pigments, or mineral fillers as prodegradants. Nor do they include plastics with TiO2-containing additives or combinations of ZnO and TiO2. Nor nitric acid or hydrochloric acid.

This same criticism was made of the 2019 HSAC review, www.biodeg.org/wp-content/uploads/2020/09/BPA-response-to-HSAC-Report-19-1-23.pdf which confused commercially available oxo-biodegradable technology with other, quite different, technologies.

5. TIMESCALE

DEFRA and HSAC are both aware of the evidence to the UK Government in 2019 of Dr. Graham Swift, one of the authors of ASTM D6954, and Vice-chairman of the relevant Technical Committee at ASTM See http://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

His evidence is that "It is not necessary or practicable to specify a precise timescale for degradation, because conditions in the open environment (unlike those in a composting environment) are variable."

"The key point is that in any given place at any given time in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item, and will not therefore contribute to the long-term pollution of the environment."

"ASTM D6954 contains a standard caveat, recognising that laboratory environments are isolated, unlike the dynamic natural environment - in which degradation and therefore biodegradation is likely to proceed more quickly. However, ASTM D6954 has been devised by myself and other specialists working in the field over many years to provide practical guidance as to how the product is likely to perform in commercial use."

"It has been my experience that results from laboratory testing are very likely to be reproduced in the real world. I can see no cause for concern that they would not, and have seen no evidence that they have not. In particular I do not consider that persistent plastic fragments and smaller, microplastics would be left behind which could have any harmful effect on the open environment, and in particular marine life."

"There is no need for degradation if the product has been collected for proper disposal. In landfills there is often sufficient oxygen for oxidation to continue, but that is not the main purpose."

6. COUNTRY-SPECIFIC ENVIRONMENT

HSAC places strong emphasis on cool, wet UK conditions, referring to findings from the Sciscione paper that degradation rates seen in hot, dry climates are not predictive for the UK. HSAC asks whether oxo-biodegradable plastics demonstrably biodegrade under UK environmental conditions.

It is necessary first to understand that chemical oxidation and microbial assimilation are uv activated processes, not climate specific processes. There is uv light and ambient heat everywhere in the world. A slower rate of oxidation in cold conditions does not imply failure, only a longer process - but still much shorter than conventional plastic – which oxo-biodegradable plastic is intended to replace for the kind of products which are commonly found as litter.

No evidence is presented that anything in polymer chemistry causes oxidation to "stop" in cold or low UV conditions; it simply proceeds more slowly. This is entirely consistent with Arrhenius type kinetics and with how all degradation systems behave.

HSAC uses climate to exclude evidence, rather than using the evidence to assess performance under varying conditions. The BPA finds that documents relied on by policymakers sometimes slide (implicitly) from: "performance varies by environment" to "performance is therefore unreliable." That is not a logically valid step.

Climate affects the speed of oxo biodegradation, not the underlying mechanism.

There is no basis for requiring uniform degradation rates across environments, and slower degradation in cooler climates does not imply non functionality.

Dr. Swift is a very experience polymer scientist and his evidence to DEFRA is "I am aware that standards similar to ASTM D6954 for testing oxo-biodegradable plastics have also been written in the UK, France, Sweden, Saudi Arabia and the UAE, but **there is really no need for separate standards for every country, as the principles are the same**."

Oxidation rate can be accelerated or slowed by formulation-choices by end-users or governments, including - type of pro-oxidant (Fe, Mn, Co, mixed systems), and balance between pro-oxidants and stabilisers in the masterbatch.

"When an oxo-biodegradable plastic is required to have a life-span of several weeks or several months, a [masterbatch] manufacturer adjusts the catalysts and anti-oxidant concentrations having regard to a laboratory test, using ASTM D6954, and correlates the degradation characteristics with real world experience to identify the formulation needed to meet the intended degradation criteria."

7. QUALITY CONTROL

Quality Control is essential in the manufacture of all plastic products, whether made with an oxo-biodegradable masterbatch or not, to ensure that no hazardous materials are included. Additionally in the case of oxo-biodegradable plastic it is necessary to ensure that the product is manufactured with the appropriate masterbatch from an approved supplier, and that it is included at the correct concentration and dispersion in accordance with the masterbatch supplier's manufacturing instructions. Also, that no materials are included in the product which would affect the rate of abiotic or biotic degradation, or would cause eco-toxicity.

For oxo-biodegradable products to perform as intended it is necessary for them to be correctly manufactured and to be tested according to ASTM D6954 or a comparable Standard (eg UK BS 8472; France AFNOR T51-808; Sweden SPCR 141; Saudi Arabia 2879; UAE 5009-2009; Jordan 2004-2012; Jamaica JS 355; Mexico MNX E288; Dominican Republic NORDOM 83-2:003; Ecuador NTE INEN 2644-13; Russian Federation GOST 33747-2016).

Products placed on the market by all industries are not always properly made, and their properties are sometimes misrepresented. For this reason trading standards authorities exist in most countries.

Oxo-biodegradable plastic products are usually not made by the supplier of the masterbatch, and it is sometimes found that the manufacturer of the plastic product has applied the supplier's logo and made claims on or about the product, but has failed to include the correct masterbatch for that type of product at the correct concentration, and has sometimes not included any masterbatch at all.

In the case of oxo-biodegradable plastic (but not "compostable" plastic") it is easy for trading-standards officers to perform random checks, because there are hand-held devices available to them. They can also send samples to the BPA or any other suitable laboratory for testing, and they can ask for evidence that purchases of masterbatch by the manufacturer are consistent with the volume of products produced, and for evidence of type-approval of the product by testing according to ASTM D6954 or the other relevant Standards. Appropriate enforcement and adequate penalties will soon reduce the number of incorrectly made products on the market.

8. Evidence Standards and Regulatory Fitness

8.1 Limitations of literature-only reviews

Peer-reviewed scientific papers are valuable for academic research **but are not designed to function as regulatory pass/fail assessments**. These studies typically use heterogeneous methods, limited material characterisation, and non-standard conditions. See 8.3 below.

8.2 International standards

International standards (ASTM, ISO, CEN) were developed to address these limitations. For oxo-biodegradable plastics, **ASTM D6954** and aligned national standards define:

- What must be measured;
- How it must be measured;
- Clear performance and safety criteria.

These standards are the appropriate evidential basis for regulatory decision-making.

It is not difficult to test for oxidation in the natural environment, and it has been "observed in a convincing manner outside laboratory conditions" for example in seawater at Bandol in the south of France, and by Oxomar.

However, **testing for *biodegradation* cannot be performed in the open environment because it would be impossible to measure CO_2 evolution under those conditions.** Scientists have therefore devised laboratory protocols over many years which simulate the natural process of biodegradation, and the degraded residue has been observed at Queen Mary University London https://www.biodeg.org/queen-mary-university-london-report/ and by Oxomar (See 7 below) to be consumed by bacteria commonly found on land and in the sea.

The type of plastic marketed as "compostable" is tested according to ASTM D6400 and EN13432 for biodegradation in the special conditions found in a composting facility. Those Standards are widely accepted, but they do not require testing of compostable plastic in a compost heap - and similarly ASTM D6954 does not require testing for biodegradation in a field or in the ocean.

In both cases therefore, plastics are tested in a laboratory according to standards designed by scientists to replicate the conditions in which they are expected to biodegrade. HSAC are critical of laboratory testing, whilst relying on laboratory-based studies of their own choosing

Dr. Swift was one of the authors of ASTM D6954, and he says www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf "Oxo-biodegradable plastics have been known and used commercially for over half a century. They were developed by the scientists who had developed conventional plastics, who found a way to render ordinary plastic susceptible to controlled oxidative degradation, by using catalysis to produce simple hydrophilic compounds, many known and recognized as biodegradable in widely disparate aerobic environments."

He continues: "We wrote D6954 at ASTM to guide the user and developer of these plastics in testing the sequential degradation process to be expected in the open environment, using existing ASTM and other certified standard methods at each stage. We called it a Standard Guide, because we reserve the title "Specification" for protocols for testing in a controlled environment eg. ASTM D 6400."

"Testing [for biodegradation] is done in the laboratory in a microbial consortium by measuring the rate and extent of carbon dioxide evolution (relative to theoretical). The microbial consortium chosen will be relevant to disposal in the open environment, and the amount of biodegradation required in order to pass the test is specified in sections 6.6.1 and 6.6.2. Similar carbon-evolution testing is done in the laboratory for compostable plastic according to ASTM D6400 and EN13432, and this method is widely accepted."

"ASTM D 6954 is designed for testing plastics which degrade and biodegrade in uncontrolled conditions in the open environment, but it is nevertheless a detailed protocol for proving degradation, biodegradation, and non-toxicity under the conditions expected to be found in the open environment."

"**ASTM D6954 contains six pass/fail tests** 1.for the abiotic phase of the test (6.3 - 5% e-o-b and 5,000DA) 2. the tests for metal content and other elements (6.9.6), 3. Gel content (6.6.1), 4.Ecotoxicity (6.9.6 -6.9.10), 5. PH value (6.9.6) and 6. for the biodegradation phase, (for unless 60 % of the organic carbon is converted to carbon dioxide the test cannot be considered completed and has therefore failed)."

"Of course, conditions in the open environment are variable, but there is no need for a standard for each of these conditions. **Provided that oxygen is present, a plastic complying with ASTM D6954 will become biodegradable much more quickly than ordinary plastic, and that is its purpose.** Oxygen is ubiquitous, and most of the plastic litter is found lying or floating around with abundant access to oxygen, but it is possible to imagine a piece of plastic in anaerobic conditions where abiotic degradation cannot proceed. However if this is in a landfill it does not matter, because the plastic has already been properly disposed of."

"It is also possible for a piece of oxo-biodegradable plastic to find itself in anaerobic conditions outside a landfill but this would be very unusual and does not invalidate the general proposition. It is for example possible for plastic to be deprived of oxygen by being heavily bio-fouled in the ocean or buried in sediment, but this is unlikely to happen quickly enough to prevent sufficient exposure to oxygen for abiotic degradation to commence. If it did happen, then that small proportion of the global burden of plastic litter would perform in the same way as ordinary plastic – no better and no worse."

"The material can be aged in the natural environment, and this has been done eg by Station d'Essais de Vieillissement Naturel de Bandol in France. However, this is a long and expensive process. Artificial ageing is therefore done simply to reduce the time and cost of testing, and does not invalidate the results. If it did it would obviously not be used, and would not be permitted by ASTM D6954." The Oxomar scientists confirm at (C6) that "Accelerated artificial ageing does not invalidate the results."

Dr. Swift continues "**Once abiotic degradation has commenced, there is no reason for it to stop save in the unlikely event that it is deprived of oxygen**. Once the molecular weight has reduced to 5,000 Daltons or less, the material would be in very small particles and would be lost if testing were continued in the open environment. At this level of molecular-weight we would expect the material to have become biodegradable, and this is confirmed by testing residue from Stage 1 for biodegradation. Once the material has become biodegradable, it can be expected to fully biodegrade, save in the very unlikely event that it is deprived of bacteria."

Dr. Ruth Rose of Queen Mary University London says in her evidence to the European Chemicals Agency on 3rd May 2018 http://www.biodeg.org/wp-content/uploads/2024/09/Scientist-Letters-combined-06.06.18.pdf **"Once biodegradation of a long carbon-hydrogen chain has begun there is no reason to believe that assimilation would not continue to occur until all the material has been consumed by the micro-organisms.** In the laboratory biodegradation is not expected to proceed as quickly or as fully as it would in the open environment since the plastic is the only source of carbon, and other nutrients cannot be replenished. Additionally, plastic in the environment has been shown to be colonised by many microorganisms, and not, as we have tested, a single species. Nonetheless, we clearly observed higher rates of oxo-plastic consumption compared to LDPE."

IN VIEW OF THIS EVIDENCE, THE ONUS IS ON THOSE WHO ASSERT THAT BIODEGRADATION WOULD STOP BEFORE COMPLETION TO PROVE IT.

8.3 Papers relied upon by HSAC

The specific papers cited by HSAC are analysed in the Annex.

Generally, HSAC's conclusions rely heavily on a subset of peer-reviewed studies. While these papers contribute to academic understanding, their **methodological constraints, limited scope, and internal inconsistencies** mean they are not suitable as a basis for regulatory control. Key issues are summarised below. Peer review is often described as the "gold standard" but even the academic literature acknowledges its limitations.

HSAC themselves say that "findings between different studies vary considerably due to differences in the polymers utilised, differences in the pro-oxidant additives utilised, differences in the test conditions applied and use of different test guidelines for the studies."

The BPA has published a dossier at www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf which shows that many papers and literature-reviews on which policymakers rely have passed peer review and been published even though they contain serious faults mentioned in the dossier and below. This dossier is not put forward as primary evidence in itself, but for the facts, arguments, and citations which it contains.

Peer reviewers do not usually repeat the experiments themselves; they do not always have access to the raw data; and they often miss methodological or statistical errors. More than 10,000 research papers were retracted in 2023 alone, the highest number ever recorded, according to *Nature* [nature.com]. The retractions were largely due to sham papers, systematic manipulation, and compromised peer review, discovered only after publication through investigations and external scrutiny.

"Retraction Watch" data cited by Nature and by publisher statements confirms that publishers themselves acknowledge these represent only a fraction of the problematic literature, describing the situation as "the tip of the iceberg.

So, a paper can be methodologically weak, based on unrepresentative samples, or analytically flawed — yet still pass peer-review and be published. There is also editorial pressure, novelty bias, and financial or other incentives, and the fact that errors are often discovered post-publication through retractions or corrections.

A significant number of academic papers cited to justify restrictions or bans on oxo-biodegradable plastics suffer from recurring methodological and conceptual errors, which are then perpetuated and widely disseminated when the papers are included in literature reviews. This is important because HSAC's review implicitly assumes that:

- published papers are correctly testing the specified technology, and
- negative results therefore reflect failure of that technology.

The BPA dossier points out that researchers often **believe that oxo-biodegradable plastic is designed to start biodegrading immediately**. They fail to understand that it has a predetermined service-life during which it can be re-used and recycled, and that only after a period of abiotic degradation after exposure in the open environment will it become biodegradable. If a researcher assumes that immediate biodegradation is the design intent, the entire experimental question is wrong before the test begins.

The BPA dossier draws attention to papers where the researchers have also made the following common errors:

Testing Without Characterising the Sample - Numerous studies use samples purchased from the market without confirming whether a pro-oxidant masterbatch is present; whether it is a suitable masterbatch for the particular application; whether it is present at the correct concentration; whether the stabilisation package is appropriate; and whether it contains anything likely to affect the rate of degradation. Without chemical characterisation it is impossible to know whether the sample tested is correctly formulated, or oxo-biodegradable at all.

From a regulatory standpoint a study that cannot verify the precise identity of its test material is invalid by definition.

Testing a product which is heavily stabilised eg with carbon-black as a colourant. Slow degradation is then the expected outcome. That is not a failure of oxo-biodegradable technology; it is a failure to design the experiment correctly.

Failing to follow any standard test method. Without a standard method, results cannot be trusted, compared, or used for regulatory or scientific decision-making, and it is impossible to know whether differences in results arise from the material itself, or differences in test design, duration, inoculum, temperature, oxygen availability, or operator behaviour.

Following the wrong standard – Some of the papers assess oxo-biodegradable plastics against standards such as EN 13432, ASTM D6400, or ISO 17088. These standards are designed for industrial composting environments and include a time-limit (180 days) which is required by the industrial composters. They are not intended to evaluate plastics designed to degrade in the open environment. Failure of a product tested under the wrong standard is scientifically meaningless.

Arguments that oxo-biodegradable plastics fail composting standard tests (eg because they do not fully biodegrade within 180 days, or because they require an abiotic step) are therefore irrelevant. Oxo-biodegradable plastics are not designed or marketed for composting, and compostability is not a valid requirement for environmental performance in the open environment.

The only internationally recognised standard specifically written for plastics intended to degrade and then biodegrade in the open environment is ASTM D6954 (which has been followed in national standards such as BS 8472, SASO 2879 etc).

Failing to continue important parts of the test for a sufficient length of time.

If terminated before the process is designed to complete, the result only shows that "Nothing happened yet." That is not evidence of failure — it is evidence of premature termination or some other fault in the testing protocol.

Inappropriate Test Conditions: Exposing products under conditions for which they were not designed (e.g. burial, anaerobic conditions, continuous immersion) tests the wrong question. Oxo-biodegradable plastic is designed to biodegrade in the open environment with access to oxygen, and testing outside that envelope cannot be used to measure its environmental performance.

Failing to compare for biodegradability, recyclability and microplastics with bio-based plastic – (which is not banned). Many studies fail to compare biodegradation rates in the open environment; microplastic formation; and recyclability; against bio-based plastics, which have well documented limitations in these respects

Without that comparison, conclusions about "better" or "worse" or "benefit" or "no benefit" are not meaningful.

Failing to Compare with Ordinary Plastic – which is also a material which is not banned: However, HSAC implicitly compares oxo-biodegradable plastic with an ideal alternative which does not exist.

Many published papers evaluate oxo-biodegradable plastics in isolation, without comparison to conventional plastics under identical conditions. The correct regulatory question is not whether a material performs perfectly, but whether it persists for a longer or shorter time in the environment; and whether it creates microplastics or toxicity; as compared to the conventional plastic it is intended to replace.

HSAC implicitly requires proof of complete biodegradation, rather than considering whether incremental environmental benefit, relative performance, or risk-reduction might justify differentiated treatment. HSAC relies on review-level statements (e.g. that PAC plastics "streamline the creation of microplastics") without demonstrating that they are microplastics, or that such plastics perform worse than conventional plastics under comparable conditions; or whether observed fragmentation represents a net increase in environmental harm, rather than a difference in degradation pathway.

Conflating fragmentation with biodegradation - Many papers equate visible fragmentation with environmental harm, but this reflects a misunderstanding of polymer science. Fragmentation is not the endpoint of oxo-biodegradation but a physical manifestation of molecular-weight reduction.

ASTM D6954 requires proof that molecular weight is reduced to approximately 5,000 Daltons or below, at which point the material no longer behaves as a plastic and is biodegradable. Many academic studies do not measure molecular weight at all, and cannot therefore substantiate claims of microplastic formation or persistence.

Incorrect Assumptions About Microplastics: Persistent microplastics exist if polymers remain at a high molecular-weight. The purpose of oxo-biodegradable technology is to accelerate molecular-weight reduction so that the material does not persist but converts into biodegradable materials. Regulatory and scientific assessments that fail to distinguish between fragments of plastic and biodegradable oxidised materials therefore reach erroneous conclusions.

HSAC repeatedly notes concerns about microplastic formation. For the reasons given in detail at https://www.biodeg.org/subjects-of-interest/microplastics/ and as proved by Intertek in the series of tests in 2025 mentioned below, oxo-biodegradable plastics do not create microplastics – on the contrary, they prevent them by converting the polymer into biodegradable materials, not persistent microplastic particles.

The evidence of Dr. Swift is "The potential for microparticle formation and persistence in the environment is a very real concern when ordinary plastic materials are littered and allowed to erode and degrade as a result of environmental forces, and this is why oxo-biodegradable plastics were invented. Microplastic formation is highly unlikely in the case of oxo-biodegradable plastics, given their oxygen reactivity and degradation into low molecular-weight oxygenated hydrophilic materials. To my knowledge over 40 years there has never been an environmental contamination problem caused by oxo-biodegradable plastic."

Conclusion

Taken together, the literature relied upon by HSAC does not demonstrate that oxo-biodegradable PE or PP performance is worse than conventional plastics in the open environment. At most, it demonstrates variability in rate and highlights the need for **standards-based, material-specific assessment**—an approach already provided for by ASTM D6954 and related standards- together with Quality Control in the industry.

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9. Independent Accredited Testing

HSAC gives very little weight to independent testing - on the basis that such work is industry-funded. However, this position is inconsistent with regulatory practice across materials, chemicals, and pharmaceuticals, as it is impossible to obtain expert evidence without payment.

Accredited laboratories such as Intertek, operating under ISO 17025, are required to demonstrate technical competence, impartiality, and auditability. Test reports by Intertek already provided to DEFRA and HSAC demonstrate high levels of biodegradation, absence of ecotoxicity, and absence of persistent microplastics.

DEFRA and HSAC have **in particular been supplied with six Reports by Intertek on Symphony Environmental's d2w oxo-biodegradable technology**, in polyethylene and polypropylene, which are the main polymers used for packaging and other items commonly found in litter. These reports are commercially confidential as this type of independent testing is very time-consuming and expensive. **The HSAC report does not engage with them.**

The reports dated 7th February 2025 show that scientific studies on samples of plastic made with d2w had **proved 94.55% biodegradation in the case of polyethylene and 92.76% biodegradation in the case of polypropylene**. They had also proved no adverse effects on plants or earthworms, and no metals above permitted levels.

These studies had therefore shown that there was very little if any plastic left which could become microplastics. (100% carbon-evolution would never be achieved because the rest of the organic carbon is used by microorganisms for their energy requirements and to build their cell-structure), and some of the residue is water.

Nevertheless, Intertek were asked to check specifically for microplastics, and their Reports dated 7th March 2025 concluded that "the potential particles observed in primary screening of the inoculum after biodegradation did not show any traces of the original sample - indicating that the biodegraded part of the original sample did not leave any of its remnant in the inoculum." This is what the BPA and many scientists have always understood.

However, in view of the importance of the 7th March Report, Intertek carried out a further detailed assessment of the data and reported on 17th March that they had found one particle in the case of polyethylene and two particles in the case of polypropylene. These results proved that there is no generation of persistent microplastics.

The two particles found were not functional plastics, because Intertek had found that the molecular weight had reduced to 4,900 Daltons in the case of PP, and 2,200 in the case of PE, so even if they had been remnants of the test materials they would no longer behave as plastics but as low-molecular-weight oligomers or short-chain polymer fragments which are biodegradable.

If the PE and PP samples had not been made with d2w, and had simply fragmented under the influence of sunlight and stress, it is to be expected that many thousands of plastic particles would have been found. Accordingly, even if the particles actually found by Intertek were particles of the PE and PP samples, **the fact that so few were found is an**

excellent result, and reinforces the view that oxo-biodegradable plastic is a very useful technology for reducing the prevalence of microplastics in the environment.

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10. The Oxomar Project

A fundamental weakness of the HSAC review is the absence of engagement with the **Oxomar** project, a three-year interdisciplinary study sponsored by the French government and conducted by public research institutions. See www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf - and the six published papers cited at C7 in the report.

Oxomar demonstrated - for oxo-biodegradable PE in marine environments - oxidation, molecular-weight reduction, microbial assimilation, and absence of ecotoxicity. Failure to engage with this study undermines the HSAC conclusions.

The Oxomar scientists reported that "**We have obtained congruent results from our multidisciplinary approach that clearly show that oxo-biodegradable plastics biodegrade in seawater and do so with a significantly higher efficiency than conventional plastics. The oxidation level obtained due to the d2w prodegradant catalyst was found to be of crucial importance in the degradation process.**"

Oxomar did not pursue the study to the point of complete biodegradation because this is expensive and is not required in order to prove biodegradability. However, 92.74% biodegradation was proved by Intertek in the tests mentioned above (Only 90% is required by EN13432 for "compostable" plastic).

Carbon 13

HSAC say that "To definitively address the question of how completely PAC plastics degrade in soil environments, HSAC recommends that studies are performed utilising isotopically labelled plastics to definitely demonstrate whether the evolved CO_2 derives from the plastic or from soil organic matter."

They seem to be unaware that **these tests were actually done as a supplement to the Oxomar project, and have demonstrated that the evolved CO_2 does derive from the plastic.** The Report from Institut de Chimie de Clermont-Ferrand, France, dated January 2022 confirms that "biodegradation of 13C-Oxo-LDPE and 12C-Oxo-LDPE showed positive results, as the Rhodococcus bacterium was able to growth on both materials." **The incorporation of 13C into the CO2 started from the beginning of the incubation and increased during the whole experiment. This confirms the use of 13C polyethylene as a carbon source by the Rhodococcus strain all along the experiment."** "This enrichment reflects the mineralization of the labelled polymer through respiration and confirms the biodegradation of oxo-polyethylene."

See also Goudriaan et al Marine Pollution Bulletin 186 (2023) 114369 *"Stable isotope assay with 13C-labeled polyethylene to investigate plastic mineralization mediated by Rhodococcus ruber"* https://doi.org/10.1016/j.marpolbul.2022.114369 "We found that our approach allows tracing isotopically labeled carbon from plastic into the mineralization product CO2, and **thus provided unambiguous proof for the mineralization of plastic-derived carbon by microbes."**

See also Vaksmaa et al *"Polyethylene degradation and assimilation by the marine yeast Rhodotorula mucilaginosa"* ISME COMMUN. 3, 68 (2023). https://doi.org/10.1038/s43705-023-00267-z "With the aid of stable isotope assays, we provide **unambiguous proof that the fungus Rhodotorula mucilaginosa uses polyethylene-derived carbon for cellular incorporation and energy gain**. Our results confirm that initial plastic photooxidation is a key process in making plastic available for subsequent microbial degradation. Most produced and discarded plastic types such as polyethylene and polypropylene float at the ocean surface and will consequently be subjected to photooxidation so that fungal degradation can commence there. **At least parts of the vast amounts of plastic litter in the ocean may thus serve as a carbon source for fungi and possibly other microbes, too."**

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11. Microplastics and Mechanism

HSAC says that "PAC plastics may have up to 5% loading by weight of a pro-oxidant chemical to enhance their UV-degradation and fragmentation into smaller pieces thus increasing their bioavailability to microbes for mineralisation to CO2." Also, "additives are "designed to enhance the rate at which they fragment." This shows that HSAC do not understand the fundamental principle of oxo-biodegradable technology. **It is not the reduction in size which creates bioavailability, it is the change in molecular structure caused by oxidation.**

Professor Ignacy Jakubowicz, one of the world's leading polymer scientists, has proved that "The degradation process is not only a fragmentation, but is an entire change of the material from a high molecular-weight polymer, to monomeric and oligomeric fragments, and from hydrocarbon molecules to oxygen-containing molecules which can be bioassimilated."
http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf

Once molecular weight falls below approximately 5,000 Daltons, the material no longer behaves as a plastic and becomes bioassimilable. Oxo-biodegradable technology is therefore **specifically designed to prevent the persistence of plastics in the environment.**

12. ECO-TOXICITY

HSAC say "While existing packaging regulations set limits on heavy metals in intact products, they were not designed for scenarios involving complete environmental degradation. However, ASTM D6954 (which is specifically concerned with plastic intended for complete environmental degradation) addresses this point by requiring ecotoxicity testing using OECD-recognised methods. ASTM D6954 (6.9.6 et seq) requires the residue to be evaluated for environmental toxicity in soil and water, and an oxo-biodegradable product will not therefore be certified if these toxicity requirements are not satisfied.

OECD ecotoxicity tests are the tools relied upon across chemicals, pesticides, and polymers, and are globally accepted regulatory instruments. Oxo-biodegradable plastic has been successfully tested by independent test houses according to:

OECD 201 Freshwater Alga and Cyanobacteria,

OECD 202 Daphnia.

OECD 203 Fish

OECD 207 – Earthworms (the worms actually increased in weight)

OECD 208 Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test

13. Regulatory Implications

A standards-based regulatory approach would allow:

- Use of ISO 17025 certified oxo-biodegradable PE and PP
- Material-specific type-approval according to ASTM D6954;
- Enforcement against non-compliant or mislabelled products;
- Measurable reduction in environmental persistence of single-use plastics.

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14. Conclusions and Regulatory Recommendation

The BPA's position is that any ban on oxo-biodegradable plastics would be **unsupported by the full body of available evidence** and would remove a proven harm-reduction tool from the policy framework. The fact that this has been done in the EU (by a questionable legislative process) does not require that it be done in the UK. See https://www.biodeg.org/eu-news/

DEFRA should:

1. Reject calls for any prohibition of certified oxo-biodegradable plastics;
2. Explicitly encourage the use of oxo-biodegradable technology for all single-use PE and PP plastic items;
3. Base regulation on internationally recognised standards and accredited testing;
4. Apply proportional, risk-based regulation aimed at reducing environmental persistence rather than rejecting entire technological options.

Oxo-biodegradable plastics are not a substitute for waste management, but they represent a scientifically grounded, standards-based means of **reducing the long-term environmental impact of unavoidable plastic leakage**.

Annex – Review of HSAC-Cited Materials

A1. Purpose and approach

This annex summarises the BPA's review of the publications, reports, and standards **cited *by HSAC in its October 2025 review, for the purpose of assessing the weight and regulatory* relevance** of the evidence on which HSAC relies.

For clarity:

- This annex is **not** presented as evidence in itself, but for the facts and arguments which it contains.

A2.– HSAC-cited materials

Abed et al (2020) See www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf OXO-PE and PE bags were obtained from a local supermarket in Muscat, Oman, and the polymer material was not characterised before the test began. Therefore it is impossible to know whether the OXO bags were correctly made with a suitable masterbatch in the right concentration or at all, and whether the plastic contained anything else which would be likely to affect the rate or extent of degradation. This renders the study of little or no value.

They question degradability of oxo- samples in the marine environment, but do not refer to Oxomar. As to biodegradation in deeper waters, oxo-biodegradable plastics have a specific gravity less than 1, so they will float on the surface and are not designed for deep submersion. This is the mistake made by the Plymouth University study by Napper & Thompson

Ammala et al. (2011) is a good paper, but it is a literature review, not a scientific study. It describes many different topics, including complex abiotic and biotic degradation mechanisms and test methods, but it is not a performance evaluation, a regulatory risk assessment, or a determination of environmental acceptability.

The authors explicitly recognise that pro-oxidant additives accelerate oxidative degradation; reduce molecular weight more rapidly than base polymers; and alter degradation pathways. They do not support any claim that oxo-additives are ineffective. They note that composting standards (e.g. EN 13432, ASTM D6400) are inappropriate for polyolefins designed for open environments. They recognise fragmentation as part of degradation, but do not equate this with increased harm – they treat fragmentation as an intermediate step, not an endpoint. They do not identify toxic harm arising from oxo-degradable additives, and do not claim that oxo-biodegradable plastics are worse than conventional plastics.

Barron & Sparks (2020) The central aim is to identify materials designed to biodegrade in marine environments without oxidation and without multi-stage degradation sequences. They therefore classify oxo-biodegradable plastics as outside the scope of their study.

By contrast, OXOMAR explicitly studies oxo-biodegradable PE in the marine environment. It is the most substantial body of marine-environment research on oxo-biodegradable polyethylene to date. OXOMAR adopted a multidisciplinary approach, combining accelerated abiotic ageing, controlled seawater incubations, microbial assays, and ecotoxicity testing.

Oxomar reported that oxo-biodegradable polyethylene films exhibited substantially greater oxidation, molecular-weight reduction, microbial colonisation, and indicators of biodegradation than conventional polyethylene, and that no acute ecotoxicity was observed.

Barron & Sparks avoid the OXOMAR results by excluding them from the scope of their study.

Devalla (Hutton Institute report to Scottish Government 2022) See www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf This report does not justify any restriction on oxo-biodegradable plastic, the purpose of which is to biodegrade much more quickly than ordinary plastic if it gets into the open environment as litter. The question is whether oxo-biodegradable plastic is better for the environment than conventional plastic, but the author does not evaluate the impact of conventional plastic at all.

The abiotic process (for both oxo-biodegradable and conventional plastics) would be slower in Scottish conditions than in a uniformly warm sunny climate.

No reason is given as to why biodegradation should stop before it is complete, but complete biodegradation is not required to provide a clear benefit over conventional plastic which fragments, but does not biodegrade at all, except over a very long timescale.

It cannot be maintained that there is not enough uv light and oxygen in Scotland to initiate the process. Once initiated it will continue even in the dark, because oxo-biodegradable is not the same as photo-degradable.

Dintcheva (2024) Pro-degradants are not mentioned at all. This paper is cited to support the proposition that "PAC plastics are primarily used in single-use applications," which is correct, but Dintcheva does not say that they are "broadly incompatible with the development of a circular economy." This proposition is not in any event sustainable because not even the most enthusiastic advocates of a circular economy would claim that it is possible to collect all the plastic – and if it cannot be collected it cannot therefore be included in a circular economy.

Oxo-biodegradable technology deals with the plastic which does not get collected.

This paper was written for a materials science audience, not regulators. It is explicitly technology-agnostic, covering: Conventional polymers, Biopolymers, additives (stabilisers, pro-oxidants, antioxidants) It is not an evaluation of oxo-degradable plastics as a policy category, a risk assessment, or a performance determination under natural environments.

Heimowska et al See www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf HSAC notes that the plastic sample "was completely destroyed after 45 months." However, the sample was not characterised before testing, and the authors could therefore have no idea whether the test sample contained a masterbatch formulated for the particular application (they are not all the same) and included at the correct concentration or at all, or to what extent the material was stabilised. The author also falls into other errors identified in the BPA dossier.

Hill et al. state that the purpose of the study is to identify an accelerated UV-weathering cycle suitable for plastics designed to be environmentally unstable; examine whether that laboratory cycle correlates with outdoor exposure; and demonstrate the utility of HT-GPC for tracking physico-chemical degradation.

The paper is useful in relation to UV-weathering, but does not claim to demonstrate biodegradation, demonstrate mineralisation, or assess equivalence between laboratory and all natural environments. As would be expected the HT-GPC data shows greater molecular-weight reduction in oxo-modified PE compared with unmodified PE under both laboratory and outdoor exposure; and progressive oxidation and chain scission. This directly demonstrates the efficacy of pro-oxidant systems.

Hill et al. therefore support the proposition that oxo-modified PE degrades faster than base PE under both lab and outdoor exposure; also that PAS 9017-style testing can provide meaningful comparative data; that degradation is progressive and measurable; and that lab testing must be carefully calibrated, not simply dismissed.

It does not support the proposition that laboratory ageing is meaningless; that oxo-degradable plastics fail in use; that fragmentation equals environmental harm; or that results from Florida are of universal application.

Mamin et al. (2023) is a mechanistic and kinetic review of oxo-additives in polyolefins, focused on radical oxidation pathways; additive chemistry (metal salts, photo-sensitisers, fillers, initiators); and reaction kinetics and activation mechanisms. It is not a field-performance study; a biodegradation or mineralisation assessment; a risk or policy evaluation; nor a review of environmental fate outcomes.

The paper's central contribution is a detailed confirmation of the chemical principles of oxo-degradation, including free-radical initiation (UV, heat, mechanical stress); propagation via oxygen uptake; chain scission through hydroperoxide decomposition; and reduction in molecular weight, as a function of this branch of chemistry.

This confirms, rather than questions, that oxo-biodegradable masterbatches do modify degradation kinetics, and the authors explicitly describe them as effective catalysts of oxidative degradation. The paper does not assert increased environmental harm; persistence of fragments; or increased risk versus conventional PE/PP. Accordingly, use of this paper to support a microplastics hazard narrative would be inappropriate.

Mastalygina et al. (2023) did not verify that their oxo-polyolefin samples contained an appropriate masterbatch at the correct concentration or at all. As a result, their findings cannot be used to assess the performance of correctly made oxo-biodegradable plastic.

This is critical when HSAC relies on Mastalygina et al. to support categorical conclusions about oxo-biodegradable plastics generally. For a correct assessment HSAC should have relied on the 2025 Intertek reports with which DEFRA had been supplied. They are reports of rigorous testing of a material of known composition by an ISO 17025 accredited test-house.

This paper by Mastalygina et al also points out the importance of quality control at the factory to ensure that bags marketed as oxo-biodegradable are correctly made.

Even if they had ascertained that the bags were oxo-biodegradable plastic correctly made, the samples were buried and thereby exposed to a very limited supply of oxygen. They would not therefore be expected to show much abiotic degradation, especially in as short a period as three months. Oxo-biodegradable plastic is explicitly designed to deal with the problem of litter in the open environment which will lie or float around on the surface exposed to oxygen and uv light. It will not normally bury itself.

Moreira et al. aimed to define and validate a UV-accelerated weathering cycle for polyethylene films that are designed to be environmentally unstable, and to correlate laboratory degradation metrics with outdoor exposure. They combined: HT-GPC (molecular-weight reduction), IR spectroscopic mapping / carbonyl index, and Drop-point testing (to identify formation of low-MW waxes/microparticles). They also correlated lab results with parallel outdoor exposure in Florida and France.

However, nowhere does the paper report:

- Identification of a specific masterbatch system
- Quantification of pro-oxidant loading
- Assessment of stabiliser/pro-oxidant balance,
- Absence of any material likely to affect the rate of degradation
- Benchmarking against a known, correctly made oxo-biodegradable plastic, nor against conventional plastic.

Again therefore, this paper cannot be used to assess the performance of a correctly made oxo-biodegradable plastic product. For that assessment HSAC should again have relied on the 2025 Intertek reports with which DEFRA had been supplied. They are reports of rigorous testing of a material of known composition according to an international standard.

Moreno et al See www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf The authors had not taken the first, and fundamental, scientific step to analyse the products to determine whether they contained a masterbatch in the right concentration or at all, and therefore had no idea whether they were biodegradable or not.

Morrison et al The samples are described as “commercially available oxo-degradable plastics” obtained from the consumer market. Identification relied only on Product claims / market availability. The samples are referred to by generic descriptions (HDPE bag, LDPE film, PP straw).

Again, there is no evidence that the authors ascertained the specific oxo-biodegradable masterbatch; confirmed the intended degradation design of the product; or verified whether the material was oxo-biodegradable at all.

The authors did perform metal analysis, using X-ray fluorescence to estimate metal presence; and ICP-MS to measure concentrations of metals in the plastic. This establishes that some transition metals were present in some samples, but critically these may be pigments or contaminants. There is no verification that the metals were in the correct chemical form (e.g. carboxylates), present at the correct loading, or balanced against stabilisers appropriately. Yet again HSAC should have relied on the 2025 Intertek reports with which DEFRA had been supplied.

Odobel et al These scientists participated in the Oxomar study (see above) They found as would be expected biodegradation of aged OXO-PE, but no biodegradation occurred in conventional PE or PS, or PLA. HSAC themselves note "clear evidence seen of biodegradation of artificially aged oxo-PE in seawater, with signs of biodegradation visible after one month."

Reddy et al confirm that PE with oxo-additive, becomes susceptible to microbial attack after sufficient oxidation, and that conventional PE does not. Reddy et al. differs fundamentally from several other papers considered in this Response because they understood the two-stage mechanism; they applied abiotic degradation before testing for biodegradation; they included proper controls, and they did not over-generalise. They did not bury samples without oxygen; immerse samples in water; or expect biodegradation without oxidation.

Rose et al https://www.biodeg.org/queen-mary-university-london-report/ This is an important scientific study, not just a literature review. HSAC notes that data suggest that artificially UV-irradiated samples of oxo-LDPE are 90-fold more biodegradable by the soil bacterium R.Rhodochrous than equivalently aged conventional LDPE.

Sable et al did apply weathering before biodegradation testing. This correctly established the necessary precondition for biodegradation, and they found that the carbonyl index increased both with CoSt loading and duration of abiotic treatment. After abiotic treatment, samples were subjected to biotic testing, and they reported biodegradation up to 36.42% during their test on PP containing 2 phr CoSt; clear surface erosion and pitting by microbes(SEM); and enhanced biodegradation relative to conventional PP.

As to toxicity, HSAC note that the authors tested the effects of degradation products on microbial growth, plant growth (Mung bean and wheat plants), earthworm survival. The data indicated that the treatment did not induce adverse effect at any of the assessed endpoints.

Schiavo et al (2019) *"Ecotoxicological assessment of virgin plastic pellet leachates in freshwater matrices."* Although not misleading in itself, this paper is mis-cited to imply that oxo-biodegradable plastics release toxic substances into the environment. However, the study did not test oxo-biodegradable plastics; it did not test degradation products; and it did not examine oxidised or weathered materials.

An oxo-biodegradable plastic would not be certified according to ASTM D6954 or its aligned national Standards if it caused ecotoxicity. As noted above, evidence has been provided to DEFRA that oxo-biodegradable plastic has been successfully tested by independent test houses according to OECD 201; 202; 203; 207; and 208.

Schiavo et al (2020) The authors tested PE and PP (and also PS for which oxo-biodegradable technology is not used) but do not identify the specific oxo-degradable masterbatch; the quantification of pro-oxidant concentration; nor verification that masterbatches are present at correct loadings.

The authors do NOT claim that oxo-degradable plastics are more toxic than other plastics; nor that oxo-degradable additives are inherently harmful; nor that degradation products pose long-term environmental risks; nor that oxo-biodegradable technology fails in the open environment or should be banned. As noted above, oxo-biodegradable plastic has been successfully tested by independent test houses according to OECD 201; 202; 203; 207; and 208.

Sciscione et al (2023) "*The performance and environmental impact of pro-oxidant-additive-containing plastics in the open unmanaged environment*" See BPA comments at www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf They say correctly that "The rate of degradation will be different for a material floating on the surface of the sea, experiencing higher temperature, oxygen and UV light, compared with in deep waters where the photo- and thermal oxidation might be limited due to reduced amounts of oxygen and light, and lower temperatures." However the specific gravity of PE and PP litter is such that it will float on the surface. It is also non-polar and hydrophobic, and most of it will not be buried on land. Oxo-biodegradation is not photo-degradation, and will continue in the absence of sunlight.

Sciscione et al refer to testing at Plymouth University and conclude "that the test period was not appropriate to test the claims of this PAC material." We agree. The Plymouth researchers also fell into other errors See http://www.biodeg.org/wp-content/uploads/2019/04/BPA-Comments-on-Plymouth-10.pdf

Sciscione et al continue "Possible formation of microplastics and cross-linking have been highlighted both by field studies and laboratory studies." That is why paras. 4.5.1 6.3, 6.4 and 7.3.2 of ASTM D6954 and comparable Standards provide for this to be tested and recorded.

Sciscione et al accept that "The level of mineralization is measured by the amount of CO_2 produced by microorganisms during bioassimilation by a respirometric method according to international standards. However, this method could lead to an underestimation of the biodegradation levels if the production of new biomass is significant, and does not take into account changes in enzymatic activity."

With regard to the abiotic phase, Sciscione et al conclude that "a good correlation was found between the samples tested under laboratory and controlled outdoor exposure."

Scott, G. *Initiation Processes in Polymer Degradation*. Polym. Degrad. Stab. 1995, 48, 315–324. https://doi.org/10.1016/0141-3910(95)00090-9 Professor Scott can be said to be the father of oxo-biodegradable technology, and was the author of the standard textbooks on the subject, including *"Polymers & the Environment*" ISBN 9780854045785; *"Degradable Polymers; Principles & Applications"* ISBN 1-4020-0790-6; *"Programmed-Life Plastics from Polyolefins: A New Look at Sustainability"* https://www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-

2001.pdf Professor Scott was for ten years the Chief Scientific Adviser to the Biodegradable Plastics Association.

Seely et al This paper explains that Py-GC/MS thermally decomposes polymers into characteristic marker fragments, and uses these fragments as chemical fingerprints to identify polymer type (PE, PP, PS, PET, etc.), additives and fillers (where detectable), and relative abundance in complex matrices (sediments, water, biota).

The authors do NOT claim that Py-GC/MS can determine biodegradability; distinguish oxo-biodegradable from non-oxo-biodegradable PE in environmental samples; identify degradation pathways (abiotic vs biotic); or assess toxicity or ecological risk. They are careful to frame Py-GC/MS as an identification and quantification tool, not a performance or hazard assessment tool.

Song et al address the following practical agronomic question, not a materials-science or environmental toxicology question: "Is degradable plastic film a viable alternative to conventional polyethylene film (PF) for improving crop productivity and soil environmental conditions?" To answer this, they conducted a three-year field experiment evaluating Traditional plastic film (PF) (polyethylene mulch), and three "degradable" films.

These degradable films are not oxo-biodegradable polyolefins; they are polyester-based biodegradable films, and the paper is not therefore relevant to oxo-biodegradable technology.

Oxo-biodegradable mulch film is however very useful in agriculture and horticulture. See https://www.biodeg.org/agricultural-plastic-products-2/ and has been successfully tested according to ISO 17556.

Theobald et al (2016) See www.biodeg.org/wp-content/uploads/2026/02/BPA-Dossier-with-links-10-2-26-optimised-V12-24-2-26.pdf This paper confirms that "Plastics are essential to modern society due to their favourable properties, low cost, and ease of processing." However "the fragmentation of plastic debris is a key pathway to the formation of microplastic pollution" and "The general high level of inertness of the samples to conditions in aquatic environments investigated in this study confirms the well-known environmental persistence of established commodity plastics." – Correct. This is why oxo-biodegradable technology was invented.

They also correctly say that "Numerous studies have analysed heavily degraded microplastic samples collected in rivers, on beaches, or in the open ocean.

However, often fundamental information, such as the original plastic composition, the time plastics have spent in the environment and the conditions they have been exposed to, is lacking." It is impossible to say therefore whether this study relates in any way to oxo-biodegradable plastic.

They also say "a few studies have deployed plastic samples into natural, predominantly marine environments, and monitored changes in their physical properties over time

(Weinstein et al., 2016; Rizzo et al., 2021; O'Brine and Thompson, 2010; Karlsson et al., 2018), but this study pre-dates Oxomar.

In most studies, commercially available products such as plastic bags were again used, with no information about the exact chemical nature of the polymer or any additives." – or "the physical conditions the samples have been exposed to during production or storage." "Both factors can be expected to significantly affect the plastics when their degradation and fragmentation behaviours are being studied." Correct - which is why often-cited reports, such as Napper & Thompson at Plymouth University are leading policymakers to the wrong conclusion.

Also (at para. 1) "neither the nature of plastic additives, nor their concentrations are usually reported. In many cases, they are presumably even unknown to the investigators carrying out the experiments and interpreting the data. Similar uncertainties often exist about the physical conditions the samples have been exposed to during production or storage prior to being tested. Both factors, however, can be expected to significantly affect the plastics when their degradation and fragmentation behaviours are being studied." – Correct.

Theobald et al were not aware of the Oxomar study and the scientific work referenced in it. Also, Theobald et al exposed the sample under conditions not likely to be expected for PE or PP litter in the real world, but they still found (at 3.11) "SEM showed that there was no noticeable effect of ageing on the surface micromorphology of [ordinary] LLDPE (Fig. SI-3), but oxo-LLDPE developed large cracks and substantial surface etching, and formed crystalline domains, reflecting the more substantial degradation catalysed by the manganese oxo-degradation additive."

It is unlikely that exposure for only one month would have reduced the molecular-weight to 5,000 Daltons, which is the approximate level required for biodegradation to commence. The authors did not measure the molecular weight before submerging the sample, so that is another reason why they did not observe the results which one would expect.

Broadly however, this study confirms that oxo-biodegradable plastic performs in the way it is designed to perform.

Vázquez-Morillas et al. (2016) tested polyethylene films containing an oxo-biodegradable (pro-oxidant) masterbatch; printed and unprinted variants; conventional polyethylene (PE) (printed and unprinted); polylactic acid (PLA) (as a biodegradable comparator); and cellulose (as a positive biodegradation control).

This is quite a good study. The polymer classes are known; oxo-biodegradable PE is clearly distinguished from conventional PE; and appropriate positive and negative controls are included. However, the paper does not disclose the pro-oxidant concentration, nor the stabiliser/pro-oxidant balance, which have important effects on degradation time.

The printed oxo-PE achieved 32.24 % conversion into CO_2 by microbial action but they allowed this to proceed for only 180 days, which is the time prescribed by EN13432/ASTM D6400 for plastics designed to biodegrade in an industrial composting facility with elevated temperatures and a highly microbial environment. As to toxicity, HSAC note that this paper reported that biodegradation products of polyethylene films containing an oxo-degradable additive did not have any effect on the germination and development of tomato plants and grass seeds.

Vázquez et al. (2019) found that the addition of an oxo-biodegradable masterbatch accelerates degradation, since after both aging processes samples with PDA were significantly more degraded than base polyolefins under same conditions. This paper does not support HSAC's conclusion that oxo-degradable plastics fail to provide environmental benefit. It supports only the narrower conclusion that complete biodegradation had not yet been demonstrated by them under their test protocol. HSAC's use of the paper therefore over-extends its findings by converting a qualified scientific limitation into a regulatory inference.

A3. Annex conclusion

Taken as a whole, **the evidence cited by HSAC, does not provide a sufficient basis for any restriction on oxo-biodegradable plastic.** A proportionate regulatory approach would instead:

- Apply performance-based standards and compliance testing (e.g., standards aligned with ASTM D6954 and relevant specifications);
- Differentiate between compliant and non-compliant products and claims;
- Use enforcement against mislabelled or non-conforming products, rather than banning the compliant technology category.