Comments on misleading evaluations of oxo-biodegradable technology in published papers.

March 2026

INTRODUCTION

“Misleading Claims About Plastics:

A Technical Analysis of papers on Oxo Biodegradable Plastic.

This comprehensive report exposes widespread inaccuracies in published papers about oxo biodegradable plastics. It clarifies the scientific evidence, corrects misleading conclusions, and sets out the legal and environmental rationale for technologies such as d2w® that enable conventional plastics to biodegrade safely in the open environment.

This report provides a detailed, evidence-based assessment of the scientific, regulatory, and policy landscape surrounding oxo biodegradable plastics. Across multiple international sources—including academic papers, government submissions, NGO publications, and EU/UN reports—the document identifies and corrects recurring errors, misinterpretations, and omissions that have influenced policy debates and public perceptions.

Drawing on peer-reviewed studies, laboratory data, real world field research, and expert technical evaluations, the report demonstrates that oxo biodegradable technology (including d2w®) is scientifically validated, environmentally beneficial, and fully compatible with existing recycling streams. It further explains how the controlled oxidation process transforms plastics which have entered the open environment as litter into biodegradable materials which are consumed by microorganisms without leaving microplastics.

Overall, the report underscores the need for evidence-based policymaking and calls on regulators, NGOs, and the scientific community to ensure accuracy and integrity when assessing technologies designed to reduce plastic pollution. It affirms that oxo biodegradable solutions are a practical, cost effective, and scientifically supported approach to mitigating plastic persistence in the environment.

The Report points out that researchers often believe that d2w 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.

It also draws attention to papers where the researchers:

A – Have simply relied on labels attached to plastic products and have not analysed the products themselves before commencing the test. They therefore have no idea whether the test sample contains a masterbatch formulated for the particular application and included at the correct concentration or at all. This invalidates the whole report.
B - Have not followed any standard test method.
C – Have followed the wrong standard e.g. ASTM D6400 or EN13432 or ISO 17088 instead of ASTM D6954.
D – Did not continue important parts of the test for a sufficient length of time.
E – Use a sample so heavily stabilized that it would take a very long time before the material became biodegradable.
F – Exposed the plastic product under conditions unlikely to be experienced in the use for which it was designed.
G – Failed to compare for biodegradability and microplastics with ordinary plastic.
H – Failed to compare for biodegradability, recyclability and microplastics with bio-based plastic.

THERE ARE HOWEVER MANY SCIENTIFIC PAPERS WHICH DO NOT FALL INTO THE ERRORS MENTIONED ABOVE, AND A LIST OF THESE IS AVAILABLE ON REQUEST FROM SYMPHONY ENVIRONMENTAL TECHNOLOGIES PLC.

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PLYMOUTH UNIVERSITY Napper, I., & Thompson, R. (2019) 'Environmental Deterioration of Biodegradable, Oxo-biodegradable, Compostable, and Conventional Plastic Carrier Bags in the Sea, Soil, and Open-Air Over a 3-Year Period', Environmental Science and Technology, 53(9), pp. 4775-4783

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SCOTTISH Government Consultation on “Market Restrictions on Problematic Single-Use Plastic Items” (2021)

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WALES “Oxo-degradable and oxo-biodegradable plastic use in agriculture and horticulture in Wales.” Written by ADAS for the Welsh Government 15th August 2022.

WORLD WILDLIFE FUND “Position Paper” on Biobased and Biodegradable Plastic.” (2023)

YASHCHUKK et al “Degradation of Polyethylene FFilm Samples Containing Oxo-Degradable Additives 71-173.” Procedia Materials Science, 1, 439-445. (2012)

COMMENTS by Symphony Environmental Technologies Plc on

Abed et al *Degradability and biofouling of oxo-biodegradable polyethylene in the planktonic and benthic zones of the Arabian Gulf*

https://doi.org/10.1016/j.marpolbul.2019.110639

Oxo-biodegradable polyethylene (OXO-PE) has been introduced to overcome the alarming levels of non-degradable plastic accumulation in the environment. This is correct. The traditional policies of "Reduce, re-use, recycle" have not been sufficient, and oxo-biodegradable technology appears now to be the only way to prevent plastics in the environment from creating microplastics and accumulating there for decades.

OXO-PE is derived from polyethylene (PE) after inclusion of metal (e.g. Cu, Ni and Fe salts) pro-oxidant additives, that are heat- and light-sensitive and can react with molecular oxygen, resulting in accelerated fragmentation and eventually facilitating microbe-mediated degradation. This is correct except that the salts commonly used are of manganese and iron.

OXO-PE is first degraded by oxidative chain scission (breakage of the polymer backbone by addition of oxygen atoms) that is catalyzed by the metal salts into oxygenated simple organic molecules including ketones, alcohols, carboxylic acids and low mass hydrocarbons. This abiotic degradation process is then followed by biotic degradation (enzymatic action of microbes) of the shorter-chain molecules. Previous research has demonstrated faster biodegradation of OXO-PE than conventional plastics in soils and composts (Ojeda et al., 2009; Corti et al., 2010; Gomes et al., 2014). This is correct.

Electron microscopy (SEM) revealed more fissure formation on OXO-PE and PE than on PET, indicating physical degradation. This is what would be expected.

The formation of hydroxyl groups and carbonyl bonds, by Fourier-transform infrared spectroscopy (FTIR), suggests chemical degradation of OXO-PE. Again, this would be expected.

We conclude that OXO-PE shows increased signs of degradation with time owing to the combination of abiotic and biotic processes, and its degradation is higher in the benthic than in the planktonic zone. Again, this would be expected.

Nevertheless, the fragmentation of OXO-PE into microplastics and their persistence in nature due to the slow biotic degradation processes remained a major concern (Sen and Raut, 2015; MacArthur et al., 2016). We have not seen the Sen and Rout paper, but MacArthur 2016 cannot be cited as authority for anything as it is a political paper, not written by scientists, as are their later papers. See https://www.biodeg.org/bpa-response-to-emf-report/ Ordinary plastics fragment into microplastics, and they are persistent due to the long abiotic degradation phase, but this is much shorter in the case of oxo-biodegradable plastics.

Professor Ignacy Jakubowicz, one of the world's leading polymer scientists, has described the oxo-biodegradation process as follows in his reply to the Ellen MacArthur Foundation http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf: "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."

After the abiotic phase, the timescale for biodegradation is not important as the material is no longer a plastic.

The lack of conclusive evidence that, in the open environment, the OXO-PE fragments are biodegraded, has created a controversy in the US and several European countries, where OXO-PE is no longer claimed as "oxo-biodegradable". In spite of that, OXO-PE is still extensively marketed in the Middle East countries in the form of cling films, sheets or carrier bags

The governments of several Middle Eastern countries realised that they could not prevent plastic waste getting into the open environment. They therefore commissioned experts to study oxo-biodegradable technology, and then legislated to make its use compulsory for a wide range of plastic products.

As to the European Union, the legislators had not followed the procedure prescribed by the REACH regulation; had failed to make an environmental impact assessment or socio-economic analysis; had failed to await the results of a scientific study being done at the time by the European Chemicals Agency; and had prematurely terminated the study. On 30th October 2018 the Agency said that they had not been convinced that microplastics were formed.

Hence, there is an urgent need to assess the fate of OXO-PE, especially in the open marine environment, where the number of studies is relatively limited. This paper by Abed et al was published in 2019, before publication of the Oxomar study on 18th March 2021 www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf Oxomar was a four-year study, sponsored by the French government, which provides conclusive evidence that, in the open environment, the OXO-PE fragments are biodegraded.

Oxomar demonstrates that “Oxo-biodegradable plastics biodegrade in seawater and do so with a significantly higher efficiency than conventional plastics,” and that “The oxidation level obtained due to the d2w prodegradant catalyst was found to be of crucial importance in the degradation process.”

Biodegradability was demonstrated by using the bacteria Rhodococcus rhodochrous and a complex natural marine community of microorganisms. Nine scientific articles arising from this research have been published in scientific journals, and results have been presented at 13 international conferences.

The OXOMAR project is a fundamental research project coordinated by the CNRS LOMIC. It combines the expertise of the French public laboratories CNRS-LOMIC, CNRS-ICCF and IFREMER-Nantes, public-private and CNEP.

The French scientists noted that they had achieved significant advances in the understanding of the biodegradation and toxicity of oxo-biodegradable plastics in the marine environment. In particular they confirmed that “accelerated artificial aging (UV, temperature) which was perfectly mastered in this project, is a tool of choice which is particularly well suited to the study of the fate of OXO-bios in the marine environment. Accelerated artificial ageing does not invalidate the results.”

The degradation of OXO-PE has been studied in terrestrial environments, including soils, landfills and mature composts as well as under laboratory settings using bacterial and fungal isolates (Rojas and Green, 2007; Ojeda et al., 2009; Fontanella et al., 2010; Corti et al., 2010; Yashchuk et al., 2012; Da Luz et al., 2013; Gomes et al., 2014; Portillo et al., 2016; European Commission, 2016; Greene, 2018). These reports revealed either faster or similar levels of degradation of naturally weathered OXO-PE compared with aged or fresh PE, and that strains like Rhodococcus rhodochrous and Pseudomonas aeruginosa could naturally degrade OXO-PE. Faster degradation would be expected.

In contrast, very little is known on the degradability of OXO-PE in the marine environment. See the Oxomar study above, and the work at Queen Mary University, London https://www.biodeg.org/queen-mary-university-london-report/

Moreover, there is a lack of information on the fate of OXO-PE when sunken into deeper waters, where factors vital to initiate OXO-PE degradation viz. light, heat and oxygen are limiting. Oxygen is ubiquitous, and most of the plastic litter is found lying or floating around with free access to oxygen in the air and on the sea. Most of the polymers in which oxo-biodegradable technology is used have a specific gravity less than 1, so they will float on the surface where sufficient oxygen, sunlight, and bacteria are available.

The degradation of OXO-PE in the marine environment depends not only on abiotic parameters (e.g. depth, light intensity/availability, temperature, pressure, current flow) but also on the fouling communities that colonize its surface. Fouling will limit the access of oxygen and light, and this is one reason why ordinary plastics take so long to complete abiotic degradation in the open environment. In the case of oxo-biodegradable plastic, the necessary exposure to light and oxygen will have occurred before any significant fouling has developed.

Simultaneous enzymatic activities of the fouling microbes result in the adsorption of the functional groups from the plastic and the eventual production of CO2 was reported to be an evidence of the plastic-derived carbon being mineralized based on laboratory experiments. This is what would be expected.

Little is known on what types of microorganisms can colonize OXO-PE when submerged in the sea, and whether these microbes could possibly play a role in plastic biodegradation. See the Oxomar and Queen Mary University studies above.

This study aims at: 1) comparing the degradability of OXO-PE, PE and polyethylene terephthalate (PET) in the planktonic (2 m) and benthic (6 m) zones of the Arabian Gulf, Oman over a period of 80 days. A period of 80 days will show abiotic degradation, but is too short for full abiotic and biotic degradation.

OXO-PE, PE and PET were used to compare their degradation and the types of microorganisms that colonize their surfaces after immersion in seawater for 80 days at Marina Shangri La, Oman - an enclosed bay area with a maximum depth of 6.5 m and negligible tidal effects. As the test specimens were submerged, the test would not be a realistic representation of what is likely to happen in practice. See www.biodeg.org/wp-content/uploads/2019/04/BPA-Comments-on-Plymouth-10.pdf

The SEM, DSC and FTIR analyses demonstrated increased signs of physical and chemical degradation of OXO-PE over time, regardless of the habitat. This is what would be expected.

OXO-PE and PE bags were obtained from a local supermarket in Muscat, Oman. If the polymer material was not characterised before the test began, it is impossible to know whether the OXO bag was correctly made with a suitable masterbatch in accordance with the instructions provided by the manufacturer of the masterbatch. This would render the study essentially worthless.

D2w MULCH FILMS – RESEARCH FROM BANGOR UNIVERSITY

By Michael Stephen,
Chairman of the BPA and a Director of Symphony Environmental

I am often asked to comment on papers purporting to show that oxo-biodegradable technology does not work, or creates microplastics. These papers look impressive, and have many citations, but Symphony's scientists always find fundamental errors. We have now seen another one.

This one is from Bangor University, called "Size-dependent effects of oxo-degradable plastic contamination on soil quality and the growth of Zea mays. Front. Agr. Sci. Eng., 2026, 13(1): 25623 https://doi.org/10.15302/J-FASE-2025623" It purports to show that d2w biodegradable plastic (which they incorrectly call oxo-degradable plastic) is not suitable for agricultural mulch film. It shows nothing of the kind.

The problem is that faulty research is often cited in literature-reviews and leads policymakers to make the wrong decisions.

We often find that researchers do not understand that d2w biodegradable plastic is not designed to start biodegrading immediately. It has a predetermined service-life during which it can be re-used and recycled, and only after a period of abiotic degradation will it become biodegradable.

We also find that researchers (a) have not followed any Standard test method (b) have followed the wrong standard eg ASTM D6400 or EN13432 (c) have no idea whether the test sample contains a masterbatch formulated for the particular application, and included at the correct concentration or at all (d) did not continue important parts of the test for a sufficient length of time (e) used a sample so stabilised that it would take a very long time before the material became biodegradable (f) exposed the plastic under conditions unlikely to be experienced by the product in the use for which it is designed.

This paper from Bangor has fallen into most of these errors.

I thought it rather odd that they should be claiming that d2w biodegradable plastic is not suitable for agricultural mulch film, because this type of plastic has been successfully used for that purpose for more than 40 years.

The authors are correct that "accumulation of plastic residues in agricultural soils has become a major environmental concern and is now ranked as one of the world's top ten environmental threats due to the impact on soil health, water quality and biodiversity." That is the reason why d2w biodegradable mulch films were invented.

At page 47 of "Degradable Polymers, Principles and Applications" (1995 - ISBN 1-4020-0790-6) Professor Gerald Scott says "The products formed by biodegradation are of benefit to the agricultural environment as biomass, and ultimately in the form of humus. Carbon is retained in the soil during biodegradation in a form accessible to growing plants, rather than by being emitted to the environment as carbon dioxide, as is the case with hydro-biodegradable polymers (e.g. pure cellulose, and starch "compostable" films) ….. Time control of biodegradation of the synthetic carbon-chain polymers is achieved by antioxidants." See also "Polymers and the Environment" (1999 - ISBN 10: 0-85404-578-3) pages 109-118 and www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf

With regard to the paper from Bangor University:

(c) and (e) Mulch films are usually thin (5 – 15 microns). In view of the thickness of the sample used (31.3 microns) it was probably from a garbage sack, which in addition to being thicker, would have been formulated to degrade over a much longer period than a mulching film. It also contained a black pigment which would hinder the effect of uv light. The remainder of this paper has therefore no relevance to a properly formulated d2w mulching film. There are other reasons as well:

(d) and (f) a d2w biodegradable mulch film is intended to lie on the surface of the field, exposed to sunlight, oxygen and heat for several months while the crop is growing. The film is formulated to degrade according to the timescale for the particular crop in the particular climatic conditions, by carefully balancing the active ingredients and stabilisers in the film formulation.

While the film is lying on the fields, a process of oxidation occurs, and by the time that the crop is harvested the molecular structure of the film has changed and it has become biodegradable. It no longer has any need for sunlight or oxygen, and can be ploughed into the soil, where it will be a nutrient for bacteria living there, and a source of carbon for next year's plants. It will not accumulate as macroplastics or microplastics in the soil.

The farmer has therefore no need to drag hundreds of square metres of plastic off the fields and dispose of it. If ordinary plastic had been used, much of it would have fragmented under the influence of sunlight and/or heat, and microplastics would have been scattered on the field by the wind and/or by the process of removal.

The authors found that "oxidative degradation of the polymer had not progressed sufficiently to form ketones, aldehydes or carboxylic acids, and they say "This is likely attributed to the lack of prior UV exposure, as UV irradiance is key to the oxidation process of ODPs, and its absence or limited exposure would significantly reduce the rate of oxidation." – Correct, so why design a study which omits this crucial step?

The authors say "Our experimental design, while potentially underestimating the degradability of ODPs exposed on the soil surface, was designed to determine their ecological impacts where UV exposure can be limited (e.g., under the plant canopy) or absent (i.e., buried in the soil)."

However, a d2w mulch film will typically be laid on the fields before there is any "plant canopy" and it will be weeks or months before a canopy has developed which would significantly affect the access of uv light, during which time the film would have had sufficient exposure to uv light and/or heat for abiotic degradation to commence. Once commenced it is unstoppable.

In fact their experimental design seriously underestimated the degradability of films exposed on the soil surface, and seems to have been designed so that the study would fail. They simply took a thick piece of "black-coloured d2w biodegradable plastic," milled it into small pieces and mixed them up with soil with very limited exposure to oxygen and uv light. They then waited for six weeks to see whether they could observe any degradation, and as would be expected they found very little.

CONCLUSION

For all the reasons mentioned above this study cannot be relied on by anyone wishing to know how a d2w mulch film would perform on the fields. The detailed analysis in this paper of the effect of macroplastics and microplastic on the soil and plants is therefore essentially about the effect of non-degradable conventional plastics, not d2w biodegradable plastics. If the authors had consulted Symphony when designing the study the results of all this work might have been useful.

One of the authors, Davey Jones, is reported as saying: "Oxo-degradable plastic should not be used in 'eco-friendly' product lines unless it can be guaranteed that the products can be collected and reprocessed." This statement is not supported by the research, and it shows a misunderstanding of the purpose of this type of plastic.   This technology is not necessary if the products are collected and reprocessed – its purpose is to ensure that products which do NOT get collected will not create microplastics and will not lie or float around in the environment for decades.

Symphony environmental technologies

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Dear Secretary of State,

OXO BIODEGRADABLE PLASTICS

We are a British SME, and are grateful for the understanding and support of The Rt. Hon. Oliver Dowden MP. We are listed on the London Stock Exchange and have been awarded their Green Economy Mark in recognition of our global contribution to the protection of the environment. We are at a critical time in our effort to expand our UK workforce as we drive our exports and foreign currency earnings materially higher.

We are committed to improving plastics so that they can protect people and their food from contamination, and so that if they escape into the open environment they will degrade and biodegrade much more quickly than ordinary plastic.

We have seen the letter addressed to you on 1st June by the BBIA, and we wish to respond as follows. Our response is in square brackets following each BBIA statement.

We the undersigned associations call upon the Government to implement a total ban on the use, sale and distribution in the UK of conventional non-biodegradable plastics containing additives, which are meant to accelerate the fragmentation of plastics into microplastics. Such plastics are variously known as "oxo degradable", "oxo biodegradable" "oxo fragmentable" "bio-assimilable" but the definitions are not exhaustive.[1]

[The definitions are to be found in CEN TR15351. The BBIA has the word British in its name but it is the UK trade association for the bio-based plastics industry, which comprises predominantly German and Italian companies, and it is important to ask why they have assembled this consortium against

[1] *We refer to any plastics to which additives are put in the master batches which disintegrate plastics into fragments and microplastics and which are not certified as "biodegradable" under the standards recognised within UK law such as BSI 13432, BSI 14995, BSI 17033.* [The Danish Maritime and Commercial Court has ruled on 11th November 2019 that it is deceptive to describe plastic tested to these standards as biodegradable, because they are not biodegradable except in the special conditions found in an industrial composting facility. Oxo-biodegradable plastics are certified according to ASTM D6954].

oxo-biodegradable plastic. This needs to be understood as part of a concerted lobbying and PR campaign over nearly 20 years by the bio-based plastics industry, upon which they must by now have spent millions of Euros.

They are obviously not spending this money and making all this effort to protect the environment – they are doing it because they (mistakenly) see oxo-biodegradable plastic as a threat to their market share. Their actions are fundamentally anti-competitive, and are designed to stifle a competing technology. Worse still - if they succeed they will have deprived policymakers of a technology which could be used to deal with plastic which has escaped into the open environment, from which it cannot be collected for recycling, composting, or anything else.]

The UK voted for the European Single Use Plastics Directive (Directive 2019/904 https://eurlex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0904&from=EN) which includes the clause at Article 5 that "Member States shall prohibit the placing on the market of the single-use plastic products listed in Part B of the Annex and of products made from oxo-degradable plastic."

[There is a procedure, set out in the REACH Regulation, designed to prevent arbitrary and commercially or politically motivated action, which must be complied with before any substance can be banned in the EU. Article 5 is the result of lobbying in Brussels by the German and Italian bio-based plastic companies, which has led the EU to ignore its own rules and to deprive citizens of their right to conduct a lawful business without due process.

The Commission commenced this procedure by asking the European Chemicals Agency [ECHA] to investigate on the basis that oxo-biodegradable plastic (which they called oxo-degradable plastic) creates microplastics. Ten months into the study ECHA declared that they were not convinced that microplastics are formed. Thereupon the Commission terminated the ECHA enquiry and the Parliament and Council imposed a ban without any scientific dossier from ECHA. They thereby deprived the oxo-biodegradable industry of all the safeguards against arbitrary conduct which REACH provides, including a review by two committees and a public consultation. This is the European Union at its worst, and what they have done is unconstitutional.]

Whilst the UK has left the EU we have retained the ambition to achieve at least the equivalent of European environmental norms. **[but we no longer have to implement arbitrary laws enacted in breach of the EU's fundamental norms, and without any justification from their own scientific experts]**

At the same time, were the UK to allow these plastics, anything containing them or packaged in them could not be exported to EU markets. **[Correct, unless the Directive is declared invalid by the EU courts before it comes into force in 2021, as it could well be, but that is no reason for banning them in the UK. By contrast no plastics, or anything containing them or packaged in them could be exported to countries in the Middle-East and Asia where oxo-biodegradable plastic is mandatory]**

The ban on the use of oxo additives regards not just the EU. The USA also has effectively stopped the sale of such additives by adjudging that the use of marketing terms such as biodegradable for plastics using these additives is considered misleading. **[This is not correct. California restricts the use of the**

term "biodegradable" in advertising, but oxo-biodegradable plastics are not banned in California or any other State, and are widely used in the USA].

Companies have been fined for using such terms and as a result these additives are not used in the USA.[2] **[The case cited was decided by an unofficial body called the National Business Bureau, which has no power to impose fines, and conducted no in-depth examination of oxo-biodegradable technology. It made recommendations about the words that advertisers should use, but it is not correct to say that a result of these recommendations these additives are not used in the USA. They are used in the USA, and for example The New York Times continues to wrap its newspapers in d2w oxo-biodegradable plastic].**

Why should this ban be implemented now? As the UK is now in the process of revising legislation on the use of plastic packaging, now is the time to act. [**Now is the time to declare that the SUP Directive will not be implemented insofar as it relates to oxo-biodegradable plastic].**

Overwhelming scientific evidence, including research commissioned by DEFRA[3] *and the EU, has demonstrated beyond doubt that claims that prodegradant additives transform polyolefin plastics into biodegradable plastics are unfounded*. **[This is not correct. It is well understood that prodegradant additives do accelerate the reduction of molecular-weight so as to transform polyolefin plastics into biodegradable plastics. Today the disagreement is only about rate and extent, though nobody doubts that oxo-biodegradable plastic will become biodegradable much more quickly than ordinary plastic in the open environment with access to oxygen. There is therefore no "overwhelming evidence" that these claims are unfounded].**

An independent review of the scientific evidence conducted by Peter Susman QC in 2019[4] at the request of Symphony Environmental concluded that:

- **oxo-biodegradable technology does facilitate the ultimate biodegradation of plastics in air or seawater by bacteria, fungi or algae, within a reasonable time, so as to cause the plastic to cease to exist as such, far sooner than ordinary plastics, without causing any toxicity; and**

- **the benefit is obvious of reducing future contributions to the scourge of plastic pollution of land and sea"**

See also the paper published subsequently by Queen Mary University London[5]]

It is scientifically well-known that all polyolefin plastics are naturally prone to oxidation under environmental conditions (aging). Such oxidation ultimately leads to fragmentation and formation of microplastics, which build up in oceans and in soil. **[Correct – and this is why oxo-biodegradable**

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[2] https://www.khlaw.com/2313
[3] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=16263
[4] https://www.biodeg.org/uk-judge-find-the-case-for-oxo-biodegradable-plastic-proven/
[5] https://www.biodeg.org/wp-content/uploads/2020/02/published-report-11.2.20.pdf

technology was invented, and why it is no longer acceptable to continue to use ordinary plastic for everyday plastic products.]

The "oxo-additives" are designed to accelerate the natural oxidation of polyolefins, causing an early fragmentation and the fragmentation of plastic products into microplastics. Thus the effect of these additives (if any) is merely to accelerate the conversion of macroplastics into microplastics, not solving the global problem of plastic pollution but worsening it. **[This misses the fundamental point about oxo-biodegradable plastics – explained by Professor Ignacy Jakubowicz[6] as follows in his reply to the Ellen MacArthur Foundation:**

"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."]

Even the claimed disintegration effectiveness is questionable, under some environmental conditions. Experiments undertaken by the University of Plymouth[7] in 2019 showed that plastic films claiming to be "degradable" due to the oxo additives in them, remained intact in the sea and in soil after 3 years. **[They exposed the bags in the open air in Plymouth, and found that Symphony's product lost strength at a significantly faster rate than the other bags - between 0−9 months (p = < 0.01).**

Indeed they found that this product had the greatest loss in tensile-strength over 27 months for all environments in which bags were tested. Conventional plastic had the least reduction in tensile strength. They also tested the bags in conditions in which a slower rate of degradation would be expected[8]]

The UK Advertising Standards Authority in 2019 also found that the use of the term "biodegradable" for dog poop bags made from oxo plastics were misleading as after 2 years these bags were still undegraded.[9] Nevertheless, they are still sold in the UK. **[The ASA did not say that after two years the bags were still undegraded. Nor did they rule that the bags would not biodegrade significantly faster than a conventional plastic bag in the open environment. They initially ruled that consumers would expect them to degrade in the open environment, but then changed their mind and said that consumers would expect them to degrade in a landfill. They are not however advertised as degradable in landfill (although they will do so where oxygen is present).]**

Moreover, such plastics are not recyclable as the powders contained in them assist degradation and therefore render instable plastic polymers when recycled together. **[This is not correct.[10] We have supplied 200,000 tons of oxo-biodegradable plastic in more than 90 countries and a high percentage is being recycled, with no difficulties encountered. However, the type of plastic promoted by the**

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6 fhttp://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf
7 https://www.plymouth.ac.uk/news/biodegradable-bags-can-hold-a-full-load-of-shopping-three-years-afterbeing-discarded-in-the-environment
8 https://www.biodeg.org/wp-content/uploads/2019/11/opa-comments-on-plymouth-10.pdf
9 https://www.asa.org.uk/rulings/ancol-pet-products-ltd.html
10 https://www.biodeg.org/recycling-and-waste/

BBIA will certainly compromise a normal recycling scheme, but they are not calling for it to be banned.]

These plastics are also not compostable and lead to confusion among consumers and retailers who consider them to be biodegradable as if they were compostable. **[They are not marketed as compostable, and even if a plastic is not compostable that is no reason to ban it. Almost all plastics in use today are not compostable.**

Confusion is actually caused by the BBIA and others continuing to use the misleading term "oxo-degradable" and by marketing plastic as compostable when it does not in fact convert into compost. This is because EN13432 requires it to convert into CO_2 gas within 180 days. Also, the German courts in Güthoff v Deutsche Umwelthilfe (2014) have held that it is deceptive to market plastic as "compostable" because it is seldom actually composted.[11] It is also confusing to call them biodegradable when the Danish courts (see footnote 1 above) have held that it is deceptive to call them biodegradable, because they are tested according to EN13432 to biodegrade in the special conditions found in an industrial composting unit.]

A very wide coalition of signatories including some of those signing here, led by the Ellen Macarthur Foundation, called for a ban as long ago as 2017 that was reiterated in 2018[12]. That is attached. We wish to remind you of the call from the Foundation and reiterate it ourselves here. **[The BBIA do not however mention that the Ellen MacArthur Foundation claimed in its 2017 report that oxo-biodegradable plastics simply created microplastics, but after meeting with Symphony Environmental they withdrew that claim and accepted in their 2019 report that they can degrade faster than ordinary plastics and are biodegradable. It is also notable that many of the signatories are bio-based plastics companies from whom EMF has received funding, or lobby organisations (eg BBIA, European Bioplastics, Australasian Bioplastics, and BPI) working on their behalf. Among the others are multinational companies whose products bearing their brand names are found littering the oceans and beaches all over the world, and who need to stop using ordinary plastic.]**

Whilst we in the UK are ourselves introducing national bans on single use plastics **[This needs to be reconsidered, because COVID-19 has shown that single-use plastic is vital for protecting people and their food from microbial contamination. Instead of being banned, single-use plastic should be made with anti-microbial technology[13]and should also be made oxo-biodegradable in case it escapes into the open environment.]**

Now is the time to also ban the scourge of plastic fragments deriving from oxo additives. We hope you will act quickly to implement this ban in the UK without further delay and respect the undertaking the UK voted for when this issue was raised in the EU. **[BBIA have admitted above that the plastic fragments found in the environment are coming from conventional plastics and that they build up over many years in oceans and in soil.**

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[11] See also https://www.biodeg.org/oregon-composters-dont-want-compostable-packaging/

[12] https://www.newplasticseconomy.org/about/publications/oxo-statement

[13] See www.d2p.net

Therefore, for that reason, and the reasons given in our responses above, the UK should ban the use of ordinary plastic for everyday plastic products, and legislate to upgrade ordinary plastic with oxo-bio technology, thereby retaining the benefits of plastic in terms of hygiene but minimising the environmental damage caused when ordinary plastics escape into the open environment. Other countries around the world[14] have already taken this progressive approach to managing the balance between the safety of their population and the protection of their environment.

For the reasons given above, the UK should never have voted for Article 5 or Recital 15 of the SUP Directive, and should refuse to introduce them into UK law].

Yours sincerely,

MICHAEL LAURIER
CEO

cc Rt. Hon. Oliver Dowden MP

[14] eg: The UAE, Saudi Arabia, Bahrain, Jordan.

COMMENT ON BRASSIOULIS et al.

Environ Sci Pollut Res (2015) 22:2584–2598

At first sight we thought there must be something wrong with either the material tested, or the experiment itself. Having read the paper the problem seems to have been with both.

Nevertheless, the reason for using biodegradable mulch film is well stated on page 2584/5 of the paper as follows:

"The main reason for the trend of increasing use of biodegradable agricultural plastics is the growing problem of management and disposal of large amounts of agricultural plastic waste. The mismanagement of the agricultural plastic waste represents a serious environmental problem."

"Polyethylene (PE)-based mulching films do not break down in soil and should never be rototilled and incorporated into the soil following the end of their useful lifetime. However, the process of recovering and recycling them, following the end of the cultivation period, is difficult, or impossible, as a large percentage of the weight of the recovered mulching film waste is foreign materials (e.g. 80 % soil, sand, etc.). Also, the cost of removing from the soil and cleaning this material is prohibitively high."

"This is the main reason why the farmers usually incorporate them into the soil by rototilling, or sometimes, they burn them in the fields, practices which, apart from being illegal, also imply a serious risk for the environment and the public health due to the accumulated PE in the soil or the toxic emissions. Thus, specifically for the case of agricultural plastic wastes that cannot be easily collected and recycled (e.g. mulching films), a very attractive alternative is the use of biodegradable materials."

In addition, as the mulch film will have been exposed to sunlight for many months in the fields it will have become brittle and unsuitable for recycling, and fragments will scatter in the wind while the film is being removed. Even if the film were still suitable for recycling, it is expensive to transport it along country lanes in large vehicles causing congestion, and to wash and reprocess the plastic - so recycling of mulch film makes little sense in economic or environmental terms.

Long before this paper was published many distinguished scientists had researched and written in peer-reviewed publications on the biodegradation of polyethylene mulching films, and the technology was well understood. Brassioulis et al say "The behaviour of polyolefins containing pro-oxidants during photo-oxidation is explained in Arkatkar et al.

(2009) by means of the cleavage occurring predominantly at the weak links of the polymers which have lower bond energies (e.g. C–H and C–O) and the subsequent formation of free radicals. The free radicals can react further with atmospheric oxygen and trigger the oxidation of the polymer that continues in a stepwise fashion producing carbonyls, aldehydes, peracids and acids (Arkatkar et al. 2009)."

At page 47 of "Degradable Polymers, Principles and Applications" (ISBN 1-4020-0790-6) Professor Gerald Scott says "The degradation products formed by oxo-biodegradation are of benefit to the agricultural environment as biomass and ultimately in the form of humus. Carbon is retained in the soil during oxo-biodegradation in a form accessible to growing plants, rather than by being eliminated to the environment as carbon dioxide, as is the case with hydro-biodegradable polymers (e.g. pure cellulose and starch)..... Time control of biodegradation of the synthetic carbon-chain polymers is achieved by antioxidants that behave similarly to naturally occurring antioxidants present in lignin and tannin."

See also "Polymers and the Environment" (ISBN 9780854045785) pages 109-118 and 461-466.

We know from our own experience, including the field trials in Wales, https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf that biodegradable mulch film has to be designed with regard to the timescale for growing the crop, and the weather-conditions likely to be experienced on the farm. Oxo-biodegradable mulch film can be programmed accordingly (by adjusting the composition of the masterbatch) but this cannot be done with bio-based plastic such as PLA.

If a farmer simply buys an "off the shelf" plastic mulch film, it is quite likely that it will not properly degrade and biodegrade in the timescale required for the particular crop in that part of the world, and this is what seems to have happened with the mulch film studied by Brassioulis et al.

THE MATERIAL

On page 2585 the authors correctly say "Environmental degradability of plastics is a multifaceted complex process strongly influenced by the nature of the plastics, as well as biotic and abiotic conditions to which they are exposed.

At p.2587 they describe the composition of the test films, from which it becomes apparent why the films lasted so long. They contain carbon-black, which is a powerful stabiliser, and this has been added at 16%, which is a very high concentration. Also, they contain 3,000 ppm of Tinuvin 783, which contains a combination of stabilisers, and they have added even more of it (4,000ppm) in LLDPE-P2. In addition to these stabilisers they have included Envirocare® AG1000 which also contains stabilisers.

Stabilizers are intended to protect plastics from the effect of weathering, so as to give them a useful service-life, but in the case of oxo-biodegradable film it is crucial to get the balance right between the prodegradant catalyst and the stabilisers. The films used for these tests had been seriously over-stabilised, and it is not surprising that figs 1, 2 and 3 show that the material had hardly degraded at all.

If it is intended to use carbon-black as a pigment in mulching film, the polymer and/or the masterbatch would have to be adjusted accordingly, to avoid over-stabilisation.

THE EXPERIMENT

We have the following comments:

In the Introduction, the authors say: "……Biodegradable polymers, disposed in bioactive environments, degrade by the enzymatic action of microorganisms, such as bacteria, fungi and algae, and their polymer chains may also be broken down by non-enzymatic processes such as chemical hydrolysis……".

However, in the case of polyethylene films, the molecular-weight of polyethylene is too high for biodegradation. It must first be reduced by oxidation, and that is the purpose of the pro-degradant masterbatch.

They say that "In order to allow a controlled and repeatable method of assessing the degradability, a number of standards have been developed that define the testing of degradability under closely monitored conditions mimicking the conditions of application. They refer to ISO 14855 "Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions" but the relevant standards, which they do not mention, are BS8472 and ASTM D6954 for "Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation." One of the authors of D6954 is Dr. Graham Swift, who explained the Standard in evidence to the UK government at www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

In the Introduction to the Brassioulis paper the authors also say: "…..Furthermore, all parameters involved in the natural complex phenomenon of biodegradation, including the diversity and efficiency of microbial communities, cannot be entirely reproduced and controlled in vitro….". Yes, but the biodegradation process can be properly measured and assessed only in lab conditions, not in outdoor conditions, and this is the reason why the standards organizations have developed standard test methods such as ASTM D6954 and BS8472.

It is recognized by the standards organizations that the biodegradation of polymers, assessed in lab conditions, represents a worst-case scenario, when compared to natural, outdoor, environmental conditions. In natural conditions, there is a synergy between the microbial activity and the degradation process and there is more than one species of micro-organism.

The authors say "…..The accumulative effects of PE fragments and the impact on the environment of the repeated use of these PE films remain a serious open issue…..". This is certainly the case with ordinary PE, and farmers should not be allowed to use it, but in the case of oxo-biodegradable plastics ASTM D6954 is specifically dealing with this issue in NOTE 1—The intended use of this guide is for comparison and ranking of data to aid in the design and development and the reduction of environmental impacts of polymers that require no more than 24 months to oxidize and biodegrade in the intended use and disposal options, and create no harmful or persistent residues under the appropriate disposal conditions (for example, two seasons of crop-growing conditions in soil)…..". So, if a mulch film is properly designed, and successfully tested according to D6954 the material will biodegrade in a maximum of 24 months and will not only avoid plastic accumulation and pollution, but will provide a source of carbon for the plants.

The Brassioulis paper does not show that the molecular weight of the degraded polymer was ascertained before the material was buried and does not therefore show that Mw had reduced below 5000 Daltons. The paper says the film was tested for Tensile Elongation, but ASTM D3826, (listed in ASTM D6954 as a PASS/FAIL condition for Tier 1) requires a minimum 95% loss of mechanical properties (Elongation at Break) for 75% of the specimens tested.

The paper says: "……The majority of these films come from the lower layer of the beds (lower film 2), and some others come from the remains of the upper layer (upper film 1)…." It is notable therefore that the lower layer of film was not exposed to direct sunlight, as it had another layer of film above, and if this is added to the fact that the films were grossly over-stabilised it is not surprising that it did not abiotically degrade as it should. Significant *bio*degradation does not occur until the molecular weight has reduced to 5,000 Daltons or thereabouts.

The way the film was gathered, folded, agglomerated, and then buried does not represent a mulch film application on a farm. The plastic film, in order to abiotically degrade and then biodegrade requires a dispersion of the material in and on the soil - which would occur on a farm. The film would not be buried as an agglomerated/multi-folded plastic mass.

On page 2590 "the losses of Tensile Strength and Elongation are relatively low, compared to the timescale for burial." This is due to over-stabilisation, and also to the fact that the film was buried multi-folded and very probably with limited oxygen due to the folding.

Not only is carbon black a powerful stabiliser, but the authors note that "it is difficult to obtain a usable FTIR transmission spectral scan from materials with large quantities of carbon (i.e. carbon black in this case) because carbon strongly absorbs infrared light in a broad range of frequencies."

On page 2592, "the melting temperature Tm and the crystallisation temperature Tc show only minor changes during their exposure under cultivation conditions. The same is indicated after soil burial for a very long period (8.5 years). .....” The reason for this is, as mentioned above, over stabilisation and the manner of burial.

“.....Similarly, Dannenberg et al. (1958) studied the peroxide free radical crosslinking reaction in polyethylene/carbon black systems and found that the crosslinking of polyethylene resulted in a decrease in density from which a subsequent decrease in percent crystallinity can be established. Furthermore, Feuilloley et al. (2005) claimed that due to the crosslinking of PE, the large PE fragments that are found in this state cannot be bioassimilated by soil bacteria, and large cumulative effects in soil cannot be ruled out.....” Yes, this is why film should be tested in the laboratory according to ASTM D6954 before being sold to farmers, as any member of the BPA would do. Para. 4.5.1 of this Standard says “It is important to establish the extent of gel and its nature or permanence in the polymer residue and report these findings.” See also paras. 6.3.1-6.3.3.

“......The CI change during the cultivation period is in agreement with the corresponding crystallinity results from the DSC analysis (Fig. 9), and it means that the upper film degraded more than the lower one.” Yes, because abiotic degradation is accelerated by uv light, from which the lower film was to a significant extent shielded.

“......According to Kalus (2007), as mulching film is often exposed to water under real cultivation conditions, the humidity can permeate easily the amorphous regions of the film and deactivate free radicals. Consequently, the formation of low molecular by-products such as carboxylic acids cannot proceed....” Yes, it is possible that rain can interfere with the carbonyl-based chemicals formation, but this process is dynamic and once the rain has stopped, the UV and ambient heat will restart the abiotic degradation process. If the masterbatch is correctly designed and dispersed in the polymer, rain will not therefore prevent abiotic degradation.

“....These earlier published research results explain the fact that the carbonyl index is zeroed after the long period of soil burial of the films in the field (Figs. 10 and 11).....” However, Jakubowicz et al (Polymer Degradation and Stability 96 (2011) 919-928) found that after two years of mineralization, 91% conversion to carbon dioxide was obtained in the soil test.

“After the long soil burial period of 8.5 years, and despite the further degradation of the mechanical properties of the films, no disintegration signs were observed. The buried films were recovered almost intact.” Yes, due to gross over-stabilisation and burial in an artificial manner which would not occur in use of the film on a farm.

Biodegradable Plastics Association

BPA Comment on the EUNOMIA REPORT

This report (Aug 2016) was commissioned by the EU from Eunomia Consultants to examine the impact of the use of Oxo-biodegradable (OBP) plastic carrier bags on the environment. The Report refers throughout to OBP as PAC (Pro-oxidant Additive Containing) plastic.

This report does not recommend a ban of oxo-biodegradable plastics.

The report was completed in August 2016 and the science has moved on since then. See e.g. https://www.symphonyenvironmental.com/resource/uk-judge-finds-the-case-for-oxo-biodegradable-plastic-proven/ and https://www.symphonyenvironmental.com/resource/queen-mary-university-london-publishes-positive-study-on-biodegradable-plastic/

The Eunomia Report introduces the subject as follows:

"The high molecular weight and hydrophobic nature of conventional plastic lends the material high resistance to biological attack. However, for situations where biodegradation is a desirable attribute, the second half of the 20th century saw attempts to develop the first plastics deliberately engineered to age upon the application of heat and light.

Within the current century, the focus has shifted to materials marketed as "oxo-degradable" or "oxo-biodegradable" plastics. These are plastics which contain additives intended to initiate degradation as well as stabilisers (anti-oxidants) intended to delay this effect until it is desired to occur if, and when, an item is discarded in the natural environment. These plastics are intended to go through both abiotic degradation (for instance embrittlement and mechanical damage) and biotic degradation processes (i.e. biodegradation), accelerated by light and/or heat, until they are, ultimately, fully bio-assimilated.

The debate around the biodegradability of PAC plastic is not finalised, but should move forward from the assertion that PAC plastics merely fragment, towards confirming whether the timeframes observed for total biodegradation are acceptable from an environmental point of view and whether this is likely to take place in natural environments."

There is no longer any justification for referring to OBP as "oxo-degradable" or "oxo-fragmentable." Oxo-biodegradation is defined by CEN/TR 15351:2006[1] as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."

1: E.2.0

Landfill

OBP is not designed to biodegrade in landfill. As the Report confirms, "aerobic degradation produces CO_2 whereas anaerobic degradation produces methane—a greenhouse gas 25 times more harmful (on a 100 years' time horizon) than CO_2." Plastics which contain a proportion of vegetable-sourced material suffer from this disadvantage. We will refer to these plastics as hydro-biodegradable plastics ("HDP") - (also loosely known as "bio-based plastics" or "bioplastics" or "compostable plastics"). OBP do not suffer from this major disadvantage.

The Report concludes "Whilst PAC plastic may biodegrade in the upper levels of a landfill in aerobic conditions and therefore produce CO_2, it has already been demonstrated that this happens at a very slow rate, and only if abiotic degradation has already occurred. The limited evidence that is available suggests that deeper in landfill under anaerobic conditions there will be little or no biodegradation taking place. In this case, the carbon is effectively sequestered, avoiding the direct release of GHGs to the atmosphere."

Composting

OBP is not designed for composting, and it is surprising that the authors of the Report have taken so much time to consider it. By contrast, HDP is marketed as "compostable" but the relevant standard (EN13432 or ASTM D6400) requires it to convert rapidly not into compost but into CO_2 gas, which contributes to climate-change but does nothing for the soil. This process cannot therefore be described as "packaging recoverable through composting" or "organic recycling."

The main purpose of HDP is to make bags which carry compostable material to an industrial composting plant and which do not have to be emptied there. OBP has in fact been trialled for this purpose in the UK and was found satisfactory by industrial composters, but it does not produce CO_2 gas quickly enough to pass EN13432, (which makes no allowance for the period of useful life during which OBP is designed NOT to degrade). The carbon therefore remains as a nutrient for the soil until it is returned to nature by the action of micro-organisms.

EN13432 is a standard written by the HDP industry representatives on CEN for their particular technology, and is not relevant to OBP (except that OBP meets the same non-toxicity requirements).

In fact the desirability of this standard must be questioned in an age where great efforts are being made to reduce CO_2 emissions. HDP is also sometimes used for packaging, in the mistaken belief that it is better to make plastic from crops instead of oil – See "Fossil Resources" below.

Recycling

The Report says "The evidence available does not support the suggestion that PAC plastic can be identified and sorted separately by reprocessors with the technology that is currently available. Furthermore, manual sorting would be time-consuming and is unlikely to be economically viable."

This is a problem with all types of plastic film, and is one reason why post-household plastic film is generally not recycled. Other reasons are that the material is often contaminated and it would not be cost-effective to clean it, given that the material from which it is made is inexpensive and readily available. It is also too costly in financial and environmental terms to collect it, transport it, sort it, bail it, store it, and reprocess it, so – as the report confirms – this is generally not done in Europe but it is exported as mixed plastic for low grade uses (not for long life uses such as building films or pipes). The separation of OBP film is therefore a non-issue, but a marker could easily be included if separation were desired.

OBP has however been designed to be recyclable during its useful life, and scientific tests have proved that it can be safely recycled together with conventional plastic, so that separation is not necessary. See http://www.biodeg.org/recycling.html

The Report continues "Evidence suggests that the impacts of prodegradant additives on recyclates can under certain circumstances be avoided with the inclusion of stabilisers. The appropriate quantity and chemistry of stabiliser would depend on the concentration and nature of the prodegradants in the feedstock." However, the report misunderstands the role of stabilisers. It is clear from the scientific reports that it is not necessary to add stabilisers unless the recyclate is being used to make long-life products exposed to sunlight, in which case the manufacturer would be adding stabilisers anyway. These stabilisers are in a quantity and with a chemistry which he would normally use, and no special arrangements are necessary for recyclate containing OBP.

"Evidence suggests that oxidised PAC plastic can significantly impair the physical qualities and service life of the recycled product." However, if an OBP carrier bag is going to be collected for recycling at all it is likely to be collected during its useful life (typically 18 months). If collected later and the plastic had oxidised it would be falling apart and would not be used for recycling. Oxidised OBP would in any event have to form a substantial proportion of the feedstock to have any effect at all.

"Recyclate made from mixtures containing unknown PAC plastic should not be used for long-life products, due to the lack of evidence surrounding the long-term impact in secondary products." There is no lack of evidence. The TCKT report dated 27th July 2016 considered this very issue, and concluded that "provided a UV-stabiliser has been included (which as demonstrated should always be the case with plastic products intended for outdoor use) there will be no negative effects from the inclusion of oxo-biodegradable recyclate. These studies also demonstrate that even without UV stabiliser the presence of oxo-biodegradable recyclates has no effect within the body of the plastic, where oxygen is not available." (The authors of the Report have read the 17th March 2016 TCKT report, but have not cited the 27th July 2016 report)

The position of the OBP industry is based on scientific reports by specialist researchers.

The Report is concerned with plastic film used to make carrier bags, not with PET bottles, for which OBP is not sold.

Anyone who wants to promote recycling should certainly be concerned about HDP, because it cannot be recycled together with oil-based plastic waste, and separation would be required. Some of it will get into the plastic waste recycling stream but we are not aware of any proposal to restrict the marketing of HDP for that reason.

The best option for recycling is conventional plastic, but this has a serious disadvantage if it gets into the open environment as litter. Thousands of tons of conventional plastic are getting into the open environment every day, where they will lie or float around and will accumulate for decades, and this is no longer acceptable.

Degradation

One of the key findings of this report is that, "without exception, the scientific evidence suggests that the conditions present during the abiotic stage (which in most studies is simulated by some form of accelerated pre-treatment) of degradation will have a significant impact on the materials' ability to subsequently biodegrade."[2]

Nobody doubts that all plastics (OBP, HDP and conventional) will fragment as they degrade, but OBP has been designed to convert rapidly at the end of its useful life into low molecular-weight materials in the outdoor environment with access to oxygen. Nobody doubts that this does occur, and the Report quotes Loughborough University who concluded that "There is no question that oxo-degradable products do degrade and fragment when exposed to sunlight and/or heat for an extended period of time. The mechanism by which this happens is well researched and reported."

Nobody doubts that the length of time that this process takes will depend on conditions in the environment. It will take longer if (rarely) it is not exposed to any sunlight, but it is not correct to say that exposure to sunlight is essential. Equally, nobody doubts that under the same environmental conditions OBP will convert to low molecular-weight materials much more quickly than conventional plastic. However, questions have been raised as to whether the whole of the plastic will convert to low-molecular-weight materials, but this is well understood and the standards for OBP place limits on gel-formation.

The Report is meant to be concerned with carrier bags, but it also mentions plastic mulch films for agriculture at some length. These can be made from OBP but a reputable supplier will formulate the polymer and additive having regard to the particular circumstances on the particular farm, and to the particular type of crop and its growing-season. Allowance will be made for exposure to UV light on the surface of the field during the growing season, and it is not therefore relevant to consider degradation times for unexposed material. Trials will also be done in situ before an OBP mulch-film is supplied in commercial quantity.

2: 4.1.3.1

Biodegradation

Nobody doubts that any plastic which has converted to low molecular-weight materials has become accessible to micro-organisms, who can use it as a food source, and that these types of micro-organisms exist on land and in the sea. The dispute is how quickly they will bioassimilate the material, and whether they will bioassimilate all of it.

Conventional plastic undergoes the same process, and low molecular-weight residues of OBP will behave in the same way as low molecular-weight residues of conventional plastic, but will have become capable of biodegradation much more quickly – within months or years instead of decades.

Once the material has become biodegradable in the open environment it really does not matter how long it takes to biodegrade completely, provided it has been proved to be non-toxic. This would matter only in the unlikely situation that there were large quantities of plastic residues in the same place, and the Report acknowledges that this is not likely in the case of carrier bags.

As to whether the micro-organisms will bioassimilate the whole of the low molecular-weight material, biodegradation of 91% has been proved in the laboratory at the Technical Research Institute of Sweden and the Swedish University of Agricultural Sciences, and 88.9% in the Eurofins laboratory in Spain. This is complete biodegradation for all practical purposes (the limit specified for HDP in EN13432 is 90% of the maximum degradation of a suitable reference material, which could be less than 90% of the actual material).

The Eunomia Report comments on the Swedish study that "with the results of the laboratory study showing over 91% conversion to CO_2, the [Swedish] author contends that the "risk of plastic fragments remaining in soil indefinitely is very low." Nowhere is such a claim for complete bio-assimilation proven in practice though." "Although it can be believed that biodegradation can be facilitated by careful engineering of the chemical package in PAC plastic, evidence is not available to definitively conclude that this will happen in real world situations with PAC plastic products being placed on the market."

The opinion of the distinguished academic team in Sweden cannot be so easily dismissed, having regard also to the scientific studies in Spain and elsewhere. What does the author of the Report mean by "proven in practice?" Evaluation of biodegradation has to be done in laboratory conditions (as is also the case with HDP) – it cannot be done in a field or an ocean or a compost heap. These tests are very expensive and are not done for the amusement of scientists. They are designed to replicate conditions in the real world. There is no reason to think that in the open environment the micro-organisms will stop before they have consumed all of the available material, and it is for those who think so to prove it.

The Report refers to the work being done at Queen Mary University London which shows that "small levels of biodegradation were observed which if left to continue at the same rate would lead to full biodegradation in around 2 years." The Report continues "It is, however, unclear how these results can be translated to behaviour in the real world. One strain of bacteria is used in the test whereas in the open environment there may be many more, as well as fungi which may also attack and break down the plastic—and therefore it may biodegrade quicker." "From the information studied, the authors of this report can believe that it is possible for a PAC plastic to fully mineralise in an open environment, with the prodegradant additives encouraging this action, and thus the polymers and entrained substances can be assimilated into the natural environment."

The chemical package in OBP is indeed carefully engineered, and that is a skill acquired as a result of tests and experiments carried out over twenty years by reputable suppliers. If the Report is suggesting that only OBP placed on the market by reputable manufacturers can be relied upon, we would agree, and this is the same in any industry and for any product.

When comparing the performance of OBP with conventional plastic, the conventional plastic will not biodegrade at all until it has acquired biodegradability after exposure for very many years, and then its performance will be much the same as OBP. The purpose of OBP is therefore to reduce very significantly the period of time that the plastic is lying or floating around and accumulating, in the environment before it becomes biodegradable.

Marine environment

The Report says, "Evidence is not available to properly understand the fate of PAC plastic in marine environments, and thus there remains a risk that plastic fragments may remain either indefinitely, or for long enough to cause significant environmental damage." Actually, although conventional plastic fragments will remain in the marine environment for a very long time, nobody thinks that plastic fragments of any kind will remain in the environment indefinitely.

Evidence is certainly available that conventional plastic may remain in the marine environment for long enough to cause significant environmental damage, and this is the reason why OBP was invented.

The Report acknowledges that abiotic degradation of OBP occurs in the natural environment, but speculates that that if marine biodegradation does not occur rapidly enough, this will result in an increase in fragments of plastic in a given area. The comparison with soil environment is very speculative. It is true that bacterial biomass and diversity are lower in seawater compared to soil, but it does not follow that biodegradation will be less efficient in marine waters.

According to Dr. Jean-François GHIGLIONE[3] "OBP will float and be at almost all times subjected to UV light, which accelerates the abiotic phase of degradation. This is not always the case in soil, where plastic pieces are often covered by soil, leaves etc and are less exposed to UV light. There are specific bacteria living in the "seasurface microlayer" (the top millimetre of the ocean surface), where bacteria are different from further below the surface. The bacteria in the seasurface microlayer are particularly adapted to a hydrophobic environment (eg where oil materials are floating) and these bacteria are known to present a high capability for hydrocarbon degradation. These bacteria are therefore potential OBP-degraders, and such an environment does not exist at the surface of soil. These bacteria are probably less abundant and less diverse than in soil, but probably more effective to degrade OBP."

Therefore, if abiotic degradation of OBP is found to generate biodegradable material at a rate that cannot be immediately consumed by marine microorganisms, the process will contribute materials which closely resemble products of organic materials naturally present in the environment, and are recognisable to microorganisms as an accessible source of food - not fragments of plastic. Some marine bacteria, such as Alcanivorax borkumensis and R. rhodochorous are noted for their ability to biodegrade hydrocarbons and they are ubiquitous in the oceans. They occur in low concentrations in unpolluted seas, but are observed to accumulate in waters polluted by oil spills. When presented with a source of carbon which is recognisable to the microorganism as food, it seems therefore that they will respond with increased populations. The relatively low concentrations of microorganisms found in the oceans is not in itself justification for expecting slow rates of biodegradation of OBP.

Evidence is available - from Station d'essais de Vieillissement Naturel de Bandol on the coast of France that oxo-biodegradable plastic will degrade to low molecular-weight materials under natural conditions in water, and samples aged under those conditions have been studied at Queen Mary University London under conditions where the abiotically degraded plastic was the only source of carbon available to the bacteria. The samples were proved to be biodegraded by bacteria commonly found in the oceans, and separate samples by bacteria commonly found on land. The degraded plastic was also proved to be non-toxic to those bacteria.

Commenting on these two pieces of work the Report notes that "during pre-ageing under water, PAC plastic is much more susceptible to UV degradation than conventional plastic (as demonstrated by the large difference in molecular weight). The biodegradation tests also indicate that bacteria can feed off plastic measured with a higher molecular weight than the 5,000 limit often used to characterise this."

The Report says that "should full biodegradation on land occur, this would reduce the quantity that may otherwise transfer to the marine environment." We agree, and this will be the case at a much earlier stage after abiotic degradation, even before biodegradation ensues.

3: Directeur adjoint de l'Observatoire Océanologique de Banyuls

The Report continues "It is not possible to conclude whether PAC plastic would increase or decrease absolute quantities of plastic in marine environments." We think it is perfectly possible to conclude that degradation which is much more rapid than for conventional plastic, and biodegradation which proceeds at the same rate as conventional plastics after they have become biodegradable, would decrease absolute quantities.

The "ocean garbage patches" have been accumulating for decades, and this would not have happened had all the plastics been OBP. The problem is getting worse every day while Europe debates, but countries in other parts of the world have already made OBP mandatory.

A piece of OBP which degrades and becomes fragmented might be carried more easily into the sea by rainwater if it is near the sea or a watercourse, but an undegraded piece of conventional plastic is more likely to be blown into the sea. If it remains on the land it will eventually behave in the same way as OBP.

The Report continues "It seems likely that the fragmentation behaviour of PAC plastics will exacerbate issues related to microplastics." However, microplastics have become a problem because conventional plastic has been eroding and fragmenting for decades, and the fragments are still fragments of plastic because their molecular weight has not reduced to the point where the material is available to microorganisms. This is not the case with OBP.

Plastic fragments are not the final products of abiotic degradation of OBPs. The inclusion of a prodegradant additive will accelerate the observable fragmentation of plastic in the environment, compared to an equivalent non-degradable plastic product, but degradation continues beyond fragmentation until the material has become low molecular weight oxidised materials which no longer resemble a polymer. These are water soluble and biodegradable.

The process is explained by Professor Ignacy Jakubowicz as follows:[4] "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."

This abiotic degradation will proceed without the involvement of microorganisms. By contrast, conventional plastics can be observed to fragment in a relatively short time frame, but will remain in the environment for a long period of time as high molecular weight microplastics.

"Working under the assumption that PAC plastic in marine environments will be more fragmented, the effect may be to reduce the impacts on wildlife in some respects (such as entanglement)." Correct

4: http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf "but to increase the impacts in others (such as physical ingestion of microplastics)." Thousands of tonnes of microplastics formed from conventional plastics are already being ingested. If these are causing harm as they pass through the digestive system, the response must be to ban plastics of all kinds – but this is clearly impracticable and disproportionate.

"The PAC plastic is more likely to fragment quicker so the impacts associated with microplastics are concentrated within a shorter period of time." "this could ultimately be worse than spreading out the impacts over a longer period of time due to an increase in the proportion of individuals, species and habitats affected, as well as the burden of impacts for an individual of a species." In our view the opposite would be the case. Fragments of conventional plastic will be a problem for decades, but once OBP has reached the fragmentation stage it is no longer a plastic (for definition see ASTM D883) and has become a food source for micro-organisms.

Standards

The principal Standards which have been written for testing OBP are ASTM D6954 (USA); BS8472 (UK); and AFNOR AC T51-808 (France); and SPCR 141 (Sweden). Variants of these standards have also been adopted in other countries. There is no CEN standard for OBP because the technical committees of CEN are dominated by representatives of the HDP industry. If this obstruction could be overcome, the Oxo-biodegradable Plastics Association undertakes to draft a suitable European Standard and present it to CEN, and to establish a scheme similar to that operated by Vincotte for "compostable" plastic. In the meantime the American, British French and Swedish standard test methods are suitable for providing the information which customers and governments need to know.

ASTM D6954 contains no less than six pass/fail criteria. 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 at least 60 % of the organic carbon is converted to carbon dioxide the test cannot be considered completed).

Non-toxicity

The OBP industry is as much concerned as anyone that its products should not introduce toxicity into the environment, and for this reason the standards for OBP require testing to confirm that the residues are harmless, according to the OECD eco-toxicity tests.

Essentially OBP are made from the same materials as conventional plastics, with the addition of only 1% of a masterbatch (most of which is ordinary polymer), and they have to pass the same tests as HDP in EN 13432 to ensure that there are is no toxicity and no metals exceeding the limits prescribed in Annex A.1.2 of EN 13432 (and Art 11.1 of the EU Packaging Waste Directive 94/62/EC). Other ingredients which manufacturers may wish to include in plastic products (eg Bisphenol A), or which may be generated by the manufacturing process, are not the responsibility of the OBP industry, and should be specifically regulated by government.

The Report says “it does appear that the PAC plastics industry can create products that have minimal toxic impact on flora and fauna. … and it is at least encouraging that almost all existing test standards for PAC plastic specify some form of toxicity test using established methods (such as germination and earthworm survival tests).”

The Report continues, “this does not mean that all products on the market avoid negative toxic effects, as there is no regulatory control currently exercised in this regard. Problems remain that (a) accreditation is not mandatory for products on the EU market, and (b) some of the standards do not have pass/fail criteria for the toxicological test results.” This is a criticism not of the OBP industry, but of CEN and the regulatory authorities in Europe, who have not sought to ensure that OBP is supplied only by reputable manufacturers, who can produce evidence that their products have been tested by recognised laboratories according to well established standards such as ASTM D6954, and of regulatory authorities who have not specified for all relevant tests what test results they would and would not find acceptable. They have however done so in the case of testing for metals by specifying in Art 11.1 of 94/62/EC the maximum concentration al lowed.

The report also says that “there remains uncertainty surrounding real world toxicological impacts.” This is also true of compostable plastic but nobody is trying to place restrictions upon it. Again, evaluation of toxicity has to be done in laboratory conditions (as is also the case with HDP) – it cannot be done in a field or an ocean or a compost heap.

Propensity to litter

It is often claimed that biodegradable plastics are likely to encourage littering, but this is seldom seen as an objection to HDP. The Eunomia Report says, “rather than speculation, objective behavioural research is required to move this topic forward in a constructive manner.” We agree.

In our view, even if there were a label describing a product as oxo-biodegradable, the type of people who cause litter are not likely to look for the label before deciding to throw a plastic item out of a car window. Further, even if it were true that biodegradability encourages littering, and supposing that there would be 10% more litter - is it preferable to have 110 plastic items which will degrade and biodegrade in a few years or even months, or 100 plastic items which will lie or float around for decades?

OBP products, like other plastic products, should be labelled to advise consumers that the product should be disposed of responsibly.

It is not acceptable to continue worrying about this speculative proposition any longer, while thousands of tonnes of conventional plastic are getting into the environment every day, which will accumulate and pollute the environment for decades into the future.

Fossil Resources

We find it difficult to understand the trend towards replacing conventional oil-based plastics with plastics derived partly or fully from crops. Although the Report does not deal specifically with this issue we think it is important to understand it when considering the materials from which carrier bags and packaging could be made.

OBP and other oil-based plastics do not cause fossil resource-depletion. This is because they are made from ethylene – an inevitable by-product of oil which used to be wasted. The oil is extracted to make fuels and lubricants, and the same amount would be extracted even if oil-based plastics did not exist.

Therefore, until other fuels and lubricants are found for vehicles, ships, aircraft and factories, it makes sense to use this by-product instead of consuming large amounts of fossil fuel in the agricultural production, transport, and polymerisation of "crop-based" plastics. See http://www.biodeg.org/biobased.html

It would therefore be misleading to describe crop-based plastics as "renewable."

Life-cycle Assessments show that when the litter metric is included OBP is the best material for making carrier bags. See http://www.biodeg.org/New%20LCA%20by%20Intertek%20%20-%20Final%20Report%2015.5.12(1)%20(1).pdf

A consortium consisting of Friends of the Earth, Surfrider Foundation, Zero Waste Europe, Ecos, and the European Environmental Bureau published a paper in 2017 in which they say "The bioplastics industry use their green-sounding credentials to position themselves as helping to speed the reduction in fossil fuel use and solving the ever-growing plastic pollution and marine litter issues. However, there is clear evidence that bioplastics do not solve many of these problems and in fact may create new ones."

**There are 19 reasons why bio-based plastics have very limited utility.
See http://www.biodeg.org/wp-content/uploads/2019/04/opa-19-reasons-why.pdf**

OPA RESPONDS TO EUROPEAN COMMISSION

A European Strategy for Plastics in a Circular Economy 16th January 2018 ("The Strategy")

-and-

REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL

on the impact of the use of oxo-degradable plastic, including oxo-degradable plastic

carrier bags, on the environment 16th January 2018 ("the Report")

Plastic products made with oxo-biodegradable technology have been successfully used for nearly forty years. They have been used, and are being used, in more than 90 countries, in volumes that we estimate to exceed 10 million tons. In the past 3 years legislation has been passed in 15 countries in favour of oxo-biodegradable plastic and discouraging or banning the use of old-fashioned conventional plastic, because the governments of these countries know that they cannot fully prevent plastic getting into the open environment. The European Commission is out of step with this international trend.

It is important to understand that oxo-biodegradable plastic is not a completely new product – it is ordinary plastic, upgraded so that it will not lie or float around in the environment for hundreds of years.

The Commission admits[1] that *"Very large quantities of plastic waste leak into the environment from sources both on land and at sea, generating significant economic and environmental damage. Globally, 5 to 13 million tonnes of plastics — 1.5 to 4 % of global plastics production — end up in the oceans every year. It is estimated that plastic accounts for over 80 % of marine litter. Plastic debris is then transported by marine currents, sometimes over very long distances. It can be washed up on land, degrade into microplastics or form dense areas of marine litter trapped in ocean gyres. UNEP estimates that damage to marine environments is at least USD 8 billion per year globally."*

The Commission's Plastics Strategy contains policies to reduce, redesign, re-use and recycle plastics, and to encourage Europe's citizens to be more environmentally-conscious. **We support all these policies,** but the fact remains that despite these efforts thousands of tons of plastic waste will still be getting into the environment, and especially the oceans, for the foreseeable future. This is so even in Europe where some countries have modern systems of waste-management, but the situation is far worse in the less developed-world, whose environmental policies the EU claims to lead.

The Commission is content to allow old-fashioned plastic to continue in use, knowing that if it gets into the environment it will lie or float around for hundreds of years as a problem for future generations. **The European Commission's policy is irresponsible.**

Plastics upgraded with oxo-biodegradable technology have been specifically developed to address this problem, and they are often referred to as "Controlled-Life Plastics."

[1] Strategy para 2

All the properties of the plastic are unaffected other than the final outcome which is to convert the material automatically into harmless biodegradable components. It is a practical and effective solution because the plastic can be upgraded during manufacture by the same factories, using the same machinery and workforce, at little or no extra cost.

There is no impact on jobs or quality of raw materials or finished products, and nor is there any disruption of the supply-chain. No hardship would be caused to anyone, which is not the case with the introduction of bio-based plastics which has caused such distress among the poorest people in Italy, or with conversion to paper packaging.[2]

The Commission says[3] that it wants to see a smart, innovative and sustainable plastics industry, where design and production fully respects the needs of re-use, repair, and recycling, and brings growth and jobs to Europe. **We agree with this vision**, and this Association exists to encourage the highest standards among its members worldwide.

PLASTIC HAS ADVANTAGES AND DISADVANTAGES

The Commission's Strategy says[4] that *"Plastic is an important and ubiquitous material in our economy and daily lives. It has multiple functions that help tackle a number of the challenges facing our society…. In packaging, plastics help ensure food safety and reduce food waste."* However, the downside is that thousands of tons of plastic are getting into the open environment every day.

OXO-DEGRADABLE PLASTICS

Those thousands of tons of plastic getting into the environment are old-fashioned conventional plastics, and they can properly be described as "oxo-degradable" because they degrade by a process of oxidation. However, the Report acknowledges[5] that *in the open environment it may take a long time, up to hundreds of years, for conventional plastics to biodegrade"* Instead, they fall into microplastics, which lie or float around for hundreds of years, and cause the damage to marine life and danger to the human food-chain which we are all concerned to avoid.

We therefore welcome the Commission's proposal to place restrictions in Europe on this old-fashioned type of plastic, but they seem not to understand the difference between oxo-degradable and oxo-biodegradable.

OXO-BIODEGRADABLE[6] PLASTICS

Let us be clear that there is a fundamental difference between these old-fashioned "oxo-degradable" plastics and oxo-biodegradable plastics, because oxo-biodegradable plastics (Oxo-bio) have been designed to convert at the end of their useful life into biodegradable materials and to biodegrade under any conditions in the open environment within a very much shorter timescale. They are then recycled back into nature by the naturally-occurring micro-organisms. The Commission has not found a single fragment of oxo-biodegradable plastic in the open environment, and they will be unlikely to find one, because it will not be there for long.

The Commission accepts[7] that the *"first stage of degradation prepares the [oxo-bio] plastic for biodegradation by reducing the molecular weight of the plastic to the point where it may be consumed by biological organisms."*

[2] http://www.biodeg.org/page29.html
[3] Para 3
[4] Para 1
[5] Para. 2
[6] Oxo-biodegradation is defined by CEN TR 15351 as "degradation identified as resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."
[7] Para 2

They also accept that *"this accelerated fragmentation would also accelerate biodegradation."* The Eunomia report[8] says *"without exception, the scientific evidence suggests that the conditions present during the abiotic stage (which in most studies is simulated by some form of accelerated pre-treatment) of degradation will have a significant impact on the materials' ability to subsequently biodegrade."*

However, the Commission's Report says[9] that *[oxo-bio] plastic fragments over time into plastic particles, and finally microplastics, with similar properties to microplastics originating from the fragmentation of conventional plastics,* but **this is a serious error**. The process is described as follows[10] by Prof. Ignacy Jakubowicz, one of the world's leading polymer scientists. ***"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."*** **This point is absolutely crucial to an understanding of oxo-biodegradable plastic technology.** It was explained to Commission officials on 30th November 2017 by the leader of the scientific team at Queen Mary University London who have made an in-depth study of oxo-biodegradation, but it seems that the officials were not listening.

This is a fundamental misunderstanding of the principles of oxo-biodegradation, which invalidates the whole report, and we continue to comment on the report as a matter of courtesy to the Commission only.

At para 4.3 the Report says *"As oxo-degradable plastic is designed to fragment faster than a conventional one it is less likely to be recovered during litter clean-up exercises, and likely to be more easily transported by wind and water. As these factors may contribute to oxo-degradable plastic being transported into the marine environment easier than conventional plastic it can be said that oxo-degradable plastic contributes to microplastics pollution and therefore poses environmental risks."* and "*As oxo-degradable plastic is likely to fragment quicker than conventional plastic, the negative impacts associated with the presence of microplastics in the marine environment are concentrated within a shorter period of time. This could ultimately be worse than spreading out the impacts over a longer period, due to an increase in the proportion of individuals, species and habitats affected, as well as the burden of impacts for an individual."*

They have clearly not understood the process explained by Prof. Jakubowicz above, and as further explained by the scientists from QMUL. The material fragments because its molecular structure has been dismantled. When the material has fragmented **it is not a microplastic**, and before it has fragmented it can be recovered during litter clean-up exercises. An intact plastic bag is more likely to be carried by the wind than the non-plastic, oxygen-containing molecules into which the plastic has converted.

How can it possibly be worse for plastics to biodegrade within a short period of time than to be left to float around collecting toxins and harming wildlife for hundreds of years?

The Eunomia Report says[11] *"From the information studied, the authors of this report can believe that it is possible for [an oxo-bio] plastic to fully mineralise in an open environment, with the prodegradant additives encouraging this action, and thus the polymers and entrained substances can be assimilated into the natural environment."*

The Commission's report says[12] *"It is clear that oxo-degradable plastic is prohibited from degradation if not first exposed to UV radiation and, to a certain extent, heat"* but **this is another serious error**. UV exposure and ambient heat will accelerate the process, but they are not essential.

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8 Paid for by the EU Commission, and published in April 2017 see para 4.1.3.1
9 Para 2
10 http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf
11 Page 45
12 Para 3.1

The Report says[13] *"Even if biodegradation may be facilitated by careful engineering of the chemical package, evidence is not available to definitely conclude that this will happen in real world situations. If the circumstances for fragmentation to take place are absent or insufficient, biodegradation will not take place."* However, it is difficult to envisage a situation in the open environment where the circumstances for fragmentation to take place are absent or insufficient, as only oxygen is required. Oxygen is everywhere in the air, and in the sea.

Biodegradation to the extent of 90% (which is all that is required by EN13432) has been documented in Spain, Sweden, and elsewhere, and the reports have been supplied to the Commission. How can they say that there is no evidence?

The tests for degradation are not done for the amusement of scientist but are designed by them to replicate what is likely to happen in the real world. Laboratory tests are designed to be performed in a shorter time than would be taken in the real world, but if this invalidated the tests the scientists would be wasting their time and would not do them.

TIMESCALE FOR BIODEGRADATION

The Report says[14] *"Looking at biodegradation of plastics as a means to avoid pollution hence only makes practical sense if this is linked to a "reasonable" time frame, and "defining a 'reasonable' time frame might differ from product to product depending also on the use of the product and its impact on the environment; the environmental impact is correlated with the time taken for complete breakdown of the polymer."*

Hundreds of years is clearly not a reasonable timescale, and the Report acknowledges[15] that *"It is undisputed that oxo-degradable (sic) plastic, including plastic carrier bags, may degrade quicker in the open environment than conventional plastic."*

It is not useful to enquire exactly how long a particular specimen in a particular place would take to biodegrade, because the Commission is well aware that timescale depends on the conditions in the environment in that place at that time. **The key point is that an oxo-bio plastic item will become biodegradable very much more quickly than a conventional plastic item in the same place in the open environment at the same time - and that is the environmental benefit.**

Oxo-bio plastic has been degraded in real time in seawater at Bandol in France, and the scientists at Queen Mary University observed the resulting material being used as a food-source by bacteria commonly found on land and in the oceans. They even have photographs taken with an electron-microscope, of the microbes actually consuming the material, and in their view there is no reason why this process should stop in the natural environment until all the material has been consumed. How therefore can the Commission say that there is no evidence?

With particular regard to the marine environment Dr. Jean-François GHIGLIONE[16] says *"Oxo-biodegradable plastic will float and be at almost all times subjected to UV light, which accelerates the abiotic phase of degradation. This is not always the case on land, where plastic pieces are often covered by soil, leaves etc. and are less exposed to UV light.* He points out that "*there are specific bacteria living in the "seasurface microlayer" (the top millimetre of the ocean surface), where bacteria are different from those further below the surface. The bacteria in the seasurface microlayer are particularly adapted to a hydrophobic environment (e.g. where oil materials are floating) and these bacteria are known to have a high capability for hydrocarbon degradation. These bacteria are therefore potential oxo-bio-degraders, and such an environment does not exist at the surface of soil.*

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13 Para 3.1
14 Para 2.
15 Para. 6
16 Directeur adjoint de l'Observatoire Océanologique de Banyuls

These bacteria are probably less abundant and less diverse in the ocean than in soil, but probably more effective to degrade oxo-biodegradable plastic."

Nobody maintains that oxo-bio is perfect, for there is of course a period of time during which it has to behave in the same way as conventional plastic, otherwise it would be useless. It is designed to have a service life during which it can be stored, re-used or recycled, which is wholly desirable. This is a necessary price to pay for a plastic which will rapidly degrade and biodegrade at the end of that period. This is surely much better than conventional plastic, which as the Commission admits, could lie or float around in the environment for hundreds of years, causing damage to living creatures and adsorbing toxins.

RECYCLING

We are aware that biodegradable plastics should not interfere with the recycling process nor the integrity of new plastic items made with recyclate. The position is as follows:

-Bio-based Plastics

The Commission accepts[17] that *if compostable and conventional plastics are mixed in the recycling process, it may affect the quality of the resulting recyclates.*

It is well known that bio-based plastics will damage both the recyclate and the new plastic items. In fact it was reported in the press in September 2017 that recyclers were finding that recyclate from Southern European countries is causing defects and ruptures of the film, and their analyses demonstrated that most of this is caused by materials used in "bio-based plastics" i.e. starch, polylactide (PLA) and polybutylene adipate terephthalate (PBAT).

This is because the governments of France, Spain, Italy, and now Greece have been persuaded by powerful lobbying groups that represent the manufacturers of "bio-based plastics" to prefer their product. Not only is it incompatible with recycling, and can be up to 400% more expensive than ordinary or oxo-bio plastic, but it contains up to 80% oil-based material. Nor does it achieve the objective of these governments to deal with plastic waste in the environment, as it is tested to biodegrade in the special conditions found in municipal composting, not in the open environment. These products are potentially harmful and can cause microplastics if they are not collected and placed into industrial composting.

-**Oxo-bio**

According to the recycling charity RECOUP ("Recyclability by Design" 2006) *"In cases where plastic products are particularly lightweight and contaminated with other materials, the energy and resources used in a recycling process may be more than those required for producing new plastics. In such cases recycling may not be the most environmentally sound option."* These are the very products in which oxo-bio technology is commonly used.

Nevertheless, the Commission is concerned that oxo-bio plastic should be identifiable and separated from other plastics collected for recycling, and they say[18] that *"Currently available technology can not ensure identification and separate sorting of [oxo-degradable] plastic by re-processors."* This is easily remedied, because the Commission could require that a tracer be included in oxo-bio plastics so that it can be identified by the existing sorting technology.

This is not however necessary. See http://www.biodeg.org/recycling.html

[17] Strategy p 12
[18] Para 5.1

OPA members have in fact been successfully recycling oxo-bio plastic for more than ten years with no adverse reports, and last year alone it is estimated that more than 800,000 tonnes were processed worldwide. The recyclers have produced no scientific evidence to justify their concerns about oxo-bio, but they are rightly concerned about bio-based plastics.

COMPOSTING

The Report points out that oxo-bio is not suitable for composting, but it is not marketed for this purpose, so why are the Commission even considering it in a report about oxo-bio? The types of plastic which *are* marketed for composting, do not convert into soil-improvers – because the relevant standard[19] requires them to convert into CO_2 gas within 180 days. There are at least 16 reasons why "compostable" plastic is useful only for niche applications and is not useful in the fight against plastic pollution of the open environment. See http://www.biodeg.org/biobased.html The Commission accepts[20] that they *"degrade under specific conditions which may not always be easy to find in the natural environment, and can thus still cause harm to ecosystems."* The Commission have also accepted[21] that *"compostable" plastic is not necessarily suitable for home-composting."*

LANDFILL

The Report also points out that oxo-bio will not degrade in the anaerobic conditions found deep in landfill, but again it is not marketed for this purpose, but unlike bio-based plastics it will not generate methane in those conditions.

The Eunomia Report says[22] *"Whilst PAC plastic may biodegrade in the upper levels of a landfill in aerobic conditions and therefore produce CO_2, it has already been demonstrated that this happens at a very slow rate, and only if abiotic degradation has already occurred. The limited evidence that is available suggests that deeper in landfill under anaerobic conditions there will be little or no biodegradation taking place. In this case, the carbon is effectively sequestered, avoiding the direct release of GHGs to the atmosphere."*

FARMING

Oxo-biodegradable plastics have been used and studied in farming for more than 4 decades as mulch films, and these studies demonstrate that the life of the film can be controlled within a short time-span without damaging the crop. This makes it unnecessary for the farmer to remove and dispose of thousands of tons of dirty plastic. Scott-Gilead were the first to publish their findings from studies in 1980 that show degradation and biodegradation in 92 days - and this is in natural ageing, not in the laboratory. See "Degradable Polymers, Principles & Applications," edited by Professor Gerald Scott, who was Professor Emeritus in Chemistry & Polymer Science at Aston University, UK.

NON-TOXICITY

The oxo-bio industry is as much concerned as anyone that its products should not introduce toxicity into the environment, and for this reason the standards for oxo-bio require testing according to OECD Standards to confirm that the residues are harmless. The Commission has not found even one gram of oxo-bio residue and shown it to be toxic.

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[19] EN 13432
[20] Strategy p12
[21] Strategy p12
[22] Para 4.1.4.1

Essentially oxo-bio is made from the same materials as conventional plastics, with the addition of only 1% of a masterbatch (most of which is itself ordinary polymer), and they have to pass the same tests[23] as "compostable plastic" to ensure that there is no toxicity and no metals exceeding the prescribed limits.

The Report mentions the use of cobalt, but it is not listed as a substance of concern in EN13432 Annex A.1.2, nor in Art 11 of the EU Packaging Waste Directive. **It is not therefore correct for the Commission to say that there is no regulation of substances of concern**. Oxo-bio does not contain any of the substances to which Article 11 or Annex A.1.2 refers, and the Commission does not suggest that it does.

Other ingredients which manufacturers may wish to include in plastic products, or which may be generated by the manufacturing process of plastic products, are not the responsibility of the oxo-bio industry, and should be specifically regulated by government.

The Eunomia Report says[24] *"it does appear that the OBP industry can create products that have minimal toxic impact on flora and fauna. … and it is encouraging that almost all existing test standards for OBP plastic specify some form of toxicity test using established methods (such as germination and earthworm survival tests)."*

The OPA has commented on the Eunomia report in detail at
http://www.biodeg.org/OPA%20Comment%20on%20EUNOMIA%20REPORT%204.9.17.pdf

FOSSIL RESOURCES

Oxo-bio does not cause oil-depletion, because it is made from a by-product of refining oil which has been extracted from the ground to make fuels. Perhaps one-day oil will not be needed for fuels and it will then be in abundant supply for other uses.

PROPENSITY TO LITTER?

The Commission thinks that to encourage oxo-bio plastics would send the wrong signal and be likely to encourage littering. On the contrary it would send exactly the right signal – that in addition to its efforts to reduce plastic waste, the Commission is determined to protect the planet against conventional plastic, which can and does get into the oceans and subsists in the environment for hundreds of years. It would also be following the example of other countries who have required the use of oxo-bio technology.

Oxo-bio cannot be distinguished from ordinary plastic by sight, touch, or smell, but even if there were a label on the product describing it as oxo-biodegradable, it is unlikely that the people who cause litter will look for the label before throwing a plastic item out of a car window. Further, even if it were true that biodegradability encourages littering, and supposing for the sake of argument that there would be 10% more litter - is it preferable to have 110 plastic items in the environment which will degrade and biodegrade in a few months, or 100 plastic items which will lie or float around for hundreds of years?

We do not think it is acceptable to continue debating this speculative proposition any longer, while thousands of tonnes of conventional plastic are getting into the environment every day, which will accumulate and pollute the environment as a serious problem for future generations.

A Life-cycle Assessment by Intertek shows that when the litter metric is included OBP is actually the best material for making carrier bags. See http://www.biodeg.org/New%20LCA%20by%20Intertek%20%20-%20Final%20Report%2015.5.12(1)%20(1).pdf

[23] EN 13432 Annex E and Annex A.1.2
[24] P 110

THIRD PARTY REPORTS

The Commission places some reliance on the Ellen MacArthur report, with which we were not impressed, and to which we have published our response at http://www.biodeg.org/OPA%20response%20to%20MacArthur%20-%2012-11-17.pdf The authors had submitted a draft to Professor Jakubowicz, who is one of the most eminent polymer scientists in the world, to which he replied that their statement about oxo-bio is not in line with his understanding nor the science in this field http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf

In particular, the Professor pointed out that **their understanding is not correct on the all-important question of whether oxo-bio merely fragments or whether it converts into biodegradable materials.**

The Commission also places some reliance on reports by "European Bioplastics" but this is a lobby group for the "compostable" plastic industry, which sees oxo-bio plastics as a threat to its profits.

What the Commission did not do, was to pay attention to the evidence provided by the experts in oxo-biodegradable technology.

REGULATION

The Eunomia Report says[25] *"this does not mean that all products on the market avoid negative toxic effects, as there is no regulatory control currently exercised in this regard. Problems remain that (a) accreditation is not mandatory for products on the EU market, and (b) some of the standards do not have pass/fail criteria for the toxicological test results."*

This is a criticism not of the oxo-bio industry, but of CEN and the regulatory authorities in Europe. They have not written an EU standard for oxo-biodegradable plastics, and it is necessary therefore to rely upon the American standard ASTM D6954 or the British standard BS8472.

No restriction of the sale of oxo-biodegradable plastic (which would be in restraint of trade) would be upheld by the European Court of Justice if it were not fully justified on the law and the evidence. The ECJ would wish to hear evidence from the oxo-biodegradable plastics industry as well as the Commission, and this report from the Commission would certainly not justify any restriction. It would be much more likely that the court would approve restrictions on conventional plastics, whose damaging effects on the environment are universally acknowledged.

Nevertheless, The Oxo-biodegradable Plastics Association has always been willing to work with the Commission and CEN to devise standards and procedures relating to both the marine and terrestrial environments.

19 January 2018

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SYMPHONY'S COMMENT ON
Ham, G-Y.; Kanami, N.; Tomonori, I.; Yamada, M. Accelerated weathering of bio- and oxo-degradable plastics and their biodegradability under soil conditions, The 34th Annual Conference of JSMCWM/ 3RINCs, 2023 - https://www.jstage.jst.go.jp/article/jsmcwm/34/0/34_495/_article/-char/en

This paper says that "Plastics are virtually irreplaceable materials in modern life. Still, there is a high probability that plastics may be trapped in a natural environment for a long period if not appropriately managed. Even when collection of plastic is effective in high income countries, the rate of plastic waste being recycled into the economy is very low, around 10% for all plastics, and the rest of them are still destined to landfill or in the natural environment and cause environmental pollution." We would agree with this.

"As an alternative to conventional plastics, ... oxo-degradable plastics modified from conventional plastics by adding oxidants or plasticizers have been introduced to the market." This is not correct. Plastics including pro-oxidant masterbatches should be described as "oxo-biodegradable." Plasticisers are used in the plastics industry for an entirely different purpose.

"They have been promoted as being able to be degraded in nature when discharged into the environment and assimilated by the microorganisms." Correct.

The authors then proceed to carry out experiments "A bioplastic film known to be composed of PLA/PBAT blend and an oxo-degradable plastic bag were used." These are very different materials, for which different test methods are prescribed by international Standards. PLA should have been tested according to ASTM D6400 and oxo-degradable (actually oxo-biodegradable) plastic according to ASTM D6954.

"These two samples were commercially available products, and they featured transparent or semi-transparent films, and their thickness ranged from 20-30 ㎛. The paper does not identify which OBP masterbatch (if any) was used and at what addition-rate, nor what level of stabilisation existed in the masterbatch and/or the film, and it cannot therefore be relied upon as having any scientific validity.

The samples were taken from the market in China, where it is not uncommon for plastic products to be marketed as "oxo-degradable" or "oxo-biodegradable" even though they do not contain the requisite masterbatch in the correct quantity or at all. Sometimes calcium carbonate is used wholly or partially instead of the masterbatch because it is cheaper. It is therefore essential in order to avoid deception of the public that no product be permitted for sale as "oxo-biodegradable" unless it is proved to contain in the correct quantity a masterbatch whose supplier can produce a report from an accredited laboratory according to ASTM D6954.

The sample materials for the tests by Ham et al. were "analyzed for chemical composition and chemical structure by Fourier Transform infrared spectroscopy (NICOLET 6700 FT-IR, Thermo Fisher Scientific, U.S.). From the result of FTIR analysis, the oxo-degradable films were confirmed to consist of HDPE and additives."

However, FTIR analysis would not show whether the film described as oxo-degradable had been manufactured with an oxo-biodegradable masterbatch in the correct quantity or at all. It would also not show what level of stabilisation was present in the masterbatch or the film. This is important because masterbatches are usually stabilised to give the plastic product a predetermined service-life before degradation even commences. Further, the film itself may contain HALS or other stabilizers or other materials that will inhibit or even prevent the oxidation process. The presence of stabilizers is ascertained by Chromatography, not FTIR.

FTIR cannot detect the salts of Co, Mn, or Fe used as catalysts in the masterbatches, because their concentration is too low. XRF Technology is therefore used to determine whether the catalyst is present in the correct quantity or at all. This was not done.

A supplier such as Symphony considers carefully which masterbatch (from a range of different masterbatches) is required for each application, but this paper by Ham et al does not give the information about the masterbatch or the test samples that would be needed before selecting a masterbatch type and/or the correct addition rate.

The level of biodegradation shown in the tests performed by Ham et al is much less than would be expected for an oxo-biodegradable plastic correctly made, so it is very likely that the sample had not been correctly made with the correct masterbatch in the right quantity and with the correct level of stabilisation in the masterbatch and the film (or any masterbatch at all). There was no control sample.

The performance of whatever OBP masterbatch (if any) was used in the study is extremely poor. After 750 hours of simulated outdoor exposure conditions the degraded film was still not going into biodegradation. The paper says that after 750 hours there was no carbonyl index increase, but the film was reported as fragmenting. This leads to the conclusion that there was something wrong with the samples and/or the tests.

Further, the average irradiance recommended by ASTM D5208 is around 0.78/0.80 W/sq. m. but the study used only 0.51.

Moreover, the study did not measure the Molecular Weight after the Abiotic Degradation – which is a critical step.

Biodegradation was assessed based on the variation of pressure inside the test chamber, but this is not a reliable measurement of CO2 evolution.

The authors also say, on page 496 "....The collected degraded PLA/PBAT blend film showed considerable deterioration, proving biodegradation......". In fact this shows degradation, not biodegradation.

For the above reasons, this paper cannot be relied upon to make any policy decisions relating to oxo-biodegradable plastic.

Oxo-biodegradable Plastics – EU Compliance

EU News - Biodeg

In making the SUP Directive 2019/904 the EU Parliament caused confusion by failing to distinguish clearly between oxo-degradable and oxo-biodegradable plastic.

We have examined the EU Commission's Guidelines (C 3762) of 31st May 2021 on the interpretation of the Directive, and have concluded for the following reasons that they are mistaken.

The Guidelines say "Article 5 of the Directive ….. makes no distinction between oxo-degradable plastic that is biodegradable and oxo-degradable plastic that is not biodegradable." This is true – because Article 5 does not mention biodegradable plastic at all. That does not however mean that oxo-biodegradable plastic does not exist.

Its existence is recognised by CEN TR15351, wherein:

(a) "Oxo-degradation" is defined as "degradation identified as resulting from oxidative cleavage of macromolecules." This describes ordinary plastic, (which does not contain an intentionally-added prodegradant catalyst). It will abiotically degrade by oxidation in the open environment and create microplastics, but does not become biodegradable except over a long period of time.

(b) By contrast "oxo-biodegradation is defined as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic (which does contain a prodegradant catalyst) degrades rapidly by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature.

Recital 15 of the Directive provides that "The restrictions on placing on the market introduced in this Directive should also cover products made from "oxo-degradable" plastic, as that type of plastic does not properly biodegrade and thus contributes to microplastic pollution in the environment." It follows from this that a type of plastic, (such as d2w biodegradable plastic), which is scientifically proved to properly biodegrade and not create microplastics, is not "oxo-degradable" plastic for the purposes of the Directive, and the Guidelines are therefore in conflict with Recital 15. The quality of biodegradability is an essential characteristic.

Not only are the Guidelines mistaken, but they are not legally binding, and were written without the benefit of later scientific evidence, including in particular the French "Oxomar" study, which proved that oxo-biodegradable plastics biodegrade in seawater and do so with a significantly higher efficiency than conventional plastics. See www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf

One of the purposes of the SUP Directive is to reduce the amount of single-use plastic products, and especially those commonly found on beaches. That is why the Directive contains a list of such products, which are banned whether they are oxo-degradable or not. There was no reason to add any restriction which could apply to oxo-biodegradable plastic products, for if they are single-use products on the list they are banned anyway. There is no evidence that oxo-biodegradable plastic products not mentioned on the list have ever been found on beaches, and it is clear that it is better for Europe’s environment for plastic to be made so that it quickly biodegrades leaving no toxic residues, instead of lying or floating around for decades and creating microplastics.

The Directive had been challenged by Symphony Environmental in the European Court in Luxembourg, because the confusion caused by the Directive had affected its business and Symphony claimed compensation. The court did not say that the EU had made a correct assessment of the technology, but it refused to award compensation simply because it held that the legislators had not exceeded the limits of their discretion.

This was a surprising conclusion, as the legislators had not followed the procedure prescribed by the REACH Regulation Arts 68-73; had failed to make an environmental impact assessment or socio-economic analysis; had failed to await the results of a scientific study being done at the time by the European Chemicals Agency; and had prematurely terminated that study. On 30th October 2018 the Agency said that they had not been convinced that microplastics were formed.

Biodegradable Plastics Association
www.biodeg.org

Biodegradable Plastics Association

A not-for-profit Association

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BPA RESPONSE TO

DEFRA's Hazardous Substances Advisory Committee (HSAC)

review (July 2019) of "oxo-degradable" plastics -

We agree with HSAC that "Many of the advantages, conveniences and indeed environmental benefits of modern life brought to us over the past 70 years have 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."

"Such applications typically employ plastics from the polyolefin family (long chain polymers formed from alkanes) and include polyethylene and polypropylene. … The benefits of these plastics come from their properties of durability, flexibility, water repellence and light weight."

HASC say that about 4% of our fossil fuels go towards plastics manufacture and they cite Hopewell et al., 2009, who in turn cite the British Plastics Federation, but the BPF themselves offer no data to support their assertion. Oil is not primarily extracted to make plastics - it is extracted to make fuels for vehicles, ships, and aircraft, and would continue to be extracted if plastics did not exist. Plastic is made from a by-product of the refining process. Some electricity is of course used to drive the machinery, and this may come from hydro, fossil-based, or renewable sources, but is less than the energy used for recycling plastics, and in the production of paper.

The BPF go on to say, and we agree, that:

• The production of plastic products uses far less energy compared to those made from alternative materials. Substituting plastics with alternatives would increase the lifecycle energy consumption of these products by approximately 57% and the greenhouse gas emissions would rise by 61%.

• Plastics reduce the consumption of oil elsewhere. They reduce the weight of vehicles, aircraft, ships, packaging and products, meaning that less fuel is burned and CO_2 emissions are lower.

• Used plastics can be recycled numerous times. If it doesn't make economic or environmental sense to recycle, then the energy can be recovered through incineration, as used plastics have a higher calorific value than coal.

The HSAC say that "There is a now a worldwide realisation that plastics, particularly those associated with single use applications, are accumulating in the environment due to their poor degradative characteristics. This is particularly notable in the marine environment, where the problem appears to be getting rapidly worse." "Based on existing studies, it might be predicted that it would take 300 to 500 years for the complete breakdown of an LDPE or HDPE product." **This is why oxo-biodegradable plastic was invented.**

The HSAC Review is notable for its failure to distinguish between oxo-degradable and oxo-biodegradable plastics. While the Review is said to be about oxo-degradable plastics, it is really about oxo-biodegradable plastics, and we will respond to the Review on that basis. HSAC say "it is not clear if such terms have been standardized" but they ought to know that they have in fact been standardized.

"Oxo-degradation" is defined by CEN (the European Standards authority) in TR15351 as follows:

"degradation identified as resulting from oxidative cleavage of macromolecules." This describes ordinary plastics, which abiotically degrade by oxidation in the open environment and create microplastics, which do not become biodegradable except over a very long period of time. No Standard has been written for measuring the degradation of these plastics.

By contrast, "oxo-biodegradation is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic degrades by oxidation (which is accelerated by a catalyst) until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature. These plastics are tested according to ASTM D6954, BS 8472, and comparable standards.

HSAC say that "Current commercial oxo [bio]degradable plastics appear to be largely related to single-use polyethylene and polypropylene packaging, and agricultural films. This is correct. As to agricultural films, see below.

HSAC continue "Within the parent material are embedded what are known as prodegradants which appear to be chiefly metal-organic complexes which help catalyse light and heat stimulated fragmentation of the polymer sheets" – Why did HSAC not ask us, instead of trying to guess? The prodegradants are usually salts of manganese or iron which catalyse the natural process of oxidation, which in turn reduces the molecular-weight. They are put into a masterbatch which also contains stabilisers, and the skill in formulating the masterbatch is to achieve the right balance between the two ingredients so as to give the finished product a suitable shelf-life and service-life.

HSAC say "It would seem that temperatures above 40 °C are necessary for the heat activated reaction to be effective (Bonhomme et al., 2003). This is not correct, and the cited work does not make that claim. If this were true we would never see degradation outside the laboratory and this is clearly not the case. Bonhomme et al use several temperatures to evaluate degradation in order to determine degradation rate at ambient conditions (this is the Arrhenius approach - by measuring the rate at different temperature you can determine how temperature effects the rate of reaction). They observed degradation even in the samples stored at 5 and 20C.

HSAC say that "a demonstration of degradation, or biodegradation being underway can be reported as an increase in carbonyl groups, a reduction in tensile strength, a reduction in molecular weight, additional CO_2 being generated or by the presence of microorganisms within the plastic structure itself (Table 2). These signals of partial degradation are different to the demonstration of the complete loss of the parent material."

Yes, this is obvious. Just showing a carbonyl peak in FT-IR, or that a material has reduced tensile-strength, is useful, but not determinative. However, since sufficiently low mw oligomers are known to be biodegradable, biodegradability can be shown by demonstrating conversion of the material to molecular weights less than 5,000 g/mol.

HSAC say that "Although this fragmentation into smaller and smaller plastic particles should be a helpful precursor to biodegradation, this has rarely been observed in a convincing manner outside laboratory conditions." HSAC will know that the EN13432 standard for "compostable" plastic requires biodegradation to be tested in a laboratory (not in a compost heap) but they seem to expect oxo-biodegradable plastic to be tested in outdoor conditions. This has been done in the

Oxomar project, sponsored by the French Government at their marine facility in the South of France. https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf

This was a three-year interdisciplinary study, and the scientists said in their report that "The goal of this task (C3Task2) was to evaluate the biodegradation of OXO-bio in marine waters. This task has been divided in two parts by (i) following several months of OXO-biocolonization by marine microorganisms under natural conditions and (ii) by evaluating the biodegradability of OXO under natural conditions as compared toa cultivated microorganism with known PE-biodegradation abilities."

In conclusion they 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." See also the report from Queen Mary University 11th February 2020. https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf Para 2.6 says "prior to testing, samples of LDPE and oxo-LDPE were surface-weathered in sea water for 82 days, undergoing natural variations in sunlight and UV intensity

"As to the correlation between laboratory tests and the real world, the evidence of Dr. Graham Swift, (Vice-chairman of the relevant Technical Committee at ASTM) is as follows: "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." https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

HSAC is incorrect in saying that "fragmentation into smaller and smaller plastic particles" is the precursor to biodegradation – the precursor is the reduction in molecular weight, which converts the plastic into monomers and oligomers with little or no tensile strength, so they fall apart.

If oxo-biodegradable technology merely caused fragmentation it would be much less useful, and the relevant Standards – ASTM D6954; BS8472; AFNOR T81-505; UAE 5009/2009; SASO 2879 etc would not include tests for biodegradation.

The process is described by Professor Ignacy Jakubowicz as follows: "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." https://www.biodeg.org/wp-content/uploads/2020/05/Reply-to-Ellen-MacArthur-Foundation-from-Prof-Ignacy-Jakubowicz-21-8-17.pdf

It is possible to test for degradation in the natural environment, and it has been "observed in a convincing manner outside laboratory conditions" for example in seawater in the south of France as noted above. It is then a simple matter to measure the molecular-weight of the degraded residue. It follows that if the molecular weight is c5,000 or less the material is biodegradable.

Table 2 in the HSAC Report shows a very simplified version of test results. Each study uses different materials and different methods, and has different objectives. A lot of time and money has been spent to tell us that oxo-biodegradable plastic doesn't meet the composting standards, which it is not designed to do. In fact, there are many reasons why even the industrial composters themselves consider that plastics marketed as compostable are not useful. https://www.biodeg.org/subjects-of-interest/composting/

There is in this HSAC Report an over reliance on simply putting samples outside, which is intuitively more pleasing but is no substitute for scientific evidence obtained in a laboratory. The cited studies are taken at face value - for example we know that O'Brine and Thompson did see advanced degradation (if you look at the data and not their conclusions) - and only trivial chemical analysis of the samples was done - only a qualitative FT-IR scan.

Yashchuk (2012) was a test on composting of film exposed for only a short time (96 hours UV). We would not expect enough degradation to see any significant results.

HSAC say "There is no guarantee that oxo (bio)degradable plastics would receive the necessary pre-treatment of light and heat to start the fragmentation process." In fact, UV light and heat will accelerate the process but elevated temperatures are not necessary, and only a short exposure to uv light is required to inactivate the stabilisers in the masterbatch. As oxo-biodegradable technology is intended for plastics which escape into the open environment as litter, it is most unlikely that they will not receive the requisite exposure to sunlight. In the hypothetical event that they did not, the performance of the plastic would be no better and no worse than ordinary plastic.

Thereafter, the performance of oxo-biodegradable plastic is quite different from photo-degradable plastic. Photo-degradable plastic requires continuous exposure to sunlight, but oxo-biodegradation will continue even in the dark.

HSAC say "There is no guarantee that discarded oxo-degradable plastics will receive sufficient light and or thermal pre-treatment before they enter waste disposal systems to facilitate degradation." However, oxo-biodegradable plastics are not intended for waste-disposal systems – they are intended to biodegrade if they get into the open environment from which they cannot realistically be collected.

A report was published in 2017 by the Ellen MacArthur Foundation and endorsed by some of the world's largest producers of the very plastic packaging which is polluting the oceans. It was also financially supported by companies who market plastic as "compostable" who see oxo-biodegradable plastics as a threat to their market-share. The Report claimed that "oxo-degradable" plastics [sic] simply fragmented into tiny pieces of plastic - but having engaged with our scientists they no longer say that.

They now admit in their May 2019 report that oxo-biodegradable (which they still incorrectly describe as "oxo-degradable") plastics are manufactured so that they can degrade faster than conventional plastics and that **they do become biodegradable**, but they say that "it is not yet possible accurately to predict the duration of the biodegradation for such plastics."

Any such prediction depends on factors which are variable in the open environment, and for that reason a broad indication only can be given as to timescale. It is however possible to say with certainty that at any given time and place in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item (Queen Mary University say 90 times faster- https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf)

That is the point. - Do we want ordinary plastic which can lie or float around for decades (HSAC say 300-500 years) or oxo-biodegradable plastic which will be recycled back into nature much more quickly? Of course, we don't want plastic in the environment at all, but that is not the present reality.

Will it fully biodegrade? It is well known that plastic whose molecular weight has been reduced is much more capable of biodegradation than ordinary plastic, and we have heard no reason from any scientist why, once degradation has commenced, it should not continue until the material has become biodegradable and biodegradation is complete. Even if it did not fully biodegrade it would be better than ordinary plastic, which would not have biodegraded at all.

It is not important how long a particular piece of plastic in a particular place will take to biodegrade – the importance of oxo-biodegradable technology is that it will reduce the overall burden of plastic in the environment.

HSAC say "There is very little helpful literature available either on long-term field trials of biodegradation or ecotoxicity tests on a range of organisms for these plastics." With regard to eco-toxicity tests, oxo-biodegradable plastics are tested according to the OECD Standards, and are non-toxic. The industry Standards for oxo-biodegradable plastic such as ASTM D6954 or BS 8472 require that the standard ecotoxicity tests be performed, and the results will be found in the reports of the independent test houses who have tested according to those standards. These are not usually published, because they are very expensive and are commercially confidential. They could however have been made available to HSAC if they had asked. The ecotoxicity tests are essentially the same as those performed on bio-based plastics according to ASTM D6400 or EN 13432.

HSAC say "It should be noted that in a review of the relative risk of 71 different chemicals found in Britain's rivers, Cu came 1st (highest danger), Mn came 7th, Fe came 8th and Ni 12th in terms of risk (Johnson et al., 2017). Consequently, the dispersion of more of these metals into the environment, particularly if they were to enter water courses would be unwelcome." Oxo-biodegradable masterbatches are usually based on Fe or Mn, and do not contain any substances in excess of the limits permitted by Art 11 of the EU Packaging Waste Directive 94/62/E or Annex A.1.2 of EN 13432.

The ecotoxicity tests are done with a much higher concentration of oxo-bio plastic than would be present in the environment.

With regard to "field trials of biodegradation" see the Oxomar report above.

The relevance of oxo-bio technology to agricultural films is that if farmers use ordinary film it will not degrade when they want it to degrade, and when they harvest their crop they will have to remove acres of contaminated plastic from their fields, which is time-consuming and therefore costly work. It cannot be burned or sent to landfill, but in some areas it may be collected for recycling.

Recycling is not however a good option, because if the film has been exposed to sunlight in the fields it will have degraded to the point where it is no longer fit for recycling, and it will also be contaminated with soil and/or organic matter. Also, collection for recycling attracts very large vehicles to country lanes, causing congestion, pollution, damage to the roads, and possibly danger of accidents. Also, the recycling process is expensive and complicated, and the resulting product is of lower quality than what you put in. There are no carbon-reduction benefits. You transport it around, then you have to wash it, then you have to chop it up, then you have to re-melt it, so the collection and recycling itself has its own environmental impact.

A better option for farmers and growers is to use oxo-biodegradable plastic, so that the plastic will degrade at the appropriate time, and can be ploughed into the soil where it will be consumed by naturally-occurring bacteria and fungi. This should be a reasoned exception to the circular economy idea. Symphony Environmental Technologies Plc has conducted successful field trials , and is able to supply a suitable product. https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf

The type of plastic marketed as "compostable" is not suitable for agricultural mulch films because the degradation time cannot be programmed, the material is not strong enough, it is too expensive, it does not properly biodegrade outside the special conditions found in an industrial composting unit, and it does not convert into compost.

HSAC say “Although there is worldwide concern over microplastic pollution of the environment, it remains the case that lethality to wildlife is more closely associated with large and intact plastic material.” This is correct, so it is highly desirable that the dwell-time in the environment of plastics as macro-plastic should be as short as possible.

HSAC then say “a plastic which disintegrates more readily, may be at odds with the current strategy of controlling losses to the environment.” Yes, all plastics, whether biodegradable or not should be collected and properly disposed of, but if an item of oxo-biodegradable plastic has not been collected during its useful life it probably never will be. It is not realistic to expect that all the plastic will be collected, and there is currently **no policy for the plastic which is not collected**. The policy should be to use oxo-biodegradable technology, which is available now, at a very low cost.

RECYCLING

HSAC then say that oxo-biodegradable plastic might compromise the quality of recycled plastics.

As to recycling, see https://www.biodeg.org/subjects-of-interest/recycling-2/

It is well known that plastics marketed as “compostable” will compromise the quality of recycled plastics, but they are not rejected by policymakers for that reason.

Plastic cannot of course be recycled unless it is collected, and oxo-biodegradable technology is intended for plastic which does not get collected. Even if the plastic can be collected, Greenpeace reported in October 2022 https://www.greenpeace.org/usa/reports/circular-claims-fall-flat-again/ that “mechanical and chemical recycling of plastic waste fails because plastic waste is extremely difficult to collect, virtually impossible to sort for recycling, environmentally harmful to reprocess, often made of and contaminated by toxic materials, and not economical to recycle.”

Any objection to oxo-biodegradable plastic, on the basis that it might contaminate a post-consumer waste stream, is clearly inapplicable if the relevant waste plastic is not going to be mechanically recycled. See the video at https://youtu.be/NLkfpjJoNkA which explains why recycling of most types of plastic makes no sense in economic or environmental terms.

Also, the presence of pro-oxidants is not important if the recyclate is to be used for short-life products such as carrier bags, garbage sacks, or general packaging, where biodegradability is desirable.

Whilst almost all pre-consumer waste (eg factory offcuts whose composition is known) is recycled, almost all post-consumer waste plastic is not. There are reasons for this, one of which is that a great deal of water is needed to wash post-consumer waste to make it useable, so the amount of waste-water generated is enormous. Moreover, this process leaves prodigious quantities of dirty solid waste, including biological waste that is hazardous and highly undesirable.

The recycling charity RECOUP says (“Recyclability by Design”) that “where plastic products are particularly lightweight and contaminated with other materials, the energy and resources used in a recycling process may be more than those required for producing new plastics. In such cases recycling may not be the most environmentally sound option.” It is too costly in financial and environmental terms to collect it, transport it, sort it, bail it, store it, and then reprocess it, and that is why it was being dumped in the forests in Asia. These are exactly the kind of products for which oxo-biodegradable technology is used.

By contrast, PET bottles are worth collecting for recycling, but oxo-bio technology is not compatible with PET and will not be found in PET bottles.

Mechanical recycling is not relevant to oxo-biodegradable agricultural film, because the intention is that it should biodegrade on the farm, where it will be organically recycled back into nature.

Users of recyclate cannot in any event assume that the recyclate does not contain pro-oxidants even if oxo-biodegradable plastic is not present. Conventional plastics may contain pro-oxidant additives that were added for different intended functionalities. For example, colorants in general can act as pro-oxidants. If they partake in the creation of radicals or reactive oxygen species, such as singlet oxygen (1Δg), they can trigger photo-degradation of the polymer matrix." Conventional plastic products have been found to regularly contain Fe, Ba, Ti, Zn, Cu and V. Some individual conventional plastic bag samples also contain Cr and Pb.

HSAC themselves say "This abiotic degradation mechanism is well known by the manufacturers and, ironically, it is common for plastics to contain additives to reduce propensity for this form of degradation. To this end, antioxidants are added to slow down abiotic degradation."

Long-life products such as damp-proof membranes are normally made from virgin polymer, but if recycled material is used for lower-grade products it would have to be stabilised anyway, as advised by the Austrian specialist laboratory TCKT in para. 1 of its March 2016 report. http://www.biodeg.org/TCKT%20Report%2017.3.16(1).pdf The experts say "long-life films should be made with virgin polymer, or be stabilized to deal with loss of properties caused by the recycling process, whether or not any pro-degradant additive is present. Such stabilization would effectively neutralize the effect of any pro-degradant additive."

Although oxo-biodegradable plastic is used for low-value items which are not worth recycling, the experts in Austria (TCKT Report para. 4) and South Africa (Roediger Report May 2012 page 3 http://www.biodeg.org/ROEDIGER%20REPORT%2021%20May%202012.pdf) have confirmed that plastic products made with oxo-biodegradable technology may be recycled without any significant detriment to the newly formed recycled product.

This accords with the experience of OPA members who have recycled many thousands of tons of oxo-biodegradable plastic over the past 20 years without any adverse effects.

The best way to deal with contaminated post-consumer plastic film is to send it to modern, non-polluting, thermal recycling facilities and to use the energy released from the plastic to generate electricity, instead of wasting it by sending to landfill.

EUROPEAN UNION

See https://www.symphonyenvironmental.com/eu-court-case-update/

CONCLUSION

In 2019 an independent review of the scientific evidence was conducted by Peter Susman QC at the request of Symphony Environmental and concluded that:

- oxo-biodegradable technology does facilitate the ultimate biodegradation of plastics in air or seawater by bacteria, fungi or algae, within a reasonable time, so as to cause the plastic to cease to exist as such, far sooner than ordinary plastics, without causing any toxicity; and
- the benefit is obvious of reducing future contributions to the scourge of plastic pollution of land and sea"

See also the paper published subsequently by Queen Mary University London noted above.

The OPA is satisfied on the scientific evidence that under normal conditions in the open environment oxo-biodegradable plastic will degrade and then biodegrade significantly more quickly than ordinary plastic, and the dwell-time of plastic in the environment will be significantly reduced. For that reason ordinary plastic should be replaced with oxo-biodegradable plastic as soon as possible.

HSAC also say:

- “we only appear to have evidence on the fate of oxo-degradable [sic] plastics containing metal-based complexes and not for those with organic prodegradants. It is not clear if organic prodegradants are present in commercial products.” OPA members use metal salts, usually of manganese or iron, and we are not convinced of the efficacy of organic prodegradants.

- “It would be useful to know if the incorporation of biodegradation promoters such as cellulose or starch offer benefits to the biodegradation of polyolefins.” The OPA does not think it does. They may cause the plastic item to fragment, but we are not convinced that they cause the plastic itself to biodegrade.

COMMENT BY SYMPHONY ENVIRONMENTAL TECHNOLGIES PLC

-on-

S.Devalla May (2022), Review Of Evidence On Oxo-Biodegradable Plastic Products, The James Hutton Institute

This report does not justify any ban 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 therefore is whether oxo-biodegradable plastic is better for the environment than conventional plastic, but the author does not evaluate the impact of conventional plastics at all.

As oxo-biodegradable plastic is intended to replace ordinary plastic, we have prepared the following comparison.

Ordinary Plastic	**Oxo-biodegradable plastic**
Fragments rapidly into microplastics when exposed to weathering.	Converts into a waxy substance which is biodegradable
Can persist in the environment for many decades	Will be biodegraded and removed from the environment up to 90 times faster.
Can be recycled without separation	Can be recycled without separation https://www.biodeg.org/subjects-of-interest/recycling-2/
Cannot be composted	Proved to biodegrade in compost in accordance with ISO 14855 However, sending any kind of plastic to a composting facility is not desirable. See

	https://www.biodeg.org/subjects-of-interest/composting/
Strong, printable and sealable, with excellent optical properties	Strong, printable and sealable, with excellent optical properties
Inexpensive	Little or no extra cost
Made from a by-product of oil and gas, which used to be wasted	Made from a by-product of oil and gas, which used to be wasted
Can be made by manufacturers in Scotland	Can be made by manufacturers in Scotland
Fit for purpose even when wet	Fit for purpose even when wet
Re-usable during its useful life	Re-usable during its useful life

Accordingly, oxo-biodegradable plastic should be encouraged and mandated for all short-life plastic products - and should not be banned.

Comment	Section / Page	Text	Comment
1	Exec. Summary; pg. 2	"Evidence gathered from literature shows that **there is no difference between** Oxo-biodegradable and oxo-degradable plastics. Both oxo-degradable and oxo-biodegradable plastics are terminologies that have been used to describe those conventional plastics (e.g., polyethylene) that contain 'Prodegradant' additives which aid in (catalyse) the degradation of the end-of-life plastic products by incorporating oxygen from atmosphere. The most commonly used commercial additives are transition metal salts."	"Oxo-degradable" and "oxo-biodegradable" plastics are distinguished by the abiotic and biotic processes of degradation. These are scientifically ascertainable and do not depend on definitions written for commercial or political purposes. The processes have been scientifically defined by the European Standards Organisation, CEN in TR15351, and it is not therefore correct to say that these terms have not been standardised. **"Oxo-degradation"** is defined by CEN as "degradation identified as resulting from oxidative cleavage of macromolecules." It is widely accepted that conventional plastic meets the definition of "oxo-degradable" because it undergoes oxidation in a short period of time (most obviously under the influence of sunlight, and/or elevated temperatures during processing or exposure) which is sufficient to result in fragmentation but not enough to result in significant biodegradability. This occurs due to the composition of the polymer, structural defects in the polymer, and/or the presence of impurities, [1–9].

			We know of no manufacturer who puts prodegradant additives into plastics and markets them as "oxo-degradable." There would be no demand for such plastics if they simply fragmented, and this terminology has therefore no relevance in the real world. "Oxo-degradable" is a political definition used by those who do not wish to admit that oxo-biodegradable plastics are biodegradable. Political definitions are not however relevant to the scientific question whether oxo-biodegradable plastics are better for the environment than conventional plastics. **"oxo-biodegradation** is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This refers to a substance, material or composition which undergoes degradation via an oxidative chemical mechanism, to such an extent as to result in substantial biodegradability in a significantly shorter timescale, promoted by an intentionally-added prodegradant. [10] The material then undergoes biotic processes, known as biodegradation. The polymer degradation is not occurring "….by incorporating oxygen from atmosphere…." The oxygen is attacking the polymer backbone through a radical mechanism and the pro-degradant catalyst is greatly accelerating the degradation process by quickly breaking down the hydro-peroxides formed during the process. The addition of oxygen (as organic functional groups) in the shorter chain molecules is the chemical transformation/result of the degradation process and not the "mechanism" The studies cited by the author in footnotes 9 and 34 correctly refer to oxo-biodegradable plastic as oxo-biodegradable plastic. The author consistently uses the term "biodegradable" which is a confusing and non-scientific term. We do not know what he means but we are guessing tat he is referring to the type of bio-based plastic marketed as "compostable."
2	Exec. Summary; pg. 2	The environmental impact of oxo-biodegradable plastic products is substantially affected by the **rate of degradation** in a specified environment (e.g., open-air, composting, landfill). The rate of	This is true for ordinary plastics. It is well documented that the rate of degradation of ordinary plastic can be increased by use of an effective prodegradant additive system, so that degradation proceeds much more quickly to the point where significant biodegradation is possible.

		degradation is dependent on several factors related to weather, soil and microbial conditions and is not easily predictable based on laboratory testing conditions alone as specified in most degradation testing standards. **Complete degradation of oxo-biodegradable plastic products** specific to the Scottish climate conditions (e.g. wet, colder, soil microbial activity) has not been proven so far. Slower rates of degradation are expected in colder Scottish climatic conditions leading to fragments/microplastics pollution. Since oxo-biodegradable plastics have been primarily designed to degrade in open-air (where there is oxygen availability), sustainable **end-of-life options** such as composting, recycling, landfill are ambiguous.	The report conflates abiotic degradation and microbial biodegradation, and fails to note the difference between the two clear phases of the process. For example: the soil and the microbial conditions are of no importance in abiotic degradation. The microbial conditions are relevant only to the second or biotic phase, and microbes are always available in the open environment. Use of prodegradant catalyst should not be confused with and is not intended to be a disposal route for plastic products. Plastics with prodegradant additives are intended to be used and disposed of in the same way as ordinary plastic via the established disposal routes, and are perfectly compatible with a circular economy. If all the plastic were disposed of via the established disposal routes there would be no need for oxo-biodegradable technology, but this is not the case, and litter is the main reason for public concern about plastic Degradation of conventional plastics in the environment already occurs and is the cause of most of the microplastics being found today. They are not caused by the use of intentionally-added prodegradant systems. The partial degradation of conventional plastic results in fragmentation, which in turn makes it difficult or impossible to collect the plastic from the environment. The purpose of oxo-biodegradable technology is therefore to mitigate the impact of littered plastics and their fragments where waste management fails to collect and process them, by significantly reducing their persistence in the environment. Successful use of prodegradant additive systems increases the rate of abiotic degradation, resulting in significant increase in biodegradability in a much shorter time period than conventional plastics. Once initiated the abiotic degradation of an oxo-biodegradable plastic will continue in the absence of light. Heat and light will accelerate the process but they are not essential. The abiotic phase has been tested in the environment at Bandol in France, but it is necessary to test the biotic phase in a laboratory to be able to assess the C to CO_2 conversion. Also to test for eco-toxicity. **The biodegradation of "compostable" plastics according to EN13432 or ASTM D6400 is tested in a laboratory, not on a compost heap.**

			Oxo-biodegradable plastics are tested according to British Standard 8472 or the American Standard ASTMD6954, as to which see https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf Complete biodegradation in a short time-frame is clearly desirable, and oxo-biodegradable plastics have been designed with that in mind. **92.74% biodegradation has been proved by Intertek in 180 days** and we have heard no reason why once initiated the process should not in practice proceed until biodegradation is complete. In theory, abiotic degradation would cease if deprived of oxygen, which is possible deep in a landfill, but degradation of plastic is neither necessary nor desirable in landfill. This is because the plastic has been responsibly disposed of, and because biodegradation in anaerobic conditions would generate methane. (This is what happens if "compostable" plastic gets into a landfill). In theory, biotic degradation would cease if deprived of bacteria, but this will not happen in the open environment. No special bacterial strains are necessary, and bioassimilation by commonly occurring bacteria such as *Rhodococcus rhodochrous and Alcanivorax borkumensis* has been proved. The abiotic process (for oxo-biodegradable and conventional plastics) might be slower in Scottish conditions than in a uniformly warm sunny climate, 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**. This is very different to the use of plastic marketed as compostable, where collection, sorting and diversion to industrial composting facilities is a necessary and intentional part of its life cycle. Oxo-biodegradable plastics are not marketed for composting, although they have been proved to biodegrade in composting. We do not in any event agree that composting of any kind of plastic is a sustainable end of life option, and **plastics should not be accepted by composting facilities.** See https://www.biodeg.org/subjects-of-interest/composting/ "Compostable" plastics are not suitable for recycling or landfill or composting, and the fact that they have any place in the market at all is due to aggressive marketing and lobbying by large companies, whose lobbyists have almost certainly been seeking to influence the Scottish government.

3	Project objectives, Par 1 (a). Pg.4	"The most common commercial Prodegradant additives are transition metal salts."	Prodegradant additives are not sold alone. They are one of the components of a Masterbatch, which typically includes the following main components: • Prodegradant catalyst / degradation promoter – this may include one or a blend of several organic salts of transition metals. They are not heavy metals. • Stabilizers – to preserve or enhance the stability of finished products during processing, shelf/service-life and to facilitate use, reuse and recycling. • Mineral fillers/extenders (where appropriate) • Carrier resin These additives are designed, not only to accelerate degradation/biodegradation when discarded as litter, but will also - by the contribution of stabilizers– enhance indoor stability (shelf-life) and preserve the polymer for/during recycling.
4	Project objectives, Par 1 (a). Pg.4	"Evidence gathered in this study has shown that when transition metal salts containing additives are added to conventional polymers, **such plastics have been referred to as both OD or OBD plastics, in several academic publications**." They are both made from conventional polymers, usually polyethylene & polypropylene, both use transition metal salts as additives, are designed to degrade in the open environments and involve same degradation mechanisms as evidenced from several journal papers/articles [8, 5 9, 13, 20, 21, 22, 23]. Use of prodegradants is an old technology [7] that has gained commercial significance more recently.	The metal salts do not contain additives – they are components of the Masterbatch. As to definitions see item 1 above. As mentioned above in item 1, oxo-degradation occurs in conventional polyolefins and vinyl polymers (PE, PP, PS, PVC, PET) and may be further promoted by modification/use of a polymer which naturally degrades, or by modification of the polymer - as in the case of ethylene carbon monoxide co-polymers. It is correct that oxo-biodegradation of plastic is not a new technology. It dates from the 1970's but has attracted attention in recent years due to increasing public concern about plastic in the environment – which it is designed to mitigate.

5	Project objectives, Par 1 (a). Pg.4	Salts of transition metals such as iron, cobalt, manganese are added typically at concentrations in 1–5 % range by weight and the plastic blends are then processed using standard production processes (extrusion, casting, injection moulding and blow moulding).	Incorrect. The 1-5% addition rate refers to the addition-rate for a masterbatch, of which the salts are only one component. See item 3 above. The Masterbatch is typically added to the polymer @1%, so the addition-rate of the salts themselves is in the order of 0.001%. This means that the amount of catalyst potentially released in the environment is at least 100 x times lower than the author suggests.
6	Project objectives, Par 1 (a). Pg.6	DEFRA (http://sciencesearch.defra.gov.uk/)- Oxo-degradable plastics are made of petroleum-based polymers (usually polyethylene) which contain additives (usually metal salts), that accelerate their degradation when exposed to heat and/or light. The plastics are fairly common in the market, being used in a range of applications including carrier bags, packaging and agricultural films. *Oxo-degradable plastics are often marketed as being 'degradable', 'bio-degradable' or 'oxo-biodegradable'*; implying a reduced environmental impact at the point of disposal compared to plastics without the additive.	See items 3-5 above for the distinction between an additive and a masterbatch. As mentioned in item 2 heat and light will accelerate the process but they are not essential. Oxo-biodegradable is not the same as photo-degradable. As to definitions see item 1 above. As to reduced environmental impact see item 2 above
7	Project objectives, Par 2. Pg.6	Various definitions for OBD plastics are quoted below from EU SUP Directive, European Committee for Standardisation CEN/TR 15351, academic publications and manufacture websites. Although the CEN/TR 15351 gives separate definitions for OD and OBD plastics, there is no mention or discussion	As to definitions see item 1 above.

		about polymer backbone and type of additives. *For the purposes of this report, both OD and OBD plastics are used to describe those conventional polymers that contain additives ('pro-degradant'- most commonly used are salts of transition metals) resulting in a two-stage degradation mechanism.*	
8	Project objectives, Par 2. Pg.7	There is no separate definition for OBD plastics. However, in the EU SUP Directive, OD plastics are defined as: "*plastic materials that include additives which, through oxidation, lead to the fragmentation of the plastic material into micro-fragments or to chemical-decomposition*". Point 15 in the Directive further describes oxo-degradable plastic as that type that "*does not properly biodegrade and thus contributes to microplastic pollution in the environment, is not compostable, negatively affects recycling of conventional plastic and fails to deliver a proven environmental benefit*".	This definition (in Art 3(3) of the SUP Directive) is a political definition which does not distinguish oxo-biodegradable plastics from conventional plastics, which undergo oxo-degradation in the environment as a result of the presence of additives added for purposes other than the intentional use of a prodegradant system, or additives which are present as a result of their manufacturing process. [2,8,9] Recital 15 does not apply to oxo-biodegradable plastic because: (a) It does properly biodegrade, but conventional plastic does not. See eg Oxomar https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf (b) It does not contribute to microplastic pollution, but conventional plastics do. However, "Compostable" plastics also create microplastics, which are then spread on land used for food-production. See below. The European Chemicals Agency (ECHA) stated on 30.10.18 that they were not convinced that microplastics are formed. Dr, Swift (see item 17 below) has testified that "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." (c) Oxo-biodegradable plastic is compostable, but conventional plastic is not. However, oxo-biodegradable plastic is not marketed as compostable, and non-compostability would not be a reason for any ban. Composting of plastic is not "recovery" because it is required to

			convert into CO_2 gas within 180 days. That is not recovery, it is wastage, and we do not believe that plastic of any kind has any role to play in the composting process, even for transporting compostable material to a composting facility. A target that 100% of all plastic packaging is to be recyclable *or compostable* by 2025 is therefore misconceived. https://www.biodeg.org/subjects-of-interest/composting/ (d) It does not negatively affect recycling. https://www.biodeg.org/subjects-of-interest/recycling-2/ The stabilization package in the oxo-biodegradable masterbatch is designed to allow the re-use and recycling of the product. It is designed to biodegrade if waste-management fails and it gets into the open environment as litter. It is not disputed that "compostable" plastic will contaminate a normal post-consumer recycling stream, so if the Scottish Government is concerned about recycling it should ban "compostable" plastic. (e) It does deliver a proven environmental benefit, but neither conventional nor "compostable" plastic does. See item 2 above. In any event failure to provide a benefit might be a reason not to use it, but would not be a reason for a ban.
9	Pg.8.	Mulching films, used in agriculture to improve crop yield, has been reported to be a significant potential source of microplastics to the terrestrial environment [47].	This reference is to the use of conventional plastics for mulching films, and makes no mention of prodegradant systems [11] The use of prodegradant systems is not the cause of microplastic formation; rather, their use is intended to mitigate the environmental impact of microplastics. For this reason oxo-biodegradable mulching films have been designed and tested https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf and they are being successfully sold by a company in Ireland. Yes, they are usually manufactured on demand because they have to be customized for the requirements of the particular crop.
10	Pg. 10	OBD plastics degrade (including biodegradation) at a faster rate	90x faster refers to the rate of biodegradation after equivalent exposure of conventional and oxo-biodegradable LDPE.

		compared to conventional plastics. According to a recent study published by researchers from Queen Mary University London, biodegradation of OBD Low-Density Polyethylene (LDPE) was found to be 90 times faster than LDPE (without additives) under artificial UV aging conditions [9].	The report confirms that oxo-degradation results in a substantially increased rate/extent of (oxo-)biodegradation brought about by use of the prodegradant system. It should be noted that the conventional film undergoes substantial (oxo-)degradation, albeit to a lesser extent than the equivalent product with the prodegradant masterbatch. This confirms that the use of a prodegradant system is not the fundamental cause of (oxo-)degradation but is able to increase its extent, and as a consequence increase the total mineralization, i.e. (oxo-biodegradation) of the material.
11	Pg. 10	However, it is the rate of degradation in a specific environment i.e., the length of time for completion of degradation, which is important.	Yes, but the important point is comparison with ordinary plastic. In the same environment the oxo-biodegradable plastic will be bioassimilated very much more quickly than the ordinary plastic. The study shows, that for any given length of exposure, the oxo-biodegradable material shows a greater extent of oxidative degradation than the equivalent conventional material.
12	Pg. 10	The longer an OBD plastic product remains in a given environment, the greater chance of increased environmental impact (such as through the persistence of small fragments/microplastics). It has been reported that, to achieve significant biodegradation in a ‘reasonable' time period, the fragments from first stage of degradation should be sufficiently small (<5000 Daltons) so that microorganisms can use the fragmented molecules as food [7, 13, 15].	This is true for conventional plastics, and the longer their dwell-time in the environment the greater their environmental impact and the greater the likelihood that toxins will adhere to them, in particular because their degradation is strongly dependent on sunlight. Therefore occlusion from sunlight after fragmentation results in their persistence in a partially-degraded state as microplastics[1,3,4]. The use of a prodegradant additive system not only accelerates the oxidation of polymers during sunlight exposure, but by catalysis of degradation mechanisms which normally require sunlight, is able to facilitate the continued degradation of plastics with or without sunlight, to the point where the molecular weight is reduced to c5,000 and the material is biodegradable. This removes the dependance on sunlight which causes conventional plastics and their fragments to accumulate for a very long time [12–14]. Where oxo-biodegradable plastics are used in place of conventional plastics, the impact on the environment is reduced by the proportionate increase in biodegradability of the material.[15]

14		OBD products are designed to degrade in open-air environments [41]. Many OBD products are low value products (single-use bags), often contaminated with biological matter, thus not permitting **re-usability**. Due to this contamination, post-consumer **recyclability** is also not practical or economically viable. Pre-consumer recycling is more feasible. However, there are concerns that presence of OBD additive-containing plastics alongside regular plastics could affect the quality and marketability of the resulting products, such as those requiring long life (e.g., damp-proof membranes) [46]. It has been reported that significant slower rates of degradation are expected in **landfill** due to prevailing anaerobic conditions if buried below the surface [20], even if degradation is initiated in the upper layer and would continue, as manufacturers claim [24]. Inherent heterogeneity of waste in landfills also increases the complexity of the biodegradation process [25]. Additionally, the UK is restricting the amount of waste going to landfill and seeking to adopt a more circular economy approach [5].	It is correct that many products for which oxo-biodegradable technology is used are low value products (eg single-use bags), often contaminated with biological matter, thus not permitting re-usability. This is the case whether the plastic is oxo-biodegradable or conventional. Yes, it is the low value and the contamination which inhibit recycling, not the oxo-biodegradability. Pre-consumer recycling includes edge trims, cut-outs and scrap which are normally recycled into the same product within the same factory, whether it is conventional or oxo-biodegradable plastic. Single use, lightweight plastics – particularly used for food use – are not widely recycled; and have a propensity for improper disposal. This is why the use of prodegradant additive systems is appropriate. If however they do get collected they can be recycled if it makes economic or environmental sense to do so, and will not compromise the quality of long-life plastics. https://www.biodeg.org/subjects-of-interest/recycling-2/ On 22nd August we wrote to the US Association of Plastics Recyclers because it was apparent to us that their position on oxo-biodegradable plastic was based on a series of fundamental misunderstandings. They have not responded. If some recyclers have created a perception that oxo-biodegradable plastic is incompatible with recycling, it is for them to change that perception. They cannot expect legislators to ban oxo-biodegradable plastic and accept the accumulation of ordinary plastic in the oceans for decades, just because recyclers are failing to correct a wrong perception. Oxo-biodegradable plastic has been successfully used for more than ten years by the largest bread producer in the western world for its bread packaging, and they encourage their customers to recycle it. Prodegradant additive systems are not intended to facilitate degradation or biodegradation in landfill, which is not necessary or desirable. Oxo-biodegradation requires oxygen, which is available in the upper layers of a landfill, but not in anaerobic environments. Plastic has a high calorific value, and we agree that it should not be wasted by being sent to landfill. The author notes that the UK is (correctly) restricting the amount of plastic waste going to landfill.

			Where plastics cannot be recycled they should be incinerated in modern, non-polluting, incinerators for energy recovery and generation of electricity - especially now that oil and gas are such expensive fuels – and this is what happens to most of the thin-film plastic packaging which gets collected. The use of prodegradant additive systems has no impact on landfill or incineration. There is no point in wasting "compostable" plastic by sending it to a composting facility where it will simply convert into CO_2 gas.
15	Pg. 11	Regarding **composting** as end-of-life option for OBD waste products, the current industrial composting standard BS 13432 timeframe (6 months; more details below) is not suitable for OBDs. Manufacturers of additives claim OBDs require longer time frames under composting conditions. However, it was found that the rate of degradation was slower in composting conditions compared to soil environment [17] including lack of completeness of degradation when using windrow composting [20].	This point is irrelevant, and the debate on oxo-biodegradable plastic has been confused by constantly referring to composting. Oxo-biodegradable plastics are not intended or marketed for composting, and we do not think that plastics of any kind have any role in the composting process. See item 2 above and 24(b) below . There is actually a need to ban plastics which falsely claim to be compostable and biodegradable. This is greenwashing, because **there is no such thing as compostable plastic**. This is because the relevant standard (EN13432) requires the plastic to convert into CO_2 gas (not compost) within 180 days. It is also greenwashing to call them "biodegradable," because they are tested to biodegrade in an industrial composting unit, not in the open environment.
16	Pg. 11	There is also a standard EN 17033:2018 specifically for biodegradable *mulch films,* but no evidence was available on OBD compliance to this standard. A very brief discussion is provided below for some of the relevant standards for soil environments [10]. Although testing to these Standards follow a 3-tier methodology, not all the details are given below (e.g., ecotoxicity part of assessments). For more detailed	ISO 17033 does not replicate conditions in the real world, because it prohibits the exposure of films to UV or heat, prior to measuring biodegradation. The exposure of agriculture mulch films to sunlight during their service life is obvious, necessary, and inevitable. Oxo-biodegradable plastics are tested to prove non-toxicity according to ASTM D6954 or BS8472 and the OECD ecotoxicity standards, and have been proved to be non-toxic to plants, daphnia, fish, and earthworms.

		information, please refer to published Standards.	
17	Pg. 11	**ASTM D6954-18-** *Standard guide for exposing and testing plastics that degrade in the environment by a combination of oxidation and biodegradation* • • Not a specification; only a guidance • • *Tested temperature range: 20 °C – 70 °C (not suitable to Scottish weather conditions)* • • *Molecular weight reduction- <5000Daltons; EAB criteria-<5%* • • ≥ 60% biodegradation to be reached but timeframe to reach this level is not defined	Specifications are used to measure degradation and biodegradation under specific conditions, such as the conditions found in an industrial composting facility. Standard Guides provide scientific criteria for testing materials intended to degrade and then biodegrade in the open environment, where conditions are variable. American ASTM 6954 and British Standard 8472 are Standard Guides, and are applicable to conditions found anywhere in the world. For an explanation of D6954 by Dr. Graham Swift, one of the authors of D 6954, and vice-chairman of D20:96, which is the relevant Technical Sub-committee at ASTM see https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf He says "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." Some people make the point that that testing is in the laboratory, not in the open environment, as to which see the evidence of Dr. Swift above. It should be noted that the tests prescribed by EN113432 and ASTM D6400 for "compostable" plastics are performed in a laboratory, not in a compost heap, but nobody makes objection to those standards or those plastics on that ground. Abiotic degradation has in fact been tested in the real world, but biotic degradation and ecotoxicity can only be tested in the laboratory. Although ASTM D 6954 is not a specification it contains no less than six pass/fail criteria. 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) 20-70C refers to accelerated exposure conditions, not conditions in the open environment, which would obviously not be found in Scotland. Yes, 5,000 Daltons is the approximate molecular weight at which a polymer becomes biodegradable. The task of oxo-biodegradable technology is to reduce it to that point in the open environment much more quickly than would be the case with ordinary plastic. Yes, 60% biodegradation is required, but it is for end-users and regulators to decide what timescale after disposal they consider to be appropriate.
18	Pg. 11	**BS 13432 (ASTM D6400)-** P*ackaging – Requirements for packaging recoverable through* ***composting*** *and biodegradation – Test scheme and evaluation criteria for final acceptance of packaging* • • 90% of total theoretical carbon dioxide evolution within 6 months • • Disintegration not >10% be >2mm within 12 weeks. • • *OBD plastics do not pass this composting standard (Manufactures of OBD claim that OBD products are designed to degrade between 2 -3 years depending on product application and environment. There is no evidence yet of complete degradability of OBD products under Scottish environmental conditions*).	These Standards are irrelevant, as they relate to industrial waste treatment process, and are not intended for products which find their way into the open environment as litter. EN13432 and D6400 require 90% biodegradation for plastic which biodegrades in the special conditions found in an industrial composting facility. It does not therefore convert into compost.
19	Pg. 12	It is worth noting that manufacturers themselves acknowledge that the	Correct. The purpose of prodegradant systems is to reduce the impact of littered plastics by facilitating faster rates of degradation and biodegradation

		rates of degradation depend on the environmental conditions.	under any conditions in the open environment, as compared with the conventional plastic products which they are intended to replace.
20	Pg.12	*OXOMAR* study […]However, this study did not make any conclusions on completeness of degradation.	The conclusions of the Oxomar study are that "We have obtained congruent results from our multidisciplinary approach that clearly shows 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." The scientists used Rhodococcus rhodochrous in the study, which is a bacterium found in both the marine and terrestrial environments. The Queen Mary University study used Rhodococcus rhodochrous and Alcanivorax borkumensis https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf Oxomar did not pursue the study to the point of complete biodegradation because the Standards do not require 100% biodegradation in order to prove biodegradability. However, **92.74% biodegradation has been proved by Intertek in 180 days** (Only 90% is required by EN13432 for "compostable" plastic). Nobody is claiming that oxo-biodegradable plastic will biodegrade to a particular extent within a particular timescale under all conditions in the open environment. The abiotic process (for both oxo-biodegradable and conventional plastics) would be slower in Scottish conditions than in a uniformly warm sunny climate, but it will continue even in the dark. The key point is that it will proceed much more quickly than ordinary plastic under the same conditions. That must therefore be a much better and more reasonable timescale than for ordinary plastic. Nobody has advanced any reason why biodegradation should stop before completion. Even if it did it would still be better than ordinary plastic, which would have fragmented but not biodegraded at all. The principal purpose of oxo-biodegradable technology is to reduce the impact of littered plastics by facilitating faster rates of degradation and biodegradation

			of the plastic products, as compared with the conventional products which they displace.
21	Pg.13	A study testing six types of mulching films (2 low density polyethylene films, 2 oxo-biodegradable and 2 biodegradable) conducted in a greenhouse growing lettuce in South-east Spain showed that the degradation time of oxo-biodegradable films was longer than biodegradable films [26].	The Scottish government is not being asked to decide whether oxo-biodegradable plastic is suitable for greenhouse horticulture, they are concerned about plastic which gets into the open environment as litter. For specialist applications we work with farmers and growers to provide films which will degrade and biodegrade according to the timescale which they require, and we have done a successful trial on a farm in Wales https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf Oxo-biodegradable mulch films should easily pass the tests in EN 17033-2018,. The films tested in the study[16] referred to in item 21 are described simply as “oxo-biodegradable”. No details are given of their composition, and it is impossible to know whether those films were designed or intended for those conditions, or whether they are oxo-biodegradable at all. It is important to use the correct oxo-biodegradable masterbatch if a film is intended to be used under glass. Conventional polyolefins and Oxo(bio)-degradable plastics undergo degradation initiated by sunlight, but the glass used in a greenhouse filters out the UVA wavelength range responsible for initiating degradation. By contrast crop-based plastics typically degrade via hydrolysis, a reaction with water, which was provided by drip irrigation. Further, the method for determination of “degradation time” is not given and is presumably by visual analysis. No details of chemical analysis of the film or soil is given. This is not adequate in order to differentiate mineralization of the various plastics, which may simply fragment. In any case, since the masterbatch formulation can vary significantly, the composition of one prodegradant additive system (if one is present in the test samples) cannot be considered representative of the technology as a whole.

22	Pg.13	Gomes et al. [31] tested OBD polyethylene films in simulated soils by the action of microorganisms in accordance with ASTM G160-03 standard, following initial accelerated aging. They concluded that although biodegradation did occur, it proceeded at a 'slow rate'. Moreover, a decrease in the rate of degradation was observed after 60 and 90 days.	The study[17] involved exposing conventional and OBD plastics for a short period of time, resulting in a low level of oxidation, prior to burial in soil. As a consequence the extent of degradation was limited from the outset by the degree of oxidation that had occurred prior to burial. Oxo-biodegradable plastics are designed to mitigate the impacts of litter which are observed to be exposed continuously to air in the environment, and are not usually buried. Conventional and oxo-biodegradable plastics undergo abiotic degradation, in parallel with bacterial colonization and biodegradation[18]. The use of a prodegradant system is designed to increase the rate of oxidative degradation in order to facilitate biodegradation in a shorter period of time. For practical reasons, it is normal for oxidative degradation be allowed to continue to Mw< 5,000 g mol^{-1} prior to evaluation of biodegradation. This is because it is impractical to evaluate degradation and biodegradation concurrently, in a controlled laboratory setting or in the open environment. Studies which monitor abiotic degradation in natural environments are unable to monitor biodegradation because of sample-losses.
23	Pg.13	Based on a review of published literature from 10 years, Abdelmoez et al. [13], concluded that complete biodegradation of pro-degradant additive containing plastics remains a doubt. Other citations that evidenced lack of completeness of degradation of OBDs over different timeframes are [9, 32, 33, 35, 39, 40].	See item 20
24	Pg.13	(a) **Risks from Fragments and Microplastics:** If OBD plastic products do not completely degrade in the environment, release of microplastics was reported to be of concern [42]. Literature on the risks and environmental impacts from microplastics such as	If the Scottish Government is concerned about microplastics it needs to focus on conventional plastics, which are the source of most of the microplastics found in the environment. That is why oxo-biodegradable plastic technology was invented. It is not practicable to ban all conventional plastics, so all short-life plastics should be made with oxo-biodegradable technology, which converts the plastic into a waxy substance which is biodegradable. As to Thomas et al see https://www.biodeg.org/wp-content/uploads/2020/05/BPA-RESPONSE-TO-LOUGHBOROUGH-REPORT.pdf

		ingestion by living organisms and carriers of pollutants is an on-going field of research and is out of scope of the current study. This report focusses only on evidence of risks associated with OBD plastic products due to potential release of fragments/microplastics. Thomas et al. [23] assessed the environmental impacts from the end-of-life OBD plastics. Their study concluded that OBD plastic products are neither suitable for conventional recycling methods nor suitable for composting due to incomplete biodegradation and concern over formation of fragments in the environment. Napper and Thompson [27] found evidence of fragments and microplastics while testing the open-air degradation of OBD, biodegradable, compostable and conventional high density polyethylene bags over a 3-year period. **(b)** Contamination from microplastics and nanoplastics as a result of fragmentation of OBD and biodegradable plastics in composts was reported by Markowicz and Szymańska-Pulikowska [34].	As to Napper & Thompson see https://www.biodeg.org/wp-content/uploads/2019/04/BPA-Comments-on-Plymouth-10.pdf In 2017 the European Commission referred to the European Chemicals Agency (ECHA), the very question of whether what they called "oxo-degradable" plastic created microplastics. This led to a Call for Evidence by ECHA, who received many hundreds of pages of scientific evidence. However, ECHA produced **no dossier to support a ban**, and on 30th October 2018 they said that they were **not convinced that microplastics were formed**. If they are not convinced, then how can the Scottish government be convinced? Furthermore, on page 2 of the Annex to the Annex XV restriction report https://echa.europa.eu/documents/10162/db081bde-ea3e-ab53-3135-8aaffe66d0cb ECHA defines 'Microplastics' as: solid particles, of less than 5 mm, ….. that are ……. **non-biodegradable in the aquatic environment**. The Oxomar report shows beyond doubt that d2w plastics are biodegradable in the aquatic environment, and they do not therefore create "microplastics." "Compostable" plastics are also generators of microplastics , but there is no proposal by the Scottish government to ban them. A study by the University of Bayreuth https://www.chemeurope.com/en/news/1176729/ shows that "finished compost from composting plants contains a large number of biodegradable plastic particles. Also, applicable legal and certification standards (EN13432, ASTM D6400 etc) are not violated by the sizes and quantities of the particles detected, so this calls into question the contribution of these standards to effective environmental protection." (b) Re Markowicz et al. The aim of this study was "to assess the possibility of composting selected bioplastics (shopping bags, waste disposal bags) together with organic waste in real conditions in an industrial composting plant."

		(c) Recently, Yang et al. [36] tested different types of mulch films including bio-based and OBD, quantified in soil under simulated UV irradiation.	The study is not therefore relevant to oxo-biodegradable plastics, because they are not intended, designed, or marketed for composting, and we do not understand why the authors thought they were. Plastics marketable as "compostable" are explicitly designed for biodegradation in the industrial composting process, so they must be collected, sorted and transported to an appropriate facility. They are falsely marketed as compostable, because they do not convert into compost, and this description should be banned. This is because EN13432 and ASTM D6400 require them to convert into CO_2 gas within 180 days, not into compost. Nor should they be sent to landfill, where they will generate methane in anaerobic conditions. They are not suitable for recycling. The Markowicz study shows that "compostable" plastics will contaminate the compost. This would also be the case with conventional plastic, so **no plastic of any kind should be accepted in composting facilities.** This is supported by the study at the University of Bayreuth noted above, and by a report on 15th July 2020 in "Waste Management" Vol. 113, Pages 312-318. The conclusions were: • In many cases, plastic bags are being replaced with "compostable" plastic bags. • Industrial composting processes do not completely remove film fragments. • Compost is thus a potential source of fragments from compostable plastic bags. • Compostable plastic fragments are then deteriorated in soil to microplastics. • Compostable microplastic results in an increase number of aflatoxigenic fungi. Even industrial composters and local authorities do not want "compostable" plastics. For example, the website of Epsom & Ewell Borough Council in the UK says: "We used to ask you to use bio-liners to line your food waste caddy, but the food-waste recycling companies found that bio-liners compost down much more slowly than the food. That slowed the process and made it much more expensive. They tried dredging the bio-liners out of the food waste, but the

			sticky bio-liners got tangled around the dredging equipment. Cleaning them off was very expensive." • The City of Exeter UK has also rejected "compostable" plastic – **Click to read** • And the City of Toronto, Canada – **Click to read** • In January 2020, the industrial composters of Oregon gave 9 reasons why they did not want it – **Click to read it** • Then the SUEZ waste-management company – **Click to read** • Then a devastating exposé on Netherlands television – **Click to read** • And another TV exposé in Canada about how compostable plastics are typically not being composted but instead sent to landfill or incineration. – **Click to read** Many areas do not have industrial composting plants, and the Welsh Government has refused to invest in them. **– Click to read.** Plant based compostable plastics are therefore going to landfill rather than composting because so many local authorities are unable to deal with them. In landfill they generate methane in anaerobic conditions, and they cannot be recycled, so the only sensible thing to do with them is incineration. Oxo-biodegradation is **not a waste management process**, such as landfill, incineration and composting. In fact oxo-biodegradable plastics are designed to maximize initial stability in order to favor reuse, recycling and recovery. Rather its purpose is to mitigate the impacts of materials which escape those processes and end up in the open environment. We do not know whether the bags tested by Markowicz had been correctly made with oxo-biodegradable technology as they were not characterised before testing, and one cannot make assumptions from the logo on the bag. It would not however be surprising if oxo-biodegradable plastic did not fully biodegrade in the composting process described in the paper, because they are not intended to do so, and are not designed to comply with EN13432 or ASTM D6400. Oxo-biodegradable masterbatches do not contain heavy metals, and indeed the presence of any kind of metal salt is at a very low level, well within the prescribed limits. See item 26 below. The contaminants found in the Markowicz study would have come from the plastic, itself, and had not been introduced by the oxo-biodegradable masterbatch.

			(c) Re Yang et al. The oxo-biodegradable film was purchased from an agricultural supplier, and there is no attempt to identify or characterize the prodegradant additive system. Prodegradant additive systems can vary in their prodegradant type, combination, and concentration; as well as stabilizer type, combination, and concentration, in order to control their stability and degradation behaviour to meet the specific requirements of the application. Therefore, the tested film cannot be considered representative of all oxo-biodegradable products, and there is no indication of the specification or intended performance of the products tested. An agricultural film designed for a short-duration crop, in cooler climates (e.g. new potatoes) would vary substantially in its composition, design and performance compared to a long term crop in warmer climates (e.g. pineapple). The latter would be designed to retain its mechanical properties longer than a conventional film through the use of stabilizers, while the former should degrade to an extent that would permit biodegradation after only a few months. Conventional films, even within the same broad polymer category, (in this case classified as polyethylene), can vary significantly in their behavior according to polymer type/blend, molecular weight, degree of branching, stabilizer content, other additives, compositions and impurities. Therefore, it is unscientific to attempt to compare conventional films with an equivalent oxo-biodegradable plastic product unless the oxo-biodegradable masterbatch is added to a polymer film of identical composition and specification. The authors confirm that fragmentation of both conventional and OBD PE agri films show chemical changes, confirmed as oxidation by FT-IR spectroscopy, and that the extent of those changes correlates positively with the degree of fragmentation. This confirms that fragmentation is not simply a physical process, but is consistent with the well-understood phenomena that oxidation of the polymer results in molecular-weight reduction which in turn results in reduction in mechanical properties – and, if accelerated by use of a prodegradant catalyst, results in rapid conversion of the polymer to hydrocarbon waxes and water-soluble oligomers which are readily biodegradable. (Eyheraguibel et al http://dx.doi.org/10.1016/j.chemosphere.2017.05.137).

			Further, the observation of particles associated with the use of a pro-degradant additive system, or increased UV exposure, is consistent with an advanced state of abiotic degradation which is in turn indicative of higher rates of mineralization (QMU 2020). The authors take no account of the positive relationship between oxidation, and biodegradability of hydrocarbons, and proceed on the flawed assumption that the particles are in a final and persistent state. The authors do not notice that the primary mechanism of oxo-biodegradable technology is to facilitate the thermal oxidation of polymers, by removing the dependence on light which conventional plastics exhibit. This is achieved by replacing photo-oxidation (limited by photolysis of peroxide oxidation intermediates) by a catalyst which facilitates the process in the absence of sunlight. Kinetics are evaluated based on UV irradiance alone – the key benefit is that OBPs continue to degrade and then biodegrade after initial degradation. The authors make no attempt to evaluate biodegradation of the aged samples, nor the composition or persistence of the material in each case. They make generalized assumptions – which are without foundation - that degradation of “compostable plastics” results in biodegradation but degradation of oxo-biodegradable plastics does not: They say “However, biodegradable mulch films are mainly constructed by polyesters, wherein the molecular structures are less compact and molecular bonds are less obstinate, thereby making it more accessible and sensitive to secondary degradations and final mineralization. Indeed, approximately 80% of carbon atoms for biodegradable materials (i.e., cellulose) can be converted into CO_2 in 90 days.” This conclusion is not supported by the present study. Conversion to CO_2 in 180 days refers to industrial composting conditions – a waste management process which is not consistent with exposure in the environment, and is in any event a wasteful route for deliberate disposal of plastic, for the reasons mentioned above in items 2,8, 15 and 24 The authors fail to appreciate the key premise of prodegradant additive systems, which is that all plastics on the market which are used for agricultural mulch films are prone to degradation leading to fragmentation, in particular under the action of sunlight. Therefore prodegradant additive systems are necessary to control degradation so that in can begin at the right time and continue more rapidly and to a greater extent in order that the material can be

			removed from the environment by microbial biodegradation (mineralization); as opposed to partial degradation due to dependence on direct sunlight exposure. This results in microplastics which are persistent in a non-biodegradable state.
25	Pg.13	Formation of microplastics were confirmed in both plastic types. However, microplastics formed from OBD mulch films were more concentrated over a narrower size range (0.2 µm – 200 µm), a phenomenon attributed to additives which the authors warn, require more critical attention	We do not know the composition or the molecular weight of the residues. However, reduced size-range is consistent with an advanced state of degradation, and therefore reduced molecular weight, which is the intended precursor to biodegradability. Prodegradant systems are intended to accelerate the degradation of polymers, in order to facilitate biodegradation at an earlier time and/or to a greater extent[5,15] than would be the case with ordinary plastics.
26	Pg. 13	Due to the low levels of transition metals added to OBD plastics, there are no shorter-term concerns of toxicological impact of metals [18]. In their review of standards for biodegradable plastics, Kjeldsen et al. [14] have reported that although metals used in the additives are naturally occurring and present in small amounts, an accumulation and increase in concentration of some of these metals may be potentially toxic. For example, cobalt at higher concentrations was found to be toxic to microorganisms. Cobalt toxicity was also reported in other studies [30,31]. Al-Salem et al. mentioned that regulating the content of heavy metals is essential for a more sustainable practice [37].	It is correct that the use in oxo-biodegradable plastics of metal salts as catalysts is at a very low level (<0.005%) and is orders of magnitude less than metals, which are present in mineral fillers, pigments and catalysts. The use of elements which may cause toxicity is prohibited in oxo-biodegradable plastics by ASTM D6954 para. 6.9.6, and BS8472 para. 9. The elements most commonly used are manganese and iron. Further, for packaging in the EU no substances are allowed in excess of the limits specified in Art. 11 of the EU Packaging Waste Directive 94/62/EC. Excessive concentrations of almost anything eg table-salt, could be toxic, but this is not permitted for oxo-biodegradable plastics. There is no evidence of accumulation of metals in the environment from oxo-biodegradable plastic, even in the case of repeated annual application in a small area of much higher amounts of plastic than would be expected in the open environment (Degradable Polymers Principles and Applications, 1st Ed. G.Scott & D. Gilead, Chapman and Hall, Ch. 8.).
	Pg. 14	**(c) Greenhouse gas emissions:** Gaffey et al. [28] attributed higher Greenhouse gas emissions per kg of product to fossil-based plastics	This study has been selectively chosen. Almost every other LCA says the opposite. See eg Intertek at https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/ The very standards by which PLA plastics are tested

		compared to Bio-based plastics (such as polylactic acid, polyhydroxyalkanoate).	(EN13432, ASTM D6400 etc.) require them to convert into CO_2 gas within 180 days, and they will convert into methane in landfill, which is even worse.

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ITALIAN COURT RULING 2015 ON MARKETING OF OXO-BIODEGRADABLE PLASTIC

This was a civil case brought by Novamont against Kromabatch (a distributor of d_2w oxo-biodegradable technology in Italy), and decided by the court in Milan on 8th January 2015. The case was about the description alleged to have been applied to the product by Kromabatch, not about d_2w itself.

Novamont is a large Italian company producing vegetable-based plastics (which are claimed to comply with EN13432) who were using legal actions to try to put their competitors out of business.

There is a very limited market for Novamont's plastics because they are too expensive, they cannot be safely recycled with normal plastics, and they are not "renewable." They are suitable for transporting organic waste to a municipal composting or biogas plant, but the plastics do not make anything useful for the soil because EN13432 requires them to convert rapidly into CO_2 gas.

d_2w Oxo-biodegradable plastic is a product which is much cheaper and more versatile. Novamont alleged that Kromabatch had publicly claimed that oxo-biodegradable plastics biodegraded in accordance with EN13432, and had therefore created unfair competition for Novamont.

The decision of the Italian court in favour of Novamont is bizarre because Kromabatch have never made that claim, and the written judgment shows no evidence that they did.

On 9th April 2015 the judge who decided this case in favour of Novamont was shot dead in his court by an enraged litigant in another case.

EN13432 is a Standard for biodegradation in the special conditions found in industrial composting, which is irrelevant to oxo-biodegradable plastic because it is not intended for composting.
It is intended to biodegrade if it escapes into the open environment, and the relevant Standard is ASTM D6954. Symphony does not claim that d2w complies with EN13432.

Perhaps Novamont has too much influence in Italy.

BPA RESPONSE TO LOUGHBOROUGH REPORT

Biodegradable
Plastics Association

On 11th March 2010 the Department for the Environment and Rural Affairs (DEFRA) of the UK Government published a Report dated January 2010 entitled "Assessing the Environmental Impacts of Oxo-degradable Plastics Across their Life-cycle." This is a report prepared by four members of staff of Loughborough University in the UK, none of whom are professors, and none of whom is a specialist in oxo-biodegradable science or technology. They state that their recommendations are their own opinions, and that their views do not necessarily reflect DEFRA policy or opinions[1].

The Oxo-biodegradable plastics industry was not given a copy of the Report before publication nor asked for its views on the Key Findings and Recommendations.

1. EXECUTIVE SUMMARY

1.1 The Loughborough report is both helpful and unhelpful toward a better understanding of the role of oxo-biodegradable technology.

1.2 It is helpful because the UK government has at last realised the importance of this technology, and has initiated an open debate on the subject.

1.3 It is also helpful because it has dealt with some of the misconceptions about oxo-biodegradable technology which had become all too common. It has confirmed that oxo-biodegradable plastics:

- ARE NOT TOXIC[2]
- CONTAIN NO HEAVY METALS[3]
- ARE SAFE FOR FOOD CONTACT[4]
- DO NOT EMIT METHANE, EVEN DEEP IN LANDFILL[5]
- DO DEGRADE ABIOTICALLY IN A NORMAL ENVIRONMENT[6]
- DO DEGRADE ABIOTICALLY UNDER ELEVATED TEMPERATURES IN LANDFILL[7]

The report has also confirmed that:

- THERE IS NO EVIDENCE THAT DEGRADABLE PLASTICS ENCOURAGE LITTERING[8]
- THERE IS NO EVIDENCE OF BIO-ACCUMULATION[9] NOR ANY HARMFUL[10] EFFECT ON THE ENVIRONMENT
- THERE IS NO EVIDENCE OF ACCUMULATION OF POLLUTANTS[11]
- PRO-DEGRADANT ADDITIVES ARE NOT HARMFUL AND HAVE NO NEGATIVE ENVIRONMENTAL IMPACT IN THE PRODUCTION AND USE PHASE[12]

1. Second page
2. 1(c) 2.3, 2.4, 6.4.1, 6.8 (xxv)
3. 2.4 (p. 13)
4. 4.1.4, 6.5.1,
5. page 14 - para 2.7,
6.Page 7/8
7.6.9
8.Page 14
9.p 13, 6.3.1, 6.3.2
10.Page 9,
11.4.1.3.3
12.Page 16

1.4 The Report is UNHELPFUL BECAUSE THE AUTHORS HAVE:

- MISUNDERSTOOD RECYCLING[13] – oxo-biodegradable plastics can be recycled
- MISUNDERSTOOD COMPOSTING[14] - oxo-biodegradable plastics are not a threat to composting
- MISUNDERSTOOD OIL-DEPLETION[15] - oxo-biodegradable plastics do not cause oil-depletion
- MISUNDERSTOOD THE PURPOSE OF OXO-BIODEGRADABLE PLASTIC[16] - it is not intended for composting, nor for long-term storage, nor to degrade deep in landfill
- MADE AN INCOMPLETE COMPARISON WITH "LONG-LIFE BAGS"[17] - they are not a better alternative to oxo-biodegradable plastics
- ACCEPTED THAT BIODEGRADATION OCCURS[18], BUT HAVE MISUNDERSTOOD TIMESCALE and EXTENT OF BIODEGRADATION[19] There is no need for oxo-biodegradable plastics to biodegrade in a very short timescale.
- CONFUSED OXO-BIODEGRADATION WITH HYDRO-BIODEGRADATION[20]

1.5 NOBODY IS SUGGESTING THAT BIODEGRADABLE PLASTIC SHOULD SIMPLY BE THROWN AWAY

1.6 However, **oxo-biodegradable plastics will degrade then biodegrade without human intervention if they do get into the open environment, leaving no harmful residues. They will do so more quickly than nature's wastes such as twigs and straw, and much more quickly than ordinary and recycled plastics.**

1.7 By contrast "compostable plastics" biodegrade under industrial composting and are useless elsewhere. They are even useless in compost because EN13432 requires almost complete conversion of the carbon in the plastic to CO_2 gas within 180 days, thus depriving the resulting compost of carbon, which is needed for plant growth, and wasting it by emission to atmosphere - contributing to climate-change.

1.8 **Even the industrial composters do not want "compostable" plastics** See https://www.biodeg.org/oregon-composters-dont-want-compostable-packaging/ https://www.biodeg.org/exeter-rejects-compostable-plastic/ Most recently Suez, one of Europe's leading waste management companies, has also rejected "compostable" plastic https://www.usinenouvelle.com/article/sacs-plastiques-compostables-le-grand-malentendu.N926789

13. 1(e), 4.3.4, C6.3, C6.14 & page 4
14. 1(a), 6.10, C5.1 C6.1 & pages 9, 12
15. Page 24
16. 1(d) (h) 1.3 & page 16, 24
17. 2.1
18. 2.2, 4.1.1
19. 1(a), 1(h) & page 28
20. 1.4

1.9 **The Loughborough report claims that oxo-degradable plastics "do not improve the environmental performance of petroleum based plastics." It should however be obvious that plastic which self-destructs at the end of its useful life, leaving no harmful residues, is better for the environment than normal or recycled plastic, which can lie or float around for decades.**

1.10 The Report contains familiar assertions which Symphony and other companies in the oxo-biodegradable plastics sector have had to face before - (usually from the "compostable" or "bio-based" plastics industry) and which they have had no difficulty in refuting (see eg. http://www.biodeg.org/files/uploaded/biodeg/OPA_Response_to_SPIBC-2.pdf)

1.11 Loughborough University did not do any experiments itself, and Symphony were concerned to find that **none of the Professors in other universities with specialized knowledge of oxo-biodegradable plastics were invited to peer-review the report.** In fact, two of the three assessors of the Report are engaged in bio-based plastics, which is a totally different product, in competition with oxo-biodegradable. One of them is a well known and very vociferous advocate of bio-based plastics, who appeared from his website (https://www.msu.edu/~narayan/general.htm) to be connected with companies that produce bio-based plastic products

2. THE PURPOSE OF OXO-BIODEGRADABLE PLASTICS

2.1 Go into any supermarket, hotel, hospital, etc. and what do you see? - Plastic.

2.2 Not just carrier-bags, but almost everything is wrapped or bottled in plastic – from frozen peas to fresh potatoes – from sandwiches to milk - beer cans to newspapers, televisions and even ironing boards. At the back of store there are acres of shrink-wrap, pallet-wrap and bubble wrap used to deliver goods in bulk. Why? – because plastic is in most cases the best and most cost-effective way to protect goods from damage, contamination and wastage.

2.3 So why are some people concerned about plastic? "Because plastic is made from oil or natural gas, or coal, which is a finite resource?" - but this is a mistake, because it is actually made from a by-product which will always be produced so long as the world needs these types of fuel, and it makes good economic and environmental sense to use the by-product.

2.4 "Because plastic waste is filling up the landfills?" - another mistake, because plastic takes up a very small proportion of space in the average landfill. In any event all combustible waste, including plastic, should be diverted to incineration when it can no longer be re-used or recycled. This is being done in other developed countries. Modern incinerators do not cause pollution, and they employ the heat for useful purposes.

2.5 Because "plastic is symptomatic of a "throw-away" society?" Well – life moves at a much faster pace whether we like it or not. We can no longer buy milk in a jug from the corner shop, and packaging has adapted to modern life. Of course we must recycle plastic where practical, but it is not enough just to use recycled plastic because, whether recycled or not, and we will never collect it all. Some will inevitably find its way into the open environment, where it could lie or float around for decades, for example in the North Pacific Gyre.

2.6 This is the real problem - to which there is a solution. It is a masterbatch which is added to conventional plastic at the manufacturing stage, and causes the plastic to degrade at the end of its service life, by a process of oxo-biodegradation, leaving no harmful residues. It is called "Controlled-life" or "Intelligent" plastic, as it is the only type of plastic whose life can be controlled. All plastic will in time fragment and completely biodegrade, but d_2w controls the process, so that the fragments are bioassimilated faster than straw and twigs and much faster than ordinary or recycled plastic. Symphony's d_2w has passed the usual eco-toxicity tests[21] and does not contain "heavy-metals." It is certified for food-contact.[22]

2.7 Plastic made with d_2w costs very little extra, because it is made with the same machinery as conventional plastic, and it causes no loss of jobs in the plastics industry. There is no need to change suppliers, but finished-products can be supplied if required.

2.8 Plastic has been used safely and cost-effectively for more than five decades.

2.9 If all the plastic found in the "North-Pacific gyre" had been made with oxo-biodegradable technology the plastic would probably have degraded and biodegraded long before it reached the gyre.

21. OWS Reports R-MST-4/1c and 4/2c 8th Mar 2006. See also Prof. G. Scott and others, Degradable Polymers: Principles and Applications, Kluwer, 2002, Chapter 13, Section 9.11, page 472, et seq.
22. RAPRA test SYP 01A 15.3.05

2.10 Nobody is suggesting that oxo-biodegradable plastics are a complete answer to plastic pollution of the environment. Of course not. They need to be seen as part of an integrated approach, which includes education, re-use, recycling, and incineration.

2.11 **Dr. Caroline Jackson M.E.P**[23] made the following statement in July 2008: "European legislation on waste has tended to concentrate on waste which can be collected, and to encourage people to reduce, re-use, and dispose responsibly of their waste, by recycling, incineration with energy-recovery, or by other disposal routes."

2.12 "However, we also need to take account of the fact that we will never succeed in collecting all the waste and that some may remain to disfigure the landscape. This is particularly the case with plastic waste, from errant supermarket bags to agricultural plastic. Where this goes uncollected it can accumulate in the environment, polluting the land and the oceans for many decades, and perhaps for hundreds of years."

2.13 She continued "Technologies have now become available which can produce plastic products such as shopping bags, garbage sacks, packaging etc. which are fit for purpose, but will harmlessly degrade at the end of their useful life. These fall into two broad categories, namely:

(a) **Hydro-biodegradable plastics, made wholly or partly from crops, which biodegrade in a highly microbial environment, such as composting, and**

(b) **Oxo-biodegradable plastics, made from a by-product of oil-refining, which degrade in the environment by a process of oxidation initiated by an additive, and then biodegrade after their molecular weight has reduced to the point where naturally-occurring micro-organisms can access the material."**

2.14 "We need to encourage both of these technologies, and to ensure that European Standards are developed which are appropriate to both. It is worth bearing in mind that the European Parliament is concerned by the use of scarce land and water resources around the world to produce biofuels in competition with food-crops and the same concern applies to growing crops to make biodegradable plastics, so I hope the European Commission will give more positive support to oxo-bio plastics."

2.15 Vegetable-based or hydro-biodegradable or "compostable" plastic is far too expensive for everyday use, it has a worse Life-Cycle Assessment than ordinary plastic,[24] and it emits methane deep in landfill. On page xvi of 6.6 the authors found evidence that "In the case of greenhouse gas emissions, **the impact of oxo-degradable PE was considerably less than PLA (polylactic acid).**"

2.16 We agree with the packaging manager of Tesco who said on 20th October 2009 that they "do not see the value in packaging that can only be industrially composted" and that "local authorities do not want to touch it, as it can contaminate existing recycling schemes."

23. Press statement 18th July 2008.Dr. Jackson was Chairman of the Environment, Public Health, and Food Safety Committee of the European Parliament, and was the Rapporteur for the EU Waste Framework Directive.
24. Germany's Institute for Energy and Environmental Research June 2009

3. BIODEGRADATION AND TIMESCALE

3.1 Oxo-degradation is defined by CEN (the European Standards Organisation) in TR15351as "degradation resulting from oxidative cleavage of macromolecules." And oxo-biodegradation as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."

3.2 **The Loughborough authors are in no doubt that abiotic degradation occurs,25 even in landfill,[26] but they are mistaken in thinking that it is initiated by light and heat.27 It is accelerated by light and heat but is initiated by contact with oxygen, and is not inhibited by moisture.** They are also mistaken in thinking that the time over which the degradation process takes place depends on the concentration of additive in the plastic.[28] It depends on the formulation of the additive. They have also confused oxo-biodegradable with photodegradable. [29]

3.3 **They have found ample evidence that BIO-degradation of oxo-biodegradable plastic does occur after the additive has reduced the molecular weight to the point where it no longer has the molecular structure of a plastic and can be accessed by naturally-occurring micro-organisms.** They found evidence of between 15% and 60% mineralisation in the laboratory but in their opinion the material does not biodegrade fast enough.

3.4 Fast enough for what? A high level of biodegradation is not to be expected from products designed for a useful life exceeding six months, as the antioxidant additives must be first consumed before degradation begins.

3.5 The authors say that "BIO-degradation of oxo-degradable plastics can only occur after they have fragmented and then proceeds very slowly, for example, at a rate many times slower than that of a compostable plastic." They are not however comparing like with like. Compostable plastics are designed to biodegrade rapidly under the highly-microbial conditions and high temperatures found in an industrial composting process, but they do not biodegrade rapidly if they are left in the open environment. The authors have advanced no evidence that compostable plastics biodegrade faster than oxo-biodegradable plastics in the open environment.

3.6 The industrial composting standards require 90% biodegradation within 180 days, and the reason for this short timescale is purely commercial. The Standards were created by the vegetable-based plastic industry for their type of plastic, and industrial composting is carried out as a business, where time is money. A Standard for oxo-biodegradable plastic is being delayed by the vegetable-based plastic industry and their allies on the Standards Committees.

3.7 However, as indicated above, oxo-biodegradable plastics are not intended for composting. They are intended to address the problem, identified by Dr. Jackson, of plastic waste which escapes into the open environment.

25. Page 7/8
26. page 54 "the oxo-degradable polyethylene recovered from the landfill trial had a significantly reduced molecular weight (4,250-4,280)."
27. 1.4
28. 1.1
29. 6.2.4
30. 6.2
31.
32. 1(a)
33.
34. EN13432, ASTM D6400 etc.
35. n 21 above

3.8 **Therefore the appropriate reference materials so far as timescale is concerned are ordinary plastics (without d_2w), and nature's wastes such as twigs and straw. The authors have not addressed these materials, but twigs and straw can take up to ten years to biodegrade and ordinary plastic can take decades.**[36]

3.9 The authors say[37] "The length of time to degradation of oxo-degradable plastic cannot be predicted accurately because it depends so much on the environmental conditions." This is correct, and it should not be claimed that an oxo-biodegradable product will degrade in anything other than an approximate timescale. The degradation period depends also on the formulation of the additive and the characteristics of the particular product. Prof. Chiellini's work shows that the rate-determining step is peroxidation and the microbes simply scavenge the low molar mass products at a rate very much faster than peroxidation.

3.10 The authors continue "It is suggested that oxo-degradable plastics left in the open environment in the UK degrade to small fragments within 2 to 5 years" but they are confusing time to mineralisation with time to fragmentation. At 2.1 they say they fragment into small pieces in one or two years. However, even 2-5 years in the open environment is a lot better than decades, and we are therefore confident that d_2w oxo-biodegradable plastics are better for the environment than ordinary plastic.

3.11 Additives are formulated according to timescales required by the customer. The technology is constantly improving, and formulations are being developed which can cause degradation then biodegradation in a very much shorter timescale than that, whilst still allowing a sufficient period of fitness-for-purpose. **These products can be controlled within a time range of a few months or years depending on customer needs**. Testing and product performance evaluation is regularly done by natural aging in the environment as well as artificial aging, of hundreds of samples every week.

3.12 The authors have found evidence that plastic "nurdles" attract toxins in a marine environment, but no evidence that they are any more likely to attract toxins than fragments of seaweed or wood or other fragments naturally present in the oceans. In any event, "nurdles" consist of pure polymer, but a fragment of oxo-biodegradable plastic which has undergone the abiotic phase of degradation is no longer a polymer and has a completely different molecular structure. The authors have found no evidence that such fragments would be harmful.

3.13 The first industrial application was in mulching films and is fully reported in the papers identified in the reference section of the Report (Annex D, references 1,9, 41, 47, 52, 55,61). Mulching films have been used continuously in successive seasons in Israel, USA, Japan, China, Taiwan and some South American countries since 1975 with **no evidence of residual plastics particles or loss of soil fertility year on year.**

36
37. 1(a)

4. RECYCLING

4.1 **Retailer B who gave evidence for the Report38 "uses oxo-degradable plastics in packaging because they do not interfere with established recycling streams**." The Loughborough authors were aware of the Oxo-biodegradable Plastics Association's Position-paper on Recycling[39], but do not appear to have allowed it to inform their opinion[40] T**hey have failed to distinguish between (a) recyclate for making short-life and long-life products; between (b) recyclate whose provenance is known and not known; (c) between products where rapid degradation is desirable and not desirable; (d) between products where recyclate is allowed and not allowed; and (e) cases where stabilisers are necessary whether there is any pro-degradant additive or not.** The OPA Position-paper makes it clear that oxo-biodegradable plastics can be recycled without necessarily adding stabilisers.

4.2 The authors appear to have focussed on recycling of post-consumer plastic waste. However, the evidence of RECOUP[41] a national charity promoting plastics recycling in the UK, is that "a limited amount of household films are currently collected, baled and sold to reprocessors, but this is often at a negative value. The plastic film also causes technical issues with sorting equipment in materials reclamation facilities. The Recoup guide currently specifies that "film should not be collected for recycling." RECOUP point out that it is **the vegetable-based "bioplastics," not the oil-based oxo-biodegradable plastics that cause problems for recyclers**.

4.3 The authors themselves accept[42] that "Barriers to recycling include: the high volume to weight ratio of [ordinary] waste plastic, which makes it expensive to collect, store and transport; high levels of contamination, which compromise the quality of the recyclate; the wide range of plastics, which requires sorting and the low market price for recyclate."

4.4 They added "in the course of this study, it was difficult to find evidence of the impact of oxo-degradables on the recycling stream. At present there seems to be very little post-consumer recycling of the sort of plastic film products where oxo-degradable plastics are usually used. This is mainly because such material is difficult to collect, is generally of poor quality and is therefore not economically viable for recyclers. Hence, at present, any deleterious effect is limited (Annex C6.4)."

4.5 The Quebec report[43] shows that oxo-biodegradable plastic is compatible with recycling, and further independent trials reach the same conclusion. http://www.biodeg.org/recycling-and-waste/

4.6 The Loughborough authors say "there is another more far-reaching concern, that now that this technology is being developed for use in other plastics, such as polyethylene terephthalate (PET), and for other applications, such as bottles, then there is more potential for a negative impact on the quality of recycled plastic from existing recycling schemes." They do not seem to be aware that oxo-biodegradable technology is not suitable for PET.

4.7 **The OPA Position Paper on Recycling** is as follows:
"The Oxo-biodegradable Plastics Association supports the recycling industry, but recycled plastics are not normally degradable and will, like ordinary plastics, accumulate for decades if they get into in the open environment. However, recycled plastic and ordinary plastic can now be made oxo-biodegradable by the inclusion of a pro-degradant formulation at the extrusion stage.

38. C 3.2
39. http://www.biodeg.org/position-papers/recycling/?domain=biodeg.org
40. 1(e)
41. C6.4
42. 1.5
43 Annex B6

4.8 According to RAPRA[44] , "Oxo-biodegradable packaging is recyclable, as would be any similar plastic material without the pro-oxidant additive.

4.9 Oxo-biodegradable plastics have been in commercial use since the 1970s, and are based on commodity polyolefins, particularly polyethylene and polypropylene. Their performance during manufacture and use is indistinguishable from that of regular polyolefins, and their biodegradation is caused by formulations that promote transition metal ion oxidation in the presence of oxygen.

4.10 The length of the useful life of an oxo-biodegradable plastic product is determined by antioxidants (processing stabilisers and UV stabilisers) contained within the formulation, which can be modified so that the plastic product degrades according to whatever timescale is required.

4.11 Obviously if any plastic is going to be recycled it will have to be collected and recycled before it has become embrittled. Oxo-biodegradable products currently have a useful life before embrittlement of at least 18 months, and if they have not been collected and recycled by then, they probably never will be.

a. New oxo-biodegradable products made with recyclate

If a new product is to be made with recycled polymer which contains or might contain a pro-degradant formulation and the new product is intended to be degradable, the process is obviously straightforward, as a pro-degradant effect is actually desired. This applies particularly to recycling of oxo-biodegradable offcuts in plastic factories, or where used oxo-biodegradable "back-of-shop" plastics (e.g. shrink-wrap pallet-wrap, bread-wrapping etc) are sent back for recycling into more oxo-biodegradable products.

b. Short-life products

If the new product to be made from recyclate which contains or might contain a pro-degradant formulation, is intended for short-life products such as refuse-sacks, bin-liners, shopping bags, bread wrappers etc. the effect of any pro-degradant formulation is unlikely to manifest itself during the intended service-life, and biodegradability for such items is in any event desirable. It is desirable because a proportion of these items will always find their way into the land or sea environment, where they would otherwise subsist for decades after they had been discarded.

c. Long-life products

Since polymers lose stabilisers every time they are reprocessed, it is good practice to add new stabilisers each time, whether the feedstock contains oxo-biodegradable plastic or not. If suitably formulated, the stabilisers will also neutralise any pro-oxidant which may still be effective. According to RAPRA[45] "Care must be taken to ensure that the cleanup of the recyclate will deal with any remaining pro-oxidant either by removal or by the addition of a neutralising agent, otherwise it may result in premature degradation of the products made with the recycled material."

44. http://www.rapra.net/consultancy/biodegradable-plastic.asp
45. Ibid.

c (1) Building Films

If the new product to be made is a plastic film intended for long-term durability - such as a building film for damp-proofing or waterproofing - the specification in some countries for some of these films requires the use of a virgin polyolefin compound[46] and recyclate is not therefore relevant. For all other building films the specification will usually require the use of stabilisers where necessary.[47] There will of course be no pro-degradant formulation in recyclate chosen from in-house scrap, or from other feedstock whose origin is known.

In the case of lower-grade building films, where no guarantee is given, these are often made from recyclate whose origin is not known, and the manufacturer should always add stabilisers as above, whether the feedstock contains a pro-degradant formulation or not.

c(2) Pipes

(1) ISO Standard 8779 "Plastics piping systems — Polyethylene (PE) pipes for irrigation" provides at para. 4.2 that only clean reprocessable material generated from a manufacturer's own production may be used if it is derived from the same resin as used for the relevant production. As the origin of the material will be known, it will not therefore be used for this purpose if it could contain any pro-degradant formulation.

(2) European Standard EN 12201-1 provides at para 4.3 that items such as PE pipes for water for human consumption, cannot be produced from recycled material other than process regrind. Residues of oxo-biodegradable materials are likewise not an issue here.

(3) SABS[48] piping is manufactured to a specification which permits the use of recyclate only from "in-house scrap." Small bore piping class 6 and 10 is usually LDPE and, larger sizes, HDPE.

"In-house scrap" is scrap which has been generated during manufacture of the SABS grade pipe which can be chipped up and added back.

There is therefore no difficulty with the manufacture of such piping, as the origin of the recyclate is known and it will not therefore be used for this purpose if it contains any pro-degradant formulation.

(4) "SABS Equivalent" piping is manufactured from 100% recycled material according to the SABS specification but is not marked. Usually HDPE with from 5-20% LDPE blended for flexibility. For a quality product where a guarantee is demanded, clean industrial scrap is used where product history (material source and material grade) is known. This will not therefore contain a pro-degradant formulation.

46. Eg South African Bureau of Standards Specification 952-1985 para. 3.2.2
47. South African Bureau of Standards Specification 952-1985 para. 3.2.1
48. South African Bureau of Standards

(5) Agricultural and Domestic piping is manufactured in South Africa from 100% LDPE scrap. Normally the same scrap is used as in (c) above, but it should only be used in low-tech situations if the origin of the recyclate is unknown. Stabilisers should always be added if there is any doubt about the origin of the recyclate, and there is a case for an industry specification for this category of piping, which would include a requirement to add stabilisers.

"Low tech situation" refers to small bore piping Class 3 and 6 used for piping water to cattle or game troughs or on domestic irrigation systems, essentially at low pressures.

D. HYDRO-BIODEGRADABLE PLASTICS

Hydro-biodegradable plastics, unlike oxo-biodegradable plastics, cannot be recycled with the most abundant components of plastic waste. They therefore have to be segregated from the waste stream and treated separately, with considerable increase in cost. Furthermore it is difficult for the manufacturers of recyclate to physically distinguish between hydro-biodegradable and normal plastic.

Hydro-biodegradable plastics have been called into question by recyclers[49] and Recoup's project manager has warned that starch-based plastics could "have a negative impact on plastics recycling as a whole.[50] .... the fear is that bioplastics will increasingly find their way into the plastics recycling stream – impacting on quality and un-doing the work done on raising public awareness of plastics recycling."

Recyclers should therefore be concerned to see that hydro-biodegradable plastics are not encouraged."

49. Materials Recycling Weekly 20 Nov 2006
50. Addressing the Local Authority Recycling Advisory Committee conference in November 2006.

5. COMPOSTING

5.1 It is not clear why the authors have attached so much importance to composting in a report on oxo-biodegradable plastics, because OBP are not intended or marketed for composting.

5.2 At 1(a) the authors give their opinion that "Oxo-degradable plastics should not be included in waste going for composting, because the plastic fragments remaining after the composting process might adversely affect the quality and saleability of the compost."

5.3 However, the evidence of the composting company who contributed to the Loughborough report[51] is that "the best policy is to allow **no plastic bags of any sort** in the green waste." Indeed in some countries[52] no plastic of any kind is permitted to enter an industrial composting process. Also, the Loughborough authors found evidence that even so-called "compostable" plastic **does not always work in industrial composting.**[53]

5.4 **As indicated above, in a January 2020 Report the industrial composters of Oregon https://www.biodeg.org/oregon-composters-dont-want-compostable-packaging/ gave nine reasons why they don't want "compostable" plastics, and in the same month the City of Exeter, UK rejected "compostable" plastic and paper. https://www.biodeg.org/exeter-rejects-compostable-plastic/ Most recently Suez, one of Europe's leading waste management companies, has also rejected "compostable" plastic https://www.usinenouvelle.com/article/sacs-plastiques-compostables-le-grand-malentendu.N926789**

5.5 The composting company who gave evidence to the Loughborough authors,[54] and the local authorities, are saying that residents cannot use 'compostable' plastic bags, because of their potentially poor compostability and because of the risk of confusion with ordinary plastic bags by both the consumer and the collection crews.

5.6 Reference is made in the Report[55] to an article which concludes that increasing use of 'compostable' bags will lead to higher contamination levels and more green waste ending up in landfill.

5.7 **Composting is not the same as biodegradation in the environment**. Composting is an artificial process operated for commercial reasons according to a much shorter timescale than the processes of nature. Therefore, Standards such as ISO 17088, EN13432, and their American (ASTM D6400-04; D6868) and Australian (AS 4736-2006) equivalents, designed for compostable plastic should not be used for plastic which is designed to biodegrade if it gets into the environment. These are specifications for the special conditions found in industrial[56] composting.

5.8 **Home composting of plastic packaging can be dangerous and should not be encouraged,** as it is often contaminated with meat, fish, or poultry residues, and temperatures may not rise high enough to kill the pathogens. See https://www.biodeg.org/exeter-rejects-compostable-plastic/

51. C6.2
52. Eg French law NFU 44/051
53. C6.2
54. C6.2
55. C6.2
56. ASTM D6400 states that it "covers plastics and products made from plastics that are designed to be composted in municipal and industrial aerobic composting facilities, and EN13432 states that it does not take into account packaging waste which may end up in the environment through uncontrolled means, ie as litter.

5.9 We do not agree that "biodegradable" is a meaningless term. It indicates that a material is capable of being bioassimilated by micro-organisms. It is no more meaningless than any other general description. We do not agree that "labelling oxo-degradable plastic products as "biodegradable" can lead to confusion on the part of consumers who may assume that "biodegradable plastics" are compostable." It is obvious that in order to see the word "biodegradable" the consumer has looked at the label, which can and should say "Not intended for composting."

5.10 The absence of a European Standard for oxo-biodegradable plastic gives the compostable plastic industry an unfair marketing advantage, which their representatives on the Standards bodies use their votes to retain.

5.11 We agree with the packaging manager of Tesco (Britain's largest supermarket) who said on 20th October 2009 that the supermarket "does not see the value in packaging that can only be industrially composted" and that "local authorities do not want to touch it, as it can contaminate existing recycling schemes." A few days earlier, Tesco's head of waste and recycling had told a conference that the supermarket group was "not taking compostable packaging any further."

5.12 We are all aware that landfill sites in the UK are filling up, but only "0.2% of the average household dustbin is plastic carrier bags.[57] The fraction of landfill represented by plastic shopping bags is 0.05%. This is based on domestic waste being 17% of landfill and plastic bags being 0.2% of the average dustbin.[58] A far greater impact on saving landfill space would be made by diverting away from landfill bricks, concrete, wood, glass and other building materials and other items such as household appliances, which occupy much more space.

5.13 All combustible waste which is suitable only for landfill, should be diverted to modern incineration facilities, as in other developed countries (eg in Zurich), where the heat energy can be put to use with no harmful effect on the environment.[59] This is particularly suitable for waste plastics, which do not retain moisture and have a high calorific value. Retailer D[60] believed that this option should be further considered. There are currently 15 Energy-from-waste plants operating in the UK.

5.14 **Composting of organic waste makes sense, but compostable plastic does not**[61]. It is up to 400% more expensive than ordinary plastic, and it converts into CO_2 gas, not compost; it is thicker and heavier and requires more trucks to transport it; recycling with oil-based plastics is impossible; it uses scarce land and water resources to produce the raw material. It is not "renewable" because substantial amounts of fossil fuels are burned and CO_2 emitted, by the tractors and other machines employed. If buried in landfill, compostable plastic will emit methane (a greenhouse gas 23 times more powerful than CO_2) in anaerobic conditions. The authors acknowledge[62] that the production of methane in landfill is undesirable.

5.15 EN 13432, ASTM D6400 and the other standards for industrial compostability are not appropriate for testing oxo-biodegradable plastics because they are based on measuring the emission of carbon dioxide during degradation over a short timescale. Hydro-biodegradable plastic is compliant precisely because it emits CO_2 (a greenhouse gas) at a high rate. Oxo-biodegradable plastics do not emit CO_2 at that rate.

57. Plastic Bag Tax Assessment, HM Treasury, UK, December 2002.
58. (Packaging and Films Association 2007).
59. See OPA Position Paper on Incineration
60. 6.3.4
61. http://www.biodeg.org/files/uploaded/biodeg/Oxo_vs_Hydro-biodegradable.pdf
http://www.biodeg.org/files/uploaded/biodeg/Hydro-biodegradable_Plastic_Production_Process.pdf
62. 1.5

5.16 If a leaf were subjected to the CO_2 emission tests included in EN13432 it would not pass! Leaves are not of course required to pass any such test, but it shows how artificial the test is.

5.17 Another problem with EN 13432 and ASTM D6400, is that they require almost complete conversion of the carbon in the plastic to CO_2, within 180 days, thus depriving the resulting compost of carbon, which is needed for plant growth, and wasting it by emission to atmosphere - contributing to climate-change.

5.18 Conversion of organic materials to CO© at a rapid rate during the composting process is **not "recovery" as required63 by the European Directive on Packaging and Packaging Waste (94/62/EC as amended),**[64] **and is not consistent with a circular economy**. It should not really be part of a standard for composting at all. Nature's lignocellulosic wastes do not behave in this way, and if they did they would have little value as soil improvers and fertilisers, having lost most of their carbon.

5.19 The EU Directive does NOT require that when a packaging product is marketed as "degradable" or "compostable" conformity with the Directive must be assessed by reference to EN13432. Although the Directive[65] provides that conformity with its essential requirements may be presumed if EN 13432 is complied with, it does not exclude proof of conformity by other evidence. Indeed Annex Z of EN13432 itself says that it provides only one means of conforming with the essential requirements.

5.20 We agree with Germany's Institute for Energy and Environmental Research[65] and Ademe, the French Agency for the Environment,[67] who concluded that oil-based plastics, especially if recycled, have a better Life-cycle Analysis than compostable plastics. The IEER added that "The current bags made from bioplastics have less favourable environmental impact profiles than the other materials examined" and that this is due to the process of raw-material production.

6. OIL-DEPLETION

6.1 Ordinary plastics are currently made from by-products of oil, natural gas, or coal. These by-products arise because the world needs fuels, and would arise whether or not the by-product were used to make plastic goods. So, nobody is extracting or importing oil, gas or coal to make plastic. Until other fuels have been developed it makes good environmental sense to use the by-product, instead of using scarce agricultural resources and water to make paper or cloth bags or vegetable-based plastic.

63. Annex II para. 3
64. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1994L0062:20050405:EN:PDF
65. Article 9(2)
66. June 2009 (http://www.kunststoffverpackungen.de/en/news/LCA%20waste%20bags%20-%20Study%20Extract%20B.pdf)
67. December 2007

7. LONG-LIFE BAGS

7.1 **These are not the answer.** They are much thicker and more expensive to make, and a large number of them would be required for the weekly supermarket shopping of an average family.

7.2 30,000 jute or cotton bags can be packed into a 20-foot container, but the same container will accommodate 2.5 million plastic carrier-bags. Therefore, to transport the same number of jute or cotton bags 80x more ships and trucks would be required than for plastic bags, using 80x more fuel, using 80x more road space and emitting 80x more CO_2.

7.3 Cloth bags are not hygienic[68] if a tomato is squashed or milk is spilled. Research by Guelph Chemical Laboratories in Canada in 2008 Microbiological Study of Reusable Grocery Bags has shown that “re-usable grocery bags can become an active microbial habitat and a breeding-ground for bacteria, yeast, mold, and coliforms. .... The unacceptable presence of coliforms - ie intestinal bacteria, in some of the bags tested, suggests that forms of E.Coli associated with severe disease could be present in a small but significant proportion of the bags.”

7.4 Whilst sometimes called "Bags for Life" they have a limited life, depending on the treatment they receive, and become a very durable form of litter when discarded.

7.5 Shoppers do not always go to the shop from home, where the re-usable bags would normally be kept, and consumers are unlikely to have a re-usable bag with them when buying on impulse items such as clothing, groceries, CDs, magazines, stationery etc. Research conducted for the Scottish Executive[69] carrier bag case studies showed that 92 per cent of people think re-using carrier bags is good for the environment but 59 per cent forget their re-usable bags and have to take new ones at the checkout!

7.6 As durable bags are a cost to the consumer and carrier-bags are expected to be provided free, one can easily understand why supermarkets are in favour of reducing the number of carrier bags and increasing the number of durable bags. Even those who give the profit to charity have saved themselves the cost.

7.7 The thin high-density vest-style carrier bag is used on average 5 times in the UK and when finished is used as a bin liner. Now the consumer is being encouraged to pay for a bag for life and also to buy a bin liner. It is therefore not reducing the impact of plastic in the environment but is reducing the spending power of the consumer who has not been told the facts.

7.8 However, for those who believe in long-term re-usable bags, they can be made from washable extended-life oxo-biodegradable plastic which will last for 3-5 years before they will harmlessly self-destruct, leaving no harmful residues.

68. www.cpia.ca/epic/media/default.php?ID=2054
www.cpia.ca/files/files/A_Microbiological_Study_of_Reusable_Grocery_Bags_May20_09.pdf http://network.nationalpost.com/np/blogs/theappetizer/archive/2009/05/20/back-to-plastic-reusable-grocery-bags-may-pose-public-health-risk.aspx
69. http://www.scotland.gov.uk/Topics/Environment/funding-and-grants/carrier-bag-case-studies/Q/EditMode/on

8. AGRICULTURAL MULCHING FILM [35]

8.1 **For many years farmers and growers have used plastic sheets to protect their crops, to save water, and to inhibit weeds, but after the crop has been harvested many thousands of square kilometres of dirty plastic have to be removed and disposed of. This is a very expensive process, and creates huge quantities of contaminated waste, which cannot be burned on the farm, or recycled into useful products.**

8.2 The Report says at 4.3.1 "Another application where compostability has been an issue is in the use of agricultural mulch films. The main reason for using them in these applications is that they can be disposed of in-situ and need not be removed and disposed of. Citing their lack of compostability, the Environment Agency does not allow un-degraded oxo-degradable plastics to be returned to the soil by ploughing in. This prohibition, fundamentally limits the application of these materials and means that oxo-degradable mulch films have only been used in trials in the UK. The NFU suggests that degradable mulch films that can be ploughed in are of potential benefit to the farmer, avoiding the need for collection and disposal that can be both costly and potentially damaging to the environment.

8.3 **Oxo-biodegradable plastic sheets have been designed to be programmed at manufacture to degrade after the harvest.** The degraded material is intended to be ploughed into the soil where it completes the biodegradation process and becomes a source of carbon for next year's plants. Alternatively it can be placed in a corner of the farm under a net, where it will degrade and disappear leaving no harmful residues.

8.4 Oxo-biodegradable plastics have been used as protective films in agriculture in many countries (including USA, China, Japan and the EU). They are applied to the land in the same way as straw to retain moisture and to increase root temperatures.

8.5 The evidence of the UK's National Farmers' Union to the Loughborough Report[70] is that "Farmers suffer from having relatively small amounts of widely dispersed plastic that needs to be collected and disposed of. A potential advantage of the oxo-degradable plastics is that they could be disposed of in-situ, thus avoiding the need for collection, with its attendant financial and environmental costs. Similarly, costs of final disposal in landfill would also be avoided."

8.6 **This would not only result in major cost and time savings for farmers, but would also divert huge quantities of material from landfill.**

8.7 "The NFU continues "However for oxo-degradable plastics to move into mainstream use, farmers would have to be convinced of their effectiveness and environmental safety." It is for this reason that Symphony Environmental has for the past three years been conducting trials under different climatic conditions in nine countries, and does not supply agricultural mulching film unless satisfied as to effectiveness and environmental safety. Vegetable-based compostable plastics would not be cost-effective nor strong enough.

70. C5.2

8.8 The Report indicates[71] that the UK's Environment Agency does not accept the ploughing in of oxo-degradable plastic mulches because it is not considered beneficial or environmentally benign. The decision was based on the results of a literature search and peer review into the composting of oxo-degradable plastics." The OPA does not think that this is a sufficient basis for depriving British farmers of the benefits of oxo-biodegradable plastics, and we would be willing to accept an invitation from the Environment Agency to discuss the matter with them.

8.9 Oxo-biodegradable plastic would satisfy Tiers 1 and 3 of EN 13432 and the other composting standards. It would not pass Tier 2 because it would not convert itself into CO_2 gas within 180 days, but as indicated above this is neither necessary nor desirable.

71. C5.1

BIODEGRADABLE PLASTICS ASSOCIATION

BPA COMMENT ON THE MAY 2019 REPORT

From the

ELLEN MACARTHUR FOUNDATION

ELLEN MACARTHUR FOUNDATION
BPA COMMENT ON THEIR MAY 2019 REPORT

The Ellen MacArthur Foundation (EMF) used to say that oxo plastic simply fragmented, but having engaged with our scientists they no longer say that. They admit in their May 2019 report that "oxo-degradable" plastics are manufactured so that they can degrade faster than conventional plastics and that *they do become biodegradable*, but they say that "it is not yet possible accurately to predict the duration of the biodegradation for such plastics."

Nobody claims that it is possible accurately to predict the duration of the biodegradation. It never will be possible, for the reasons mentioned below, and for that reason a broad indication only can be given as to timescale. It is however possible to say with certainty that at any given time and place in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item. That is the point. - Do we want ordinary plastic which can lie or float around for decades, or oxo-biodegradable plastic which will be recycled back into nature much more quickly? Of course, we don't want plastic in the sea at all, but that is not the present reality.

The author of the MacArthur Report is not a polymer scientist, nor even qualified in chemistry.

THE PLASTICS PROBLEM

Plastic is immensely useful and is the best way to prevent food wastage and sickness, by protecting our food from contamination and damage[1] - and has a much better LCA than other materials used for packaging but there is one fundamental problem – that if it gets into the open environment as litter it will lie and float around for decades, and perhaps 100 years. That is the reason why there is so much opposition to plastic, but it is now possible to solve this problem by redesigning the plastic itself, with oxo-biodegradable technology.

Plastic waste has been identified as a serious environmental problem by many governments around the world, and measures have been proposed for reducing the amount of plastic in use and for redesigning and recycling plastic products. These are laudable aims and we support them, but it is wholly unrealistic to think that these measures are soon going to prevent all plastic waste getting into the open environment, even in the developed world.

It was reported in 2019 that 600,000 tonnes of plastic are being dumped by 22 countries in the Mediterranean Sea every year, and the situation is even more alarming at global level, with 8 million tonnes ending up in the sea each year. This plastic will rapidly fragment into microplastics which can lie or float around for many decades, and banning peripheral items like drinking straws, cotton buds, and microplastics in cosmetics, is not going to solve the problem. A substantial amount of plastic will continue to get into the open environment from which it cannot realistically be collected, and it is this fraction of plastic waste for which most governments have no answer.

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[1] See the Denkstatt Report and "Replacing Plastics with Alternatives Is Worse for Greenhouse Gas Emissions in Most Cases"; " Closing the Perception-Reality Gap for Sustainable Fresh Food Plastic Packaging 2024" "Plastic is Better than Paper"

INNOVATION

Fortunately, the very scientists who developed plastics have been working for more than 30 years to upgrade plastic products so that they remain fit for purpose but will become biodegradable if discarded at the end of their useful life and will then be recycled back into nature by bacteria and fungi much more quickly than ordinary plastic. Their efforts have resulted in a technology which has become known as oxo-biodegradable (or oxo-bio) plastic. This is essentially environmental insurance, which automatically removes unwanted plastic if it becomes litter.

The only environmental conditions necessary for oxo-biodegradation are oxygen and bacteria, both of which are ubiquitous in the open environment.

No special conditions are therefore necessary – unlike the type of plastic marketed as "compostable" which is designed to be taken to an industrial composting facility.

Oxo-biodegradable plastics are not intended to replace litter control, but to deal with the consequences on the surface of land or water of failure to control litter. Landfill is not their primary purpose, but they will biodegrade if disposed of in landfill.

It is said by EMF that oxo-bio plastic packaging is - by its very design - not meant for long-term reusable applications. This is correct. It is meant for packaging which might become litter, and which is not normally reusable. This does not for example include PET bottles, which *are* worth collecting for recycling or re-use. Oxo-bio technology is not employed in products intended for high value uses; it is intended for short-life products of the kind that are prone to littering.

Oxo-biodegradable plastic products are made from ordinary polyethylene or polypropylene. They are made in the same way as normal plastic products, but the manufacturer adds a masterbatch such as d2w which accelerates a change in the molecular structure soon after its useful life has expired so that it ceases to be a plastic. This type of plastic can therefore be made by ordinary plastics factories at little or no extra cost. It places a much lower burden on fossil resources than crop-based plastic, because it is made from ethylene, a by-product of refining oil for fuels, which used to be wasted.

A Life-cycle Assessment by Intertek in May 2012[1] confirmed that oxo-biodegradable plastic had the best LCA of all materials used for making carrier bags and bread bags.

One would expect organisations such as EMF, dedicated to protecting the environment, to want to work with the oxo-bio industry and other suitably qualified experts, to understand the technology and campaign for it to be used as an alternative to ordinary plastic. They should not be asking themselves "is oxo-bio plastic perfect?" but "is oxo-bio plastic better for the environment than ordinary plastic?"

CONFUSION

It is said by EMF that *"Oxo-degradable plastics and similar materials are marketed and referred to in different ways, including oxo-biodegradable, photo/thermo-degradable, oxo-fragmentable or pro-oxidant additive containing plastics - a terminology we believe may confuse consumers, policymakers and companies."*

So as to avoid further confusion it should be noted that oxo-bio plastic is not made from food-crops such as corn-starch. Those are hydro-biodegradable plastics (often misleadingly described as "compostable" plastics), which are not a solution to plastic litter, and are unsuitable for everyday use for 21 reasons.

We agree that there is a need for clarity, and oxo-biodegradable plastics should be referred to as such. Policymakers and commentators should stop referring to oxo-biodegradable plastics as "oxo-degradable," "photo/thermo-degradable," "oxo-fragmentable," or "pro-oxidant additive-containing" plastics.

EMF themselves create confusion by failing to distinguish between oxo-degradable plastic (which fragments but does not biodegrade except over a very long time) and oxo-biodegradable plastic (which has a different chemical structure and becomes biodegradable much more quickly).

They say that unless otherwise stated, all references to oxo-degradable plastics are deemed to refer to oxo-degradable and oxo-biodegradable plastics. This is misleading because these two types of plastic have fundamentally different characteristics and cannot be treated alike. They cite (but then forget) the CEN definition of oxo-biodegradation in TR 15351 as *"degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."*

The distinction between degradation (the abiotic phase) and biodegradation (the biotic phase) is crucial. These two steps involving first the oxidation and reduction of molecular weight, and then the consumption of the oxidized residues by microorganisms, occur continuously during the process of degradation.

Further confusion is caused by including a discussion of compostable plastics in a report on oxo-bio plastic, when it is well-known that oxo-bio plastics are not marketed for composting, and are not designed to comply with the standards for compostable plastics such as EN13432 and ASTM D6400. Further confusion is caused by including in a report on oxo plastics enzymatic plastics, which are neither oxo-degradable nor oxo-biodegradable.

As to oxo-biodegradable plastics, it is said that there are *"claims that such plastics, when they end up in land or aquatic environments, degrade into harmless residues within a period ranging from a few months to several years."* These claims are correct, and the difference in timescale results from the formulation of the plastic product (some are designed to degrade faster than others) and the conditions in the environment where they are lying or floating (sunlight and heat will accelerate the process but are not essential).

Polyethylene and polypropylene, have a specific gravity less than 1, so they will float on the surface

It is said by EMF that *fragmentation should then accelerate the process of biodegradation i.e. the breakdown triggered by microorganisms into naturally-occurring molecules such as carbon dioxide and water, but the speed of this biodegradation process depends on multiple criteria. These criteria include the fragment size, the quantity of additives, and the environmental conditions to which the material is subjected.*

This is partly correct, but it is not fragmentation into small pieces which makes the material available to micro-organisms, it is the reduction of the molecular weight of the fragments. Also, the rate of degradation does not depend on the *quantity* of additives, but the balance within the additive between prodegradants and stabilisers.

According to EMF *"During this time evidence suggests that fragments from oxo-degradable plastics contribute to microplastic pollution and this poses an environmental risk, particularly in the ocean."* In fact, after studying oxo-bio technology for ten months the European Chemicals Agency said that they were not convinced that microplastics are formed. However, even if microplastics were formed, this is not a good reason to be opposed to oxo-bio plastics, because it is known that the conventional plastics which they are designed to replace, will without doubt fragment and contribute to much more persistent microplastic pollution, which poses a greater environmental risk, particularly in the ocean. See Microplastics

Oxo-biodegradable plastic is expected to degrade and biodegrade *"over a time-scale short enough for particles not to accumulate in ecosystems."* Clearly oxo-biodegradable plastic products cannot be designed to degrade instantly, for they would have no useful life, but they are designed to degrade and biodegrade much more quickly than conventional plastics so that there is a much shorter dwell-time for any particles to accumulate in eco-systems.

In fact, if oxo-bio plastics had been brought into use even a few years ago the enormous ocean garbage patches would not have accumulated, and the plastic would have biodegraded and returned to nature

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It is known that conventional plastic fragments do not even become biodegradable for many decades. No government has ever defined what they mean by "a reasonable timescale" but they understand that oxo-bio plastic takes a much shorter time to become biodegradable than ordinary plastic.

EMF say that they are not sure that oxo-bio plastic will fully biodegrade, but we have seen no reasons (and EMF do not give any) why, once biodegradation has commenced, it should not continue until it is complete.

THE SCIENTIFIC EVIDENCE

EMF cite a large number of reports, but as a general point, we have found that reports and literature-reviews by researchers who are not experts in oxo-biodegradable technology show a lack of understanding of the mechanism by which oxo-biodegradable plastics acquire biodegradability, and the function of the stabilisation package. This leads to testing in conditions, and according to standards, inappropriate for oxo-biodegradable plastics.

For example, failure to run the TIER 1 test in ASTM D6954; or failure to run that test until the TE[%] < 5% or Mw < 5000 Da; or testing under anaerobic conditions, or failure to understand that the product contains stabilisers which delay the onset of degradation, means that their attempt to study oxo-biodegradation is often ineffective.

A case in point is the 2015 Michigan State University Report by Selke et al.

Another case in point is the 2007 Chico report. The author does not mention the source of "oxo-degradable LDPE" used in the tests, while other materials are clearly described and the source specified. It is not therefore known which OBP masterbatch was used, in which concentration, and with which stabilization package. One cannot therefore judge the performance for which it was designed, nor even be sure that it was oxo-biodegradable plastic at all. In addition, the Chico report makes the statement: "LDPE with additive is not biodegradable as it does not meet the requirements of ASTM D-6400". This is irrelevant, as D6400 is a standard for biodegradation in the special conditions found in industrial composting, and not for biodegradability in the open environment for which oxo-bio plastic is designed. The relevant standard for OBP is ASTM D6954.

The material studied by Chico was not abiotically degraded, as required by Tier 1 of D-6954 as a first, critical step, and it is not therefore surprising that subsequent attempts to measure biodegradation according to ASTM D-5338 showed poor results. Further, testing the material in anaerobic conditions shows a fundamental misunderstanding of the technology, as it is axiomatic that oxygen is required. Finally, the Chico experiments cannot have been properly designed and/or performed, as even the Kraft paper control, PLA lids, sugar cane lids, corn starch trash bags, and Ecoflex bags showed no fragmentation after 60 days.

The 2015 UNEP report does not show that oxo-degradable plastics simply fragment into small pieces including microplastics. Indeed it admits that they may be utilised by micro-organisms, but questions the rate and extent (to which we have referred above). Further, this report is not based on original experimental work and the author is a geologist rather than a polymer scientist. The micro-particles of plastics found in the oceans were from ordinary plastics.

Another case in point is the recent experiments at Plymouth University by marine biologists. If the researchers had been polymer scientists who understood the process of abiotic degradation they would have understood that an oxo-biodegradable shopping bag contains stabilisers to give the product a useful service life and which would have delayed the onset of abiotic degradation of the bag. Simply to say that it had not degraded after two years gives a false impression.

The researchers at Plymouth should also have understood that oxo-biodegradable bags are intended to degrade if they become litter in the open environment on land or sea with an abundance of oxygen and usually exposed to sunlight, and that the experiment they performed was not therefore a fair test. This is because they had submerged it in a dark environment under a pontoon.

EMF say that *"oxo-degradable plastics left in the open environment, in the UK, degrade to small fragments in two to five years, and they will still remain visible as litter before they start to fragment."* What they do not say is that the fragments are biodegradable but ordinary plastic will degrade to small fragments and will remain visible for very much longer before they become biodegradable.

The biodegradability of oxo-biodegradable polymers has been extensively studied and reviewed in scientific articles (e.g. **Ammala et al., 2011; Koutny et al., 2006a; Singh and UK - 617509644.1 5; Sharma, 2008. Albertsson and Karlsson, 1980; Chiellini et al., 2006; Jakubowicz et al.,2006; Ojeda et al., 2011Albertsson et al., 1987; Bonhomme et al., 2003; Corti et al., 2010; Jakubowicz et al., 2011).**

According to **Gewert et al** "Abiotic degradation produces carbonyl groups that increase the hydrophilicity of the polymer and thus increase its availability for biodegradation".

Dussud et al compared three polyethylene-based polymers, with similar surface roughness, and observed increase in oxidation and hydrophilicity brought about by the inclusion of a prodegradant additive and then by oxidative degradation, which is a clear factor in the ability of organisms to colonize the material. During these experiments, the degree of colonisation (cell count) is not only an indication of the ability of microorganisms to physically populate the surface of the material, but is also influenced by each material's ability to act as a source of nutrients for the microorganisms.

Eyheraguibel et al identified the products of degradation facilitated by a prodegradant additive in an OBP as oxidised oligomers. The characterisation of the oligomers, before and after exposure to the bacterial strain R. rhodochorus, provides insight into the oligomeric products of polyolefin degradation and their biodegradability. The paper demonstrates that after sufficient molecular weight reduction, the oligomers are soluble in water and that the most and undergo near-total biodegradation: 60% biodegradation after only four days, up to 95% after 240 days.

Arraez et al say "The design of materials with the ability to degrade once their service life has finished is one of the industrial approaches to face the problems of accumulation of plastic wastes in the environment. The purpose of such process is to generate chemical changes in the polymer structure as a result of oxidation in air. This is achieved by using special additives called pro-oxidant/pro-degradants (oxo additives) consisting of organic salts of metals .... The degradation process induced by the incorporation of oxo additives in polymers is called oxo-biodegradation and is defined as the process of transforming complex molecules into simpler elements from oxidation reactions that promote the cleavage of the chemical bonds, the incorporation of polar groups, and the reduction in molecular weight in polymer chains favouring their interaction with microorganisms in the environment, transforming them into bio-assimilable materials. Microorganisms such as bacteria fungi and algae use the oxidation products of the polymer chains as carbon sources resulting in the formation of carbon dioxide, water, and biomass."

In August 2019 **Queen Mary University London** published a report, the main findings of which were that:

- Oxo-Biodegradable plastic demonstrated up to 90 times more biodegradation than conventional plastic, when aged for the same period of time.
- The degraded material was biodegraded by bacteria found in soil and marine environments.
- Molecular-weight reduction is a critical factor in the rate and extent of biodegradation, showing that biodegradability increases as molecular-weight reduces.
- The use of a prodegradant catalyst such as that in a d2w masterbatch, caused a rapid reduction of molecular-weight.
- The plastic samples tested for biodegradation were abiotically degraded under both real life and laboratory conditions.

The most recent independent review of the scientific evidence is by Peter Susman QC, a former Deputy Judge of the High Court in England. He found that oxo-biodegradable plastic:

• does facilitate the ultimate biodegradation of plastics in air or seawater by bacteria, fungi or algae, within a reasonable time, so as to cause the plastic to cease to exist as such, far sooner than ordinary plastics, without causing any toxicity;

• that "the benefit is obvious of reducing future contributions to the scourge of plastic pollution of land and sea";

• that oxo-biodegradable technology is compatible with composting and recycling.

EMF often cite European Bioplastics, SPI Bioplastics Council, European Plastics Converters, Biodegradable Products Institute, and Sustainable Packaging Coalition as authorities, without making clear, contrary to FTC Claim 260.6(e) Example 2, that these are trade organisations supporting commercial products in competition with oxo-biodegradable plastic. By contrast, EMF did not cite any of the peer reviewed scientific publications published in 2017 and 2018 considered by **Peter Susman QC**.

In particular they fail to cite the evidence from **Professor Ignacy Jakubowicz** which EMF had itself requested, 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."* They are then recycled back into nature by the naturally-occurring micro-organisms. This point is absolutely crucial to an understanding of OBP.

According to **Dr. Graham Swift**, **Vice-chairman of the ASTM Technical Committee on Biodegradable Plastics** *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."*

"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."

Dr. Swift is one of the authors of ASTM D6954. He says *"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. If it did, 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."

Claims

It is alleged that some claims made by companies in the biodegradable plastics industries are misleading, but EMF do not specify who is making the claim and exactly what the claim is. Misleading claims are sometimes made about motor cars, but the way to deal with this is to ban the misleading claims, not the cars.

The "precautionary principle" is often relied upon, but the correct way to give effect to the precautionary principle in the EU is to refer any concerns to the European Chemicals Agency (ECHA) under Article 69 of REACH for an investigation and report.

The EU Commission published a report in January 2018, but that report did not recommend a ban on "oxo-degradable" plastics, and no such ban was included in the draft Directive submitted by the Commission to the Parliament and Council.

Instead the Commission said that "a process to restrict the use of oxo-plastics in the EU will be started" and it asked ECHA to investigate "oxo-degradable" plastics because the Commission thought that they created microplastics. However, in October 2018 ECHA advised that it was not convinced that microplastics are formed. It was at about this time that a ban on "oxo-degradable" plastic[1] was added to the draft Directive in the Environment Committee of the Parliament.

[1] The Single-use Plastics Directive (Recital 15) is intended to ban plastic that "does not properly biodegrade and thus contributes to microplastic pollution in the environment, is not compostable, negatively affects the recycling of conventional plastic and fails to deliver a proven environmental benefit." It is therefore important to be clear

There is a well-established procedure for restricting products, laid down in Articles 68-73 of REACH, but the EU have ignored these procedures, and the Directive is therefore open to legal challenge.

The EU have pre-empted the conclusion of the ECHA study (which they have now terminated) and have thereby deprived all stakeholders, of the safeguards which those Articles contain, including a scientific dossier under Annex XV, review by two committees, and public consultation. - This is astonishing.

The ECHA investigation into oxo-degradable plastics is the only one to have ever been terminated due to legislation circumventing the process.

The members of the European Parliament's Environment Committee, were persuaded by lobbyists in 2018 to pass legislation against oxo-degradable plastic without a proposal from the Commission, without any impact assessment or socio-economic analysis, and without any dossier from their own scientific experts, ECHA. This legislation has delayed the adoption of oxo-biodegradable technology in the EU, with the result that thousands of tonnes of ordinary plastic have escaped and continue to escape into the European continent and its coastal waters, where it will lie or float around for decades.

Symphony Environmental Technologies Plc brought a legal action against the European Union in its own court in Luxembourg to prove that its ban on oxo-degradable plastic was unlawful. Oxo-degradability is not the same as oxo-biodegradability (CEN TR15351), but confusion had arisen as to whether the legislation applied to both. Symphony should have won the case.

The court said that the exercise of legislative discretion "implies the need to anticipate and evaluate ecological, scientific, and technical matters of a complex and uncertain nature" but the legislators were not scientifically qualified to do that. The only EU body qualified to do so is the European Chemicals Agency (ECHA).

The court accepted Symphony's argument that "if the legislature is not to adopt arbitrary measures, which cannot be rendered legitimate by the precautionary principle, it must ensure that any measures that it takes, even preventive measures, are based on as thorough a scientific risk assessment as possible." Also that the "scientific assessment should be based on the best scientific data available." The legislators failed these legal tests. They had not carried out "as thorough a scientific risk assessment as possible" and their scientific assessment was not based on "the best scientific data available."

The best scientific evidence would have been the report of the European Chemicals Agency (ECHA) who were actually studying oxo-degradable and oxo-biodegradable plastic when the legislation was being considered. The Institutions could not be heard to say that the best scientific evidence was not available because they had themselves prematurely terminated the ECHA enquiry. They had also failed to make an environmental or socio-economic impact assessment, and they disregarded the doubts already expressed by ECHA in October 2018 as to whether microplastics were formed.

Surprisingly, the court held nevertheless that the legislators had not exceeded the limits of their discretion.

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that it is not intended to ban oxo-biodegradable plastic, because there is solid scientific evidence that d2w oxo-biodegradable plastic does properly biodegrade, does not contribute to microplastic pollution and does not negatively affect the recycling of conventional plastic.

An even more disturbing feature of this case is that evidence paid for by the Defendants (such as the Eunomia Report, on which the court placed much reliance) - is acceptable, but evidence paid for by the Claimants (Symphony) "has little probative value." (This point is made nine times in the judgment). However, as professional witnesses and laboratories have to be paid, how is a Claimant against the EU to adduce any expert evidence before their courts which has any "probative value?" This places the Claimant at an unacceptable disadvantage before the EU court, and fundamentally impairs the whole Judgment. In addition, the court was unable to take account of important evidence, such as the Oxomar Report from France, which became available after 2019.

OTHER ARGUMENTS

There are a number of make-weight arguments in the EMF statement – for example that biodegradable plastic will encourage littering. EMF are reluctant to make this argument against crop-based biodegradable plastic, but in any event it is mere speculation. In the opinion of Peter Susman KC "the criticism alleging that oxo-biodegradable plastic technology would materially encourage littering [can only be regarded] as fanciful and unrealistic

Much of the littering is accidental, and the argument is not therefore relevant to this. Insofar as it is deliberate, would the kind of person who throws plastic litter out of a car window look first at the label (if there is one) to satisfy himself that it is biodegradable? Suppose however for the sake of argument that EMF are right and that there would perhaps be 10% more plastic litter - is it better to have 110 oxo-bio items that will have biodegraded within a few months or even a few years, or 100 ordinary plastic items that will persist for a century or more?

Degradable plastic products (both oxo and hydro biodegradable) have been available to the public for more than 20 years but there is no evidence that people dispose more carelessly of them.

In our view it is not acceptable to continue debating this speculative proposition any longer, while thousands of tonnes of conventional plastic are getting into the environment every day, which will pollute the environment for decades into the future.

EMF claim that oxo-bio is incompatible with a circular economy, but the opposite is true. Ordinary plastic can certainly be recycled if it can be collected, but what of the plastic on land or sea which cannot be collected? If that plastic were oxo-bio it would complete the circle by being recycled back into nature by bacteria and fungi. It is said that oxo-bio products go against two core principles of the circular economy: designing out waste and pollution; and keeping products and materials in high-value use. However, these statements are not well founded. Oxo-biodegradable plastic products are not intended to be wasted. They can be reused and recycled during their useful life – and carrier bags frequently are. It is designed to biodegrade only if it has not been collected for re-use and recycling, but has instead escaped into the open environment as litter.

RECYCLING

It is claimed that *"oxo-degradable plastics negatively affect the quality and economic value of plastic recyclates."* However,

> according to the recycling charity RECOUP[1] "In cases where plastic products are particularly lightweight and contaminated with other materials, the energy and resources used in a recycling process may be more than those required for producing new plastics. In such cases recycling may not be the most environmentally sound option.

These are the very products for which OBP technology is commonly used.

Separation of the different types of polymer is a problem with all types of plastic film, and is one reason why post-consumer plastic film is not attractive to recyclers. Other reasons are that the material is often contaminated, and it would not be cost-effective to clean it, given that the material from which it is made is inexpensive and readily available.

It is also costly in financial and environmental terms to collect it, transport it, sort it, bale it, store it, and then reprocess it, so it is generally sold as mixed plastic for low grade uses (not for long-life uses such as building films or pipes, which are normally made from virgin polymer or from used-plastics of known type and provenance).

It is said that "oxo-degradable plastic packaging cannot be detected by current technology at sufficient scale to be sorted out from conventional plastics." This is easily remedied by requiring the inclusion of a tracer in the OBP at manufacture which the equipment can recognise, but it is not necessary because oxo-biodegradable plastic can be safely recycled without separation. See reports by specialist researchers in Austria and South Africa.[2]

It is clear from these scientific reports that it is not necessary to add stabilisers unless the recyclate is being used to make long-life products, in which case the manufacturers of those products would be adding stabilisers anyway. These stabilisers are in a quantity and with a chemistry which they would normally use, and no special arrangements are necessary for recyclate containing OBP.

Most ordinary waste plastics will have been exposed to UV radiation, in particular agricultural film, and may have oxidised to some extent, but not enough to become biodegradable. Recyclers of mixed plastic wastes have no way of knowing which have been exposed and for how long, and it is also known that printing inks, and other chemicals will affect the recycling process. Therefore, the industry already has the problem of identification when dealing with post-consumer plastic films, and deals with it by using those materials for low-value/short-life applications such as carrier bags and garbage sacks.

In the last four years alone, enough masterbatch has been sold by one OPA member to make 600,000 tonnes of OBP products from polyethylene and polypropylene.

[2] http://www.biodeg.org/recycling-and-waste/

We know that OBP products have been successfully recycled for the past 20 years by OPA members and their customers around the world, and in those 20 years we have heard no reports of any difficulty encountered.

Our experience is entirely consistent with the specialist reports, that oxo-bio plastic can be safely recycled, and the recyclers have presented no technical evidence and no actual experience, to the contrary.

These unfounded points about recycling are not a sufficient reason to continue to use ordinary plastic, thousands of tons of which are getting into the oceans every day. These will undoubtedly create microplastics and will pollute the environment for many decades into the future.

It is time for a much better dialogue between the recyclers and the OBP industry. If we can combine oxo-biodegradable technology with the three R's of 'Reduce, Reuse and Recycle',and add a fourth R – "Remove," we can all help win the battle against plastic waste - for the lasting benefit of future generations.

Before leaving the topic of recycling, the specialist researchers also confirmed that crop-based 'compostable' plastics cannot be safely recycled with oil-based plastics. Therefore, anyone who wants to promote recycling should certainly be concerned about bio-based plastic. Some of it will get into the plastic waste recycling stream – especially as it is being promoted for carrier bags and packaging.

CONCLUSION

The EMF Report indicates that it is endorsed by a large number of companies and organisations, some of which are aggressively promoting a competing plastic technology, and others are themselves producers of many of the plastic articles which are found as litter in the environment. EMF has been formally requested by lawyers acting for an OPA member to declare the amounts of money received from those companies and organisations, but it has failed to do so.

It could reasonably be inferred that the Report was published by EMF with the improper motive of assisting a commercial and political campaign against the oxo-biodegradable plastics industry.

If EMF succeed in their campaign against oxo-biodegradable plastic, they will have deprived the world of the only means yet available to deal with long-term pollution of the environment by the plastic waste which cannot be collected for responsible disposal.

RESPONSE TO MSU REPORT

Making Plastic Smarter
Symphony environmental

MICHIGAN STATE UNIVERSITY

We have carefully considered the report 'Evaluation of Biodegradation-Promoting Additives for Plastics" by the researchers at the Schools of Packaging and Biosystems and Agricultural Engineering, Michigan State University (MSU). It is likely to cause confusion in the marketplace.

We discussed the protocol for this testing at length with MSU prior to the commencement of the programme, but it was clear that they did not understand the basic principles of oxo-biodegradable technology, namely that oxidation is necessary to create the chemical changes in the material that will make it biodegradable. This is clearly stated in ASTM D6954, which is the American standard for Plastics designed to degrade and then biodegrade in aerobic conditions. This point was made directly to Susan Selke on a technical visit to MSU on 27th April 2011.

Nevertheless MSU decided to subject oxo-biodegradable materials to a series of tests that were inappropriate for the purposes for which oxo-biodegradable plastics are intended. The MSU tests were for anaerobic biodegradation, industrial composting, and soil burial, but oxo-biodegradable plastic is designed to combat the blight of littering in the open environment.

Anaerobic biodegradation has no relevance to oxo-biodegradable plastic, which requires oxygen in order to oxidise. We made it clear to MSU that subjecting these materials to anaerobic conditions, where there is no prospect of oxidation occurring, would merely confirm the inertness of oxo-biodegradable plastics under those conditions. It is not therefore surprising that they found no degradation.

With regard to the test presented in figure 1 of the MSU report, it is worth commenting that activity of the cellulose controls at 35°C are more active than those at 50°C. This seems improbable and suggests poor reproducibility or control of their technique.

Oxo-biodegradable plastics are designed to be durable and may be manufactured to have a useful life of between six months and five or more years. If littered they will oxidise in the open environment and become biodegradable. They are simply not designed to oxidise and rapidly mineralise in the timescale of an industrial composting test.

Whilst the aerobic composting test is irrelevant for an oxo-biodegradable product and the results were entirely predictable, there are some further issues with the MSU approach that need to be mentioned:

- For this test to be valid, according to the recognised standards (ASTM D5338 and its equivalent ISO 14852), the cellulose control needs to obtain 70% biodegradation in 45 days. In the data presented in Figures 2b and 2d the cellulose control achieves only 55% biodegradation after 70 days, and so the test is not valid.

- The progress of the cellulose biodegradation curve is itself erratic, dipping after 60 days, suggesting problems with the inoculum used for the test.

- ASTM D 6954 clearly states that the biodegradation test should be performed after the plastic has been oxidised to achieve a Mw reduction to 5kDa or less. MSU attempted the biodegradation test on material with an average molecular weight of 31.4kDa, so failure was inevitable.

- The attempt to biodegrade a powder with a Mw of 22KDa is again flawed. Whilst this material had a lower molecular weight it remained above 5kDa, but more important it had not achieved those properties through oxidation and will not therefore have acquired the potential to biodegrade.

- The reference to a loading of 1% to 5% shows again a failure to understand oxo-biodegradable technology. By increasing the amount of masterbatch the efficacy of the prodegradant remains relatively constant – but the action of the stabilisers within the masterbatch is significantly increased. Thus, by increasing the 'dosage' the test material becomes less biodegradable.

The third element of the study, the soil burial tests, are likewise of little value. Oxo-biodegradable plastics without access to oxygen to promote abiotic changes will not biodegrade, and certainly not in the short timescale of this test.

Symphony did offer advice to MSU on how to construct an appropriate study for oxo-degradable polyethylene, but since they had their own project funding we were unable to dissuade them of the unsuitability of their approach.

Symphony tried to assist and funded a parallel two-year study that would be conducted according to the established ASTM 6954 protocol. The protocol was not however followed and it became apparent that MSU did not have the experience or equipment necessary to conduct these tests. Symphony decided to terminate the project after 1 year.

21st April 2015

Being aware of these problems, and in order to prove the biodegradability of the films used by MSU, Symphony asked Prof. Jacques Lemaire at the Centre National d'Evaluation de Photoprotection (CNEP; University Blaise Pascal, Clermont -Ferrand, France) to evaluate them. The films were proved to be biodegradable.

On 15th March 2014, at the Global Plastics Environmental Conferencein Florida we expressed our misgivings Dr. Selke when the results were revealed by her in a presentation entitled 'Independent Study on the Claims of Oxobiodegradable Additives." We publicly voiced our concern regarding the methodology, credibility and accuracy of the entire project, but no corrections or acknowledgements followed.

It is difficult to avoid the conclusion that the testing protocols selected and the headline results claimed and published around the world, were designed to harm the oxo-biodegradable plastics industry.

Analysis of "High incidence of false biodegradability claims related to single-use plastic utensils sold in Brazil" by Beatriz Barbosa Moreno et al. (41 Sustainable Production and Consumption (2023) 1-8).

By Telmo F. Ojeda[1] and Radu Baciu[2]

Abstract

It is greenwashing to affix to a product a label claiming biodegradability if the product is not biodegradable, but Moreno et al had not taken the fundamental scientific step, to determine whether they were biodegradable or not. Nor had they ascertained that products claiming to contain pro-oxidant additives, actually contained pro-oxidant additive in the correct proportion or at all.

Plastic products should not be sold as oxo-biodegradable, nor bear the logo of a masterbatch supplier, unless the seller can produce evidence that the product has been correctly made with that supplier's masterbatch which has been successfully tested according to ASTM D6954 or equivalent.

There is no doubt that a PE or PP product properly made with a reputable oxo-biodegradable masterbatch such as d2w, will fully biodegrade much more quickly than ordinary plastic under any conditions in the open environment, without leaving microplastics or harmful residues. Many reports have been published which appear to question this, but have themselves been refuted.

It is remarkable how many authors do not distinguish between oxo-biodegradable plastics and plastics marketed as "compostable" which are completely different technologies. They then spend time to prove that oxo-biodegradable plastics are not compostable according to EN13432 or ASTM D6400, but these plastics are not intended for composting. They are intended to biodegrade if they get into the open environment as litter.

Another common fault is to test products from the market which claim to be oxo-biodegradable without confirming that they have been made with the correct amount of masterbatch, or any masterbatch at all. Yet another fault is to test the sample under conditions not likely to be experienced by plastic litter in the real world and/or to use samples which have been so heavily stabilised as to be unlikely to degrade in any realistic timescale. These papers are therefore of very little value, but they are constantly cited and re-cited in the literature reviews.

It is true that "most consumers do not have a proper understanding of the meaning of terms such as bioplastic, bio-based biodegradable and compostable" However, many organisations, including the EU, and NGOs, cause confusion by treating oxo-degradable and oxo-biodegradable as though they were the same. They also describe plastics as "compostable" knowing that these plastics convert into CO_2, not into compost.

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[2] Polymer scientist with 38 years' experience of the theory and practice of oxo-biodegradability; and Director of Technical at Symphony Environmental Technologies, UK.

Moreno et al cite studies showing that "increasing world population and changes in society's lifestyle have led to a large production and consequent inadequate disposal of solid waste in natural environments. Plastic polymers are currently recognized as the most abundant and frequent type of residues found in natural environments around the world."

Policies of "Reduce, re-use and recycle" have been popular now for more than ten years, but it is clear that they are not solving the problem. Plastic cannot and should not be banned entirely for the foreseeable future even in the developed world[3] so, in addition to the 3-R's, the plastic itself needs to be made so that it will biodegrade much more quickly if it gets into the open environment leaving no microplastics or eco-toxicity. Plastic is made from a by-product of refining oil, so for as long as petroleum products are needed for engines it makes sense to use the by-product instead of using land, water, and energy resources to make plastic from vegetable matter.

GREENWASHING

For the purposes of their paper Moreno et al obtained from supermarkets in Brazil a selection of plastic products bearing labels claiming biodegradability, and they say that they are examples of "greenwashing."

Yes, it is of course greenwashing to affix to a product a label claiming biodegradability if the product is not in fact biodegradable, but we were surprised to see that the authors had not taken the first, and fundamental, scientific step to test the products to determine whether they were biodegradable or not. Further, they say that 93.8% claimed to contain pro-oxidant additives, but they had not tested to determine whether the products contained pro-oxidant additive, in the correct proportion or at all.

Twenty-nine of the 45 items collected for this study were made of polystyrene, but oxo-biodegradable technology is not suitable for that type of plastic. It is therefore most unlikely that any of them would have been found to contain oxo-biodegradable masterbatch, and therefore most unlikely that they were biodegradable.

The other items eg knives, forks, plates cups etc. were probably made from the type of plastic marketed as "compostable" (which does not contain oxo-biodegradable masterbatch). It would be greenwashing to describe that type of plastic as biodegradable, because it is tested to biodegrade in the special conditions found in an industrial composting facility, not under normal conditions in the open environment. It would also be greenwashing to describe it as compostable, because in a composting facility it converts into CO_2 gas, not into compost.[4]

The authors say that "most consumers do not have a proper understanding of the meaning of terms such as bioplastic, bio-based biodegradable and compostable." This is correct and the remedy lies in clearer labelling and better education, and by banning the descriptions of "biodegradable" and "compostable" mentioned above. The use of the word "bioplastic" should also be banned because it causes confusion. Does it mean a plastic product made wholly or partly from vegetable materials, and if so in what proportion? Does it mean a plastic which is biodegradable, and if so by hydro-biodegradation or oxo-biodegradation?

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[3] https://www.biodeg.org/wp-content/uploads/2019/11/Denkstatt-report.pdf Also, Life-cycle assessments by Intertek have shown that plastic has a better LCA than the other materials used for packaging. https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/ see also

[4] 90% conversion to CO_2 within 180 days is required by EN13432 and ASTM D6400. See also https://www.biodeg.org/subjects-of-interest/composting/

"Oxo-degradation" is defined by CEN (the European Standards authority) in TR15351 as "degradation resulting from oxidative cleavage of macromolecules." This describes ordinary plastics, which abiotically degrade by oxidation in the open environment and quickly create fragments, but do not become biodegradable except over a very long period of time.

"Oxo-biodegradation" is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic degrades by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature.

Regrettably, many organisations, including the EU, and many of the NGOs, cause confusion by treating these two technologies as though they were the same.

Moreno et al do not show anything printed about "pro-oxidants" on the products in their sample except polypropylene drinking straws. Polypropylene made with d2w masterbatch has been tested by Intertek according to ISO 14855 and biodegraded as to 95.05% in 180 days.

The suppliers of oxo-biodegradable masterbatches to the plastics industry do not make the plastic products or write the labels. This is done by the manufacturers of the products and the retailers. So, even if the authors had tested the products and the labels had been proved to be false, it is rather like blaming Mercedes for making false claims because someone had applied a Mercedes badge to a car which did not work properly and which Mercedes had not manufactured.

It is true that irresponsible manufacturers and retailers are all too often deceiving their customers by claiming that products are oxo-biodegradable by affixing the logo of a reputable masterbatch supplier, such as Symphony's d2w logo, but not including the masterbatch in the right quantity or at all. Plastic products should not therefore be sold as oxo-biodegradable in Brazil or anywhere else, nor bear the logo of a masterbatch supplier, unless the seller can produce evidence that the product has been correctly made with that supplier's masterbatch which has been successfully tested according to ASTM D6954, BS8472, SASO 2789, ASTM D5338, ASTM D5988, ISO 14855, ISO 17556 or similar.

OXO-BIODEGRADABLE PLASTIC

It would not be greenwashing to describe as biodegradable a polypropylene or polyethylene product correctly made with an oxo-biodegradable masterbatch.

There is no doubt that a PE or PP product properly made with an oxo-biodegradable masterbatch such as d2w which has been tested according to ASTM D6954 or equivalent, will render the plastic fully biodegradable much more quickly than ordinary plastic under any conditions in the open environment, without leaving microplastics or harmful residues. However, many reports have been published which appear to question this, and they are constantly repeated in the literature reviews. These reports and reviews are then used by authors such as Moreno et al to claim that "the biodegradability of oxo-polymers has been widely refuted."

Many of these reports and reviews have themselves been refuted.[5]

It is remarkable how many authors do not distinguish between oxo-biodegradable plastics and plastics marketed as "compostable" which are two completely different technologies. They then expend time to prove that oxo-biodegradable plastics are not compostable according to EN13432 or ASTM D6400, but these plastics are not intended for composting. They are intended to biodegrade if they get into the open environment as litter, and although they will biodegrade in compost they will not necessarily do so in the short timescale required by the industrial composters.

Another common fault is to test products from the market which claim to be oxo-biodegradable without confirming that they have been made with the correct amount of masterbatch, or indeed any masterbatch at all. These papers are therefore of very little value, and the current paper by Moreno et al, and the papers cited by them by Nazareth et al (2019); Markowicz et al (2019); and Napper & Thompson (2019) fall into that category. Another common fault is to test the sample under conditions not likely to be experienced by plastic litter in the real world (Napper & Thompson; Requejo et al) and/or by using samples which have been so heavily stabilised as to be unlikely to degrade in any realistic timescale (Brassioulis et al).

The authors cite a paper by Gomez et al (2013) who said that no degradation of polypropylene occurred even after amendment with additives meant to confer biodegradability. However, this paper is irrelevant to oxo-biodegradable plastic, as the materials they tested were not oxo-biodegradable. They were made with a different technology, by ECM Biofilms and Biotec Environmental.

Moreno et al say that "experimental studies have already reported the lack of degradation of commercial utensils falsely claiming biodegradability (Sanahuja et al., 2021; Nazareth et al., 2019). However, the paper by Sanahuja relates to bio-based materials and it is not therefore surprising that they showed insufficient biodegradation in the open environment, because as mentioned above they are designed to biodegrade in the special conditions found in an industrial composting facility.

A much more scientific investigation of degradation in the marine environment is the four-year study sponsored by the French government, known as the Oxomar project. [6] The French scientists reported that "We have obtained congruent results from our multidisciplinary approach that clearly show that these plastics biodegrade in seawater and do so with a

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[5] https://www.biodeg.org/wp-content/uploads/2022/04/BPA-Response-to-EMF-report-19-4-22.pdf
https://www.biodeg.org/wp-content/uploads/2023/06/BPA-analysis-of-WWF-position-paper-6-6-23.pdf
https://www.biodeg.org/wp-content/uploads/2020/05/BPA-RESPONSE-TO-LOUGHBOROUGH-REPORT.pdf
https://www.biodeg.org/wp-content/uploads/2019/04/BPA-Comments-on-Plymouth-10.pdf
https://www.biodeg.org/wp-content/uploads/2020/05/response-to-msu.pdf
https://www.biodeg.org/wp-content/uploads/2015/09/Response-to-UN-2015-Report.pdf
https://www.biodeg.org/wp-content/uploads/2022/10/BPA-Comment-on-the-Eunomia-Report-2016-1.pdf
https://www.symphonyenvironmental.com/wp-content/uploads/2022/09/bpa-responds-to-european-commission-2.pdf
https://www.biodeg.org/wp-content/uploads/2023/02/BPA-Response-to-SAM-Report-Feb-2021.pdf

[6] https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf

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."

It is possible for plastics in the oceans to become bio-fouled and to adsorb toxins, and to sink to the bottom, but this is because they can persist in the oceans for many decades. The advantage therefore of oxo-biodegradable plastics is that they will be in the oceans for a very much shorter time.

Moreno et al cite a literature review by Abdelmoez et al (2021) which concludes that "it is undisputed that oxo degradable (*sic*) plastic, including plastic carrier bags, degrades quicker in the open environment than conventional plastic. Complete biodegradability of oxo-biodegradable plastics probably occurs once the molecular weight is below 5000. The molecular weight can reach this range if the plastic remained for not less than 1 year in the environment which has warmth, bacterial activity, and moisture. At this level, the polymer no longer exists and is a wide range of discrete oxidized species. Bacteria and fungi find these species suitable as a carbon source that can be assimilated into their lifecycle resulting in the formation of biomass and CO_2 under aerobic conditions."

With regard to industry Standards, Moreno et al cite a paper by Viera et al (2021) assessing several technical standards used to certify biodegradability of plastics, which they say "demonstrated that experimental settings used by these norms do not amply cover actual environment conditions, although there may be exceptions among European standards (EN 13432; EN 17228; and EN 17033) The first two are for bio-based polymers which are designed to biodegrade in special conditions, and are not therefore relevant to oxo-biodegradable technology. The last one provides a test for agricultural mulch film, which can be passed by an oxo-biodegradable polymer.

Viera et al did not however mention the test most widely used for plastic which is designed to biodegrade in the open environment. This is ASTM D6954, as to which see the evidence to the UK government of one of its authors, Dr. Graham Swift.[7] This standard has recently been re-approved by ASTM, and has been followed by the Standards authorities in other jurisdictions, including the UK, Saudi Arabia, UAE etc.

Moreno et al say "some European standards providing test schemes and evaluation criteria for the final acceptance of packaging (EN 13432) and terminology for bio based plastics polymers products (EN 17228) would be more suitable." They would be completely unsuitable for oxo-biodegradable plastic, as they are tests for plastics which biodegrade in the special conditions found in an industrial composting facility, not in the open environment.

They say that "the European Union Standardization Committee (EN 17033) accepts a maximum period of six months to reach at least a 90 % degradation rate." In fact this standard (5.2.1(a)) allows 24 months.

The authors allege that metals present in oxo-biodegradable masterbatches may induce toxicity, but oxo-biodegradable masterbatches are not allowed to contain metals at levels above those permitted by the US Environmental Protection Agency (40CFR62, 40CFR150-189, 40CFR260-299, 40CFR300-399, 700-799, or 49CFR100-180), or by Art. 11 of the EU Directive 94/62/EC. Also, ASTM D6954 requires the material to be tested for eco-toxicity, according to the OECD Standards.

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[7] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

It is crucially important to understand how hydrocarbon polymers degrade in the environment by a combination of peroxidation and bioassimilation and how the free-radical chain mechanism can be controlled by antioxidants. Many of the critics of oxo-biodegradable plastic do not understand that it is a two-stage process, and expect it to start biodegrading immediately.

It would be possible to make oxo-biodegradable plastic so that it starts to degrade very quickly, but it would then have no useful life and could not be re-used or recycled. Sustainability must in practice be a compromise between commercial viability and environmental acceptability.

Abiotic peroxidation of hydrocarbons has been extensively studied over the past 50 years by Professor Gerald Scott[8] and other polymer scientists, who realised that polyethylene and polypropylene could cause an environmental problem if it escaped from the waste management process and ended up in the open environment as litter.

So, knowing that most of it would not be collected, they discovered that if they introduced into the normal polyethylene or polypropylene a tiny amount of a catalyst (which is usually a salt of manganese or iron) the plastic would not start to degrade while in storage and would perform in exactly the same way as normal plastic while in use, but if discarded into the open environment would rapidly become biodegradable, and be consumed by bacteria in the same way as nature's wastes.

So, their idea was that manufacturers would stop using ordinary plastic and would upgrade it with their new technology at little or no extra cost. Sadly, this has not been adopted widely enough, so the plastic continues to lie or float around for decades. Prof. Scott said just before he died in 2013 that if his invention had been more widely adopted the ocean plastic garbage patches would be very much reduced.

The loser here is the environment, because ordinary plastic is still being used to make products which get into the open environment every day, where thousands of tons of it will lie or float around for decades. This plastic should urgently be made instead with oxo-biodegradable technology, so that it will biodegrade much more quickly and will not leave harmful residues. It would take very little time to make the change, as no special equipment is required, and little or no extra cost.

The reason why ordinary plastic is not biodegradable is that it comprises long entangled chains of molecules, which give it a high molecular-weight, and this is too high for the material to be accessed by microbes. The molecular-weight of ordinary plastic does reduce naturally over time but it takes very many years -some say 100 years - before ordinary plastic ceases to be a plastic and has become hydrophilic oligomers. So, what the pro-oxidant catalyst does is to cause the molecular chains to be dismantled by oxidation so that the material is no longer a plastic and becomes biodegradable. The important thing is not the size of the fragments, but the molecular-weight, and the polarity/hydrophilicity of the oxidized molecules.

Light and heat will accelerate the process, but it will continue (more slowly) even in dark, cold, conditions. Moisture is not necessary for oxidation, and does not prevent it. In the oceans, mechanical wave energy also contributes to the process of abiotic degradation.

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[8] "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

So that is what d2w oxo-biodegradable plastic is for - but what is it NOT for?

1. It is NOT a disposal route. The plastic is designed to be reused, recycled, and disposed of like normal plastic, but the pro-oxidant technology will make sure that if it gets into the open environment as litter the molecular weight will reduce very rapidly so that it becomes biodegradable.

2. It is NOT necessary for landfill, and landfill operators do not want biodegradation unless the landfill is designed to collect the methane, which most landfills are not.

3. It is NOT for Composting.[9] Five short points on plastic marketed as "compostable":

(a) It does not deal with the problem of plastic litter in the environment, because it is tested to biodegrade in a composting facility, not in the open environment.

(b) It does not convert into compost (EN13432 and ASTMD6400 require it to convert into $C0_2$ gas). It is therefore designed for a deliberate linear process and is not circular. The material is intended to be wasted and lost to atmosphere by conversion into CO_2.

(c) It cannot be re-used, recycled, or made from recyclate

(d) It can leave microplastics in the compost and in the open environment[10]

(e) It is not necessary for processing food-waste, and is not wanted by industrial composters and local authorities.

ARGUMENTS AGAINST OXO-BIODEGRADABLE PLASTIC

There are a number of issues which are always raised:

MICROPLASTICS

Some opinion-formers are still saying that microplastics are caused by oxo-biodegradable plastics, and that the problem would be solved if they were banned. In fact oxo-biodegradable technology is designed to prevent microplastics, not to create them.

Some of the microplastics found in the environment are coming from tyres and man-made fibres, and recycling is also a source of microplastics,[11] but most of the microplastics found in the environment are created by the fragmentation of ordinary plastic when exposed to sunlight. These fragments are very persistent because their molecular weight is too high for microbes to consume them, and can remain so for decades.

That is why oxo-biodegradable plastic was invented. This type of plastic falls apart because the molecular chains have been dismantled and it is no longer a plastic. It will then be consumed by naturally-occurring bacteria and fungi. (When the Ellen MacArthur Foundation asked Professor Jakubowicz for his advice, he made this point, but they omitted it from their paper).[12]

The European Chemicals Agency (ECHA) were asked to study oxo-biodegradable plastic in December 2017. They made a Call for Evidence, and said after 10 months study that they had not been convinced that it creates microplastics. ECHA have never provided a dossier to support any ban on oxo-biodegradable plastic by the EU, and there is no evidence that microplastics from oxo-biodegradable plastic have ever been found in the environment.

[9] https://www.biodeg.org/subjects-of-interest/composting/
[10] https://www.chemeurope.com/en/news/1176729/
[11] https://www.sciencedirect.com/science/article/pii/S2772416623000803
[12] https://www.biodeg.org/wp-content/uploads/2019/11/emf-report-1.pdf

Oxo-biodegradable plastic has been used for bread wrappers for 15 years by the largest bread producer in the world (Grupo Bimbo) and has been compulsory in the Middle East for nearly 15 years. There have been no problems with microplastics or recycling.

RECYCLING

It is sometimes said that oxo-biodegradable plastic will contaminate a recycling stream and is incompatible with a circular economy. That is not correct,[13] but it is correct for "compostable" plastics - which are not recyclable.

In addition to the studies cited in the preceding footnote, polyethylene products made with d2w oxo-biodegradable masterbatch were tested in November 2023 by AIMPLAS[14] in accordance with the Protocol published by the Association of Plastics Recyclers (APR) of the United States, and found to be recyclable without separation from a post-consumer waste stream, with no detriment to the process nor to the new product made with the recyclate.

It is also said that recycling is preferable to biodegradation. Yes, but it is not possible to recycle plastic which has escaped into the open environment from which it cannot realistically be collected. The ONLY way to prevent it accumulating is oxo-biodegradation.

FULLY BIODEGRADE?

Has it been shown that oxo-biodegradable plastic will fully biodegrade? Yes, tests have been done by Intertek showing biodegradation of 92.74% (The percentage required by EN13432 for "compostable" plastic is 90%), and no reason has been shown why biodegradation should stop before it is complete. Tests will never find 100% carbon-evolution because some of the material converts into water and biomass.

Even if it did not fully biodegrade, it would still be better than ordinary plastic, which would have created persistent microplastics but would not have biodegraded at all to any significant extent.

LABORATORY TESTING

EN13432 for "compostable" plastic requires biodegradation to be tested in a laboratory (not in a compost heap) but it is sometimes suggested that oxo-biodegradable plastic should be tested only in outdoor conditions. See however the statement of Dr. Graham Swift (Vice-chairman of the Technical Committee D20:96 at ASTM) who says "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."[15]

Further, the goal of the Oxomar[16] project mentioned above, was to evaluate the biodegradation of OXO-bio in marine waters. See also the report[17] from Queen Mary University London by Rose et. al 11th February 2020. Para 2.6 says "prior to testing, samples of LDPE and oxo-LDPE were surface-weathered in sea water for 82 days, undergoing natural variations in sunlight and UV intensity."

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[13] https://www.biodeg.org/subjects-of-interest/recycling-2/
[14] https://www.aimplas.net/
[15] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf See also www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf at page 620
[16] https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf
[17] https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf

HOW LONG TO BIODEGRADE?

Some commentators say that they cannot be sure how long the plastic will take to biodegrade in the open environment, but it will be many times faster than ordinary plastic when exposed under the same conditions in the open environment. Queen Mary University say (at para. 2.3) up to 90 times faster. As oxo-biodegradable plastic is not intended for composting, it does not need to meet the very short timescales required by the industrial composters, for biodegradation in the special conditions found in their facilities.

EUROPEAN UNION

It is difficult to understand how it was possible for the EU to impose a ban[18] without any dossier from their own experts, the European Chemicals Agency (ECHA) showing any justification for such a ban. As mentioned above, the Commission had asked ECHA to study[19] whether these products created microplastics. ECHA received hundreds of pages of evidence but they were not convinced that microplastics were formed. They were instructed by the Commission to terminate the study.

The Commission's draft Directive did not include any ban on oxo-degradable or oxo-biodegradable plastic, but the Parliament proceeded to legislate against oxo-degradable plastic in terms which have confused people into thinking that it applies to oxo-biodegradable plastic, and they circumvented all the safeguards against arbitrary legislation provided by Arts. 69-73 of the REACH Regulation.

For this reason, the Directive has been challenged in the General Court of the EU in Luxembourg and the case was heard by five judges on 20th March 2023. Their decision is awaited.

PROPENSITY TO LITTER

It is necessary to affix a label to the type of plastic marketed as "compostable," because it must not be recycled and has to be taken to an industrial composting facility, but there is no need to label products as oxo-biodegradable. This is because they are short-life items which are intended to be used and disposed of in the same way as ordinary plastic products, including recycling.

Even if they had a label, it would be irrelevant to the plastic litter which escapes into the environment by accident eg blown by the wind from municipal waste collection and landfills. There is some deliberate littering, but it is fanciful to suppose that the kind of person who throws a plastic bag out of a car window would check the label first to confirm that it is biodegradable.

CONCLUSION

This paper by Moreno et al contributes to the confusion about oxo-biodegradable technology, and therefore damages the environment in Brazil and around the world by contributing to delaying the much wider adoption of this very useful technology.

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[18] (by Art. 5 of the Single-use plastics Directive 2019/904)

[19] (under Art 69 of the REACH Regulation)

This Comment by Ojeda and Baciu (2024) https://doi.org/10.1016/j.spc.2024.08.024 on the work by Moreno et al. (2023) has in turn been commented on by Moreno et al in the same Journal at Vol.41 (2023) 1–8. https://www.sciencedirect.com/science/article/abs/pii/S2352550924002513?via%3Dihub

They say that "the global governance of oxo(bio)degradable plastics must be evidence-based." In fact, the very purpose of the Ojedo and Baciu article was to explain that the paper by Moreno et al was not evidence-based.

For the purposes of their paper Moreno et al had obtained from supermarkets in Brazil a selection of plastic products bearing labels claiming biodegradability, and they said that they are examples of "greenwashing" but the authors had not taken the first, and fundamental, scientific step to test the sample products to determine whether they had been manufactured to be biodegradable or not.

They said that 93.8% of the sample products claimed to contain pro-oxidant additives, but they had not tested to determine whether the products contained a pro-oxidant masterbatch in the correct proportion or at all.

All they can say about that is "it is widely known that greenwashing practices can be assessed using frameworks based on product-label analyses." That is perhaps why these assessments are of no scientific value, as labels applied to products for marketing purpose are not a reliable indicator of the composition of the plastic.

Ojeda and Baciu point out that irresponsible manufacturers and retailers are all too often deceiving their customers by claiming that products are oxo-biodegradable by affixing the logo of a reputable masterbatch supplier, such as Symphony's d2w logo, but not including the right masterbatch in the right quantity or at all. Quality control is therefore essential and it should be enforced by spot-checks carried out by the regulatory authorities.

They also point out that plastic products should not be sold as oxo-biodegradable nor bear the logo of a masterbatch supplier, unless the seller can produce evidence that the product has been correctly made with that supplier's masterbatch which has been successfully tested according to the Standards for testing Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation such as ASTM D6954, Mexican E-288, BS8472, SASO 2879 or similar. They should NOT be tested in accordance with Standards designed for composting such as ASTM D6400, EN13432 or similar.

The first step in any scientific work is to ascertain by scientific means what the composition of the plastic test sample actually is, instead of making assumptions based on product labels. For that reason alone, the paper by Moreno et al, is of no scientific value.

Twenty-nine of the 45 items collected for this study were made of polystyrene, but oxo-biodegradable technology is not used for that type of plastic. Plastic items such as knives, forks, plates cups etc. and advertised as biodegradable are often made from the type of plastic marketed as “compostable” (which does not contain oxo-biodegradable masterbatch). It would be greenwashing to describe that type of plastic as biodegradable, because it is tested to biodegrade in the special conditions found in an industrial composting facility, not under normal conditions in the open environment. It would also be greenwashing to describe it as compostable, because in a composting facility it converts into CO_2 gas, not into compost.

They then say that the Comment by Ojeda and Baciu “presents a lot of wrong or scientifically unsupported information regarding the supposed biodegradability of oxo-plastics, overall, in defense of d2w masterbatch.” This is in itself an unscientific statement, as the information said to be wrong or scientifically unsupported is not identified, and no evidence is adduced to support this criticism.

Ojedo and Baciu are very experienced specialists in oxo-biodegradable polymer science, and their opinion is itself scientific evidence, but Moreno, Jimenez and de Castro are not. In addition, Ojeda and Baciu do cite scientific evidence, including the post important study conducted in recent years. This is the four-year study sponsored by the French government, known as the Oxomar project, and the six scientific studies cited at C7 of the report. See www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf The French scientists reported at C6 that “We have obtained congruent results from our multidisciplinary approach that clearly show that these 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.”

Moreno et al place reliance on a section of the Single-use plastics Directive, which was enacted in the European Parliament by an unscientific and thoroughly disreputable process, to which Ojeda and Baciu refer in their comment. See https://www.biodeg.org/eu-news/ There appear to be ongoing attempts to mislead the Brazilian Parliament by a similar process, to the great detriment of the Brazilian people and their environment.

The EU legislation against “oxo-degradable” plastic was passed without any dossier from the European Chemicals Agency showing any cause for concern about this type of plastic. In making the SUP Directive 2019/904 the EU Parliament caused confusion by failing to distinguish clearly between oxo-degradable and oxo-biodegradable plastic.

Confusion is due to the fact that the prohibition of 'oxo-degradable plastic' and its definition in the legislation were not a considered view of the Commission included in its draft of the Directive, but were inserted at a late stage in the Environment Committee of the Parliament as a result of lobbying on behalf of the "compostable" plastics industry.

In the EU, the REACH Regulation 1907/2006 sets out procedures for the evaluation of substances before they can be banned. These are set out in Articles 68-73 and are designed to ensure that there is a proper scientific assessment and as a safeguard against arbitrary legislation. In this case those Regulations were circumvented.

There was no Environmental Impact Statement or Socio-economic Analysis. There had been three reports to the Committee by their own Rapporteurs on the subject of Single-use Plastics, but none of them made a case for banning oxo-degradable or oxo-biodegradable plastic. Further, the Committee failed to await the results of a scientific study actually being done at the time by the European Chemicals Agency; and the Commission prematurely terminated that study. On 30th October 2018 the Agency informed the BPA that they had not been convinced that microplastics were formed.

On 7th July 2025 the Environmental Protection Agency of the Republic of Ireland (an EU member-state) confirmed in writing to Symphony Environmental that "The d2w technology has been scientifically demonstrated to undergo full biodegradation without leaving behind persistent microplastics or toxic residues. This conclusion is supported by independent studies," including in particular the French "Oxomar" study, and a series of tests by Intertek.

BPA Comments on Plymouth Study

by Napper & Thompson

"Environmental Science & Technology"
April 2019

Oxo-biodegradable plastic technology is intended to deal with plastic litter on the surface of land and sea which can lie or float around for decades. It does this by including a catalyst in the polymer which accelerates oxidation, which in turn causes a reduction in molecular weight and renders the material biodegradable, much more quickly than ordinary plastic, and does not leave microplastics to persist in the environment.

The process is described by Professor Ignacy Jakubowicz of the SP Technical Research Institute of Sweden, as follows:

"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."

The researchers at Plymouth tested two types of carrier-bag said to have been made from oxo-biodegradable plastic, which they labelled Oxobio1 (bearing Symphony's d_2w logo), and Oxobio2 (bearing the EPI logo). They did not investigate or record the chemical composition of the bags, so it is not known whether they had been correctly made, with the right balance between their prodegradant and anti-oxidant components.

The researchers also tested a compostable bag, a conventional bag, and a bag said to be "bio-renewable" whose chemical composition is unclear.

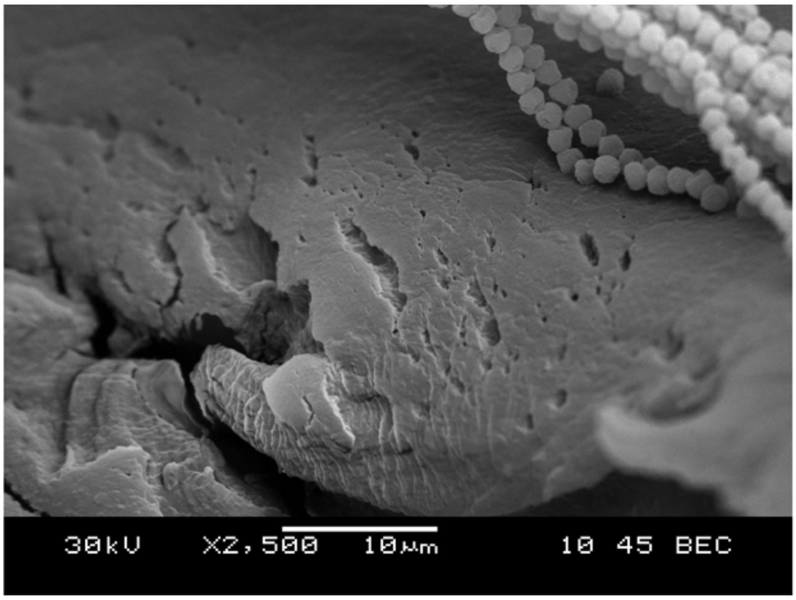
They exposed the bags in the open air in Plymouth UK, and found that Oxobio1 lost strength at a significantly faster rate than the other bags - between 0–9 months ($p = < 0.01$). Indeed they found that Oxobio1 had the greatest loss in tensile stress over 27 months for all environments in which bags were tested. Conventional plastic had the least reduction in tensile stress.

Throughout the 27 months of this experiment, Symphony's Oxobio1 was the only bag type to lose tensile stress significantly faster compared to biodegradable, conventional and Oxobio2 bag types.

This is what we would expect, and in parallel with loss of tensile strength we would expect the molecular-weight of the polymer to have reduced significantly, and the polymer to become substantially biodegradable. However, the researchers, who are marine biologists not polymer scientists, do not seem to be aware of the fundamental principles of polymer degradation as explained in ASTM D6954, which is the industry-standard for testing oxo-biodegradable plastic. They did not therefore measure the molecular weight, which is a crucial indicator of biodegradability. They did however find changes in chemical composition by FT–IR analysis which were indicative of oxidation.

By contrast, researchers at **Queen Mary University London** https://doi.org/10.1101/719476 did measure the molecular weight of oxo-biodegradable plastic . Their study showed that:

- **Molecular-weight reduction is a critical factor in rate and extent of biodegradability**
- **The use of a prodegradant catalyst caused rapid molecular-weight reduction;**
- **The degraded polymer was then biodegraded by bacteria commonly found in soil and marine environments**
- **Oxo-Biodegradable plastic demonstrated up to 90 times more mineralisation than ordinary plastic**
- **There is similar biodegradation whether the polymer is degraded in the laboratory or under real-life conditions**



Bacteria anchored to the plastic and evidence of pitting from biotic degradation of the plastic. The holes in the plastic are roughly the same diameter as a single bacteria (1µM).

The researchers at Plymouth would have known that oxo-biodegradable plastic products are intended to degrade under conditions in which plastic litter is likely to be found in the open environment, namely on the surface of land and sea where there is abundant oxygen and where the process is likely to be accelerated by sunlight and heat.

Nevertheless they also buried the bags in soil, and it is not therefore surprising that they found that degradation proceeded much more slowly. Because the researchers are not polymer scientists they seem to have been unaware that oxo-biodegradable plastic products contain stabilisers which delay the onset of degradation so as to give them a reasonable service life, during which time they can be re-used and recycled.

The stabilisers are rapidly deactivated by sunlight, but the burial in soil at Plymouth did not allow for this mechanism to operate as it would if the bags had been littered. Even buried oxo-biodegradable bags which had first been exposed to sunlight would likely show much more degradation than was observed at Plymouth. If there is no exposure to sunlight at all, the stabilisers will deactive anyway but more slowly.

Similarly, they immersed the bags in seawater at a depth of approx. 1 metre under a pontoon with little or no sunlight, and again it is not surprising that degradation proceeded much more slowly than one would expect if the bags had been littered. It is notable that this was the only one of the Plymouth tests selected by the BBC for a broadcast on 19th July 2018, and which therefore gave a false impression of the experiments.

The polymers in which oxo-biodegradable technology is used have a specific gravity less than 1, so they will float on the surface where oxygen, sunlight, and bacteria are available. Oxygen is ubiquitous, and most of the plastic litter is found lying or floating around with free access to oxygen in the air and in the sea, 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, and biodegradation in anaerobic conditions is not desirable – because it generates methane.

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 sunlight and oxygen for abiotic degradation to occur. If it did, 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.

CONCLUSION

In order to ascertain whether an oxo-biodegradable plastic bag would perform as intended if it became litter in the open environment, it is not sufficient to take a supermarket bag and make assumptions as to its chemical characteristics, expose it for a number of years, and then examine its physical characteristics. A competent scientist would carry out a properly designed and recorded experiment, which would start with a scientific characterisation of the specimen. He would in particular wish to know whether the molecular weight of the polymer had reduced during the experiment, as he would know that biodegradability depends on reduction of the molecular-weight.

'it is not sufficient to take a supermarket bag and make assumptions as to its characteristics'

The Plymouth researchers failed, before the experiment commenced, to ascertain and record in respect of the chosen specimens:

- whether the polymer film contained a prodegradant additive, and if so, the type and quantity of additive
- whether the film contained one or more anti-oxidants, and if so the type and quantity of anti-oxidants.
- the molecular weight of the film
- the carbonyl optical density of the film

They failed during the experiment

- to expose the polymer film on the surface of the water, with access to oxygen and sunlight.
- To measure the carbonyl optical density – at each time point

They failed at the end of the experiment to measure:

- the molecular weight
- whether the film still contained one or more anti-oxidants, and if so the type and quantity of anti-oxidants.

They failed to use a standard testing protocol appropriate for the material being tested ie ASTM D6954 for oxo-biodegradable material, and to record the data and produce the detailed report required by that protocol.

Biodegradable Plastics Association

A not-for-profit Association limited by Guarantee
EU Registration no: 370641927438- 79

BPA response to Scottish Government Consultation

on "Market Restrictions on Problematic Single-Use Plastic Items"

1. INTRODUCTION

1.1 Coronavirus has made everyone realise that single-use plastic is very useful to protect us from the spread of disease, and it is in use today for a wide variety of personal protective equipment and packaging. This is not a temporary phenomenon, because people are never going to forget the need to protect themselves and their food from microbial attack.

1.2 Plastic is one of the few materials in common use which can itself be made antimicrobial, and plastic made with antimicrobial technology has been tested according to ISO 21072 to destroy 99.9% of viruses within one hour of coming into contact with it. All single-use plastics should now be made with anti-microbial technology. (see https://www.symphonyenvironmental.com/wp-content/uploads/2020/09/Antimircobial-Optimised.pdf.pdf)

1.3 They should also be made with oxo-biodegradable technology because some of this plastic will get into the environment after its useful life. That is the reason for this consultation by the Scottish Government, as described by the Minister when she says "this consultation proposes the introduction of market restrictions – effectively a ban – on the single-use plastic items most commonly found littered on European beaches." This is reinforced by para. 1.1 of the consultation document. The problem with plastic is litter.

1.4 It was to address the problem of plastic litter that oxo-biodegradable plastic was invented forty years ago by the scientists who had themselves created plastics and who realised that the durability which they had achieved could be a problem. They therefore found a way to cause the molecular structure of the plastic to convert automatically by oxidation into low molecular-weight materials which are biodegradable. They called this process "oxo-biodegradation" and it occurs anywhere in the open environment where oxygen is present, without any need to take the plastic to a composting facility. Light and heat will accelerate the process, but they are not essential.

1.5 An OPA member, Symphony Environmental Technologies Plc received a letter on 29th October 2020 from the Rt. Hon. Theresa Villiers MP., the immediate past Secretary of State for the Environment in which she says "We are all aware that plastic which has escaped into the open environment as litter is causing a serious problem, and that governments are taking measures to reduce the amount. Nevertheless it is realistic to expect that despite those measures a significant amount of plastic will continue to get into the open environment from which it cannot easily be collected for recycling or anything else.

1.6 I gather that your company has sought to address this problem by developing a type of plastic known as "oxo-biodegradable," which converts into non-toxic biodegradable materials if it gets into the open environment, without any need to collect it and take it to a composting facility.

1.7 I am also aware that by Directive 2019/904 the EU has banned "oxo-degradable" plastic as from July 2021 because they think it creates microplastics, but they have not distinguished oxo-degradable from oxo-BIOdegradable plastic. I am concerned that having commenced the process required by REACH before any substance can be banned, the EU did not complete the process and imposed the ban notwithstanding that their own scientific experts (ECHA) advised that they are not convinced that microplastics are formed.

1.8 I am writing to say that as a former UK Secretary of State for the Environment I see no justification for banning oxo-BIOdegradable plastic. In fact I consider this technology can play a positive role in tackling plastics pollution because it enables everyday plastics to biodegrade safely and quickly if they get into the open environment."

2. A CIRCULAR ECONOMY FOR PLASTICS

2.1 The OPA would agree that plastic is a resource which should not be wasted, and that it should therefore be re-used and recycled where it makes economic and environmental sense to do so. Recycling makes more sense for some of types of plastic (eg PET) than for others (eg. PE and PP).

2.2 However, no government in the UK has a policy for dealing with plastic waste which has escaped into the open environment, from which it cannot be collected and disposed of in the right way, and cannot therefore fit into a conventional circular economy.

2.3 Their blind spot is that despite their best efforts a significant amount of plastic will continue to get into the open environment for the foreseeable future, which cannot be collected for recycling or anything else.

2.4 Oxo-biodegradable technology is specifically designed to deal with this problem, by causing the plastic to become biodegradable much more quickly if it gets into the open environment. It is not designed to biodegrade in landfill because biodegradation of anything in anaerobic conditions generates methane. Nor is it designed for composting, and European Standard EN13432 is not therefore relevant. It can be recycled if collected during its useful life.

2.4 The reason why single-use plastics have met so much opposition is because the plastics industry has failed to offer policymakers a way to deal with the single-use plastic products which get into the open environment all over the world, where they lie or float around for decades. It is the sight of animals and birds entangled with plastic which has generated monumental public concern and has created plastiphobia, leading to outright bans.

2.5 The plastics industry could have addressed this problem, to the great benefit of themselves and the environment, by making everyday plastic products with oxo-biodegradable technology so that they would become biodegradable much more quickly and would be recycled back into nature by bacteria and fungi. However, (probably because of their internal power-structure) Plastics Europe have dismissed this technology instead of engaging with the experts in the oxo-biodegradable plastics industry and seeking to understand it better and to explain it to their members and to the public.

2.6 They have concentrated instead on redesign and recycling, but it must be obvious to them that this cannot deal with the plastic which escapes into the open environment from which it cannot be collected. Nor can the so-called compostable plastics, which have to be collected and taken for composting. The OPA does not consider that there is in fact any useful role for plastics in the production of compost (see https://www.biodeg.org/subjects-of-interest/composting/).

2.7 The Scottish government now has an opportunity to adopt a policy for dealing with plastic which has escaped into the open environment, and especially the oceans, from which it cannot realistically be collected for recycling or anything else, and without banning items which are useful to citizens.

3. THE EU DIRECTIVE

3.1 Para. 1 of the Scottish consultation says that "This consultation is seeking views on the introduction of market restrictions – effectively a ban – for problematic single-use plastic (SUP) items *and all oxo-degradable products* in line with Article 5 of the EU Single-Use Plastics Directive (EU) 2019/904."

3.2 However, this Directive no longer applies to the UK, and on 21st December 2020 an OPA member, Symphony Environmental Technologies Plc commenced a legal action against the Commission, Parliament, and Council of the European Union in relation to their decision to adopt Article 5 of the Directive. Symphony has been advised by three Barristers, all experts in EU law, that this part of the Directive is confusing and illegal, and substantial damages are being claimed.

3.3 Symphony and the OPA have explained to EU officials the difference between oxo-degradable and oxo-BIOdegradable plastic but the Directive has not made this clear. The Directive has not used the standard definitions set out by the European Standards organisation CEN in TR15351 – see below.

3.4 "Oxo-degradable" plastic breaks up into fragments which can lie or float around in the environment for decades, but "oxo-biodegradable" technology causes ordinary plastic to degrade if it gets into the open environment and to biodegrade in the same way as nature's wastes, being recycled back into nature.

3.5 The main purpose of the Directive is to ban single-use plastics most often found on the beaches, but in addition to the specified items it includes all items made with "oxo-degradable plastic."

There is no evidence that any items made with oxo-BIOdegradable plastic have been found on the beaches or anywhere else.

3.6 The EU fails to acknowledge that the billions of persistent microplastics in the open environment, including the oceans, are actually coming from the fragmentation of ordinary and bio-based plastics which have not been upgraded with oxo-BIOdegradable technology.

4. ILLEGALITY

4.1 In addition to causing confusion, Symphony has been advised that the ban is actually illegal because there has been a failure to accord due process, and because it is disproportionate and discriminatory. Any purported ban in the UK would face a similar legal challenge if it were not made clear that it does not apply to oxo-biodegradable plastic.

4.2 The EU has a well-established procedure, set out in the REACH Regulation 2006/1907, for determining whether substances should be banned. This procedure was designed to avoid the kind of arbitrary action which has occurred in this case.

4.3 Neither the Commission's report dated January 2018, nor the Eunomia Report of August 2016 recommend a ban on oxo-biodegradable plastic, but the 2018 report said that "a process to restrict the use of oxo-plastics in the EU will be started."

4.4 Accordingly, and in compliance with the REACH procedure, the EU Commission requested the European Chemicals Agency ("ECHA") under Article 69 of REACH to investigate its concerns regarding microplastics. The OPA submitted scientific evidence to ECHA on oxo-BIOdegradable plastic and on 30 October 2018 ECHA said that they were not convinced that it created microplastics.

4.5 The Commission then made the extraordinary decision on 8 May 2019 to terminate ECHA's investigation and to slip a few words into the draft Directive to impose a ban as from 3 July 2021, citing microplastics as a reason. The Commission's proposal to the Parliament had not mentioned a ban on oxo-degradable plastic, and the amendment seems to have been the work of lobbyists acting for rival commercial interests. Never before has an ECHA investigation been circumvented by legislation.

4.6 Only if ECHA had recommended a restriction, supported by the detailed dossier prescribed by Annex XV of REACH, their recommendation would have had to be considered by two committees under Articles 70 and 71 of REACH, and also by a stakeholder consultation under Article 71(1), before any restriction could be proposed under Article 73. None of these procedures prescribed by EU law have been complied with.

4.7 Symphony is represented in this case by Josh Holmes QC and Jack Williams, Barristers of Monckton Chambers, Grays Inn, London - the UK's leading experts in EU law, and by Keystone Law, Solicitors of Chancery Lane, London. Symphony has also been advised by Professor Sir Alan Dashwood QC, the author of "Wyatt & Dashwood's European Union Law."

5. THE SCOTTISH CONSULTATION

5.1 The consultation paper seems to be influenced by the EU Directive (which is no longer applicable in the UK) and offers only three paragraphs in support of its draconian proposal for a complete ban of oxo-degradable plastics, whether single-use plastics or not, and whether commonly found on beaches or not.

5.2 Oxo-degradable and oxo-biodegradable plastics are not distinguished from each other in the consultation, and are not mentioned at all in the Scottish EPECOM Report of September 2020 "Ending the Throwaway Culture: Five Principles for Tackling Single-use Items."

5.3 The consultation paper cites the Eunomia Report of August 2016, which does not recommend a ban. It also cites "Moving away from single-use - Guide for national decision makers to implement the single-use plastics directive" published on 10th October 2019 by "Rethink Plastic Alliance" but this document does not attempt to provide any scientific justification for why oxo-biodegradable plastics should be banned.

5.4 The Scottish consultation paper says on page 12 that "a significant body of evidence suggests that, in reality, oxo-degradable plastics simply break down into small fragments" but as mentioned above this is the very issue on which ECHA were consulted, and were not convinced. No scientific authority for this suggestion is cited in the consultation, and in fact the Eunomia report says that "The debate around the biodegradability of PAC plastic is not finalised, but should move forward from the assertion that PAC plastics merely fragment…"

5.5 The suggestion in the consultation paper that oxo-degradable plastics simply break down into small fragments is true of oxo-degradable, but not of oxo-biodegradable, plastics, and it seems to have been taken from the Ellen MacArthur Foundation report of November 2017. However, after listening to evidence from the OPA's scientists about oxo-biodegradable plastics EMF now admit in their May 2019 report that these plastics are manufactured so that they can degrade faster than conventional plastics and that they do become biodegradable.

5.6 The Scottish consultation paper also asserts that they "negatively affect the recycling of conventional plastic" but there is no attempt to ban "compostable" plastics, which will certainly contaminate the recycling of conventional plastic. In fact oxo-biodegradable plastic is compatible with recycling (see https://www.biodeg.org/subjects-of-interest/recycling-2/) and no court would accept that it posed for that reason a threat to human health or the environment sufficient to justify a ban.

5.7 The consultation paper also gives as a reason "the difficulty for the consumer to identify the material" but there is no reason why consumers would need to identify the material. It is used to make short-life items, and should be treated exactly like ordinary plastic, for it is only if it escapes collection and ends up in the open environment that its performance is any different. Contrast plastic intended for composting, which *would* need to be identified to consumers. In any event the Scottish government may require whatever labelling it pleases.

5.8 There is mention of Wales on page 13 of the consultation paper. The OPA has responded to the Welsh consultation paper at https://www.biodeg.org/wp-content/uploads/2020/10/opa-response-to-wales-19.10.201.pdf

5.9 None of the papers cited in the Scottish consultation document on this issue were written by polymer scientists, and none of them were peer-reviewed.

6. OXO-BIODEGRADABLE PLASTIC

6.1 It is essential to distinguish between oxo-degradable and oxo-biodegradable plastics.

"Oxo-degradation" is defined by CEN in TR15351 as "degradation identified as resulting from oxidative cleavage of macromolecules." This describes ordinary plastics, which degrade by oxidation under the influence of light and heat in the open environment and create microplastics, but do not become biodegradable except over a very long period of time. Oxo-degradable (as distinct from oxo-biodegradable) plastic has been banned for good reason in Saudi Arabia, the UAE, and elsewhere for a wide range of everyday plastic products, and it should also be banned in Scotland.

6.2 Nobody makes plastic and sells it as "oxo-degradable" but this terminology is used by the EU Commission, and others who are reluctant to acknowledge the difference between oxo-degradable and oxo-biodegradable plastic.

6.2 "Oxo-biodegradation" is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic degrades by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature by cell-mediated phenomena. It does not create microplastics.

6.4 Oxo-biodegradable plastics are tested according to ASTM D6954; BS 8472, and similar Standards, which prescribe tests for biodegradation as well as for abiotic degradation. They also include tests to ensure that there is no toxicity and no prohibited metals or gel content above the prescribed level. Plastic should NOT therefore be banned if it is proved to be oxo-biodegradable by tests performed according to these Standards. Recent tests for OPA members by Eurofins Laboratories show 88.9% biodegradation within 121 days.

6.5 It is possible for enforcement authorities to ascertain quickly, using a portable xrf device, whether a product sold as oxo-biodegradable is actually oxo-biodegradable, but this cannot be done with other forms of biodegradable or "compostable" plastic.

6.6 Microplastics are seen today as the main problem with plastics. They are tiny pieces of plastic, which are being found on land, in the sea, and now even in the air we breathe. Most of them are created by the fragmentation of ordinary plastics caused by the effects of uv light and mechanical stress. The problem is that although these plastics are fragmenting, their molecular-weight remains too high for biodegradation, so they persist in the environment, getting smaller and smaller over a period of many decades.

6.7 However, if plastic products are made with oxo-biodegradable technology, and get into the open environment intentionally or by accident, the molecular-weight of the plastic will reduce much more quickly and it will cease to be plastic. It will then have become a source of nutrition for naturally-occurring micro-organisms. This technology is suitable for almost all products made with polyethylene or polypropylene, but is not used for Polyethylene Terephthalate (PET) or Polyvinylchloride (PVC).

6.8 Because conditions in the open environment are variable a broad indication only can be given as to timescale. It is however possible to say with certainty that at any given time and place in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item.

6.9 It is not important how long a specific piece of plastic in a particular place will take to biodegrade – the importance of oxo-biodegradable technology is that it will reduce the dwell-time and therefore the overall burden of plastic in the environment much more quickly than would otherwise be the case. Of course, we don't want plastic in the environment at all, but that is not the present reality.

6.10 There is resistance to this technology from some large companies who make "bio-based plastics" and from other large companies who will not spend an extra 1% on oxo-biodegradable technology to protect the environment from their products, which everyone can see with their name on them, littered all over the globe.

6.11 There has however been aggressive lobbying of governments and international institutions, coming especially from Germany and Italy. One of their lobbying organisations, the BBIA has recently lobbied the UK government in a letter which contains many misleading allegations see https://bioplasticsnews.com/2020/06/04/battle-biodegradable-oxo-compostable-industry/

7. THE SCIENCE

7.1 Policymakers know that thousands of tons of plastic are getting into the open environment every day, and that we may soon have more plastic in the ocean than fish, but what are they doing about it? They are trying to reduce the amount of plastic we use, and to recycle as much of it as possible, but they know that some of it will still get into the open environment.

7.2 Foremost among the scientists who invented oxo-biodegradable plastics was Professor Gerald Scott, who was Professor of Chemistry at Aston University, and was in later years the Chief Scientific Adviser to the OPA. He published the results of his work in many scientific publications including "Polymers and the Environment" - Royal Society of Chemistry 1999 and "Degradable Polymers: Principles and Applications"- Kluwer Academic Publishers 2002. He was also the holder of several patents for the technology. All of Professor Scott's published work, and that of many other scientists on this subject, both published and unpublished, can be made available to the Scottish Government on request.

7.3 In these publications the polymer scientists have made it clear that oxo-biodegradable plastic will degrade and then biodegrade in the open environment very much more quickly than ordinary plastic, leaving no persistent fragments and no toxicity. Polymer scientists were the authors of the standards for oxo-biodegradable plastics (ASTM D6954 and BS 8472) and it is not therefore correct for anyone to say that there is insufficient evidence, or that there are no relevant standards.

7.4 Oxo-biodegradable plastic will prevent plastic lying or floating around for decades, and it has been used successfully around the world for more than 20 years. It has been used by the largest bakery in the western world for more than 10 years with no problems relating to the environment or to recycling, and a few forward-looking governments in the Middle East have actually made it compulsory.

7.5 In 2018 the scientific evidence was reviewed by a distinguished former deputy judge of the High Court in England. https://www.biodeg.org/uk-judge-find-the-case-for-oxo-biodegradable-plastic-proven/ This has been confirmed by later research published by Queen Mary University London in February 2020. https://www.biodeg.org/wp-content/uploads/2020/05/published-report-11.2.20-1.pdf Para. 2.3 of this report shows that the biodegradation of oxo-LDPE was 90-fold greater than that of LDPE.

7.6 Most recently, on 4th September 2020 scientists at the Laboratoire d'Océanographie Microbienne (LOMIC) reported on a four-year study funded by the French government, of oxo-biodegradable plastics in the marine environment. See below under "Marine Environment."

7.7 Life-cycle analyses have been done, which show that oxo-biodegradable plastics have good environmental credentials. See below.

7.8 So why are all governments not making oxo-biodegradable plastic mandatory, and instead trying to ban it and allowing ordinary plastic (which they know causes microplastics) to continue in use? In some cases because they are under inappropriate pressure from multinational commercial interests, and in others because they see no complete consensus among the scientists. There is however sufficient consensus to enable a decision to be made. There is consensus on the following points:

- Ordinary plastics fragment into microplastics under the influence of weathering, but for many decades their molecular-weight remains too high to allow biodegradation.
- Adding a pro-degradant catalyst at manufacture reduces the molecular-weight much more quickly if the plastic escapes into the open environment.
- The only environmental conditions necessary for oxo-biodegradation are oxygen and bacteria, both of which are ubiquitous in the open environment. No special conditions are necessary.
- Bacteria found on land and sea are able to consume the low molecular-weight residues of plastic.
- These residues are not toxic
- There are already Standards in place which are suitable for testing oxo-biodegradable plastic.

Disagreement remains about:

7.9 *RATE*: How long it takes before the plastic becomes biodegradable. Timescale depends on the composition of the plastic, how old it is when it gets out into the environment, and the environmental conditions to which it is exposed. Sunlight and heat are not essential, but they will accelerate the process, and it is most unlikely that a piece of plastic litter will not be exposed to one or both of these.

7.10 Plastic litter tends to blow around on the surface of land or float on the surface of water, where oxygen and light are abundant but if exceptionally it gets quickly into cold, dark, conditions it will degrade more slowly but still more quickly than conventional plastic. The abiotic process of degradation is unstoppable unless the plastic is completely deprived of oxygen, which will not occur in the open environment. If of course the plastic is collected and taken to landfill or incinerated, it has been responsibly disposed of and is no longer a problem.

7.11 It is known that conventional plastic fragments do not become biodegradable for many decades, but it is possible to say with certainty that at any given time and place in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item. That is the point. - Do we want ordinary plastic which can lie or float around for decades, or oxo-biodegradable plastic which will be recycled back into nature much more quickly?

7.12 *EXTENT:* Will it fully biodegrade? It is well known that plastic whose molecular weight has been significantly reduced is biodegradable, and we have heard no reasons from any scientist why, once the process has commenced, it should not continue until biodegradation is complete.

7.13 *CONSENSUS*: In summary therefore, there is sufficient consensus to enable decision-makers to conclude that oxo-biodegradable plastic is better for the environment than ordinary plastic, and to decide to stop plastic accumulating in the environment, by requiring it to be oxo-biodegradable. Delay about this is no longer an option, because thousands of tons of plastic are getting into the open environment every day where they will lie or float around for decades.

8. RE-USABLE BAGS AS AN ALTERNATIVE?

8.1 It is obvious that a new single-use bag or package is much less likely to spread disease than one which has been re-used a dozen times.

8.2 Re-usable bags are rarely, if ever, washed, and are often stored in a cupboard or boot of the car where germs can multiply. Deadly micro-organisms such as Coronavirus, E.coli and Campylobacter can be transferred to food inside the bag.

8.3 On 18th August 2020 The Daily Telegraph wrote "The bag for life is not a synthetic comrade with you until your last breath, it turns out - more an acquaintance briefly entertained before being roundly ditched. Or so say Morrison's, who have begun phasing out their plastic offerings in favour of reusable paper ones over concerns that a bag for life had in fact become a 'bag for a week' habit among British shoppers."

8.4 With regard to their environmental credentials, scientists at RMIT University, Melbourne found that reusable shopping bags are only beneficial to the environment if they are used at least 104 times. This is because thicker plastic bags require more plastic and more energy to produce than lightweight bags. Also, they will create greater plastic pollution, including microplastics, if they escape at the end of useful life, unless they are made with oxo-biodegradable technology, which can be programmed to start degrading in whatever timescale is required.

8.5 There is therefore a solution for those who still prefer re-usable bags. They can be made with both oxo-biodegradable and anti-microbial technology which can be incorporated into the polymer used for making the bags, and can also be incorporated into the laminate coating inside jute or cloth bags.

9. PAPER AS AN ALTERNATIVE?

Isn't it better to use paper instead of plastic?

9.1 Some supermarkets (most recently Morrisons and Waitrose) have shifted to single-use paper bags, but this is a worrying trend, as paper bags can have much higher environmental impacts. A 2011 study for the Northern Ireland Assembly found that paper bags generally require four times as much energy to manufacture as plastic bags, and cause 70% more atmospheric pollution. The process uses huge amounts of water and creates unpleasant organic waste. Recycling of paper is often uneconomic and uses toxic chemicals. When it degrades, paper will emit methane in anaerobic conditions. Manufacturing paper requires trees to be cut down, but plastic is made from a by-product of oil refining, which will be available until the day when all engines are driven by electricity .

9.2 A stack of 1,000 new plastic carrier bags would be around 2 inches high, but a stack of 1,000 new paper grocery bags could be around 2 feet high. It would take at least seven times the number of trucks to deliver the same number of bags, creating seven times more pollution and road congestion.

9.3 Also, because paper bags are not as strong as plastic, people may use two or three bags inside each other. Paper bags are not normally re-used, and are useless if they get wet.

9.4 A February 2018, Life cycle assessment of carrier bags in Denmark concluded that "When factors like ozone depletion, human and ecosystem toxicity and water and air pollution are accounted for, paper bags would need to be reused 43 times to have a lower impact than the average plastic bag." They are not of course durable enough to do this.

9.5 "There have been unforeseen consequences in the Irish Experience [taxing plastic bags] resulting in an increase in the use of paper bags which are actually worse for the environment …" … (Ben Bradshaw, UK Environment Minister, 4 August 2006).

9.6 plastic straws are a much better alternative to paper, provided that they are made oxo-biodegradable.

10. REFILLABLES?

10.1 Concern with the in-store refill model is the reduction in shelf-life for some products. Some fresh drinks would last just two days if poured into a customer's own bottle, compared to 20 to 30 days in a factory-sealed container.

11. LIFE CYCLE ASSESSMENTS

11.1 Plastic is actually the best material for a wide range of everyday uses. Not only is it much the best for protecting our food from contamination and preventing food-waste and disease, but it also has a much lower global-warming potential than other materials used for packaging, according to LCA's performed by Intertek. https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/

11.2 Plastic is made from a by-product of refining oil, which is extracted to make fuels, and these fuels would be made whether plastic existed or not, so plastic is not itself causing any depletion of fossil-resources. When the plastic becomes waste, its calorific value can be used to generate heat and electricity if, instead of being sent to landfill or if unsuitable for recycling, it is sent to modern, non-polluting, thermal-recycling units.

11.3 A Life-cycle Assessment by Intertek shows that when the litter metric is included, OBP is the best material for making carrier bags. See https://www.biodeg.org/wp-content/uploads/2020/09/intertek-final-report-15.5.121.pdf This is referred to at footnotes 45 and 50 in the Environmental Assessment for the Scottish consultation.

11.4 The only problem with plastics is the length of time they can lie or float around if they escape into the open environment, but this problem can now be solved as explained above.

12. "COMPOSTABLE" PLASTIC AS AN ALTERNATIVE?

12.1 "Compostable" plastics are not relevant to the main problem facing governments today – ie plastic waste which has escaped into the open environment, from which it cannot realistically be collected and taken to a composting facility.

12.2 A "Grocer" magazine survey of more than 1,000 individuals in 2019 found that "consumers think that plant-based compostable plastics are the most environmentally friendly packaging materials," but most consumers don't realise that "compostable" plastic does not convert into compost. It is required by ASTM D6400 and EN13432 to convert rapidly into CO2 gas, and the last thing the planet needs is more CO2. Further, if you can collect a piece of plastic there are better things to do with it than waste it by turning it into CO2.

12.3 The German courts in Güthoff v Deutsche Umwelthilfe (2014) decided that it is deceptive to market plastic as "compostable."

12.4 Also, many consumers do not know that "compostable" plastic is tested to biodegrade in an industrial composting facility – not in the open environment. In November 2019 a Danish court ruled in Ellepot v Sungrow that "compostable" PLA plastic plant pots must not be described as biodegradable.

12.5 These plastics are often marketed as renewable, but this ignores the fossil fuels used in the agricultural production process by the machines which clear the land, plough the land, bring the seeds to the farm and sow them, harrow the land, bring the fertilisers and pesticides to the farm and spread them, harvest the crop and transport it to the factory, and by the machines which polymerise the raw material.

12.6 This marketing claim also ignores the land and water resources devoted to producing the raw materials, which could be used for growing food. EASAC (March 2020 report) says that "replacing PE by a bio-PE would require almost all (93.5%) of global wheat production" which would of course be completely unsustainable.

12.7 Although these plastics are marketed as "bio-based" they can contain up to 60% oil-based material, but this is hardly ever mentioned in the marketing material.

12.8 As mentioned above, conversion of organic materials to CO2 at a rapid rate during industrial composting does not create compost, and is not "recovery." Nature's lignocellulosic wastes do not behave in this way, and if they did they would have little value as soil improvers and fertilisers, having lost most of their substance and their carbon.

Another problem with polymers manufactured from crops, is that they not only use scarce land and water resources, but they have significant impacts upon eutrophication due to the application of fertilizers to land.

12.9 On 15th July 2020 a report appeared in "Waste Management" Vol. 113, Pages 312-318. The conclusions were:

- In many cases, plastic bags are being replaced with compostable plastic bags.
- Industrial composting processes do not completely remove film fragments.
- Compost is thus a potential source of fragments from compostable plastic bags.
- Compostable plastic fragments are then deteriorated in soil to microplastics.
- Compostable microplastic results in an increase number of aflatoxigenic fungi.

12.10 Moreover, plastics marketed as compostable are far too expensive for everyday use, and there are few industrial composting facilities available. In any event the industrial composters do not want plastic of any kind.

12.11 In January 2020, the industrial composters of Oregon gave 9 reasons why they did not want it: https://bioplasticsnews.com/wp-content/uploads/2019/04/Oregon-composters-dont-want-Compostable-Packagine.pdf

12.12 Then the City of Exeter UK rejected it. https://www.biodeg.org/rejects-compostable-plastic-and-paper/

12.13 Then the City of Toronto, Canada https://www.cbc.ca/news/technology/plastic-packaging-compostable-plastic-marketplace-1.5487617

12.14 Then the SUEZ waste-management company https://www.usinenouvelle.com/article/sacs-plastiques-compostables-le-grand-malentendu.N926789

12.15 Then a devastating exposé on Netherlands television https://bioplasticsnews.com/2020/02/17/the-composting-fairy-tale/

12.16 And another TV exposé in Canada about how compostable plastics are typically not being composted but instead sent to landfill or incineration. https://www.cbc.ca/news/technology/plastic-packaging-compostable-plastic-marketplace-1.5487617

12.17 Many areas do not have industrial composting plants, and the Welsh Government has refused to invest in them. https://www.bbc.co.uk/news/uk-wales-47238220

12.18 Plant-based compostable plastics are going to landfill rather than recycling because so many local authorities are unable to deal with them.

12.19 "Compostable" resins are worse than conventional or oxo-biodegradable plastics when it comes to oxygen transmission-rate or moisture vapour transmission-rate. These resins are also water sensitive, and their physical, optical, mechanical, and chemical properties are inferior.

12.20 There are at least 21 reasons why "Compostable" plastic is not useful https://www.biodeg.org/wp-content/uploads/2020/05/21-reasons-why-1.pdf

13. HOME COMPOSTING

13.1 Home composting of plastic is dangerous and should not be encouraged. This is because householders are unlikely to be aware of any Standard for home-composting, and would probably not understand it anyway. Home composting is not therefore likely to be conducted by a process appropriate for plastic.

13.2 A study for the French government at https://www.ademe.fr/sites/default/files/assets/documents/compostage-domestique-industriel-sacs-plastiques-papier_2019.pdf says that "composting management must be in line with good practices recommended by ADEME (weekly brews for one month and then every 1 to 2 months, humidity control), - the average ambient temperature over the first three months of composting must be close to that of the standard: outside temperature of 25oC - 50oC. It is unlikely that all of these conditions will be met by individuals."

13.3 The study also shows that "plastic bags are poorly disintegrated and biodegraded if good domestic composting practices are not applied. It also shows that, even when good practices are followed, there are still a few pieces of plastic bags of micrometric or even millimetre size in composts beyond the standard year of home composting."

13.4 In addition, the study says "it appears that the biodegradation of plastic bags suitable for domestic composting makes little or no contribution to the formation of humus because, in accordance with the biodegradation tests of these materials according to the NF T 51-800 standard, at least 90% of the carbon organic dioxide is converted into carbon dioxide."

13.5 Worse still, there is a danger that the plastic may have been contaminated by pathogens e.g. from putrifying food, and that the temperature in a home compost may not be high enough to kill those pathogens.

14. RECYCLING

14.1 Users of any plastic recyclate cannot assume that the recyclate does not contain pro-oxidants.

14.2 Conventional plastics may contain pro-oxidant additives that were added for different intended functionalities. Moura et al. (1997) described that colorants in general can act as pro-oxidants. If they partake in the creation of radicals or reactive oxygen species, such as singlet oxygen (1Δg), they can trigger photo-degradation of the polymer matrix." "Conventional plastic products (n = 23) were found to regularly contain Fe, Ba, Ti, Zn, Cu and V. Some individual conventional plastic bag samples also contained Cr and Pb" "Thus, a potentially much higher number of plastics on the market may match the current legal definition of oxo-degradable plastics without being advertised or intended as such, i.e. unintentional ODP."

14.3 Further, the Austrian specialist laboratory TCKT said in para. 1 of its March 2016 report. https://www.biodeg.org/wp-content/uploads/2020/06/TCKT-Report-17.3.161.pdf that "long-life films should be made with virgin polymer, or be stabilized to deal with loss of properties caused by the recycling process, whether or not any pro-degradant additive is present. Such stabilization would effectively neutralize the effect of any pro-degradant additive."

14.4 Although oxo-biodegradable plastic is used for low-value items which are not worth recycling, the experts in Austria (TCKT Report para. 4) and South Africa (Roediger Report May 2012 page 3 https://www.biodeg.org/wp-content/uploads/2020/12/ROEDIGER-REPORT-21-May-2012.pdf have confirmed that if anyone wished to recycle them, they may be recycled without any significant detriment to the newly formed recycled product.

14.5 This accords with the experience of OPA members who have recycled many thousands of tons of oxo-biodegradable plastic over the past 20 years without any adverse effects.

14.6 The experts also found that "compostable" plastics are not recyclable in a conventional plastic waste-stream. This is well known, but is seldom heard as an objection to that type of plastic.

14.7 Having considered all the issues mentioned above policymakers have to decide whether recycling is any sufficient reason to object to oxo-biodegradable technology and continue to allow ordinary plastic to be used for short-life packaging, which could get into the open environment and lie or float around for many decades. In our view it is not.

15. STANDARDS

15.1 We sometime hear it said that there are no robust standards for testing oxo-biodegradable plastics.

15.2 The main Standards for testing oxo-biodegradable plastic are ASTM D6954 (USA); BS8472 (UK); AFNOR AC T51-808 (France); and SPCR 141 (Sweden). Variants of these standards have also been adopted in other countries, such as SASO 2879 in Saudi Arabia, and 5009/2009 in the UAE

15.3 ASTM D6954 contains six pass/fail criteria. 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 at least 60% of the organic carbon is converted to carbon dioxide the test cannot be considered completed).

15.4 It is for customers and governments to decide what timescales are acceptable to them.

15.5 European standard EN 13432 and ASTM D6400 apply to biodegradation of plastic packaging under industrial composting conditions, but they are not appropriate for testing oxo-biodegradable plastics because they require the emission of CO_2 (a greenhouse gas) at a very high rate.

15.6 If a leaf were subjected to the CO_2 emission tests included in these Standards it would not be considered biodegradable or compostable.

15.7 EN 13432 does not apply at all to applications other than composting of packaging, and para. 1 makes it clear that it does not apply to packaging waste which may end up in the environment through uncontrolled means, i.e. as litter.

16. NON-TOXICITY

16.1 The Oxo-biodegradable industry is as much concerned as anyone that its products should not introduce toxicity into the environment, and for this reason the Standards for oxo-bio require testing to confirm that the residues are harmless. They have to pass the same tests as "compostable" plastic to ensure that there is no toxicity and no metals exceeding the prescribed limits.

17. THE MARINE ENVIRONMENT

17.1 On 4th September 2020 scientists at the Laboratoire d'Océanographie Microbienne (LOMIC) reported on a four-year study funded by the French government, of oxo-biodegradable plastics in the marine environment, citing six earlier scientific reports.

17.2 The purpose of the ANR-OXOMAR project is to investigate whether oxo-biodegradable plastics will fully biodegrade in a reasonable time in the marine environment, and to investigate whether oxo-biodegradable plastic or its by-products create any toxicity in the marine environment. It involves the complementary expertise of four independent laboratories (CNEP, LOMIC, ICCF, and IFREMER).

A summary of the results says:

17.3 "We have obtained congruent results from our multidisciplinary approach that clearly shows 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. Out of the six-formulations tested, the Mn/Fe pro-oxidant was the most efficient, with no toxic effects under our experimental conditions. Biodegradability was demonstrated either by using the culture bacteria Rhodococcus rhodochrous or by a complex natural marine community of microorganisms."

17.4 According to Dr. Jean-François Ghiglione, one of the LOMIC scientists "Oxo-bio plastic will float and be at almost all times subjected to UV light, which accelerates the abiotic phase of degradation. This is not always the case on land, where plastic pieces are often covered by soil, leaves etc. and are less exposed to UV light." He points out that "there are specific bacteria living in the "sea-surface microlayer" (the top millimetre of the ocean surface), where bacteria are different from those further below the surface. The bacteria in the sea-surface microlayer are particularly adapted to a hydrophobic environment (e.g. where oil materials are floating) and these bacteria are known to present a high capability for hydrocarbon degradation."

17.5 "Some marine bacteria, such as Alcanivorax borkumensis and R. rhodochorous are noted for their ability to biodegrade hydrocarbons and they are ubiquitous in the oceans. They occur in low concentrations in unpolluted seas but are observed to accumulate in waters polluted by oil spills. When presented with a source of carbon which is recognisable to the microorganisms as food, it seems therefore that they will respond with increased populations. The relatively low concentrations of microorganisms found in unpolluted oceans is not therefore a reason for expecting slow biodegradation."

17.6 Evidence is available - from tests done in real time at the Bandol research station on the coast of France that oxo-bio plastic will degrade to low molecular-weight materials under natural conditions in water, and samples aged under those conditions were studied at Queen Mary University London where the abiotically degraded plastic was presented as the only source of carbon available to the bacteria.

The samples were proved to be biodegraded by bacteria commonly found in the oceans, and separate samples were biodegraded by bacteria commonly found on land. The degraded plastic was also proved to be non-toxic to those bacteria.

17.7 " For the OPA response to the Plymouth report see https://www.biodeg.org/wp-content/uploads/2020/05/opa-comments-on-plymouth-10.pdf

18. AGRICULTURE

18.1 Oxo-biodegradable plastic mulching films have been successfully trialled in Wales. For the report see https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf

18.2 The commercial benefit of using oxo-biodegradable plastic film is that the farmer will no longer have to pay to have acres of contaminated plastic removed from his farm. The environmental benefit is that heavy vehicles will no longer have to drive around the country lanes collecting contaminated plastic, consuming fossil fuels, emitting pollutants, and occupying road space.

19. PROPENSITY TO LITTER?

19.1 It is sometimes claimed that biodegradable plastics are likely to encourage littering, but if true, this also applies to bio-based plastics.

19.2 However, even if there were a label describing a product as biodegradable, it is unlikely that the people who deliberately cause litter will look for the label before deciding to throw a plastic item out of a car window. Further, even if it were true that biodegradability encourages littering, and supposing for the sake of argument that there would be 10% more litter - is it preferable to have 110 plastic items in the environment which will degrade and biodegrade in a few years or even months, or 100 plastic items which will lie or float around for many decades?

19.3 It is not acceptable to continue debating this speculative proposition any longer, while thousands of tonnes of conventional plastic are getting into the environment every day, which will accumulate and pollute the environment for decades into the future.

20. GENERAL ISSUES

20.1 For the reasons given above, the OPA would not wish it to be thought that we agree with the general proposition that single-use plastics should be banned. However, we do consider that they should no longer be made with conventional plastic.

20.2 In January 2020 a report was published by the Green Alliance https://www.green-alliance.org.uk/plastic_promises who had interviewed representatives from five of the UK's major supermarkets as well as from major consumer goods and beverage companies. One of them had received complaints saying that "plastic is evil and has no place, regardless of any positives it might have in addressing food waste and what not… the complaints have been ferocious."

20.3 However, the report finds that "Worryingly, the brands report that decisions to switch away from plastic are often made without considering the environmental impact of the substitute materials chosen." Multiple interviewees indicated the desire to avoid "kneejerk reactions" and another noted: "there's a lot of pressure to move to alternatives, which aren't necessarily better from an environmental and climate-impact point of view."

20.4 The Report says that some decisions have been taken knowing it could actually increase environmental burdens. One supermarket representative was frank: "We are aware that [by switching from plastic to other materials] we may, in some cases, be increasing our carbon footprint" and a brand representative bluntly complained about misinformation being spread about the environmental credentials of non-plastic single use packaging formats:

"The past year has really annoyed me with companies coming out and boasting about not using plastic, even when they're in single use glass, and their carbon emissions are going to be off the scale."

21. CORONAVIRUS

21.1 The virus has shown that it can defeat the human immune system, so it is essential to destroy it before it gets into the human body. The pandemic has made everyone realise that single-use plastic is essential to protect us from the spread of disease, and plastic can be given anti-microbial properties.

21.2 The most effective way to protect against microbes is not by spraying or wiping, but by making surfaces in contact with microbes permanently lethal to bacteria and viruses. This can be done simply and at reasonable cost with plastic, but not with any of the alternative materials such as paper, carboard, cloth, jute, glass, or metal (except silver, which is too expensive).

21.3 To see how it can be done with plastic see https://bioplasticsnews.com/2020/07/23/symphony-environmental-first-plastic-stop-corona-virus/

London 31st December 2020

BPA comment on:

The performance and environmental impact of pro-oxidant additive containing plastics in the open unmanaged environment - a review of the evidence

Fabiola Sciscioni, Helen C. Hailes, Mark Miodownik

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EXECUTIVE SUMMARY

It is important at the outset to understand why oxo-biodegradable technology is necessary everywhere in the world. After more than ten years it is now clear that despite “Reduce, Re-use, Redesign, Recycle” the problem of plastic in the open environment is getting worse. Oxo-biodegradable plastic is not the solution to this problem, and it is not offered as an alternative to better waste management, but it will make a significant difference. Some of the governments in the Middle East have sent experts to examine oxo-biodegradable technology, and have made its use compulsory for a wide range of plastic products.

This paper by Sciscione et al is yet another literature review. The starting point for any study of this subject is the work of Professors Gerald Scott and David Wiles who were the inventors of the technology, but they are not mentioned. Sciscione et al did no original research, unlike the four year Oxomar study sponsored by the French government, and the work at Queen Mary University.

Sciscione et al do not deny that a polymer cannot biodegrade until the molecular weight is reduced; that an oxo-biodegradable masterbatch accelerates the reduction in molecular weight by oxidation, and that microorganisms biodegrade the residues. They are concerned only with rate and extent of biodegradation, and with proof of non-toxicity.

As to rate, the key point is that an oxo-biodegradable plastic will biodegrade in a much shorter timescale than an ordinary plastic in the same place, under any outdoor conditions anywhere in the world. As to extent they give no reason to believe that once biodegradation has begun the bioassimilation would not continue until all the material has been consumed by the micro-organisms. As to toxicity, oxo-biodegradable plastics have to be tested according to international ecotoxicity Standards.

Oxo-biodegradable plastic should not be sold unless it is correctly made with a masterbatch which has been tested by an accredited laboratory in accordance with ASTM D6954 or a comparable Standard.

ANALYSIS

In the introduction to the Oxomar report (B2) the scientists said “Of the 300,000 tonnes of plastic waste found today on the surface of the oceans, more than half are made of polyethylene. The degradation of polyethylene (PE) by microorganisms is very slow and even when coupled with physicochemical degradation (abrasion, UV, waves, etc.), degradation times exceed several decades in the marine environment. One solution consists of integrating additives that promote the oxidation of PE to make it more accessible to biodegradation: The lack of knowledge about this product has led to recent measures banning the marketing of oxo-degradable plastic Our objective was to provide solid scientific data on the fate of OXO-bio at sea.”

They concluded (at C5) that “We have obtained congruent results from our multidisciplinary approach that clearly shows 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.”

Sciscione et al suggest that the oxo-biodegradable plastic was tested only with a terrestrial bacterium, but the Oxomar report at B 2 says “we tested the biodegradability of the various OXO-bio films using either a pure strain known to degrade PE (Rhodococcus rhodochrous), or a complex bacterial inoculum from the marine environment.”

The original research at Queen Mary University London,
developed a novel method to evaluate the biodegradability of plastic samples based on the monit oring of bacterial respiration in aqueous media via the quantification of CO_2 produced, where th e only carbon source available is from the polymer. Rhodococcus rhodochrous and Alcanivorax b orkumensis were used as model organisms for soil and marine systems, respectively." The scientists found (at 2.3) that "the biodegradation of oxo-LDPE was 90-fold greater than that of LDPE, and said (at para. 3)
"This is the first example of work where aging, chemical structure of plastic, and biodegradability have been connected. The method provides a robust and reproducible approach for comparing di fferent types of polymers and evaluating the effect of environmental and/or artificial aging."

The Sciscione abstract says: "Pro-oxidant-additive-containing (PAC) plastics is a term that describes a growing number of plastics which are designed to degrade in the unmanaged natural environment (open-air, soil, aquatic) through oxidation and other processes. It is a category that includes 'oxo-degradable' plastics, 'oxo-biodegradable' plastics and those containing 'biotransformation' additives."

The category does not in fact include "oxo-degradable plastics." Oxo-degradation is defined by CEN TR15351 as "degradation identified as resulting from oxidative cleavage of macromolecules." This describes ordinary plastic, (which does not contain an intentionally-added prodegradant catalyst). It will abiotically degrade by oxidation in the open environment and create microplastics, but does not become biodegradable except over a very long period of time. Nobody puts a pro-oxidant additive into plastic and calls it "oxo-degradable."

"Biotransformation" is a description used by a small private company to describe its oxo-biodegradable product.

Oxo-biodegradation is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic (which does contain a prodegradant catalyst) degrades rapidly by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature.

Sciscione et al continue: "There is evidence that a new standard PAS 9017:2020 is relevant to predicting the timescale for abiotic degradation of PAC plastic in hot dry climates under ideal conditions (data reviewed for South of France and Florida)."

PAS 9017 is useful, but it is only a publicly available specification. The industry standard for Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation is the US Standard ASTM D6954. This Standard was written in 2004 by a committee of polymer scientists, and was reviewed and revalidated in 2024. One of the authors of the Standard, Dr. Graham Swift, has explained it to the UK government in evidence submitted to them. Sciscione et al do not seem to be aware of this evidence.

Sciscione et al accept that the most frequently used standards to confirm the biodegradability of PAC plastics are ASTM D6954 (and BS 8472 which follows D6954) but they say that these Standards do not set clear pass criteria and cannot be considered as specification standards. However, as Dr. Swift explains: "We wrote D 6954 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."

"ASTM D 6954 is designed for testing plastics which degrade and biodegrade in uncontrolled conditions in the open environment, and it is a detailed protocol for proving degradation, biodegradation, and non-toxicity under the conditions expected to be found in the open environment. Biodegradation in industrial composting or anaerobic digestion is not relevant, and is dealt with in a separate Standard - ASTM D6400."

"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)." Samples of oxo-biodegradable plastic have been tested by Intertek and other accredited test-houses who found 90% or more biodegradation, with no heavy metals or ecotoxicity.

Sciscione at al 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." It should be noted that the specific gravity of PE and PP litter is such that it will float on the surface, and most of it will not be buried on land. In any event, oxo-biodegradation is not photo-degradation, and will continue in the absence of sunlight.

Sciscione et al say that other standards which do specify pass criteria are the Swedish SPCR 141 which is based on ASTM 6954 and BS 8472, and the French AFNOR AC T51 808. They accept that Professor Jakubowicz, the author of the Swedish Standard, found 91% biodegradation - the remaining 9% would be biomass and water. In addition Professor Jaques Lemaire, the author of AFNOR AC T51 808, has tested a sample of oxo-biodegradable plastic and certified that it complied with that standard.

Sciscione et al continue: "There are no reliable data to date to show that the PAS 9017: 2020 predicts the timescale for abiotic degradation of PAC plastics in cool or wet climatic regions such as the UK or under less ideal conditions (soil burial, surface soiling etc.)."

They say "Both studies from 2021 gave a timescale and evidence of correlation between the abiotic degradation of film samples upon accelerated laboratory weathering and outdoor exposure in South of France and/or Florida according to the criteria of PAS 9017 : 2020. However, in climates such as the UK, central and northern Europe with their lower temperatures, lower sunshine hours and UV intensity, degradation under PAS guidelines might take longer than the four months in the South of France or 90 days in Florida"

As Dr. Swift explains: "I am aware that standards similar to ASTM D6954 for testing oxo-biodegradable plastics have been written in the UK, France, Sweden, Saudi Arabia and the UAE, [and now Mexico] but there is really no need for separate standards for every country, as the principles are the same. It is true that abiotic degradation may proceed more quickly in a hot, sunny, country than in a cold, dark country, but that is not a difference in principle."

"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. If it did, 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 important point to remember is that an oxo-biodegradable plastic will biodegrade in a much shorter timescale than an ordinary plastic in the same place, under any outdoor conditions anywhere in the world. Governments can set any time limit they choose for particular uses in their territory, but should be careful not to be caught by the "180-day trick." This short timescale is required by the industrial composters, and suits "compostable" plastic, which is designed to biodegrade in the special conditions found an industrial composting facility, but it has no relevance to the problem facing governments – namely plastic in the open environment for which oxo-biodegradable technology is designed. This will biodegrade much more quickly than ordinary plastic, but not necessarily within 180 days.

Sciscione et al, continue "Most PAC plastics studied in the literature showed biodegradability values in the range 5–60% and would not pass the criteria for biodegradability set in the new PAS 9017: 2020." However, as indicated above, biodegradation to 90% or more has been proved according to ASTM D6954, so there must be something wrong with a test showing significantly less than that. As Dr. Swift said "Legislators in any country of the world need only specify that material claiming oxo-biodegradability must be tested according to ASTMD6954, and may not be marketed as oxo-biodegradable unless a satisfactory test report from an accredited laboratory is produced."

We are often sent peer-reviewed papers purporting to show that oxo-biodegradable technology does not work. They look impressive but we always find a fundamental error. For example the authors (a) have not followed the procedure described in ASTM D6954 or have not followed any standard at all. (b) have followed the wrong standard eg ASTM D6400 or EN13432 (c) did not characterise the sample before starting the test, and therefore have no idea whether it contains an oxobiodegradable masterbatch at the correct concentration or at all. (d) did not continue important parts of the test for a sufficient length of time (e) used a sample so heavily laden with stabilisers that it would take a very long time before the material became biodegradable (f) failed to understand that oxo-biodegradable plastic is not intended to degrade immediately, but is stabilised to have a useful life and to be re-used (g) exposed the sample under conditions unlikely to be experienced by plastic litter in the open environment eg buried or submersed instead of lying or floating on the surface.

The problem is that this faulty research gets into literature-reviews and leads policymakers to make the wrong decisions.

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 fell into all of the errors mentioned at (a) (c) (d) (f), and (g) above. See the BPA analysis of these tests at Plymouth.

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.

And "Systematic eco-toxicity studies are needed to assess the possible effect of PAC additives and microplastics on the environment and biological organisms." This is why para 6.9 of ASTM D6954 and comparable Standards provides for ecotoxicity to be tested and recorded.

They question whether the extent of biodegradation was limited to the surface of the polymer. If they had understood oxo-biodegradation, they would know that oxidation occurs on the surface on both sides of a film exposed to oxygen, and it is the low molecular weight oxidation products (below 5,000 Daltons) which are consumed by the bacteria. Gradually bioerosion and mechanical erosion exposes more material to oxidation, until the whole film has been oxidised and consumed. Obviously this process takes longer for a thick film than a thin film.

They also question whether complete biodegradation occurs, but offer no reason why this process, once begun, should stop, unless the material is deprived of oxygen and/or bacteria, which is most unlikely with litter. As to the abiotic phase Dr. Swift says “Once abiotic degradation has commenced, there is no reason for it to stop save in the unlikely event that it is deprived of oxygen.”

Sciscione et al also question whether biodegradation would proceed more slowly or quickly in the open environment as compared with the laboratory.

Dr. Ruth Rose of Queen Mary University London says in her evidence to the European Chemicals Agency on 3rd May 2018 “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.”

Sciscione et al themselves 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.”

They say “These polymers may be oxidised or polymerized but should have a melting point below 140°C. All films containing the additive met this requirement after weathering, whereas the films without the additive showed a drop point above 140°C. This is consistent with the presence of the additive accelerating film degradation and conversion into a wax.”

Dr. Swift’s evidence is that “The material can be aged in the natural environment, and this is sometimes 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 have been permitted by ASTM D6954.”

A new report is about to be published, showing a good correlation between exposure in the laboratory and exposure in the open environment.

In the Oxomar Report at B2 “We first compared the data on the aging of LDPE in a natural environment, compared to artificial aging, by the action of ultraviolet (UV A and B) and temperature (SEPAP incubator 12.24.H). This process makes it possible to artificially accelerate the physico-chemical degradation processes, which would take several decades in the natural environment in the case of ordinary polymers.”

Sciscione et al question the suitability of oxo-biodegradable plastic for agricultural mulch films – as to which see the section on agriculture on the BPA website. The BPA has analysed the paper by Brassioulis, from which it is apparent that the sample did not degrade as expected because it was heavily stabilised. Sciscione et al review the results of trials on different types of soil in Australia and conclude that "The film with the pro-oxidant showed shorter times to embrittlement than the virgin polymer under all conditions."

As to microplastics, Sciscione et al say "The most recent studies of PAC plastics [2023] showed that the endpoint of the degradation/weathering process resulted in the formation of waxes, and the authors indicated that microplastics are not formed during the degradation of the film containing the PAC additive. By contrast, the films without the additive showed a slower degradation and the authors speculated that microplastics might therefore form during the erosion of the polymer." See also "Subjects of interest - microplastics."

It is important to remember that microplastics are created by the fragmentation of ordinary plastic under the influence of weathering. These are very persistent, but oxo-biodegradable technology deals with this by making the plastic biodegrade.

Sciscione et al say that "it is very hard for a single material formulation to suit all conditions, all weathers, all soil types and all geographies. We agree with this, and that is why a wide range of formulations have been developed by Symphony Environmental, which are designed for a wide range of weathers, soil types, and geographies.

In conclusion, as Intertek said in their evidence to the European Chemicals Agency in 2018:

"Almost all the micro-plastics found in the oceans have come from the fragmentation of conventional plastics. Although conventional plastics can fragment quite quickly on exposure to sunlight and mechanical stress, the fragments remain for years at a molecular mass which is too high for biodegradation. This means that conventional plastics can persist in the ocean for decades before they become biodegradable. This is why the micro-plastics tonnage in the oceans has built up: the inflow and dwell time exceeds the outflow (outflow being disappearance due to biodegradation). If the dwell time were shorter, and/or the inflow lower, build up would not occur and the micro-plastics problem would not exist."

"The faster degradation and subsequent biodegradation of oxo-biodegradable plastics means that they enter the eco-system as waste plastic in the same way as conventional plastic, but they degrade, and then ultimately biodegrade to natural materials and are recycled back into nature in less time than conventional plastics. This means that oxo-biodegradable plastics have a shorter dwell-time in the ecosystem. In the case of micro-plastics in oceans, a shorter dwell time means a net reduction in the overall amount of micro-plastics in the oceans."

"The oceanic micro-plastic problem has arisen because the dwell time of conventional plastics is too long compared to the rate of arrival of more plastics. If the dwell time were shorter (i.e. conventional plastics degraded faster) and/or the incoming flow was less, the ocean would be able to handle a certain amount of plastics. The plastic contamination would disappear from the system (through biodegradation) faster than it would arise in the system (through waste plastic reaching the ocean) and there would be no build up. It is simple, undeniable physics, little different from the physics of flow of liquids through pipes. Oxo- biodegradable plastics, through biodegrading faster, and thus having a shorter dwell time in the system, have the potential to aid the problem rather than worsen it."

"Any improvement in the speed of degradation must be useful. Considering very approximate order of magnitude figures, if conventional plastics were considered to take say 20 to 200 years to biodegrade in the oceans, and oxo-biodegradable plastics take say 1 to 10 years to biodegrade, already the oxo-biodegradable plastics are showing potential to make a positive, rather than negative, contribution to the issue."

"Various stakeholders have offered opinions on oxo-biodegradable plastics, including raising doubts about their efficacy and even doubting the point of them. Oxo-biodegradable plastics have been criticised for:

(a) Increasing the amount of plastics, which is obviously illogical. The presence or not of an oxo-biodegradable additive in a plastic does not change the amount of plastic.
(b) Encouraging a throw-away society, which of course they do not. The littering and inappropriate waste management that leads to the oceanic micro-plastic problem occurs irrespective of any additives in the plastics. Much of the littering is accidental, and the kind of people who deliberately throw litter do not care whether the plastic may be a type of biodegradable plastic.
(c) Being less desirable for re-use and recycling. Oxo-biodegradable plastics are not antagonistic to re-use and recycling. As has been demonstrated by the technical reports, and in practice over years of recycling, the tiny amounts of oxo-biodegradable additive in the system make no difference to recycling or re-use.
(d) Not being supportive of the circular economy. There is a clear theoretical benefit to a circular economy. However, that is a different issue from the current harsh reality of micro- plastic pollution. If society wished to eliminate anything that is not supportive of the circular economy, it should first stop burning oil, which is a non-circular threat to sustainability that is orders of magnitude greater than the amount of oil going into making useful products such as plastics. The material used to make plastics is in any event an inevitable by-product of the process of making fuels, and the same amount of oil would be extracted from the ground if plastics did not exist."

"Some of the opinions voiced by some parties have led some stakeholders to consider a potential ban on oxo-biodegradable additives. This seems unjustified, unnecessary, and counterproductive. For the foreseeable future, conventional plastics will continue to be used all over the world, in increasing amounts due to global development, despite the efforts of environmentalists and governments in some countries. Even if oxo-biodegradable technology was no longer available on the European market, large quantities of conventional plastics will continue to enter the ecosystem and will remain there as a problem for future generations. Therefore, a ban would be ineffective because it would have no perceivable impact on the problem."

"A ban of any product would normally be justified only where there existed proof of significant harm. In the case of oxo-biodegradable plastics, the worst possible case (based on the views of the most sceptical stakeholders) could be that oxo-biodegradable plastics are little different from conventional plastics in terms of environmental impact. The best possible case is that they would be beneficial in relation to the micro-plastics issue. The point is that the range is neutral-to-good, not harmful. Therefore, a ban does not seem to be logical or justified."

"Perhaps the most important point is this: whatever the speed of degradation, it is faster than that of conventional plastics. The different opinions of various stakeholders concerning the speed of degradation, and the different findings of the research that has been carried out to date, are simply a matter of degree."

Biodegradable Plastics Association
A not-for-profit Association

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27th April 2023

SUSTAINABLE PACKAGING COALITION
POSITION STATEMENT

RESPONSE BY THE BPA

It has come to our attention that in February 2023 an organisation called the "Sustainable Packaging Coalition" (SPC) had issued a position statement on "DEGRADABILITY ADDITIVES IN PETROLEUM-BASED PLASTICS"

Having read this statement we think, for the following reasons, that it is an irresponsible document, and should be withdrawn.

The SPC must be well aware that plastic packaging is a significant component of the millions of tons of plastic litter which get into the open environment, and especially the oceans, every year. They are interested in "Reduce, Re-use and Recycle" but they offer no constructive policies for dealing with litter which can not realistically be collected from the open environment for recycling or anything else.

They are aware that a technology has been invented for dealing with this problem, but far from encouraging its use by the packaging industry, they are trying to persuade them against it. Their rationale is given in their statement as follows, but it is muddled and misleading. They have made no attempt to engage with the BPA to clarify their understanding.

1. Additives Have a Negative Impact on Recyclability
Plastics have two inherent attributes that make them ideal for recovery: their high embodied energy content qualifies their value for controlled energy recovery.

This is correct, but it has nothing to do with recyclability.

… their exceptional durability renders them ideal for recycling. Additives that are fundamentally designed to compromise the structural integrity of a recyclable material are counterproductive to efforts to recycle more materials and to extract as much future value as possible from existing materials.

This shows a failure to understand oxo-biodegradable technology. Oxo-biodegradable plastic is plastic which can be made in the same way and with the same materials as ordinary plastic. It is designed to have a service life appropriate to the particular product, during which it can be re-used and recycled, and during that time it is, like ordinary plastic, inaccessible to bacteria, so biodegradation cannot occur. The statement that it has a negative impact on recyclability is simplistic, for the reasons given in detail at https://www.biodeg.org/subjects-of-interest/recycling-2/

Additives Contribute to Microplastics on Land and in Water

Most additives are designed to break plastics down into smaller pieces in order to make it sufficiently available to the microorganisms that perform biodegradation. These fragmented pieces may be invisible to the naked eye, yet their effects as microplastics have been shown to be seriously detrimental.

The additives are not designed to break plastics down into smaller pieces. They are designed to reduce their molecular weight by oxidation and thereby to convert the plastic into a biodegradable material. It is not the *size* that matters, but the molecular weight.

If ordinary plastic is discarded into the open environment, it will rapidly become brittle and will create microplastics. These will not be biodegradable, because their molecular weight is too high, and they will therefore lie or float around for decades. However, if the plastic had been upgraded at manufacture with oxo-biodegradable technology, it would oxidise much more rapidly and would become accessible to bacteria. At that point biodegradation will commence, and the material would be removed from the environment by the naturally-occurring bacteria.

Terrestrial litter is likely to migrate, either by human or natural means, into a marine environment. Additives that are designed to enable biodegradation in terrestrial (on-land) conditions are not tested or designed to be effective in marine conditions. This is because marine conditions have a wider variability in temperature, microbial and nutrient availability, and exposure to sunlight.

This is not correct. Before making statements of this kind the SPC should have read and understood the report of the Oxomar project https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf This was a four-year study into oxo-biodegradable plastic sponsored by the French government, which concluded that: "We have obtained congruent results from our multidisciplinary approach that clearly shows that 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."

In a marine environment, any fragmentation of petroleum-based plastic will exacerbate its harmfulness as pollution. Whether or not biodegradation successfully occurs in these various environments and conditions, petroleum-based plastics should not be designed to encourage fragmentation.

This is not correct either. As mentioned above, the harmful fragments are created by the embrittlement of ordinary plastics when exposed weathering. They will float around in the ocean for very many years until they become biodegradable, and during that time toxins will be attracted to their surface, and will then find their way into the tissues of marine creatures who ingest the fragments. However, if the plastic is oxo-biodegradable, its dwell-time in the ocean would be very much shorter. It would therefore be less likely to be ingested by marine creatures and less likely to attract toxins.

3. Additives are not an Enabler for Compostability
Compostability describes a material's ability to successfully undergo biological decomposition and transformation into a stabilized organic matter within a specified period of time. To beneficially complete the natural biological cycle, biodegradation should occur in a managed and controlled environment, such as an industrial composting operation. The material must also break down in a way that is non-toxic and harmless to human health and the environment.

This is a correct statement in relation to kitchen and garden waste which is sent for composting and converts into compost, which is a valuable soil-improver. However, this has nothing to do with plastics. Even the type of plastic marketed as "compostable" does not convert into compost – this is because ASTM D6400 and EN13432 require it to convert into CO2 gas within 180 days.

Petroleum-based plastics made with biodegradability additives do not break down in such a manner. To date, these additives have not enabled non-compostable plastics to become compostable.

This is not correct. Oxo-biodegradable plastic has been proved according to ISO 14855 to biodegrade in a composting facility as to 88.9% in 121 days, but oxo-biodegradable plastic is not marketed for composting. For the reasons explained at https://www.biodeg.org/subjects-of-interest/composting/ the BPA does not consider that plastic of any kind has a useful role in the composting process.

Landfills - The SPC does not support the use of any kind of degradability additives in packaging, including additives that seek to make packaging more degradable (i.e. break down more rapidly) in landfills.

Abiotic degradation of oxo-biodegradable plastic cannot occur in anaerobic conditions. It is not intended to break down more rapidly in landfills, because if a piece of plastic has been taken to landfill it has been responsibly disposed of and there is no need for degradation. Oxo-biodegradable technology is intended to deal with the millions of tons of plastic litter which get into the open environment, and especially the oceans, every year, and which do not get collected for recycling, for landfill, or for anything else.

BPA analysis of:

"An investigation into the stability and degradation of plastics in aquatic environments using a large-scale field-deployment study."

Theobald et al.
Science of The Total Environment, Volume 917

20th March 2024

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 – to deal with the microplastics by reducing the level of inertness and making the plastic biodegradable in the open environment without any human intervention.

At para. 1 "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." Correct.

"While many studies provide beneficial insights into the global distribution and extent of plastic pollution, most offer limited information about the environmental exposure history leading to their state. An alternative approach is to monitor plastic degradation under controlled and often harsh laboratory conditions, which artificially accelerate their chemical and physical ageing processes. These studies can contribute to understanding the fate of plastics in the environment and their subsequent fragmentation into smaller particles. They have the advantage of being faster and easier to perform than tests under real-life conditions in natural environments." – Correct. See the evidence of Dr. Graham Swift to the UK Government

"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). However, in most studies, commercially available products such as plastic bags were 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.

Another factor is that the researchers then proceed to test the sample under conditions unlikely to be experienced by plastic litter in the real world. In para.1 "Three marine sites and one wastewater treatment plant (WWTP) oxidation pond were chosen, and the samples *remained submerged there for up to one year*." However, the specific gravity of polyethylene and polypropylene is less than 1, so they will float on the surface. Theobald et al have fallen into the same error as Napper and Thompson.

Theobald et al then proceed to say (at 3.2.2) that "no convincing evidence was found for manganese-catalysed photooxidation and chain scission occurring upon exposure to the aquatic environments and at 3.2.1 OxoLLDPE (aged) remained largely unaltered during exposure to natural conditions, with the crystallites and cracks induced by ageing still visible and no indications for further changes. 3.2.3 While there were substantial effects inflicted on oxoLLDPE by artificial ageing, only limited changes could be detected in the deployed samples, independent of the presence of artificial ageing. No major degradation effects from submersion on aged oxoLLDPE could be observed."

They admit (at 3.1.5) that "both submersion in water and biological colonisation can explain the much slower degradation of oxoLLDPE compared to artificial ageing. Similarly, oxo-degradable polymer films are typically found to be rather stable when not exposed to direct sunlight, for example, due to submersion in seawater rather than when floating on the sea surface (Napper and Thompson, 2019; Biber et al., 2019)"

Also (at 3.2.2) "A possible explanation for this finding can be shielding of the samples from UV radiation by water or biofilm growing on the surface." This is correct. Biofilm is a significant factor in the case of ordinary plastic, because its dwell-time in the ocean is much longer.

In addition, "80% of the ocean's pollution ends up there from land sources, which would usually receive direct UV exposure before entering the water, where it will also float and continue to be exposed to direct UV radiation."

At 5. They say "different deployment strategies could be tested, including conditions that would include stronger exposure to direct, unfiltered sunlight, such as floating rather than submerged samples, or deployment on beaches rather than in the water." – Correct.

"Such experiments would provide highly informative insights into the fate of plastics in situations where more intense UV irradiation is present which is likely to affect the changes in their chemical and physical properties."

In the four-year Oxomar study at the French marine laboratory the scientists reported (at C2) "The objective of OXOMAR was to provide solid scientific data on the fate of

OXO-bios at sea, by evaluating the abiotic (task 1) and biotic (task 2) degradation of OXO-bio in natural conditions." As to task 1, they say (at C.6) "we confirm that accelerated artificial aging (UV, temperature) which was perfectly mastered in this project, is a tool of choice which is particularly well suited to the study of the fate of OXO-bios in the marine environment. Accelerated artificial ageing does not invalidate the results."

"The goal of Task 2 was to evaluate the biodegradation of OXO-bio in marine waters. This task has been divided in two parts by (i) following several months of OXO-bio colonization by marine microorganisms under natural conditions and (ii) by evaluating the biodegradability of OXO under natural conditions as compared to a cultivated microorganism with known PE-biodegradation abilities (Rhodococcus rhodochrous ATCC ® 29672 TM)."

"In the case of waste discarded in the environment, the pro-oxidants catalyze the normal processes of oxidation chemistry so that molecular-mass reduction occurs in orders of magnitude faster than would otherwise happen. The oxidation (thermo and/or photo-oxidation induced by the pro-oxidants) of OXO-bio polymers results in the formation of short molecular chains whose molecular mass is under 5000 Daltons: these molecules bear oxygenated groups such as carboxylic acids, alcohols, and ketones."

"It is well understood that the oxidation step transforms non oxygenated long chains (for example (CH2)n) - which cannot be accessed and assimilated by microorganisms - to short molecular chains, which can be integrated into the metabolism of microorganisms. Theoretically, the oxidation step transforms non oxygenated long chains (for example (CH2)n) - which cannot be accessed and assimilated by microorganisms - to short molecular chains, which can be integrated into the metabolism of microorganisms."

An at C6. "We have obtained congruent results from our multidisciplinary approach that clearly shows 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."

Theobald et al do not appear to have been aware of this important study and the scientific work referenced in it, and they do not cite it.

Notwithstanding that Theobald et al exposed the sample under conditions not likely to be expected for PE or PP litter in the real world, 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). In contrast, oxoLLDPE developed large cracks and substantial surface etching, and formed crystalline domains, reflecting the more substantial degradation catalysed by the manganese oxo-degradation additive." Yes, this would be expected.

3.1.2 "FTIR analysis revealed that oxoLLDPE underwent the most pronounced changes in surface chemistry (predominantly oxidation. .... The carbonyl index (CI) for oxoLLDPE increased strongly from 0.47 before ageing to 1.69 for the aged sample. In contrast, the CI of [ordinary] LLDPE was not significantly affected by the ageing process, highlighting the need for the catalyst to accelerate UV-induced oxidation." Correct.

3.1.4 "both the tensile stress and elongation at maximum force dropped by about 25–30 % upon ageing ... This finding highlights the crucial role the manganese catalyst plays in accelerating the degradation processes." Correct.

3.1.5. "Of all the plastics, ageing had the most dramatic effect with respect to tensile testing for oxoLLDPE."

The study was focused on microplastics creation/generation, but no microplastics were generated during the study. In due course microplastics would have been formed by the ordinary LLDPE, but not by the oxo-LLDPE, which would have converted into biodegradable materials.

The samples exposed to the environment were produced by the authors. These samples and their masterbatch were not commercial products, and the information given is not sufficient to tell whether they would have performed in the same way as a properly manufactured oxo-biodegradable product if correctly tested.

According to 2.1.2 Accelerated weathering was performed according to ASTM D4329–13/ASTM G154 test cycle C. Samples were exposed to 8 h of irradiation (UVA-340 ultraviolet light with an irradiance of 0.890 W/m2 at 340 nm) followed by 4 h of darkness (condensation) at 50 ◦C. The total duration of the test was 800 h [approx. 1month]"

ASTM D4329–13 provides at 8.2.2 "The minimum exposure time used shall be that necessary to produce a substantial change in the property of interest for the least stable material being evaluated."

It is unlikely that exposure for only one month would have reduced the molecular-weight to 5,000 Daltons, which is the 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.

In conclusion this study confirms that oxo-biodegradable plastic performs in the way we would expect.

BPA response to UCL Report

20th May 2023

EXECUTIVE SUMMARY

This is yet another literature review of the science relating to oxo-biodegradable plastic.

The UCL paper says *"Globally, 22% of the annual plastic production enters terrestrial and aquatic environments where they can remain for decades."* Measures such as deposit-return schemes and ocean and beach clean-ups can help, but the open environment is so vast that the *only* practical way to deal with this problem is to make the plastic oxo-biodegradable.

Studies and literary reviews have been going on now for more than 40 years, but it seems unlikely that all scientists will ever agree with each other on this subject, (or on most other subjects). This is a classic example of the best being the enemy of the good, and in the meantime thousands of tonnes of ordinary plastic are getting into the open environment every week.

Oxo-biodegradable plastics have a serious practical application. They are intended to perform in the same way as normal plastic, but to biodegrade if waste-management fails and they end up in the environment as litter. They are *not* therefore intended as part of any waste-management strategy. Reduce, re-use and recycle are all very well but a large quantity of plastic does get into the open environment, and there is no other way to prevent it accumulating. Oxo-biodegradable plastic should therefore be made compulsory, as it already is in the Middle East.

The most recent and important piece of scientific research on this subject is Oxomar – a four-year project sponsored by the French government, which says *"We have obtained congruent results from our multidisciplinary approach that clearly shows that oxo-biodegradable plastics biodegrade in seawater and do so with 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."*

The authors of the UCL paper have devoted a lot of time to show that as conditions in the open environment are variable it is not possible to predict the precise rate of biodegradation. However, this was already well understood, and this is why only an approximate timescale is given by the manufacturers.

There is no point therefore in doing further work in trying to establish precise timescales. Instead, attention needs to be focussed on the fact that an oxo-biodegradable plastic would oxidise and become biodegradable in the environment significantly more quickly than ordinary plastic at the same time and place.

The UCL authors point out that testing according to climatic conditions in South Florida would not show a degradation timescale applicable to conditions in the UK or Northern Europe. This is correct. Abiotic degradation may proceed more quickly in a hot, sunny, country than in a cold, dark country, but that is not a difference in principle.

The industry standards for oxo-biodegradable plastic are ASTM D6954 and BS8472. They contain six pass/fail tests, including tests for gel-formation/ cross-linking, and eco-toxicity.

The UCL authors say that they cannot be sure that the plastic will fully biodegrade, but Symphony has a report from Eurofins laboratories showing 88.9% biodegradation, and another from Intertek showing 92.74% (only 90% is required by EN13432 or ASTM D6400 for plastic marketed as compostable). Also, the UCL authors cite testing done by Prof. Jakubowicz in Sweden showing 91%. Testing will never find 100% carbon-evolution, because some of the material converts into water and biomass.

Even if it did not fully biodegrade it would still be better than ordinary plastic, which would have fragmented quite quickly under the influence of sunlight but would not have biodegraded at all.

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.

The European Chemicals Agency (ECHA) made a Call for Evidence in 2017, and informed the BPA after 10 months study that they had not been convinced that microplastics were formed.

Oxo-biodegradable masterbatches do not contain heavy-metals. They do not contain lead, and do not contain any substances in excess of the limits permitted by Art. 11 of the EU Packaging Waste Directive 94/62/EC. Symphony has tested products made with its d2w masterbatch according to the OECD eco-toxicity tests 201, 202, 203, 207, and 208 and they were all found to be non-toxic.

Oxo-biodegradability is the *only* way to remove enough plastic litter from the open environment, and if it had been widely adopted when it was invented, there would be no ocean garbage patches. There is now an urgent need for wide adoption of this technology before the problem gets even worse. This paper by UCL is an interesting survey of the literature, but provides no reason why oxo-biodegradable technology should not be made compulsory for a wide range of plastic products, as it already is in the Middle East.

ANALYSIS

In his evidence to the UK Government in 2019 https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf Dr. Graham Swift, one of the scientists who wrote ASTM D6954, says *"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."*

See eg. "Polymers and the Environment" by Professor Gerald Scott, published by the Royal Society of Chemistry (ISBN-10: 0-85404-578-3).

"As the degradation progresses, the hydrophobic polymeric substrate is converted into low molecular weight oxygenated, hydrophilic species suitable for biodegradation by most microbial species in most aerobic environments, and particles of plastic are not left behind. Note: oxygen is always needed for oxidation, but moisture is not, and once initiated, oxidation will continue even at low temperature or if the material is occluded from UV light. Heat and UV radiation merely enhance the rate of degradation."

The UCL authors say *"The durability and resistance to degradation of plastics are due to their high molecular weight ………….The degradation process can be accelerated by the addition of pro-oxidants ………….Evidence that PAC plastics can physically degrade into lower molecular weight fragments upon exposure to light and heat has been demonstrated and the oxidative mechanisms are now well understood and accepted."*

The most recent and important piece of scientific research on this subject is Oxomar – a four-year research project sponsored by the French government https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf The UCL authors make only a short reference to this, but crucially the Oxomar report says *"We have obtained congruent results from our multidisciplinary approach that clearly shows that oxo-biodegradable plastics biodegrade in seawater and do so with 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."*

See also the report from Queen Mary University London 11th February 2020. https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf Para 2.6 says "*prior to testing, samples of LDPE and oxo-LDPE were surface-weathered in sea water for 82 days, undergoing natural variations in sunlight and UV intensity.*" Para 2.3 says it biodegrades up to 90 times faster than conventional plastic.

The UCL authors focus on a test method published as PAS 9017, but this is not a standard. The industry standard for Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation is the American ASTM 6954, and the British equivalent is BS8472. They also erroneously include polystyrene and PVC in the polyolefin family. These polymers are styrenics and vinyl-based polymers, not "polyolefins". This classification is important, as there are no applications for oxo-biodegradable technology in styrenics or vinyl-based polymers.

TIMESCALE

The authors of the UCL paper have spent a lot of time to show that as conditions in the open environment are variable it is not possible to predict the precise rate of biodegradation. This was already well understood, and this is why only an approximate timescale is given by the manufacturers. In addition to the factors mentioned by UCL there are other factors, such as the formulation and addition-rate of the prodegradant masterbatch, and of course how old the polymer is at the time of disposal and the extent to which it has been exposed to heat and/or sunlight.

There is no point therefore in doing further work in trying to establish precise timescales, because it is not possible. Instead, attention needs to be focussed on the fact that an oxo-biodegradable plastic would oxidise and become biodegradable significantly more quickly than a conventional plastic at the same time and place. That is a significant environmental benefit.

It is possible to make oxo-biodegradable plastic so that it starts to degrade immediately after it has been made, but there would be no point in that, as the product needs to have a shelf and service life.

Dr. Swift says: *"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."*

"Oxidation is particularly relevant to the chemistry of oxo-biodegradable plastics since it influences the commencement and degree of biodegradation. In research and development, when an oxo-biodegradable plastic is required to have a performance life span of several weeks or several months, a 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."

"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 <u>more quickly</u>. 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. There is no need for degradation if the product has not been left in the open environment. In landfills, there is sufficient oxygen initially for oxidation to continue and the plastic is likely to disintegrate, but that is not the main purpose."

The UCL authors cite a paper commissioned by DEFRA which estimated that 2–5 years are necessary for these plastics to degrade in the open environment in the UK. That is a lot better than 50-100 years in the case of ordinary plastics. The reports from Eurofins and Intertek mentioned below have shown biodegradation in 121 days and 180 days respectively.

The UCL authors say that biodegradation under laboratory conditions could over-estimate biodegradation in the environment, but they also say *"this method [CO_2 evolution] could lead to an underestimation of the biodegradation levels if the production of new biomass is significant*." In evidence submitted to ECHA on 3rd May 2018 Dr. Ruth Rose of Queen Mary University London said *"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*." (the marine bacterium Alkanivorax borkumensis).

GEOGRAPHY

The UCL authors point out that testing according to climatic conditions in South Florida would not show a degradation timescale applicable to conditions in the UK or Northern Europe. This is correct, and an allowance would have to be made by any customer or government concerned with disposal in cooler climates. Dr. Swift says *"I am aware that standards similar to ASTM D6954 for testing oxo-biodegradable plastics have 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. It is true that abiotic degradation may proceed more quickly in a hot, sunny, country than in a cold, dark country, but that is not a difference in principle."*

STANDARDS

The ASTM D6954 and BS8472 standards contain 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).

Dr. Swift continues:

"We wrote D 6954 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."

"ASTM D 6954 is designed for testing plastics which degrade and biodegrade in uncontrolled conditions in the open environment, and is a detailed protocol for proving degradation, biodegradation, and non-toxicity under the conditions expected to be found in the open environment. Biodegradation in industrial composting or anaerobic digestion is not relevant here, and is dealt with in a separate Standard - ASTM D6400."

"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."

EXTENT

As to the extent of biodegradation, the UCL authors say that they cannot be sure that it will fully biodegrade, but Symphony has a report from Intertek showing 92.74% biodegradation and another from Eurofins laboratories showing 88.9% (only 90% is required by EN13432 or ASTM D6400 for plastic marketed as compostable). Also, the UCL authors cite testing done by Prof. Jakubowicz in Sweden showing 91%. Testing will never find 100% because some of the material converts into water and biomass.

Dr. Swift says *"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 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. If it did, 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."*

As to gel formation and cross-linking, as noted above the industry standards require samples to be checked for this.

Even if it did not fully biodegrade it would still be better than ordinary plastic, which would have fragmented quite quickly but would not have biodegraded at all.

The UCL report cites studies by Vazquez et al and says *"In general, a good correlation was found between the samples tested under laboratory and controlled outdoor exposure. The films containing the PACMB additive showed a much higher degree of degradation compared with the control samples."* They continued *"A drop melting point test was used to determine whether the degradation of the films led to the formation of waxes, according to ASTM D3954-15 …. All films containing the additive met this requirement after weathering, whereas the films without the additive showed a drop point above 140°C. This is consistent with the presence of the additive accelerating film degradation and conversion into a wax."*

The UCL report concludes that "*What is evident from both laboratory and field studies is that the abiotic degradation is a crucial step for biodegradation to take place."*

MICROPLASTICS

Some of the microplastics found in the environment are coming from tyres and man-made fibres, and recycling is also a source of microplastics. See https://www.sciencedirect.com/science/article/pii/S2772416623000803 Also, from mulch films which have embrittled under the influence of sunlight in the fields.

However, most of the microplastics found in the environment are caused by the fragmentation of ordinary plastic products when exposed to sunlight. These fragments are very persistent because their molecular weight is too high for microbes to consume them, and can remain so for decades.

This is why oxo-biodegradable plastic was invented. The plastic falls apart because the molecular chains have been dismantled and it is no longer a plastic. Professor Ignacy Jakubowicz (Sweden) advised the Ellen MacArthur Foundation about this as follows, but they omitted it from their reports ""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." https://www.biodeg.org/wp-content/uploads/2019/11/emf-report-1.pdf

Dr. Swift says "*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."*

"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."

The European Chemicals Agency (ECHA) were asked to study oxo-biodegradable plastic in December 2017. They made a Call for Evidence, and they informed the BPA after 10 months study that they had not been convinced that it creates microplastics.

The UCL report says *"the most recent studies of PAC plastics showed that the endpoint of the degradation/weathering process resulted in the formation of waxes, and the authors indicated that <u>microplastics are not formed</u> during the degradation of the film containing the PAC additive. By contrast, the films <u>without the additive</u> showed a slower degradation, and the authors speculated that microplastics might therefore form during the erosion of the polymer."*

ECO-TOXICITY

The UCL authors questioned whether toxic chemicals might leach out of the plastic into the environment. However, if the plastic contained toxic chemicals they would leach out whether the plastic was oxo-biodegradable or conventional, and increasingly governments are banning the use of toxic chemicals in plastic products.

With regard to oxo-biodegradable plastics, the industry standards mentioned above contain eco-toxicity tests which have to be satisfied. Symphony has tested products made with its d2w masterbatch according to the OECD eco-toxicity tests 201, 202, 203, 207, and 208 and they were all found non-toxic. Oxo-biodegradable masterbatches do not contain heavy-metals. They do not contain lead, and do not contain any substances in excess of the limits permitted by Art. 11 of the EU Packaging Waste Directive 94/62/EC.

The UCL study cites a report which *"evaluated the ecotoxicological effect of PAC plastics on the germination or development of tomato plants, and it <u>did not show any adverse effect</u>. In other work by Sable et al. PP photo-aged film samples containing Co stearate as the pro-oxidant were tested against mung bean and wheat plants and earthworms. <u>None of these films was found to be toxic</u> against earthworms, and the seedlings in the growth medium showed that the average plant growth levels were the same."*

In addition, ecotoxicity tests were carried out by Intertek and Eurofins during the testing mentioned above, and in the Oxomar study on embryos or larvae of fish (Dicentrarchus labrax), sea urchins (Paracentrotus lividus), oysters (Crassotrea gigas), ascidians (Phallusia mammillata), cephalochordates (Branchiostoma lanceolatum) and on microalgae (Skeletonema marinoi, Chaetoceros calcitrans, Tetraselmis suecica, Emiliania huxleyi).

CONCLUSION

Oxo-biodegradability is the only way to remove plastic litter from the open environment, and if it had been widely adopted since the time it was invented, there would be no ocean garbage patches. There is now an urgent need for wide adoption of this technology before the problem gets much worse. This paper by UCL is an interesting survey of the literature, but provides no reason why oxo-biodegradable technology should not be made compulsory for a wide range of plastic products, as it already is in the Middle East.

Biodegradable Plastics Association
www.biodeg.org

Biodegradable Plastics Association

A not-for-profit Association

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US PLASTICS PACT

Their Report on PROBLEMATIC AND UNNECESSARY MATERIALS is fundamentally mistaken insofar as it relates to compostable and biodegradable plastics.

A. The type of plastic marketed as "compostable" is problematic and unnecessary

B. Oxo-biodegradable plastic is necessary and is not problematic.

A. "COMPOSTABLE"

Plastic marketed as compostable is:

PROBLEMATIC because it:

1. Does not convert into compost (EN13432 and ASTMD6400 require it to convert into $C0_2$ gas).
2. Is intended for a deliberate linear process and is not circular. The material is intended to be wasted by conversion into CO_2 and lost to atmosphere.
3. Cannot be re-used, recycled, or made from recyclate
4. Leaves microplastics in the compost and in the open environment
5. Does not deal with the problem of plastic litter in the environment which cannot be collected

UNNECESSARY, because it is not wanted by industrial composters and local authorities. People should not be encouraged to buy plastic bags for home composting, when they could use a bucket. It does not in any event biodegrade properly in a home compost.

It should not be described as compostable or biodegradable. It should not be encouraged, and should instead be banned. For details see https://www.biodeg.org/subjects-of-interest/composting/

B. OXO-BIODEGRADABLE

NECESSARY
This type of plastic has been specifically designed to deal with plastic which escapes into the environment from which it cannot be collected for recycling, composting or anything else. This is not an intended disposal route - it is an insurance in case waste-management fails. It is the ONLY way to deal plastic in the open environment and is therefore NECESSARY.

86-90 Paul Street, London EC2 4NE, United Kingdom www.biodeg.org / E:: Info@biodeg.org

NON-PROBLEMATIC

Oxo-biodegradable plastic is not problematic because:

1. It does not create microplastics. It is not disputed by anyone that most of the microplastics found in the environment are coming from the fragmentation of ordinary plastic, and that they are very persistent. The European Chemicals Agency were not satisfied that oxo-biodegradable plastic creates microplastics, and ECHA have never provided a scientific dossier in support of any ban on oxo-biodegradable plastic.

2. It should be used and disposed of in the same as ordinary plastic. It can be re-used and recycled and is perfectly compatible with a circular economy. See https://www.biodeg.org/subjects-of-interest/recycling-2/

3. It will fully biodegrade. Eurofins and Intertek have done tests showing biodegradation of 88.9% within 121 days and 92.74% within 180 days, respectively. No reason has been shown why biodegradation should stop before it is complete. The percentage required by ATM D6400 for "compostable" plastic is 90%. Even if it did not fully biodegrade it would still be better than ordinary plastic, which would not have biodegraded at all.

ASTM D6400 for "compostable" plastic requires biodegradation to be tested in a laboratory (not in a compost heap) but some critics suggest that oxo-biodegradable plastic should be tested in outdoor conditions. As to the correlation between laboratory tests and the real world, see the statement of Dr. Graham Swift, https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf who says "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."

The Oxomar project was a three-year interdisciplinary study, sponsored by the French Government https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf and the scientists said "The goal of this task (C3Task2) was to evaluate the biodegradation of OXO-bio in marine waters. This task has been divided in two parts by (i) following several months of OXO-bio-colonization by marine microorganisms under natural conditions and (ii) by evaluating the biodegradability of OXO under natural conditions as compared to a cultivated microorganism with known PE-biodegradation abilities."

They reported that "We have obtained congruent results from our multidisciplinary approach that clearly shows that oxo-biodegradable plastics biodegrade in seawater and do so with a significantly higher efficiency than conventional plastics. The oxidation obtained due to the d_2w prodegradant catalyst was found to be of crucial importance in the degradation process."

See also the report from Queen Mary University London https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf Para 2.6 says "prior to testing, samples of LDPE and oxo-LDPE were surface-weathered in sea water for 82 days, undergoing natural variations in sunlight and UV intensity."

4. It leaves no toxic residues, and is tested to OECD ecotoxicity standards

5. It is not disputed that biodegradation will be many times faster than ordinary plastic. Queen Mary University say up to 90 times faster https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf para 2.3

6. Although recycling is preferable to biodegradation, it is not possible to recycle plastic which has escaped into the open environment from which it cannot realistically be collected. The ONLY way to deal with it is biodegradation

31st July 2024

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See below Symphony's comment on:

"OXO-DEGRADABLE AND OXO-BIODEGRADABLE PLASTIC USE IN AGRICULTURE AND HORTICULTURE IN WALES."
Written by ADAS for the Welsh Government 15th August 2022

The author says that the use of plastic in crop-production is essential for a successful UK horticultural and agricultural industry. He details the significant extra costs which would be imposed on farmers and growers if oxo-degradable and/or oxo-biodegradable plastic were banned, including the disposal costs of used plastic films.

We would agree, but the problem with this paper is that the author is confused about the materials he is dealing with.

The author thinks that an oxo-biodegradable plastic is made from polymer with a biomass filler such as starch. These were tried in the past, but they are no longer considered useful because the starch degraded and the polymer did not, and microplastics were the result. An added disadvantage was that, like the PLA plastic marketed as "compostable" they were not compatible with recycling.

He thinks that polymers with the addition of a masterbatch such as d2w is oxo-degradable - designed simply for abiotic degradation, with the result that they break down and fragment and then "blow all over the place."

He does not appear to understand that the effect of the oxidation promoted by the masterbatch is to dismantle the molecular chains within the polymer and thereby reduce the molecular weight, by a process that is continuous until the plastic is transformed into non-plastic biodegradable compounds found in nature. This gives bacteria access to the compounds, which are then bioassimilated by them, and this why this material is called oxo-biodegradable, not oxo-degradable.

This process also converts the character of the material from hydrophobic to hydrophilic, so that the degrading particles stick to the soil and do not "blow all over the place." He thinks that the particles are harmful to the environment, but the residues from oxo-biodegradable plastics have been tested according to the OECD protocols and found to be non-toxic to plants, daphnia, earthworms and fish.

He is also confusing oxo-biodegradable and photo-degradable plastic. Abiotic degradation of oxo-biodegradable plastic is not simply light-induced – it is also thermally-induced, which means that degradation will continue even in the dark, so even the "tuck" at the edge of the mulching film will degrade and then biodegrade.

No indication is given as to whether the author, or the technical reviewer have any qualifications in polymer science. It does not appear from this paper that they have.

Symphony Environmental have already conducted successful trials of mulching films in Wales, and the Report of these trials is publicly available on Symphony's website but the author seems unaware of them.

We have communicated with the Welsh Authorities and it is clear that there is no public demand in Wales, nor any sufficient reason, for a ban on oxo-biodegradable plastic.

See also Billingham et al "Environmentally Degradable Plastics based on Oxo-biodegradation of Conventional Polyolefin Films"

See also "Agricultural Film Overview"

There are two scientific papers cited in this ADAS paper.

1. Chapman S. "Biodegradable Plastics for Agriculture" IBERS, Aberystwyth University for Farming Connect 2018 says that:

"The discovery of plastic and its range of beneficial applications has changed the way we live our lives. Plastic serves several important functions in today's society such as protecting vulnerable products from damage whilst in transit, and from contamination or damage from moisture, microorganisms and light. The use of plastic films for soil mulching reduces weed growth, water use and the washout of nutrients from the soil. Therefore, soil mulching contributes to a more sustainable agricultural production system."

"An estimated 2-3 million tons of plastics are used in agriculture each year and by far the biggest use of plastic in agriculture is for mulch films and silage wrap. These are typically made from polyethylene (PE) because it is cheap, easily processed, highly durable and flexible."

"However; it is because of PE's non-biodegradable nature, that it is now becoming an environmental concern. Rather than biodegrade, PE undergoes a process of light induced 'oxo degradation', which results in the breakdown of PE film, in the presence of light, to microplastics, that are unobservable to the human eye. The concern here is that microplastics are finding their way into the food chain and the effects of microplastic bioaccumulation on animal and human health are not yet fully understood."

Oxo-biodegradable technology was invented, to improve on "light induced 'oxo degradation'" to convert oxo-degradation into oxo-biodegradation by catalysing the process of oxidation and reducing the molecular weight of the polymer to enable bioassimilation by micro-organisms in the soil instead of persisting as microplastics for decades before eventual biodegradation. However the author does not appear to be aware of this technology, and concentrates instead on bio-based films made by Bayer, and the starch-based Mater-Bi plastic, produced by Novamont. He confirms that both of these proved to be too expensive and too heavy for agricultural purpose. He also considers polyhydroxyalkanoates (PHA), polyhydroxy butyrate (PHB's) and polybutylene succinate (PBS) which he says also have practical limitations and are too expensive.

The author points out that "most mulch films are produced from petroleum-based plastics, usually polyethylene (PE) which result in a considerable waste disposal problem. Because of the non-biodegradable nature of PE, disposal options are limited to being burnt, sent to landfill, recycled or simply left in the field, with each option presenting different environmental burdens. Burning of plastics releases aromatic hydrocarbons and results in indiscriminate exposure and it is for these reasons that the Incineration Directive (Directive 2000/76/EC) was drafted, which prohibits uncontrolled burning of waste."

He continues "The useful life of mulch film exceeds the duration of crop cycles so is usually left in the soil. Collection of the residual plastic is time-consuming and involves the use of machines and hand labour, and collected plastic requires ongoing collection and disposal costs."

"If left buried, PE films will never completely disappear from the field, leaving remnants which remain in the soil, which clog and choke machines when ploughing and harrowing fields. PE is recyclable, hence PE mulch films should be recycled. However, when contaminated with soil, sand, silage or other materials, this becomes more challenging."

“There are currently only two facilities in the UK (Rhymney and Dumfries) that can recycle contaminated agricultural plastic. The environmental issue associated with landfill is being addressed by the Landfill Directive (2014), which will phase out the landfilling of all recyclable waste by 2025. “

In short, this paper provides very good reasons why oxo-biodegradable plastic films should be used in agriculture instead of conventional or bio-based plastics.

2. Portillotto F, Yashchukbic O, Hermida E “Evaluation Of The Rate Of Abiotic And Biotic Degradation Of Oxo-Degradable Polyethylene” Elsevier Volume 53, August 2016, Pages 58-69

This paper confirms that “Plastics are very versatile materials that enable many applications due to properties such as flexibility, hardness, lightness; they are also excellent as a barrier against the permeation of gases, present various mechanical and physical properties, good optical properties (transparency) and ease of manufacture and molding of complex parts.” We would agree with this.

The authors say that “Firstly we must consider that these materials are produced from oil, natural gas and coal; despite being secondary products, their origin remains dependent on non-renewable sources such as fossil fuels.” Yes, but for so long as fossil fuels are required for engines it make sense to use the by-product of refining them, to make plastic instead of using scarce land and water resources (and fossil resources) to make bio-based plastics or paper.

The authors continue “Second, the accumulation of waste of some inert plastics such as polyolefins, although not posing risk of ecotoxicity, generate major drawbacks.” Yes, this is why oxo-biodegradable technology was invented, to prevent them accumulating in the environment for decades.

“In the Province of Buenos Aires, more than 4 million tons/year of MSW (17%) are plastics. To reduce their impact on the environment, the law 13868 was enacted. This legislation prohibits the use of plastic bags in supermarkets, warehouses and shops in general, and promotes the replacement of such bags by those made of degradable materials so to reduce their environmental impact.”

“Under this legislation, traditional polyethylene bags were replaced by bags made from polyethylene and labelled as biodegradable, oxo-degradable or oxy-degradable. This attribute stems from the addition of special additives to standard thermoplastics in order to accelerate the degradation products.” Yes, but the terminology is not correct.

This paper confirms that “the additive plays a crucial role in the degradation and subsequent decay of the molecular weight.” Yes, this is the crucial difference between oxo-degradation and oxo-biodegradation. Reduction in molecular weight is essential to enable biotic degradation.

The authors note that “The critical dose decreases significantly when increasing the temperature of the photo-degradation assay.” Yes, this is because an oxo- biodegradable plastic is not just photo-degradable, and abiotic degradation will be promoted thermally as well as by uv light. This is important because the molecular weight of an oxo-biodegradable plastic will continue to reduce even in the absence of light.

They say that “It was observed that although the additive increased the abiotic photodegradation, the molecular weight reduction in compost was not enough to reach the maximum biotic degradation level established by international standards for biodegradable materials.” They are referring to EN13432 but this (and ASTM D6400) are standards for plastic designed for biodegradation in the special conditions found in an industrial composting facility, in the short timescales required by the composting industry, not for polyolefin plastic designed to biodegrade in the open environment, for which the relevant standard is ASTM D6954 or BS 8472.

BPA ANALYSIS OF WWF POSITION PAPER

6th June 2023

The World Wildlife Fund (WWF) has recently published a "Position Paper" on Biobased and Biodegradable Plastic. It says that "WWF has a responsibility to communicate clearly and consistently on topics that impact WWF goals" but this paper fails to do so.

PLASTICS GENERALLY

There is however a lot we can agree with in this section. They say:

"Global plastic pollution is an increasingly urgent environmental crisis. and one which has amassed significant public attention in recent years. Plastic pollution threatens aquatic and terrestrial ecosystems around the world. An estimated 8 million tons of plastic waste enter the oceans every year." They continue "Plastic does not belong in nature. WWF has a global strategy in pursuit of the vision of No Plastic in Nature by 2030. WWF is working to stop the flow of plastic into nature, eliminate unnecessary plastic, and improve the sustainable production and management of the remaining necessary plastic."

This is a laudable goal, but WWF cannot guarantee that by 2030 plastic will not be escaping into the open environment, even in the developed countries.

This is why oxo-biodegradable plastics were invented, and if they had been more widely adopted there would be substantially less plastic in the open environment. It would have biodegraded long ago and been cleaned out of the environment by naturally-occurring micro-organisms. Oxo-biodegradation is NOT an intended disposal route, and is certainly not "touted as the solution." It simply recognises the reality that plastic does escape into the open environment, and the technology is there as a long-stop if all else fails.

Banning plastic is not a solution, and WWF themselves say "WWF does not advocate for elimination of all plastic because when one material is reduced or eliminated from the global material system, environmental costs can be transferred to another part of the system. Material substitution can cause its own trade-offs and the benefits of plastic may be lost (for example plastic packaging can keep food fresh, protected and safe, and therefore minimize food waste). Prioritizing reduction is key, but we must take a careful and holistic approach."

Agreed. Life-cycle Assessments show that plastic has the best LCA for common packaging applications. See https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/ See also the Denkstatt Report from Germany which concludes that it would be a mistake to ban plastic and use other packaging materials instead See https://www.biodeg.org/wp-content/uploads/2019/11/Denkstatt-report.pdf

BIOBASED PLASTICS

WWF say "This is a complex topic and WWF needs a position from which the network as a whole can speak clearly and consistently about the role bioplastic can potentially play in a circular economy, how it is used, and in which systems it can be responsibly and sustainably used. There is high demand for a science-based position on this topic that supports the overarching vision of No Plastic in Nature." However, this paper does not provide it.

They say that "Compostable plastic breaks down and becomes usable, non-toxic soil conditioner under controlled conditions." This is a fundamental mistake, because the Standards for this type of plastic (ASTM D6400, EN13432 etc.) require it to convert into CO_2 gas within 180 days.

It does not therefore convert into a soil conditioner, and it is deceptive to describe it as "compostable." It is instead wasted by being emitted to atmosphere from composting facilities as a greenhouse gas, and there is nothing circular about that. Even worse if it gets into landfill, it generates methane in anaerobic conditions.

On 2nd December 2022 the UK Environment Minister said: "Compostable plastics must be treated in industrial composting facilities to be broken down and, when processed incorrectly, can be a source of microplastics, and contaminate recycling streams. This packaging does not contribute to a circular economy in the same way as packaging that can be reused or recycled into new packaging or products do, as compostable plastic packaging is generally intended to be used only once."

Also, it cannot be recycled or be made from recyclate. WWF say "PLA can contaminate PET mechanical recycling streams."

WWF believe that "compostable" plastic can play a potentially beneficial role, and may be appropriate for specific uses, but will only be advantageous if collection and processing is sufficient to recover the material." The idea that plastic marketed as compostable can be advantageous or beneficial seems to follow from their mistaken belief that it "breaks down and becomes usable, non-toxic soil conditioner." It is in fact a "linear 'take-make-dispose' industrial model" which WWF do not accept.

The industrial composters and digestors and local authorities do not want it, even for collecting food-waste. See https://www.biodeg.org/subjects-of-interest/composting/ For example, Epsom Borough Council in the UK tells its citizens "We used to ask you to use bio-liners to line your food waste caddy, but the food waste recycling companies found that bio-liners compost down much more slowly than the food. That slowed the recycling process and made it much more expensive. They tried dredging the bio liners out of the food waste, but the sticky bio-liners got tangled around the dredging equipment. Cleaning them off was very expensive, so they found that using ordinary plastic bags was, overall, much more cost-effective."

On 14th November 2022 the UK Minister for the Environment confirmed that "evidence suggests these materials are often stripped out at the start of the process and landfilled or incinerated"

Plastics marketed as "compostable" are not advantageous or beneficial even for home-composting . On 2nd December 2022 the UK Environment Minister said "HM Government notes the findings from UCL's study into the home composting of plastics. The study has shown that home composting is not a viable destination for managing plastic waste."

WWF say that "If appropriately sourced, [biobased plastics] may offer environmental advantages over their fossil-based counterparts. However, their overall climate footprint still depends on the entire life cycle of the plastic product, including end-of-life management." Indeed it does, and Life-cycle Assessments by Intertek show that fossil-based plastics (especially if oxo-biodegradable) are a better material for common packaging applications. See above.

WWF say that "Biobased plastics offer the opportunity to achieve greenhouse gas emission savings." However, the comparison between different types of polymers needs to be made using an LCA that will consider GHG emissions during manufacturing, storage and use, and also the potential for recycling.

The polyolefins made from oil do generate some CO_2 during manufacturing, but oil is extracted primarily to make fuels, and whatever WWF say or do, these fuels will be required for the foreseeable future, even in the developed world.

Plastic is made from a by-product of oil which used to be wasted, and it is better to use this by-product whilst available instead of using agricultural resources to make plastic.

Biobased polymers require fertilisers, water, pesticides, and tractors and other equipment which consume fuels and emit pollution and GHG. They also use energy and generate GHG during the polymerisation process. WWF say that "agriculture has serious impacts on our planet and biobased plastics today are largely made from agricultural commodities. Their production can have complex effects on landscapes."

This is mitigated to some extent if the raw-material can be produced from non-agricultural products such as marine algae, and this is being done by a French company called Eranova.

Then there is the biodegradation process, in which biobased polymers such as PLA release a higher % of CO_2 or, potentially methane (CH4), than polyolefins.

So, we don't see how biobased materials "would release a lower volume of GHG compared to their fossil-based counterparts.

If the biobased material is not biodegradable, it will pollute by accumulation in the outdoor environment. For example, the PE produced from sugar-cane stover - unless an oxo-biodegradable masterbatch is added.

As to this source of raw material, WWF say "Residues used for bioplastic production can displace the original uses, which include ground cover, fuel, fodder, fertilizer, fibre, animal feed, and pulp and paper. It is important to consider the environmental impacts of the substitutes that are used to replace residue materials, as this can significantly influence the environmental footprint of residue-based bioplastics. Furthermore, the removal of cellulosic and agricultural harvest residues from fields (i.e. where they would otherwise be left as ground cover) can have serious impacts on soil health and stability. Sustainable removal rates are highly variable, and currently each case must be considered individually."

WWF are correct when they say that bio-based plastics are "as likely to become plastic pollution as fossil-fuel based plastics."

WWF say "lab tests are insufficient to prove true biodegradability in all potential conditions." However, EN13432 and ASTM D6400 for plastic which biodegrades under composting conditions requires biodegradation to be tested in a laboratory (not in a compost heap). As to oxo-biodegradable plastic see the evidence to the UK government of Dr. Graham Swift (Vice-chairman of the relevant Technical Committee at ASTM) https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf He says "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."

OXO-BIODEGRADABLE PLASTIC

WWF "believes that materials should not be designed to end up in nature." They "should be designed with the intention that they will be recaptured and not littered into natural Ecosystems."

We can all agree with that, but WWF must know that despite best intentions large quantities of materials, including plastics, do not get recaptured and do end up in natural ecosystems. Therefore, **whilst materials should not be *designed* to end up in nature, they should be designed so that if they do end up in nature their dwell-time is as short as possible and they do as little damage as possible**. This is why oxo-biodegradable plastic was invented.

In this paper WWF discuss “oxo-degradable” plastics which, according to them, contain additives to promote oxidation. However, nobody puts pro-degradant additives into plastics and describes them as oxo-degradable. They are described as oxo-biodegradable.

WWF do not appear to understand the difference between oxo-degradable and oxo-biodegradable plastic. “Oxo-degradation” is defined by CEN (the European Standards authority) in TR15351 as “degradation identified as resulting from oxidative cleavage of macromolecules.” This describes ordinary plastics, which abiotically degrade by oxidation in the open environment and create microplastics, but do not become biodegradable except over a very long period of time (WWF say hundreds – or even thousands - of years).

By contrast, “oxo-biodegradation is defined by CEN as “degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively”. This means that the plastic degrades by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature. Only oxygen is necessary for the abiotic process of oxidation, and WWF are incorrect in thinking that moisture is necessary for this process. Also, raised levels of light and heat will accelerate the process, but are not necessary.

In the manufacture of oxo-biodegradable plastics, a masterbatch containing a catalyst and stabilisers is added at the manufacturing stage to products being made from polyethylene or polypropylene. They perform as normal plastics, and the stabilisers give them a useful storage and service life. During that time they can be re-used and recycled, See https://www.biodeg.org/subjects-of-interest/recycling-2/ and are perfectly compatible with a circular economy.

If however plastics escape into the open environment as litter, they can lie or float around for decades, and this is the reason why there is so much public concern about plastic. Oxo-biodegradable technology addresses this problem by causing them to convert rapidly into biodegradable materials. This is the *only* way to prevent plastics which have escaped into the oceans from accumulating there for decades. The three R’s are not enough. There needs to be a fourth R – “Remove.”

However, WWF say “Oxidation brittles and fragments the material with the intention to be digestible by microorganisms, but evidence shows that this desired effect is not achieved” and “there is no credible evidence that these additives result in environmentally advantageous outcomes,” and “oxo-degradable materials, do not result in better environmental outcomes, and contribute to microplastic pollution.” They also say “in aquatic environments, biodegradable materials may not biodegrade because the optimal conditions (temperature, UV exposure, oxygen level, microorganisms, physical disturbance) are unlikely.”

WWF do not seem to be aware that oxo-biodegradable plastics have been studied by scientists for more than 40 years. See e.g., “Degradable Polymers, Principles and Applications” (ISBN 1-4020-0790-6) and “Polymers and the Environment” (ISBN 10: 0-85404-578-3). The most recent work is a four-year interdisciplinary study, sponsored by the French Government https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf to evaluate the biodegradation of oxo-biodegradable plastic in the marine environment. They reported that “We have obtained congruent results from our multidisciplinary approach that clearly shows 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.”

As to microplastics – WWF say “Plastic pollution has been found in even the most remote environments, it takes hundreds or even thousands of years to degrade in nature (plastic has not been around long enough to know for sure), and it affects wildlife through entanglement, ingestion, and habitat impacts. The release of primary microplastics and the abrasion of macroplastic into smaller pieces, called secondary microplastics, are of significant concern because these plastics can more easily access ecosystems and wildlife."

Some of the microplastics found in the environment are coming from tyres and man-made fibres, and recycling is also a source of microplastics. See https://www.sciencedirect.com/science/article/pii/S2772416623000803 However, most of the microplastics found in the environment are caused by the fragmentation of ordinary plastic when exposed to sunlight. These fragments are very persistent because their molecular weight is too high for microbes to consume them, and can remain so for decades.

Again, this is why oxo-biodegradable plastic was invented. The oxo-biodegradable plastic falls apart because the molecular chains have been dismantled and it is no longer a plastic. (When Ellen MacArthur Foundation asked Professor Jakubowicz for his advice He made this point, but they omitted it from their report). See https://www.biodeg.org/wp-content/uploads/2019/11/emf-report-1.pdf

Also, the European Chemicals Agency (ECHA) were asked to study oxo-biodegradable plastic in December 2017. They made a Call for Evidence, and received a large volume of evidence, including evidence from Intertek https://www.biodeg.org/wp-content/uploads/2021/01/Intertek-Report-to-ECHA-24.5.18.pdf and they said after 10 months study that they had not been convinced that it creates microplastics. ECHA have never provided a dossier to support any ban on oxo-biodegradable plastic, and there is no evidence that any microplastics found in the environment are from oxo-biodegradable plastic.

WWF expect the plastic to completely degrade into substances found in natural ecosystems within a timespan that will not cause ecological harm.

Has it been shown that oxo-biodegradable plastic will completely biodegrade? Yes, tests have been done by Intertek according to ASTM D6954 showing biodegradation of 92.74% (The percentage required by EN13432 and ASTM D6400 for "compostable" plastic is only 90%), and no reason has been shown why biodegradation should stop before it is complete. However, testing will never find 100% carbon-evolution because some of the material converts into water and biomass. Even if it did not fully biodegrade it would still be better than ordinary plastic, which would have created persistent microplastics but would not have biodegraded at all.

WWF cannot be sure how long oxo-biodegradable plastic will take to biodegrade in the open environment, but it is not disputed by anyone that it will be many times faster than ordinary plastic when exposed under the same conditions, and that the dwell-time in the environment will therefore be much shorter. Queen Mary University say up to 90 times faster https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf para 2.3.

AGRICULTURAL MULCH FILM

WWF say "In situations where the application severely limits the option to recover the material and there is an inherent limiting factor that prevents integration of the material into the recycling stream, biodegradable plastic may prove beneficial. For example: agricultural film."

"Biodegradable characteristics may be beneficial for agricultural film because it is difficult to recover all of the material, and the contamination and degradation of the material makes it very unlikely to be recycled, meaning these films are usually landfilled or burned. Even when removed, some pieces of agricultural film are often left behind in fields and end up ploughed into soil."

"Also, agricultural film is an example of an application in which plastic is shed during the use phase of the material and is in constant contact with organic material. Therefore, biodegradability may offer net benefits in this specific application because conventional plastic would degrade more slowly. In general, biodegradable film designed to be above or slightly below the surface of the soil may result in less impact than conventional film."

We agree with that.

Farmers all over the world spread thousands of square kilometres of plastic sheet on their fields to protect their crop from weeds and to reduce the evaporation of water. Essentially, farmers have three options:

Conventional plastic – after the harvest the farmer has to drag hectares of plastic off his fields. He cannot burn it on the farm, and burying it is not a good idea because it is labour-intensive and effectively puts the site out of cultivation, so he has to pay for it to be taken away. Some farmers send their plastic for recycling but it is usually contaminated with mud and other contaminants, so recycling does not make a lot of sense in economic or environmental terms when you consider the cost of hauling the plastic off the field, loading a large truck, and driving it along country roads to a recycling facility often many miles away – using fossil fuels, causing congestion, and emitting pollution. The plastic then has to be washed and the contamination has to be disposed of - and then the plastic has to be processed into recyclate.

Also, having lain on the fields exposed to sunlight it is likely to have degraded to the point that it is not fit for recycling, and fragments will be scattered by the wind whilst being removed.

Bio-based Plastic – this is expensive and may not be strong enough to resist tearing. Most important, the timescale for degradation cannot be programmed.

Oxo-biodegradable plastic - Oxo-biodegradable mulch films have been studied by scientists for more than 20 years. At page 47 of "Degradable Polymers, Principles and Applications" Professor Scott says "The degradation products formed by oxo-biodegradation are of benefit to the agricultural environment as biomass, and ultimately in the form of humus. Carbon is retained in the soil during oxo-biodegradation in a form accessible to growing plants, rather than by being eliminated to the environment as carbon dioxide, as is the case with hydro-biodegradable polymers (e.g. pure cellulose and starch)."

The next time the field is ploughed, the biodegradable material will be bio-assimilated by the bacteria and will provide a source of carbon for next year's crops.

By taking note of the climatic conditions in the area, and the growing-cycle of the particular crop, the oxo-biodegradable plastic film can be made to last for as long or short a time as the farmer requires, by using the correct formulation. Time control of degradation is achieved by antioxidants in the masterbatch that behave similarly to naturally occurring antioxidants present in lignin and tannin. See also "Polymers and the Environment" pages 109-118 and 461-466.

Symphony Environmental have run successful field trials in Wales - See https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf.

With regard to the edges of the mulch film, which are buried to hold it in place, they will still biodegrade because, unlike photo-degradable plastic, an oxo-biodegradable plastic does not need constant exposure to sunlight.

COMMENTS ON YASHCHUK et al

"Degradation of Polyethylene Film Samples Containing Oxo- Degradable Additives." Procedia Materials Science, 1, 439-445. (2012)

The authors say that they tested (a) polyethylene (PE), and (b) polyethylene with the d2w® oxodegradable additive (PE + AD), but no scientific description is given of the composition of these materials. The material labelled PE+AD might have been correctly made with a suitable masterbatch or it might not. This deficiency is enough to invalidate the whole paper, but for the sake of argument we will assume that it was correctly made.

<u>3.2. Abiotic degradation of PE and PE+AD films</u>

The authors recognise that "at a given dose, the CI (carbonyl index) of PE+AD is higher than for PE, emphasizing the proto-degrading effect of the additive."

They then say that "Before the biodegradation assessment, samples were UV irradiated at 0,89 W/m2 and 70 °C for 96 hours (dose = 307 kJ)."

96 hours is only four days, which is not a sufficient period of abiotic degradation, and this is the reason for the strange results found in the experiment.

There is an ASTM test designed specifically for plastic which degrades and then biodegrades if it gets into the open environment. This is ASTM D6954, and is the test method which the authors should have used, but it was not mentioned.

Para. 6.3 of ASTM D6954 says "For thin films, the exposure period would be the time required for the film to reach 5 % or less elongation to break (Practice D3826) and the fragmented film to reach a recorded average weight-average molecular weight (*MW*) of 5000 or less."

The authors have performed elongation-at-break tests, but they have not stated the values obtained. ASTM 3826 provides (at 10.2) that "The material is considered degraded to the brittle point when 75 % or more of the test specimens have a tensile elongation of 5 % or less."

Nor have the authors measured by chromatography the molecular weight of the material tested for biodegradation. This is crucial, because significant biodegradation does not commence until the molecular weight has reduced to 5,000 Dalton or less.

Moreover, the authors say (para. 2) that the polymer samples tested for biodegradation were 6,5 x 9,5 cm and 50 +/-2 microns thickness…" This shows that the material tested for biodegradation was not sufficiently abiotically degraded. A material with a molecular-weight of 5,000 Daltons or less is not able to maintain a geometrical shape, as it crumbles into small pieces of low molecular-weight material.

<u>3.3. Biotic degradation of PE and PE+AD films</u>

"… after the first 14 days of biodegradation of PE and PE + AD samples 14,1 mg and 50,6 mg of CO2 were accumulated; this means biodegradation rates 0,8 % and 5,0 %, respectively, as shown in Fig. 4."
The authors say "We claimed that the high microbial activity in the vessels with the PE + AD samples could be attributed to the presence of low molecular weight chains, as shown by the high value of CI after the abiotic treatment; this agrees with previous results (Jakubowicz, 2003; Corti et al., 2010)."

Yes, what is happening here is that during the four-day period of abiotic degradation a small amount of the material on the surface had been degraded, and this is being consumed by the microbes. Hence the much higher rate of biodegradation of the oxo, as distinct from the ordinary polymer.

They then report that "after 20 days of incubation, the biodegradation in the vessels with PE + AD reached a plateau that lasted 10 days, and then the biodegradation matched the curve of the PE samples." Yes, this is because the small amount of abiotically degraded material in the PE+AD sample had then been consumed.

The authors suggest that "These results might be attributed to two different sources of nutrients for the microorganisms: the additive and the PE chains of lower molecular weight." However, the only part of the masterbatch (which they call the additive) which could provide any nutrition for the microbes, is the stearate, but this is present in such small quantities as to be insignificant.

They then say "In fact, the first plateau in the curve of biodegradation of PE + AD samples might be associated to an increase of the microbial activity due to the presence of the additive." Yes, as already explained, the additive would have caused a small amount of abiotic degradation in the four days for which it was exposed, and the microbes would have consumed the small amount of low molecular material thereby created.

"After 90 days of incubation, about 24 % of biodegradation took place for both types of samples; this value agreed with the CO2 accumulation in the blank experiment. "

The authors explain this by saying that "In the vessels with pieces of PE film without additive, the microorganisms have no additive as source of nutrients so, the biochemical chain scission [enzymes] took place slowly until the density of low molecular weight chains (or equivalently the carbonyl index) reached the values for the UV irradiated PE + AD. When this happened, the biodegradation rate has the same dependence on time for both materials."

<u>3.1. Degradation of oxo- shopping bags</u>

The authors say that they tested "Several shopping bags collected from shops in Buenos Aires City labelled as "oxo-degradable".

No scientific description is given of the composition of the shopping bags. Some might have been correctly made with a suitable masterbatch and some might not.

We are not therefore surprised that the authors abandoned the tests on these bags. They said "Due to the disparity in the mechanical response of shopping bags labelled "oxo-degradable", a set of samples cut from PE and PE+AD films were used to standardize the study effects of the additive on the degradation."

In para. 1 The authors say that "there are still concerns about the potential toxicity of the additives as well as their possible negative effects on the recycling of conventional polymers."

That is why ASTM D6954 provides for ecotoxicity testing at paras. 6.9.1 to 6.9.10. We have many ecotoxicity tests according to the OECD standards showing that plastic made with d2w is not toxic.

Plastic made with d2w has also been tested for recyclability. See https://www.biodeg.org/subjects-of-interest/recycling-2/

BPA comment on:

Heimowska, A. “Environmental Degradation of Oxo-Biodegradable Polyethylene Bags”
Water (2023), 15, 4059.

https://doi.org/10.3390/w15234059

We often find that researchers do not understand that d2w biodegradable plastic is not designed to start biodegrading immediately. It has a predetermined service-life during which it can be re-used and recycled, and the author of this paper acknowledges that *“there are two stages of degradation, namely abiotic and biotic.”* If the plastic product is discarded into the environment after serving its purpose it will then oxidise on exposure to oxygen. Only after a period of oxidation, which reduces the molecular-weight, will it become accessible to microbes and start to biodegrade. As the process will be accelerated by sunlight and heat, the more sunlight and/or heat the faster the process and vice-versa. Moisture is not relevant to the abiotic stage.

This is why the author finds that *“Abiotic parameters (oxygen, temperature, solar radiation) played a more important role in the degradation process [ie the first stage] of oxo-biodegradable polyethylene, than biotic parameters (microorganisms)*” and “*These results confirm the importance of abiotic degradation for polymers with d2w additive, as was emphasized by Ojeda et al.” and “The key role that abiotic degradation plays in the biological decomposition of plastic is highlighted by experiments by Rose et al. on artificially aged samples of polyethylene with d2w additive.”* https://www.mdpi.com/1422-0067/21/4/1176

Pre-oxidation is therefore essential for oxo-biodegradable plastics, and Standard Test Methods which exclude that process are not suitable for testing this type of biodegradable plastic.

The author says that *“Oxo-biodegradable polymers do not degrade as quickly as biodegradable ones.”* If by “biodegradable ones” she means hydro-biodegradable ones this is correct, because they are intended to start to biodegrade immediately, but provided they are in a composting environment.

Here are some of the common errors we find in published papers:

(a) Failure to distinguish between oxo-biodegradable and hydro-biodegradable plastics, and between oil-based and vegetable-based plastics
(b) Failure to characterise the sample before testing.
(c) Failure to measure the molecular weight (as distinct from the physical weight).
(d) Exposing the plastic product under conditions unlikely to be experienced in the use for which it is designed.
(e) Failure to understand that, as the name implies, oxobiodegradable plastic is designed to degrade by a process of oxidation, not hydrolysis, nor (until oxidation has occurred) by enzymatic action.
(f) Failure to follow any Standard test method.
(g) Failure to compare with ordinary plastic for biodegradability and microplastics.
(h) Using a sample so heavily stabilised that it would take a very long time before the material became biodegradable.
(i) Failure to compare with bio-based plastic for biodegradability, recyclability and microplastics.
(j) Following the wrong Standard eg ASTM D6400 or EN13432 or ISO 17088.
(k) Failure to continue important parts of the test for a sufficient length of time.

This paper by Heimowska falls into errors (b) – (h)

(b) *Page 4 "Polyethylene (HDPE) bag samples containing a pro-oxidant additive (d2w—Symphony Environmental—UK), with 0,02 mm thickness, were obtained in "Castorama" market from Rumia, Poland.*

The sample was not characterised before testing, and the author could therefore have no idea whether the test sample contained a d2w masterbatch formulated for the particular application (they are not all the same) and included at the correct concentration or at all. This invalidates the entire paper, but we will comment on the remainder of the paper as a matter of courtesy.

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 manufacturer of the oxo-biodegradable masterbatch, and it is sometimes found that the manufacturer of the plastic product has applied the 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.

It is easy for trading-standards to detect this by random checks, because there are hand-held devices available to them. They can also send samples to the BPA or any other laboratory for testing, and they can ask for evidence that the factory has purchased a sufficient quantity of masterbatch for the volume of products produced, and for evidence of type-approval 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.

(c) *Failure to measure the molecular weight*. This is essential, because the purpose of oxo-biodegradable technology is to reduce the molecular weight by oxidation so that the material becomes biodegradable. There is an important distinction between a fragment of plastic (which could persist in the environment for decades) and a fragment of a low-molecular weight material which is biodegradable and not persistent. See https://www.biodeg.org/subjects-of-interest/microplastics/ The author is not correct in saying that *"decomposition of oxo-biodegradable plastics produces plastic micro particles that accumulate in the natural environment."*

(d) *Exposing the plastic product under conditions unlikely to be experienced in the use for which it is designed.* The reason why oxo-biodegradable plastic was invented is because it is not possible to collect all the plastic products after they have served their purpose, and significant amounts do get into the open environment despite the policies of most governments over the past 15 years to "reduce, re-use, and recycle."

The products concerned are mostly lightweight films and other packaging products which will usually lie on the surface of the ground, and as they have a specific gravity of less than 1, they will float on freshwater or seawater. In all these cases they will usually have abundant exposure to oxygen and sunlight, but in this experiment the sample was submerged in a pond two metres below the surface.

On page 6 the author says *"The oxygen content in air is 20.98%, but the dissolved oxygen content in natural waters is in the range of 0 to 14 mgO2/dm^3. Waters take up oxygen primarily from the atmosphere. A second source of oxygen in water is that given off by plant photosynthesis. The amount of oxygen from photosynthesis is much less than from the air."* As the process of oxidation requires access to air, it is not surprising that the author finds a slower rate of degradation when artificially submerged in a pond. A consequence of this slower rate of degradation is that biofilms have more time to form on the surface of the sample and further inhibit access to oxygen.

Also, as the rate of oxidation is accelerated by sunlight it is not surprising that submerging the sample two metres below the surface will reduce the amount of sunlight and will slow the rate of oxidation.

Similarly, in this experiment a sample was immersed in distilled water in the laboratory with no plant photosynthesis and much reduced access to oxygen and sunlight. It is again not surprising to find a slower rate of oxidation.

This is why the author finds that *"the oxo-biodegradable polyethylene samples were hardly prone to degradation in natural freshwater, but more vulnerable to environmental weathering."* And this is why experiments of this kind should be conducted according to the relevant Standard Test Methods such as ASTM D6954 – see below.

The fastest rate of oxidation in this experiment was found in the sample exposed to "natural weathering" by exposure on the surface of a garden in Poland. *"ATR-FTIR analysis and microscopic observations confirm the degradation taking place in natural environments."* where *"after 45 months, the samples were completely assimilated into the environment"* - that is to say that both the abiotic and biotic stages had been completed. This is a lot better than conventional plastic, but we would expect this process to be completed even more quickly with a sample which had been correctly made with d2w technology.

It appears from the performance of the sample that it did contain some pro-oxidant masterbatch, but it is not known whether it contained a d2w masterbatch of the right type and included at the correct percentage. Also it is not known to what extent the product, or the PE resin, had been stabilised – see below.

Further, for the latter part of the 45-month period the molecular weight of the specimen would have been reduced to the point where it was no longer a plastic, but molecular-weight was not measured in this experiment.

(e) *Failure to understand that, as the name implies, oxobiodegradable plastic is designed to degrade by a process of oxidation, not hydrolysis.* This is why on page 16 the author finds that the sample is resistant to hydrolysis.

(f) *Failure to follow any Standard test method.* ASTM D6954 was designed by scientists to simulate the conditions expected in the environment. See www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf This US Standard has been replicated in many other countries 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; Russia GOST 33747-2016 etc.

There is no *"lack of consistent evidence about the rate of abiotic and biotic decomposition"* which is well known and understood by polymer scientists after more than 40 years research. The most important piece of work was the four year "Oxomar Project," sponsored by the French Government which reported (at C5) *"We have obtained congruent results from our multidisciplinary approach that clearly shows 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."* See www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf and the published papers cited at C7.

On page 13 the author, Ms. Heimowska, mentions the possibility of cross-linking, which can inhibit the degradation process. It is for this reason that para. 4.5.1 of ASTM D6954 provides that *“Gels are cross-linked structures arising from the free radical nature of oxidative degradation. Normally, gels are not available to biodegradation.”* Para. 6.6.1 therefore provides that “the gel content generated in Tier 1 must be no higher than 10 %.”

These Standards also provide for eco-toxicity testing, to ensure that there are no toxic residues left behind – including through the accumulation of transition metals.

The author notes that *“The degradation testing of oxo-degradable plastics can be carried out through accelerated laboratory tests (UV aging tests with a UV fluorescence or xenon chamber*)” but does not mention ASTM D6954, and she is not correct in asserting that “there is no standardization of test procedure.”

The author mentions the European Union. The EU had some justification for banning “oxo-degradable” plastic, but had no justification for banning “oxo-biodegradable” plastic and did not do so. See https://www.biodeg.org/eu-news/

(g) *Failure to compare for biodegradability and microplastics with ordinary plastic*. This is important, because any policymaker evaluating oxo-biodegradable plastic needs to compare it with the available alternatives. The author makes no direct comparison but says that *“Polyethylene (PE) has the largest share of the polymer market, accounting for around a third of the polymer products produced. Globally, 22% of the annual production of plastics enters terrestrial and aquatic environments, where they can stay for decades. One strategy for reducing plastic pollution is to design materials so that they degrade more quickly in air when exposed to heat and UV light.”* The complete oxidation and biodegradation in this experiment of the d2w PE sample in 48 months is a lot better than a conventional PE alternative which creates persistent microplastics and lies or floats around for decades.

(h) Using a sample so heavily stabilised that it would take a very long time before the material became biodegradable. As the sample used for this experiment was not characterised, it is not known to what extent the manufacturer of the PE resin or the manufacturer of the plastic product, added stabilisers, or pigments which would have a stabilising effect. These would slow the rate of oxidation.

(i) *comparison of biodegradability, recyclability and microplastics with bio-based plastic.* It was not within the scope of this paper to examine bio-based plastics such as those marketed as “compostable.” These are designed to biodegrade in the special conditions found in industrial composting, so they are not relevant to the problem of plastic which escapes into the open environment. Even in compost they can create microplastics which are then spread on agricultural land. See https://www.biodeg.org/subjects-of-interest/composting/ Also, these plastics are not recyclable with ordinary plastic but oxo-biodegradable plastic products are. See https://www.biodeg.org/subjects-of-interest/recycling-2/

SYMPHONY COMMENTS ON

"Environmental degradation of plastics containing pro-oxidant additives and their toxicological impact in desert ecosystems"
Diya Alsafadi et al - Case Studies in Chemical and Environmental Engineering Volume 13, (2026) 101311

EXECUTIVE SUMMARY

This report shows the **critical importance of rigorous Quality Control (QC) in the manufacture of all plastic products—whether conventional plastics or those incorporating an oxo biodegradable (PAC) masterbatch**. This is essential to ensure that no hazardous substances are introduced.

For plastic products made with oxo biodegradable technology, QC has an additional and indispensable role:

- verifying that an **approved masterbatch** has been used. (A masterbatch is a precisely formulated combination of catalysts and stabilisers in a carefully chosen polymer matrix).
- verifying that the masterbatch has the **correct formulation for the intended use** of the plastic product.
- verifying that the masterbatch is included in the polymer at the **correct concentration and with proper dispersion**;
- confirming that in addition to the masterbatch no substances have been introduced that **would affect the abiotic or biotic phases of degradation**;

This report illustrates that if these steps have not been taken, the plastic product cannot be expected to degrade and biodegrade in the manner required for a compliant oxo biodegradable (d2w®) product.

The report also shows the critical importance of **sample-selection** and following very **strict test procedures** if studies of this kind are to have any value to industrial and commercial stakeholders and policymakers.

Limitations of the RSS paper

The biodegradation data and conclusions **cannot be relied upon** because:

- The samples were simply taken from the market, and it was not established before testing that the samples contained **the correct pro-degradant masterbatch at the correct concentration or at all,** and that they had been manufactured according to the instructions of the masterbatch supplier.
- The test did not follow ASTM **D6954 or SASO 2879**, and the **exposure period was insufficient.**
- **Sample and control weights** were not adequately measured or reported.
- The degree of **stabilisation** in the samples was not measured or reported.
- **$CaCO_3$ correction** was omitted.

- There was no positive-control **CO2 normalisation**
- The samples contained materials **capable of altering** the abiotic and/or biotic degradation profile.

We will nevertheless comment in detail on the paper for the purpose of **Quality Control**, and **guidance for future testing**.

Quotations from the paper are in italics

THE INTRODUCTION

"The unique properties of plastics, such as durability, flexibility, water resistance, light weight and affordability, make them the ideal material for a diverse range of applications in our daily lives. - Correct

The most widespread plastics material is in the form of single-use disposable items that are made from polyolefins such as polypropylene (PP) and polyethylene (PE) which represent 50 % of the approximately 350 million tonnes annual production of plastics. - Correct

However, it is now recognized that these single-use plastics represent a real challenge for environmental pollution and waste management due to their extremely poor degradation and biodegradation properties in the natural environment. - Correct

To help address the plastics pollution problem, the plastics industry has developed and produced ''oxo-biodegradable'' plastics" and "The accumulation of single-use plastic materials poses significant environmental and waste management challenges. Pro-oxidant additive-containing (PAC) plastics have been introduced in many regions to mitigate these impacts." - Correct

However, *"Concerns have been raised that the existing environmental conditions differ significantly from the optimal conditions required for initial oxidation of PAC plastics, meaning that this material may not fully degrade under realistic conditions, resulting in partial degradation and fragmentation into microplastics."*

This paper may be thought to cast doubt on the efficacy and safety of oxo-biodegradable plastic, but this is not the case.

The study shows that oxo-biodegradable plastic products are suitable for degradation and biodegradation in the hot, dry, environment of the Middle East. With regard to other environments, the process of abiotic and biotic degradation is the same in cold, wet, environments, but it would proceed more slowly under those conditions. It would nevertheless always be faster than conventional plastic under the same conditions. See www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

For oxo-biodegradable products to perform as intended under realistic conditions it is essential for them to be correctly manufactured with the appropriate type of an oxo-biodegradable masterbatch which has been 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; India 17899; Jamaica JS 355; Mexico MNX E288; Dominican Republic NORDOM 83-2:003; Russian Federation GOST 33747-2016).

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 plastics Quality Control is necessary to ensure that the product is manufactured with the correct 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.

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 oxo-biodegradable 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.

It is easy for trading-standards officers to detect this by random checks, because there are hand-held devices available to them. They can also send samples to the BPA (www.biodeg.org) or any other laboratory for testing, and they can ask for evidence that purchases of masterbatch match 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.

This study *"examined the abiotic degradation of PAC plastics under accelerated laboratory conditions and in an open-air environment with a hot, dry climate. Residual materials from abiotic degradation were then subjected to aerobic biodegradation in soil, and the final products were evaluated for plant toxicity."* Biodegradation was shown, and there was no plant toxicity.

"Fourier-transform infrared spectroscopy (FT-IR) analysis revealed the formation of acids, ketones, and aldehydes on the polymer surface due to oxidation under accelerated conditions." This is what we would expect, and shows that the technology is working.

"In open-air exposure, the reduction in weight-average molecular weight (Mw) was used to assess degradation." This is the correct test for measuring abiotic degradation.

"A rapid Mw decrease occurred within the first three months, and after fifteen months, 50 % of the samples showed low Mw (<5.0 kDa)." A material with a molecular weight of 5,000 Daltons or less no longer behaves as a plastic, and is biodegradable. The samples with slow rates of degradation and low levels of biodegradation may not include a prodegradant masterbatch at all as Mn & Co can be present as pigments, and Fe is commonly found in base polymers. This is why the study should have been carried out on samples known to have been correctly manufactured with an approved masterbatch. The metals table shows

wide variability in Mn/Co and very high Pb/Cr, consistent with uncontrolled market sourcing rather than certified formulations of known composition.

The abiotic residues were subsequently mineralized in soil, achieving 15–20 % biodegradation after 350 days. This timescale was an arbitrary choice by the authors, as EN 17033 (para, 5.2.1(a)), ASTM D6954 (para. 1.5 note), SASO 2789 (para. 5.5.1) and other relevant standards allow 730 days. Apart from this, the most likely reason why only 15-20% was achieved in some samples is that of the five samples chosen for biodegradation testing, none are shown to contain prodegradant at a sufficient level.

The presence of the other elements shown in Table 1 are also relevant. For example lead chromate (as a yellow pigment) may hinder biotic degradation and cause eco-toxicity. (Sample 23 had 839.52 ppm of lead and 137.73 ppm of chromium). This is why manufacturers need to be advised if Pb or Cr are present in test samples, so that they may remove them from the materials used for commercial production.

Also, Table S1 describes each sample, and includes colour. Most samples are stated to have a colour, such as black (Carbon black) or white (Titanium dioxide), both of which have the potential to prevent or hinder oxidation due to their interaction with UV radiation.

The study does not report stabiliser levels or masterbatch identity/loading, which are material descriptors essential for Tier 1 interpretation and replication.

Another factor is insufficient oxidation prior to biodegradation testing. ASTM D6954, requires a recorded average weight-average molecular weight of 5,000 Daltons or less, and the lower the Mw, the easier it is for micro-organisms to access and utilise the polymer. Insufficient oxidation will result in low levels of biodegradation and may be due to an incorrect concentration of prodegradant catalyst and/or excessive stabilisation in the sample, and/or an inadequate dispersion of the masterbatch within the polymer.

Another factor is that commercial products such as shopping bags often contain about 30% calcium carbonate as a mineral filler The study did not subtract the non organic fractions (such as calcium carbonate) from the sample weight. The paper states that $ThCO_2$ was based on "the carbon content for PAC plastics… measured by dry combustion using an elemental analyser." There is no report of separating inorganic carbon (TIC) from organic carbon (TOC), nor any assay or adjustment for $CaCO_3$ The companion data file lists composition attributes (thickness, and metals), but no carbonate or filler content, and no deduction of non organic fractions from the carbon basis.

Why it matters: If $CaCO_3$ is present, total carbon includes inorganic carbonate carbon; using that in $ThCO_2$ inflates the theoretical denominator and depresses the computed % biodegradation. Mass balance transparency is limited: with no per film mass, no TIC/TOC split, and no filler assay; % mineralisation values are not independently reproducible against a purely organic carbon basis.

The paper specifies a test aliquot of "200 mg" for each biodegradation jar (soil test), but it does not report the mass of all the 38 plastic films as collected/received, nor the mass of the positive controls used in each vessel beyond the same 200 mg aliquot convention

Another important factor is that the study had omitted positive-control CO_2 normalisation. *"The biodegradation percentages were calculated from the ratio between the actual net CO_2 production and the theoretical CO_2 production ($ThCO_2$). The $ThCO_2$ values were measured from the carbon content…"* The study uses ASTM D5988 and calculates % biodegradation as net CO_2 / $ThCO_2$, where $ThCO_2$ is derived from measured total carbon of each material (no normalisation to the CO_2 of a fully mineralising positive control).

Cellulose and PHBV were run as positive controls, and the paper reports that they reached ≈85% in 350 days—this demonstrates microbial activity, not a normalisation basis for test samples. There is no step in the study that scales the sample's CO_2 against the positive control's CO_2 to yield a relative %. Instead, results are expressed directly vs. $ThCO_2$.

"Samples not pre-exposed to open-air conditions showed only 5 % mineralization, confirming that prior thermal and photo-oxidation enhanced biodegradability" and "prior exposure of PAC plastics to thermal and photo-oxidation processes through natural weathering accelerates their biodegradation." That is correct. The purpose of oxo-biodegradable technology is to deal with plastic litter exposed in the open environment.

Also, *"… the conventional plastic sample without pro-oxidant additives showed the lowest mineralization level (less than 5 %) after 350 days of incubation."* This shows how important it is to include an oxo-biodegradable masterbatch.

"Eco-toxicity tests indicated that the biodegradation products did not affect the growth of the studied plant species." This is what would be expect. Symphony has extensively tested for eco-toxicity according the OECD Standards, and has tested to ensure that its d2w masterbatches are not endocrine-disrupters.

The authors state correctly that *"Many studies in the literature have investigated the degradation of PAC plastics under natural outdoor exposure. In these studies, samples degradation was typically assessed through visual inspection, mass change, scanning electron microscopy (SEM), and differential scanning calorimetry (DSC) [[33], [39]]. These methods, however, cannot precisely determine the exact level of degradation as outlined by international standards for abiotic degradation of PAC plastics (ASTM D6954-04, 2013; PAS 9017, 2020; SASO 2879, 2016) Measuring changes in molecular weight over time provides a clearer insight into the degradation processes."*

The study investigated the performance of the products in storage and found that "*the pro-oxidant additives incorporated into the PAC plastic samples were heat-sensitive and did not require light radiation to activate the degradation of the polymer at 45 °C."* This is important because it means that abiotic degradation will occur even in the absence of sunlight.

All PAC plastics films aged at 23 °C ± 2 °C and 50 % RH remained stable for twelve months, with the polymer's Mw remaining constant." If storage for longer periods and/or at higher temperatures, is desired, then additional thermal stabilisation should be added, either to the masterbatch or to the polymer product.

Other specific comments:

Comment	Section / Page	Text	Comment
	1. Introduction	"Similar legislations are being adopted later in the Kingdom of Saudi Arabia and Jordan. Given this trend, there is a pressing need to evaluate the fate of PAC plastics, particularly in the open environment of the Middle East, where research studies in these hot climatic regions remain relatively limited."	In the Middle-East governments are concerned about plastic pollution of the open environment. They realise that it is not possible to collect all the plastic after it has served its purpose and several governmets have made it mandatory to use an approved oxo-biodegradable masterbatch for a wide range of plastic products.
	2. Materials and methods, 2.1. Samples and standards reference material	"Thirty-eight PAC plastics samples with different technical applications have been provided by local suppliers in the market. A polyethylene sample free from pro-oxidant additives was also supplied as a control sample."	This study on products taken randomly from the market, shows the importance of ensuring that the manufacturer of the product has used the correct masterbatch in the correct concentration, and has not added any toxic materials, or materials which would affect the rate of degradation/biodegradation. It would have been helpful to include a positive control (i.e., an oxo-biodegradable sample confirmed to have been correctly made)
	2. Materials and methods, 2.2. Analytical methods	"The extent of polymer oxidation was monitored using Fourier-transform infrared spectroscopy (FTIR) (IR-Prestige-21, Shimadzu). The FTIR spectra were recorded in the range of 400–4000 cm^{-1}, in absorbance mode, with 40 scans at a resolution of 2 cm^{-1}."	This is similar to the method used in Symphony's laboratories, but the equipment is slightly different. For determination of polymer oxidation at Symphony, the infrared (IR) spectra are recorded by transmission, in accordance with ISO 10640 using a Thermo Scientific Nicolet iS10 Fourier transform infrared (FT-IR) Spectrometer fitted with a Smart

			OMNI-Transmission accessory. Spectra are collected across the range 400 to 4,000 cm^{-1}, ≥16 scans, with a resolution of 4 cm^{-1}. There is no reference to ISO 10640 in this paper. It is stated that they acquire their spectra "in absorbance mode", and we have assumed they use a transmission accessory. This needs to be clarified, as it affects oxidation calculations, especially as spectra are much more resolved when collected via ATR. It is desirable that ISO 10640 be followed in any future testing.
	2. Materials and methods, 2.3. Abiotic treatment of plastic samples using an accelerated weathering tester	"The abiotic treatment was conducted using an accelerated weathering tester (QUV-basic, Q-LAB, Cleveland, USA) fitted with black panels. The 38 PAC plastics samples, in addition to the control sample (without pro-oxidant additives) were prepared with dimensions of 20 cm × 20 cm and exposed to control irradiance at 0.89 W/(m2.nm) using UVA lamp 340 nm, for 48 h at 50 °C and relative humidity RH = 50 % [23]. The exposure in the accelerated weathering instrument was followed by treatment of the sample films in an aerated oven at 70 °C for 330 h"	It is difficult to see how irradiance was controlled during the experiment, and how they have obtained the stated data. More advanced accelerated weathering testers with irradiance control are used in Symphony's laboratories, and the ageing parameters are slightly different. Symphony tests in accordance with ASTM D5208 – "Standard Practice for Fluorescent Ultraviolet (UV) Exposure of Photodegradable Plastics, Cycle C—continuous UV with uninsulated black panel temperature controlled at 50 ± 3°C." This standard specifies that control irradiance must be 0.78 ± 0.02 W/(m2 · nm) at 340 nm. We do not expose samples exclusively to constant UV, but instead, combine with elevated temperatures and cease UV exposure after a pre-set time, to demonstrate continuous oxidation even in the dark. We recommend that ASTM D5208 be used in any future testing.

	2. Materials and methods, 2.4. Open environment natural ageing conditions	"Twelve PAC plastics samples (100 cm × 70 cm) were allocated in a wood frame covered by stainless-steel sheet with approximately 1.5 cm openings (Fig. S1)."	Why were 12 samples chosen out of the 38, and how were the samples selected?
	3. Results and discussion 3.1. Initial screening and abiotic degradation of plastic samples	"The metal analysis results presented in Table 1 revealed significant amounts of transition metals, including cobalt (Co), iron (Fe), manganese (Mn), and nickel (Ni), in all samples. This suggests that all the PAC plastics contained organic complexes of transition metals (organic ligand compounds and transition metal ions) acting as pro-oxidants. The most commonly used organic compounds include carboxylates, dithiocarbamates, stearates, acetylacetonates, and others [4]." "The contents of toxic heavy metals in most of the tested samples were below the maximum limit values set by national (Saudi Arabia) and international (Europe and Canada) standards, as shown in Table 1. However, heavy metals such as zinc (Zn), lead (Pb), chromium (Cr), and	Co, Fe, and Mn are the most common elements used as pro-oxidant catalysts - typically as stearates. Ni can present as residue from the catalysis of polyolefins. The problem is that manufacturers of plastic bags and other products may sometimes include other materials which may be toxic and/may affect the rate of degradation/biodegradation. This is an issue which relates to plastic products generally, whether they are oxo-biodegradable or not. Pb & Cr are toxic individually, and also when they are in the inorganic (and typically insoluble) compound form, lead(II) chromate, $PbCr_4$. Lead chromate has a "vivid" yellow colour, and can be used as a pigment in polyolefin applications.

		cobalt (Co) were detected in certain samples, including sample No. 13, No. 1, No. 12, and No. 23. The concentrations of these metals exceeded the limits specified in the standards (Table 1). It should be highlighted that the level of lead detected in sample No. 23 was 839.5 mg/kg, which is 17 times higher than the permissible limit of 50 mg/kg, as shown in Table 1. Lead is a neurotoxin, even small amounts can lead to health issues including spatial, visual, and speech difficulties, as well as anaemia, particularly in children [30]. Additionally, lead can persist in the environment and negatively affect seed germination [31]. The source of lead in plastics samples may be attributed to the use of inorganic pigments, stabilizers and slip agents in plastic industry [32]."	Approved masterbatches such as d2w do not contain any materials above prescribed levels. Strict quality controls need to be established and enforced in the manufacture of all plastic products to ensure that the manufacturer does not add materials which may be toxic and/or may affect the rate of degradation/biodegradation.
		"In previous study most of the 33 single-use plastics samples collected from local markets in Mexico city and advertised as ''oxo-biodegradable plastics'' exceed the standard international limit for Cr, Cu, Zn, Mo, and Pb with	We agree that it is essential for local authorities to test and control the metals content, not only in PAC plastics products but in all plastic products, to ensure the safety of these materials.

		the maximum concentrations of 1586 mg/kg, 1898 mg/kg, 1492 mg/kg, 95 mg/kg, and 7528 mg/kg, respectively [33]. Although a limited number of PAC plastics samples (4 out of 38) in this study were found to be contaminated with heavy metals, these metals could potentially leach into food, water resources, and soil after the plastics are disposed of in the environment. Hence,	
		"In this study, the rate of the abiotic degradation of PAC plastics samples at outdoor open environment conditions was analyzed in terms of reduction of weight average molecular weight (Mw). This key parameter specified in the standards to determine whether a PAC plastics can break down and meet the requirement for biodegradability [29,35]. The weight average molecular weights (Mw) for plastic films were measured at zero time (before incubation) and every three months. A significant decrease in the Mw was observed for PAC plastics samples aged in the four sites for the first three months (April–June).	We would expect the sample No.13, aged in Ma'an at a maximum daily temperature of 32.4 °C to show an almost immediate reduction in Mw, from 159 kDa to value down to 7.6 kDa. Also, we would expect the Mw of sample No.9 incubated in Aqaba at 36.9 °C to drop significantly from 139.6 kDa to 18.3 kDa. Although temperatures in the 30's seem quite high, they are relatively low when assessing the thermodynamics and mechanisms of oxidation. Some of the samples did not demonstrate such a large reduction in Mw. That is because they contained a very low concentration of Mn and may have contained no masterbatch at all. This is further evidence of the need for Quality Control by factories making plastic products.

		For example, the sample No.13 that aged in Ma'an at a maximum daily temperature of 32.4 °C showed an almost immediate reduction in Mw, from 159 kDa to value down to 7.6 kDa. The Mw of sample No.9 incubated in Aqaba at 36.9 °C dropped significantly from 139.6 kDa to 18.3 kDa. The reduction in the Mw was not as sharp for samples No.25 and No.21, incubated in Amman. This could be attributed to the lower oxidative stresses including, light irradiance and temperature (maximum daily temperature = 27.1 °C) during April to June at this site."	The masterbatches used in the study are not identfied, and could be from suppliers other than Symphony, which may not have been tested according to ASTM D6954 or SASO 2879. The authors are correct that "the type of pro-oxidant additive used is the primary factor influencing this outcome, with environmental conditions playing a lesser role."

CONCLUSION

For the reasons mentioned above, this study cannot be used to assess the performance of d2w® or any other properly formulated and quality-controlled system. The results reflect **the behaviour of plastics that lacked a functional pro degradant system or were manufactured with one that was incorrectly incorporated, or contained other substances that were inappropriate**.

This paper shows the **importance of Quality Control in factories producing any kind of plastic product.** In the case of oxo-biodegradable plastic products, QC must also ensure that the correct masterbatch is selected for the desired performance (eg long or short shelf-life, slow or fast degradation etc.) and that the product contains no toxic materials or materials (eg pigments) likely to affect the rate of degradation or to inhibit biodegradation.

The paper shows that reports of testing are not useful unless **all the characteristics of the sample are known** before the test begins. If samples are simply taken from the market at random they may not have been correctly made. They may not contain an approved masterbatch in the correct concentration or at all.

There are a number of research papers in the literature (some of which are cited in this paper) which doubt the efficacy of oxo-biodegradable plastics. **Here are some of the common errors we find in these published papers:**

(a) failure to characterise the sample before testing, and therefore having no idea whether the test sample contains a masterbatch formulated for the particular application and included at the correct concentration or at all.

(b) failing to follow an appropriate standard (eg ASTM D6954) or following the wrong Standard (eg ASTM D6400 or EN13432 or ISO 17088).

(c) failing to distinguish between oxo-biodegradable and hydro-biodegradable plastics, and between oil-based and vegetable-based plastics

(d) failing to measure the molecular weight (and the physical weight) of samples and Controls at key stages in the process.

(e) exposing the plastic product under conditions unlikely to occur in the use for which it is designed.

(f) using a sample so stabilised that it would take a very long time before the material became biodegradable.

(g) failing to understand that, as the name implies, oxobiodegradable plastic is designed to degrade by a process of oxidation, not hydrolysis, nor (until oxidation has occurred) by enzymatic action.

(h) failing to compare with ordinary plastic for biodegradability and microplastics.

(i) failing to compare with bio-based plastic for biodegradability, recyclability and microplastics.

(j) failing to continue important parts of the test for a sufficient length of time.

(k) failing to understand that oxo-biodegradable plastic is not intended to start to degrade immediately. It has a built-in storage and service life, during which it can be collected and then re-used and recycled.

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BPA COMMENT ON

Science Assessment of Plastic Pollution

by

Environment and Climate Change Canada/ Health Canada

October 2020

4.1.1 Biodegradable, compostable, biobased and oxo-degradable plastics

This assessment is inaccurate and out-of-date (BPA comments in italics)

Biodegradable, compostable, biobased and oxo-degradable plastics are often regarded as potential solutions to the accumulation of plastic litter and waste. Some of these terms are explicitly defined elsewhere in the context of various certifications (e.g., ASTM D6400, ASTM D6868-19, and ASTM D883-20a).

The Standard relevant to oxo-biodegradable plastics is ASTM D6954 See www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf – this Standard is not mentioned.

The following provides a brief overview of these plastics as they relate to the issue of plastic pollution……… Oxo-degradable plastics, which are sometimes referred to as oxo-biodegradable plastics, are formulated using conventional polymers with the addition of heat and UV-activated additives to accelerate their fragmentation into microplastics.

Not correct. Oxo-biodegradable plastics contain a masterbatch which comprises a carefully formulated combination of catalysts and stabilisers in a polymer matrix. Masterbatches are not a "one-size fits all" technology, and can be formulated for different applications eg for long or short storage/service-life and for slow or rapid degradation in warm or cold environments.

The masterbatch does not accelerate their fragmentation into microplastics – it accelerates the process of oxidation which changes the character of the material. Professor Ignacy Jakubowicz (one of the world's leading experts in this technology) has described the process as follows: "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." They do not therefore leave microplastics behind.
http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf

While it is expected that accelerated fragmentation would also accelerate degradation, the degree and speed of fragmentation are dependent on environmental conditions such as temperature and light intensity, which vary from day to day, and according to local conditions.

The process will proceed more quickly under warm sunny conditions than under cold dark conditions, but it will still proceed more quickly than ordinary plastic in any location. It is not necessary for an oxobiodegradable plastic to degrade and biodegrade at the same rate everywhere in the world and at all times of the year.

Therefore, there is no conclusive evidence that accelerating fragmentation will enable degradation.

This is a non-sequitur. A variable rate does not invalidate the statement by Prof. Jakubowicz above, and no reason has been advanced as to why degradation, once commenced, should stop before biodegradation is complete. A series of tests have been conducted by Intertek in 2025 which showed biodegradation of more than 90% with no significant generation of microplastics.

Given that fragmentation of oxo-degradable plastic requires oxygen and that the majority of plastics in landfills will not have direct access to oxygen, little to no biodegradation of oxo-degradable plastics is expected in deeper landfill layers.

Oxo-biodegradable technology is designed to deal with plastic which has escaped into the open environment as litter, not plastic which has been collected and sent to landfill. It has however been proved to biodegrade in landfills, which are not completely anaerobic

In addition, there is insufficient evidence to indicate that oxo-degradable plastics will biodegrade in a reasonable timeframe in the marine environment.

This is not correct. See the four-year "Oxomar" study sponsored by the French government, and the published work cited on page 17 of the Oxomar report.
www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf
The French scientists reported (at C5) that "We have obtained congruent results from our multidisciplinary approach that clearly shows 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."

Overall, there is a lack of significant evidence that biodegradable, compostable, biobased, and oxodegradable plastics will fully degrade in natural environments.

Those plastics may not fully biodegrade in natural environments, but oxo-biodegradable plastic will - as explained by Prof. Jakubowicz above.

"Oxo-degradation" is defined by CEN (the European Standards authority) in TR15351 as "degradation identified as resulting from oxidative cleavage of macromolecules." This describes ordinary plastic, (which does not contain an intentionally-added prodegradant catalyst). It will abiotically degrade by oxidation in the open environment and create microplastics, but does not become biodegradable except over a very long period of time. It is well known that fragmentation is accelerated by colorants and other additives, but they do not cause biodegradation.

By contrast, "oxo-biodegradation is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic (which does contain a prodegradant catalyst) degrades rapidly by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature.

Further studies would assist in understanding the environmental impacts of different types of biodegradable, biobased, compostable and oxo-degradable plastic, particularly in comparison to conventional, petroleum-based plastics.

These types of plastic may leave microplastics, but oxo-biodegradable plastic will not. There have now been a very large number of studies, and there is no doubt that oxo-biodegradable plastics will fully biodegrade in the open environment much more quickly than ordinary PE and PP, leaving no microplastics or toxic residues.

Biodegradable Plastics Association

Biodegradable Plastics Association
www.biodeg.org

A not-for-profit Association

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COMMENT ON

Markowicz et al "Analysis of the Possibility of Environmental Pollution by Composted Biodegradable and Oxo-Biodegradable Plastics" Geosciences Journal 27th October 2019.

This is a 20-page report which examines the performance of various types of bioplastics in the industrial composting process. It shows that even those marketed as compostable contain metals and leave microplastics. See also a study by the University of Bayreuth https://www.chemeurope.com/en/news/1176729/ which shows that "finished compost from composting plants contains a large number of biodegradable plastic particles.

They also found a quantity of metals in the compost, and they said that sources of metals such as zinc, lead, copper, and cadmium in the test materials can be additives such as dyes, fillers, antioxidants, stabilisers, or plasticisers used in the production of various types of plastics. None of these metals are used in oxo-biodegradable masterbatches. This evidence does not therefore support a ban on oxo-biodegradable plastic, but it does support a ban on putting plastic bags of any kind into a composting facility.

In fact many industrial composters are already refusing to accept plastic bags of any kind into their facility. See https://www.biodeg.org/subjects-of-interest/composting/

In Parliament on 14th November 2022 the UK Minister for the Environment confirmed that "evidence suggests these materials (ie plastic bags) are often stripped out at the start of the (composting) process and landfilled or incinerated"

It is difficult to see why Markowicz et al included oxo-biodegradable plastics in their study, as these are not marketed for composting. They are intended to deal with plastic which gets into the open environment as litter.

OBPs are a modification to and designed to replace conventional polyolefins used in packaging. The work does not assess the relative behaviour as compared to equivalent conventional products – they did not test a single ordinary product - and therefore cannot determine if the behaviour is a result of prodegradant additives or simply natural degradation of polyolefins, particularly when they introduce UV exposure – since we know that conventional polymers are susceptible to photo-oxidation as their primary mode of degradation.

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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 TiO_2 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 TiO_2-containing additives or combinations of ZnO and TiO_2. 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.

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 CO_2, 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 CO_2." 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**.

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.

February 2021

www.biodeg.org

OPA Response to

'Biodegradability of Plastics in the Open Environment'
Report by Group of Chief Scientific Advisors (GCSA) European Commission, Directorate-General for Research and Innovation, dated 14th December 2020

and

'Biodegradability of Plastics in the Open Environment'
Report by Science Advice for Policy by European Academies (SAPEA). dated 14th December 2020

The Oxo-biodegradable Plastics Association

A not-for-profit Association limited by Guarantee

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EXECUTIVE SUMMARY

- The GCSA Report notes that *"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."* It is therefore no **longer acceptable to continue using ordinary plastic**, which fragments into microplastics and can lie or float around in the environment for decades.

- The report continues: *"Some plastic products, 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."***

- Fortunately the scientists who developed plastics had the foresight to identify the problem and provide us with a solution. They called it oxo-biodegradation, because they put a catalyst into ordinary plastic which accelerates oxidation so as to reduce the molecular weight to the point where it can be bioassimilated. This is not the same as oxo-degradable plastic.

- Oxo-biodegradable plastic is not designed to circumvent or replace current waste disposal practices, nor to prevent movement toward a circular economy. **It is not put forward as "a solution to littering."**

- Oxo-biodegradable plastic exists to deal with the *failure* of waste-management, by ensuring that plastic which has escaped into the open environment will biodegrade much more quickly and be **removed from the eco-system by naturally-occurring bacteria.**

- It is designed so that during its useful life it can be used, re-used, and recycled in the same way as ordinary plastic, and can itself be made from recyclate. It does not rule out more circular and useful end-of-life options if it does not escape into the open environment.

- The authors of the GCSA Report seem to be **searching for the holy grail, but they will never find it.** They are looking for a type of plastic whose timescale to complete biodegradation under any conditions in the open environment is very short and can be accurately predicted.

- When a plastic product is made, it is not known what the conditions will be at the time and in the place where it is discarded, nor will it be known into which category of open environment eg land or sea, temperate or tropical, it will be discarded. Therefore it is **impossible for the speed of degradation and biodegradation to be ascertained in advance**.

- *"Even when certified to biodegrade in a particular environment, seasonal and microbiological variations in nature mean that* ***we need to accept uncertainties around actual biodegradation rates."***

- The Report says that *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."* **This is the timescale for which oxo-biodegradable plastic is designed.**

- The Report accepts that *"In the open environment the CO_2 release [which is the indicator of biodegradation] cannot be captured and measured."* For that reason controlled laboratory mineralization experiments such as ASTM D6954 have been devised by polymer scientists. Recommendation 2.2.2 in the Report is to require testing under laboratory and ***simulated* environmental conditions**.

- **Oxo-biodegradable mulch films** can be programmed at manufacture to degrade soon after the harvest. The degraded material can then be ploughed into the soil where it completes the bio-degradation process and becomes a source of carbon for next year's plants.

- Oxo-biodegradable plastics should not be confused with other technologies which claim biodegradability, including those which are mixed with starch so that the starch biodegrades, leaving the polyethylene or polypropylene behind. Nor should oxo-biodegradable plastics be confused with enzymatic plastics.

- There is nothing wrong with composting garden and kitchen waste, but no plastics of any kind should be introduced into the process. There are at least **21 reasons why plastic marketed as "compostable" is not useful**·

- **Plastics marketed as compostable are an irrelevance**, because the main problem facing governments today is plastic waste which has escaped into the open environment, from which it cannot realistically be collected and taken to a composting facility.

- Most consumers don't realise that "compostable" plastic **does not convert into compost,** and it is therefore **deceptive to market it as compostable**. It is required by EN13432 to convert rapidly into CO_2 gas. If you can collect a plastic product there are better things to do with it than turn it into CO_2. This is not consistent with a circular economy.

- The SAPEA report notes at 5.4.2 that *"If compostable plastics are introduced into the open environment, their certifications no longer apply."* **It is deceptive to market plastics designed to biodegrade in a composting facility as "biodegradable**."

- The EU has a well-established procedure, set out in the REACH Regulation 2006/1907, for determining whether substances should be banned. This procedure has not been complied with. The European Chemicals Agency is **not convinced that oxo-biodegradable plastic creates microplastics,** and the purported ban of oxo-degradable plastic is under **legal challenge in the courts of the EU.**

- **Oxo-biodegradable plastic has been well described by Intertek** (one of the world's largest inspection and certification companies) in their evidence to ECHA of 24th May 2018. They made the following points:

  - The material used for making plastics is an inevitable by-product of the process of making fuels, and the **same amount of oil would be extracted** from the ground if plastics did not exist.
  - Almost all the micro-plastics found in the oceans have **come from the fragmentation of conventional plastics**. The fragments remain for years at a molecular mass which is too high for biodegradation.

- The oceanic micro-plastic problem has arisen because the **dwell-time of conventional plastics is too long** compared to the rate of arrival of more plastics. Any shortening of the dwell-time must be useful.
- Whatever the speed of degradation of oxo-biodegradable plastic, it **is faster than that of conventional plastics.**
- Oxo-biodegradable plastics **do not encourage a throw-away society**.
- Oxo-biodegradable plastics are **not antagonistic to re-use and recycling**.
- **A ban does not seem to be logical or justified**.

"It is important to ensure that consumers are provided with clear and correct information." The OPA and its members agree with that, and are willing to work with governments to agree definitions and to devise advertising and labelling criteria.

1.0 INTRODUCTION

1.1 The GCSA report is entitled *Biodegradability of Plastics in the Open Environment*, but is mainly concerned with the few applications where biodegradability in the open environment is the intended disposal route. *"Plastics intended for composting under controlled conditions are … outside its scope."* The authors of the report do a disservice by focusing on plastics which are designed to biodegrade in a time frame of days or weeks. They are non-circular, they are designed for single-use, and cannot be recycled. They are designed to biodegrade in very specific environments and to convert into CO_2 in a few weeks.

1.2 The report notes[1] that *"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. 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."* It is therefore no longer acceptable to continue using ordinary plastic, which fragments into microplastics and can lie or float around in the environment for many decades.

1.3 The Report also notes that *"Some plastic products, 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."*

1.4 That is the reason why oxo-biodegradable plastic was invented.

2.0. OXO-BIODEGRADABLE PLASTIC

2.1 The problem of plastics in the environment is well known, but what is the solution? One solution is to reduce the use of plastics, and this is being done, but plastic is one of the best materials for protecting food and other products from damage and contamination. It can be made anti-microbial[2], and has a better LCA than the alternative materials.[3] However, even if the use of plastic is reduced, and even if waste-management systems are improved, it will not be possible for many years, if ever, to prevent the discharge of waste plastic into the open environment, including the oceans.

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[1] 1.2
[2] www.d2p.net
[3] https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/

2.2 It is important to be aware that oxo-biodegradable plastic is not a waste-management option. It is not designed to circumvent or replace current waste disposal practices, nor to prevent movement toward a circular economy, and it is not put forward as "a solution to littering." It exists to deal with the *failure* of waste-management, by ensuring that plastic which has escaped into the open environment will biodegrade much more quickly and be removed from the eco-system by naturally-occurring bacteria.

2.3 If there were no failure of waste management there would be no plastic litter, and oxo-biodegradable plastic would not be needed, but even in the developed world it will be many years, if ever, before this has been achieved – not least because much of it is accidentally discharged. The situation in the less-developed world is much worse. In the meantime while governments debate the matter time and time again, many thousands more tons of plastic are entering the environment every week, where it will lie or float around for decades, but if oxo-biodegradable technology were more widely employed it would be possible to shift the balance so that the rate of accumulation can be slowed and then reversed.

2.4 Fortunately the scientists who were developing plastics in the early days had the foresight to identify the problem more than 50 years ago and provide us with a solution. One of those scientists was Professor Gerald Scott, who was scientific adviser to the OPA until he died in 2013. We have been working with his technology for 20 years now, and one member company alone (Symphony Environmental) has sold enough masterbatch to make 1,747,900 tonnes of oxo-biodegradable plastic products worldwide.

2.5 The scientists called the process "oxo-biodegradation," because they included a catalyst in ordinary plastic which accelerates oxidation after the useful life of the product, so as to reduce the molecular weight to the point where it can be bioassimilated. The catalyst is introduced into the plastic as part of a masterbatch, which also includes stabilisers to give the product a useful service-life before it degrades.

2.6 Oxo-biodegradable plastic is designed so that during its useful life it can be used, re-used, and recycled in the same way as ordinary plastic, and can itself be made from recyclate. It therefore offers the benefits of biodegradability in a much shorter time frame but does not rule out more circular and useful end-of-life options if it does not escape into the open environment.

2.7 Oxo-biodegradable plastics are tested according to American (ASTM D6954); British (BS 8472) and other national standards to prove degradability, biodegradability, and non-toxicity. ASTM D6954 has been in use for nearly 20 years, and was revalidated in 2018, but it is dismissed in the SAPEA report in one paragraph.[4] As to this, see the evidence to the UK Government of Dr. Graham Swift,[5] one of the authors of D6954 and Vice-chairman of the relevant committee of ASTM.

2.8 The SAPEA report says[6] *"evidence in support of Step 1 for oxo-additive-containing-polymers often stems from experiments in which the activation of the additive is conducted at temperatures and light intensities that are higher than those found in the open environment. The accelerated weathering conditions during the tests are deliberately chosen to facilitate the additive-induced breakdown process and were justified by arguing that higher rates under accelerated weathering conditions can be used to extrapolate lower rates of the same process under open environment conditions at lower temperatures or light intensities."*

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[4] 4.4.9

[5] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf

[6] 2.6.1

2.9 As to this, see the evidence of Dr. Swift,[7] that *"Artificial ageing is 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 have been permitted by ASTM."*

2.10 The SAPEA Report says[8] "*In the scientific literature on degradable or environmentally degradable plastics, many claims of degradability have been made. However, merely reporting weight loss is not a proof of degradation."* It seems that the authors are confusing weight-loss with molecular-weight loss. Simple weight loss will show degradation, but the molecular weight may still be too high for biodegradation to occur. By contrast, molecular-weight loss (which is measured in Daltons and is required by ASTM D6954 to be reported) shows that the molecular structure is being dismantled, so that the material will be no longer a plastic and will be biodegradable.

2.11 It is easy to show by simple observation whether a piece of plastic has disintegrated, but this does not show that it has biodegraded. The GSCA Report accepts[9] that *"In the open environment the CO_2 release [which is the indicator of biodegradation] 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."*

2.12 Controlled laboratory mineralization experiments such as ASTM D6954 have therefore been devised by polymer scientists. When used in combination with real-time natural oxidation experiments, laboratory experiments can confirm biodegradability with a high degree of confidence. Indeed Recommendation 2.2.2 in the GCSA Report is to require testing under *laboratory and simulated environmental conditions*.

2.13 The authors advance no reasons why, once commenced, biodegradation will not continue until it is complete. The evidence of Dr. Swift[10] is that *"Once abiotic degradation has commenced, there is no reason for it to stop save in the unlikely event that it is deprived of oxygen."* Similarly *"Once the material has become biodegradable, it can be expected to fully biodegrade, save in the unlikely event that it is deprived of bacteria."*

2.14 Unfortunately, the report simply dismisses oxo-*biodegradable* technology in one paragraph[11] on the ground that oxo-*degradable* plastic has been banned by EU Directive 2019/904 as from July 2021. As to this, see below. The dismissal is also based on some points raised in the SAPEA report, which are considered in this response.

2.15 The Rt. Hon. Theresa Villiers MP, former Secretary of State for the Environment of the United Kingdom said in a letter to Symphony Environmental Technologies Plc dated 29th October 2020:

"We are all aware that plastic which has escaped into the open environment as litter is causing a serious problem, and that governments are taking measures to reduce the amount. Nevertheless it is realistic to expect that despite those measures a significant amount of plastic will continue to get into the open environment from which it cannot easily be collected for recycling or anything else.

I gather that your company has sought to address this problem by developing a type of plastic known as "oxo-biodegradable," which converts into non-toxic biodegradable materials

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[7] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf
[8] 1.3
[9] 2.2.3
[10] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf
[11] 1.3.5

if it gets into the open environment, without any need to collect it and take it to a composting facility.

I am also aware that by Directive 2019/904 the EU has banned "oxo-degradable" plastic as from July 2021 because they think it creates microplastics, but they have not distinguished oxo-degradable from oxo-BIOdegradable plastic. I am concerned that having commenced the process required by REACH before any substance can be banned, the EU did not complete the process and imposed the ban notwithstanding that their own scientific experts (ECHA) advised that they are not convinced that microplastics are formed.

I am therefore writing to say that as a former UK Secretary of State for the Environment I see no justification for banning oxo-BIOdegradable plastic. In fact I consider this technology can play a positive role in tackling plastic pollution because it enables everyday plastics to biodegrade safely and quickly if they get into the open environment."

2.16 Dr. Matthew Offord MP said[12] *"As a longstanding member of the Environmental Audit Committee and committed environmentalist, I certainly see no justification in the UK, now an independent nation, following Article 5 of the EU's Directive and banning oxo-biodegradable plastic. As my colleague and former Environment Secretary Theresa Villiers notes, this technology can play a positive role in tackling the scourge of plastic pollutants."*

2.17 Indeed, there are countries in the Middle East[13] who have carried out their own due-diligence, and have made it mandatory to use oxo-biodegradable technology for a wide range of everyday plastic products made in or imported into their territory.

2.18 The authors of the GCSA Report seem to be searching for the holy grail, but they will never find it. They are looking for a type of plastic whose timescale to complete biodegradation under any conditions in the open environment is very short and can be accurately predicted, but a plastic product has to be fit for purpose for a reasonable time, and the report itself makes the obvious point that conditions in the open environment are variable. It says[14] *"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."*

2.19 When a plastic product is made, it is not known what the conditions will be at the time and in the place where it is discarded, nor will it be known into which category of open environment eg land or sea, temperate or tropical, it will be discarded. Therefore it is impossible for the speed of degradation and biodegradation to be ascertained in advance. The report says [15] that *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."* This is the timescale for which oxo-biodegradable plastic is designed.

2.20 The SAPEA report at 5.6.2 says *"Even when certified to biodegrade in a particular environment, seasonal and microbiological variations in nature mean that* ***we need to accept uncertainties around actual biodegradation rates,*** *even if the receiving environment matches the certification."* The OPA agrees with this.

[12] Letter to Symphony Environmental 8th February 2021
[13] Saudi Arabia, the UAE, Bahrain and Jordan
[14] 1.4.5
[15] 1.4.3

2.21 As the report is about the biodegradability of plastics, it is important to note that none of the members of the Group of Scientific Advisers are polymer scientists. They include a political scientist, a sociologist, a nuclear physicist, an economist, an expert in electronics, and a professor of divinity.

2.22 It is perhaps understandable that the Group has failed to grasp some of the fundamental features of polymer degradation. For example, they fail to acknowledge the critical importance of abiotic degradation processes as a precursor to the ultimate biodegradation of polymers, and their proposed definitions at 1.4.3 of the GCSA Report are therefore too narrow. The authors are focused on plastics which can suffer direct microbial or enzymatic attack (such as bioplastics intended for composting – even though they are expressly excluded from the scope of the report).

2.23 Although the GCSA Report says that *"Plastics intended for composting under controlled conditions are … outside its scope"* we find in the list of "experts and stakeholder representatives consulted" in Annex 3, representatives of European Bioplastics, the BBIA, ASOBIOCOM, Assobioplastiche, PHA Platform, and OWS. These are all experts in plastics intended for composting under controlled conditions, and include well-known lobbyists against oxo-biodegradable plastic, which they see as a competitor.

2.24 The Oxo-biodegradable Plastics Association and its member companies and their scientists were not consulted, nor were they invited to the SAPEA Expert workshop; the Sounding Board Meeting; or the Stakeholders Meeting. We find this conduct unacceptable for a publicly-funded body.

2.25 The authors have not done any experimental work cited in the Reports, so the reports are no more than literature-reviews, and the list of references does not include any of the very many scientific studies on oxo-biodegradable plastic.[16] There are however several references to the Plymouth University report by Napper and Thompson, upon which the OPA has commented. [17]

2.26 The GCSA report notes that *"It is important to ensure that consumers are provided with clear and correct information."* The OPA and its members agree with that, and are willing to work with governments to agree definitions and to devise advertising and labelling criteria, but we have yet to receive an invitation.

3.0 EUROPEAN UNION

3.1 Directive 2019/904 purports to ban "oxo-degradable" plastic, but the Directive fails to make a clear distinction between oxo-*degradable* and oxo-*biodegradable* plastic[18], and it is under legal challenge in the EU courts.

3.2 The EU has a well-established procedure, set out in the REACH Regulation 2006/1907, for determining whether substances should be banned. In December 2017, in compliance with the procedure, the EU Commission requested the European Chemicals Agency ("ECHA") under Article 69 of REACH to investigate its concerns regarding microplastics. The

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[16] See eg the references cited by Peter Susman QC in Annexe 1 at https://www.biodeg.org/wp-content/uploads/2020/05/qc-opinion.pdf See also https://www.biodeg.org/very-important-study-on-biodegradable-plastic/ and https://www.biodeg.org/all-news/new-french-study-confirms-d2w-oxo-biodegradable-plastic-will-biodegrade-in-seawater/

[17] https://www.biodeg.org/wp-content/uploads/2020/05/opa-comments-on-plymouth-10.pdf

[18] Defined in CEN TR15351

OPA submitted scientific evidence to ECHA on oxo-BIOdegradable plastic, and ECHA advised the OPA[19] that they were not convinced that it created microplastics.

3.3 The Commission then made the extraordinary decision to terminate ECHA's investigation, and the EU proceeded to impose a ban effective from 3 July 2021, citing microplastics as a principal reason.

3.4 Only if ECHA had recommended a restriction, supported by the detailed dossier prescribed by Annex XV of REACH, the recommendation would have had to be considered by two committees under Articles 70 and 71 of REACH, and also by a stakeholder consultation under Article 71(1), before any restriction could be imposed. None of these procedures prescribed by EU law have been complied with.

3.5 Accordingly, OPA member, Symphony Environmental (www.d2w.net) has commenced a legal action against the Commission, the Parliament, and the Council of the European Union, claiming damages which could amount to tens of millions of Euros.

4.0 PLASTICS IN THE ENVIRONMENT

4.1 The GCSA report says at 1.4.4.1 *"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 extremely slowly in the open environment, thus hindering the conversion to CO2, CH4 and new microbial biomass."* The SAPEA report says[20] "*polyolefins consist of a carbon chain with covalent carbon-carbon bonds, which no natural enzyme can cut directly."*

4.2 This is why plastic litter has such longevity in the open environment. This is in turn why there is so much public opposition to plastic, and its longevity is what oxo-biodegradable technology is designed to overcome.

4.3 Oxo-biodegradable masterbatches remove the dependence on sunlight, so that degradation will continue if the plastic becomes occluded from light. Whilst sunlight and heat will accelerate the process, they are not essential. The same stabilizers used in conventional plastic will protect oxo biodegradable plastic from premature degradation for as long as they are in storage, use and reuse.

4.4 There is a lot of evidence cited in the report of the creation of microplastics by the fragmentation of conventional plastics, and their harmful effects on human health and the environment. The overwhelming majority of microplastics come from ordinary plastics. It is for this reason that oxo-biodegradable plastics are needed, for the longer plastics and their fragments remain in the environment the greater the harm. Oxo-biodegradability provides a mechanism for cleaning them out of the eco-system by a natural process of bioassimilation by micro-organisms commonly found on land and sea.

4.5 Professor Ignacy Jakubowicz of Sweden, one of the world's leading polymer scientists, explained the process as follows[21] *"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*

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[19] Email 30th October 2018

[20] 1.3

[21] Letter to Ellen MacArthur Foundation https://www.biodeg.org/wp-content/uploads/2020/05/Reply-to-Ellen-MacArthur-Foundation-from-Prof-Ignacy-Jakubowicz-21-8-17.pdf

oligomeric fragments, and from hydrocarbon molecules to oxygen-containing molecules which can be bioassimilated."

4.6 The SAPEA report[22] cites the 2017 report of the Ellen Macarthur Foundation in support of the proposition that oxo-additives do not render polymers biodegradable, but there is no mention of the 2019 report. In the 2017 report they said that oxo-bio plastic simply fragmented, but having met with an OPA scientist they no longer say that. They admit in their 2019 report that "oxo-degradable" plastics (they mean oxo-biodegradable plastics) are manufactured so that they can degrade faster than conventional plastics and that they do become biodegradable.[23]

4.7 As mentioned above, when the European Chemicals Agency were asked to consider the matter, they were not convinced that microplastics were formed by oxo-biodegradable plastics.

4.8 There is also a problem caused by large pieces of plastic (macro-plastics), which oxo-biodegradable technology is also designed to address. The SAPEA report says (5.5.4) *"while persisting in the environment, large items of biodegradable plastics pose a risk of entanglement and ingestion by terrestrial and aquatic wildlife and smothering of habitats by acting as physical barriers, in the same manner as conventional plastics."* Oxo-biodegradable technology will significantly reduce this problem.

5.0 INTERTEK REPORT

5.1 Oxo-biodegradable plastic has been well described by Intertek (one of the world's largest inspection and certification companies) in their evidence to ECHA dated 24th May 2018[24] as follows:

1. Intertek has carried out a wide range of work on polymers, including various life Cycle Assessments (LCAs) and other environmental studies. Intertek produced two LCAs on plastic bags and oxobiodegradable plastics.[25] The second one, carried out in 2012, included an assessment of oxobiodegradable plastics and included the litter metric.

2. Oxo-degradable plastics are conventional plastics which degrade by oxidation but do not become biodegradable for a long period of time. By contrast, oxo-biodegradable plastics are plastics which are designed to become biodegradable in a shorter time. Oxo-biodegradation is defined in CEN/TR 15351 as "degradation identified as resulting from oxidative and cell-mediated phenomena, either simultaneously or successively." It is not clear whether the reference to ECHA includes oxobiodegradable plastics, but this document is concerned with oxo-biodegradable plastics.

3. Oxo-biodegradable plastics are conventional plastics that contain a metal-based catalyst or catalysts that are designed to speed up the breakdown of polymer molecules until they are reduced to a size that is able to be biodegraded. Polymers

[22] 2.6.1

[23] For OPA comment on this report, see https://www.biodeg.org/wp-content/uploads/2020/05/emf-report-3.pdf See also OPA comment on the Selke report also cited by SAPEA https://www.biodeg.org/wp-content/uploads/2020/05/response-to-msu.pdf

[24] https://www.biodeg.org/wp-content/uploads/2021/01/Intertek-Report-to-ECHA-24.5.18.pdf

[25] https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/

comprise long molecular chains in the region of 250,000 Daltons in mass (one Dalton is the mass of one hydrogen atom). Polymers need to be broken down into the region of 5,000 Daltons before organisms can feed on them and achieve biodegradation. Conventional plastics eventually break down to this size, but oxo-biodegradable plastics are designed to achieve it much faster.

Conventional plastics and oxo-biodegradable plastics are the same (apart from the addition of a small amount of catalyst in the case of oxo-biodegradable plastics), and the mechanisms of biodegradation are the same; oxo-biodegradable plastics are simply designed to achieve biodegradability sooner. Conventional plastics may take up to a century to be reduced in size to 5,000 Daltons (the rate is highly variable depending on environmental conditions and other factors), whereas oxo-biodegradable plastics are likely to reach 5,000 Daltons significantly sooner (again, the rate is variable, but is designed to be faster than conventional plastics).

4. Oxo-biodegradable plastics are made with a plastic masterbatch containing a catalyst that promotes degradation by oxidation in the presence of oxygen, and which reduces molecular weight to the point where biodegradation can occur. The masterbatch typically makes up 1% of the plastic it is used in. The masterbatch is itself mostly polymer, with the catalyst (or catalysts) making up only a small portion of the 1%. Therefore, the amount of catalyst in the plastic product is low -typically lower than other additives in conventional plastic such as colourants, UV inhibitors, stabilisers,-extenders and so on.

5. The catalysts used in oxo-biodegradable plastics are metallic catalysts, often based on manganese, iron or cobalt, that are considered safe. **They are not on any known toxic lists**; for example, they are not among the hazardous substances listed in Art 11 of the Packaging Waste Directive 94/62/EC. Also, oxo-biodegradable plastics are tested according to the same eco-toxicity tests prescribed by EN13432 Annex E for plastics intended for composting (even though oxo-biodegradable plastics are not intended for composting). They are shown to be non-toxic by OECD standard testing. Plastics (whether oxo-biodegradable or not) may contain other less desirable substances- for which there may be evidence of harm, such as Bisphenol A - and authorities are taking appropriate steps to restrict the use of these substances.

6. Various stakeholders offer differing opinions about how much faster degradation of oxo-biodegradable plastics occurs compared to conventional plastics. The somewhat limited research that has been carried out to date shows that the speed range of degradation may be from marginally faster than normal plastics, to very significantly faster, depending on such factors as the formulation of the masterbatch and the extent to which the plastic is exposed to UV light and heat.

   "Polyethylenes containing pro-oxidant substances degrade by exposure to the environment, resulting in decreased molar mass and incorporated oxygen in the chain in the form of carboxylic groups. This exposure to natural weathering for a period of 3-4 months decreased the mechanical properties of polyethylene (containing about 80 mg kg-1 of cobalt), causing disintegration of the material. Saturated humidity increased abiotic oxidative degradation and biodegradation, as compared to natural humidity. The polyethylene bags mineralized about 12% of the original carbon in compost at 58 degrees C for three months after being exposed for one year to natural weathering. Exposure periods longer than three months and environmental moisture exert little influence on the degradability of cobalt-activated PE. There was low biodegradation of conventional PE films exposed to natural weathering for one month or longer, and fungi belonging to the genera Aspergillus

and Penicillium grew on oxo-biodegradable PE films in environments with saturated humidity." [26]

"........Oxo-biodegradable plastics are conventional plastics, such as High Density Polyethylene (HDPE), commonly used in carrier bags, which also include additives which are designed to promote the oxidation of the material to the point where it embrittles and fragments. This may then be followed by biodegradation by bacteria and fungi at varying rates depending upon the environment." [27]

"Extrapolations from a laboratory study on a particular LDPE film engineered with a short service life suggest that almost complete degradation in soil can be achieved within two years." [28]

"The debate around the biodegradability of PAC plastic is not finalised, but should move forward from the assertion that PAC plastics merely fragment, towards confirming whether the timeframes observed for total biodegradation are acceptable from an environmental point of view and whether this is likely to take place in natural environments." [29]

"From the information studied, the authors of this Report can believe that it is possible for an OBP plastic to fully mineralise in an open environment, with the prodegradant additives encouraging this action, and thus the polymers and entrained substances can be assimilated into the natural environment." [30]

7. In ideal conditions for degradation, such as where the plastic has been exposed to UV light, heat, humidity, and mechanical stress, there is no doubt that the rate of degradation is significantly faster than that of conventional plastics. *"While all biomaterials, including plastics, will invariably biodegrade in the marine environment, the rate of this process, even in the benthic sediment, is several orders of magnitude slower compared to light-induced oxidative degradation of plastics."* [31]

8. In non-ideal conditions, the degradation rate may be only marginally faster than that of normal plastics. (Oxo-biodegradable plastics are designed this way, so that they do not degrade in storage or use, - only after use.) This is why the research shows a wide range of degradation rates. The key point is that the rate is faster. How much faster, and under what scenarios, is a matter of debate.

9. Oceans have high humidity and high UV levels in the surface layers where oxo-biodegradable plastics are likely to be found if they are in the ocean (since they tend to float). This would suggest that the speed of conversion to biodegradable materials may be in the upper part of the speed range. There has not been extensive research on this aspect, and as other reports have pointed out, further research needs to be undertaken. However, the research that does exist appears to show significant degradation for oxo-biodegradab1e plastics. The crucial timescale is the time it takes for the molecular weight of the polymer to reduce from circa 250,000 Daltons to 5,000

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[26] Ojeda "Abiotic & biotic degradation of oxo-biodegradable Polyethylenes" – 2009 Polymer Degradation & Stability 965-970.

[27] Eunomia, "The impact on the use of "oxo-degradable" plastic on the environment," Report on project conducted for the European Commission DG Environment, 2016

[28] ibid

[29] ibid

[30] ibid

[31] A. L. Andrady, "Wavelength sensitivity of enhanced photodegradable polyethylenes, eco and LDPE/MX," Camile Dreyfus Laboratory, 2011.

Daltons or less. After the material has reduced to 5,000 Daltons or less, it is available for biodegradation, and biodegrades in much the same timescale as other biodegradable material, having regard to environmental conditions. The effectiveness of oxo-biodegradable plastics in oceans has been studied at Bandol in France [32] where oxo-biodegradable plastic was aged in seawater, where it successfully degraded to circa 5,000 Daltons in mass.

"The weathering test on sea water surface, performed to point out the behaviour of samples containing pro-degradant d2w additive in wet environments (films and bags accidentally released in oceans or lakes), points out very promising behaviours. Assuming that there is correlation between oxidation rate and elongation at break, film FA6224 A would present a 50% loss of mechanical properties in three weeks, and a total loss in three months, when exposed in summer period in Mediterranean climate." [33]

To demonstrate that this material was biodegradable, the residues were exposed at Queen Mary University London to A. borkumensis (a bacterium commonly found in oceans) and were seen to be consumed by the bacteria as a food source, indicating biodegradability. *"Our results show that oxo-biodegradable plastic is biodegradable by bacteria commonly found in the open environment both on land and in the oceans, after the molecular weight of the plastic has been reduced by oxidation promoted by the pro-degradant additive."* [34]

10. **Perhaps the most important point is this: whatever the speed of degradation, it is faster than that of conventional plastics**. The different opinions of various stakeholders concerning the speed of degradation, and the different findings of the limited research that has been carried out to date, are simply a matter of degree.

11. The faster degradation and subsequent biodegradation of oxo-biodegradable plastics means that they enter the eco-system as waste plastic in the same way as conventional plastic, but they degrade, and then ultimately biodegrade to natural materials and are recycled back into nature, in less time than conventional plastics. This means that oxo-biodegradable plastics have a shorter dwell-time in the ecosystem. In the case of micro-plastics in oceans,[35] a shorter dwell time means a net reduction in the overall amount of micro-plastics in the oceans. **The oceanic micro-plastic problem has arisen because the dwell-time of conventional plastics is too long compared to the rate of arrival of more plastics.** If the dwell-time were shorter (i.e. conventional plastics degraded faster) and/or the incoming flow was less, the ocean would be able to handle a certain amount of plastics. The plastic contamination would disappear from the system (through biodegradation) faster than it would arise in the system (through waste plastic reaching the ocean) and there would be no build up. It is simple, undeniable physics, little different from the physics of flow of liquids through pipes. Oxo-biodegradable plastics, through biodegrading faster, and thus having

[32] M. Beraud, "Outdoor and accelerated ageing tests on polymers and other materials," Station d'Essais de Vieillissement Naturel de Bandol, 2015.

[33] ibid

[34] K. Richardson, "An investigation into the biodegradation of plastics by alcanivorax borkumensis and phodococcus rhodochorous," Queen Mary University London, School of Biological and Chemical Sciences, 2017.

35 J. Verschoor, "Towards a definition of microplastics: considerations for the specification of physic o- chemical properties," Netherlands Institute for Public Health & the Environment, p. 116, 2015.

a shorter dwell-time in the system, have the potential to aid the problem rather than worsen it.

12. Research could be carried out to demonstrate this, but none has been carried out to date, as far as is known. Ideally, research would be designed to arrive at an approximate value for what dwell-time or biodegradation rate would result in micro-plastics declining rather than building up in oceans. There would be many challenges to determining such a rate. For example, the rate of arrival of plastics into the oceans appears to be continuing to rise in some parts of the world. This is largely a result of rising consumption and continuing inappropriate waste management in growing economies. Therefore, any figure would have to take account of future trends of inputs of plastics into the marine environment, and such forecasting is bound to have errors.

What can be said now, even ahead of such research, *is that* ***any shortening of the dwell-time must be useful.*** *Any improvement in the speed of degradation must be useful*. Considering very approximate order of magnitude figures, if conventional plastics were considered to take say 20 to 200 years to biodegrade in the oceans, and oxo-biodegradable plastics take say 1 to 10 years to biodegrade, already the oxo-biodegradable plastics are showing potential to make a positive, rather than negative, contribution to the issue.

13. Some commentators have suggested that an acceptable biodegradation rate should be faster than this - such as 60 days. Certainly, such fast biodegradation would be ideal once the micro-plastics were in the oceans. However, slower rates would still be fast enough to reduce the micro-plastics population in the oceans (subject to research). The issue with very fast biodegradation rates is that these rates risk compromising the purpose of the plastics. A plastic product that fails in use is a waste of resources. **Plastics need to fulfil their function before biodegrading.** Therefore a 60-day rate, while perhaps theoretically commendable, is unlikely to ever be viable or even desirable for the majority of plastics.

14. The amount of oxo-biodegradable plastics in the ocean is currently tiny compared to all plastics. **Almost all the micro-plastics found in the oceans have come from the fragmentation of conventional plastics**. Although conventional plastics can fragment quite quickly on exposure to sunlight and mechanical stress, **the fragments remain for years at a molecular mass which is too high for biodegradation.** This means that conventional plastics can persist in the ocean for decades before they become biodegradable. This is why the micro-plastics tonnage in the oceans has built up: the inflow and dwell-time exceeds the outflow (outflow being disappearance due to biodegradation). If the dwell-time were shorter, and/or the inflow lower, build up would not occur and the micro-plastics problem would not exist.

15. Various stakeholders have offered various opinions on oxo-biodegradable plastics, including raising doubts about their efficacy and even doubting the point of them. Oxo-biodegradable plastics have been criticised for:

(a) **Increasing the amount of plastics - which is obviously illogical.** The presence or not of an oxo-biodegradable additive in a plastic does not change the amount of plastic.

(b) **Encouraging a throw-away society, which of course they do not**. The littering and inappropriate waste management that leads to the oceanic micro-plastic problem occurs irrespective of any additives in the

plastics. Much of the littering is accidental, and the kind of people who deliberately throw litter do not care whether the plastic may be a type of biodegradable plastic.[36]
(c) Being less desirable for re-use and recycling. **Oxo-biodegradable plastics are not antagonistic to re-use and recycling.** As has been demonstrated by the technical reports, and in practice over years of recycling, the tiny amounts of oxo-biodegradable additive in the system make no difference to recycling or re-use.
(d) Not being supportive of the circular economy. There is a clear theoretical benefit to a circular economy. However, that is a different issue from the current harsh reality of micro-plastic pollution. If society wished to eliminate anything that is not supportive of the circular economy, it should first stop burning oil, which is a non-circular threat to sustainability that is orders of magnitude greater than the amount of oil going into making useful products such as plastics. **The material used to make plastics is in any event an inevitable by-product of the process of making fuels, and the same amount of oil would be extracted from the ground if plastics did not exist.**
(e) **Increasing micro-plastics. That would be alchemy**: the amount of micro-plastics is obviously the same, it is simply that they appear faster and then disappear faster than conventional plastics.

16. Some of the opinions voiced by some parties have led some stakeholders to consider a potential ban on oxo biodegradable additives. This seems unjustified, unnecessary, and also counterproductive. For the foreseeable future, conventional plastics will continue to be used all over the world, in increasing amounts due to global development, despite the efforts of environmentalists and governments in some countries. Even if oxo-biodegradable technology was no longer available on the European market, large quantities of conventional plastics will continue to enter the ecosystem and will remain there as a problem for future generations. Therefore, a ban would be ineffective because it would have no perceivable impact on the problem.

17. A ban of any product would normally be justified only where there existed proof of significant harm. In the case of oxo-biodegradable plastics, the worst possible case (based on the views of the most sceptical stakeholders) could be that oxo-biodegradable plastics are little different from conventional plastics in terms of environmental impact. The best possible case is that they would be beneficial in relation to the micro-plastics issue. The point is that the range is neutral-to-good, not harmful. **Therefore, a ban does not seem to be logical or justified**.

See also other scientific evidence submitted to ECHA[37]

6.0 AGRICULTURE

6.1 The SAPEA Report says *“Agricultural plastic mulch films are widely used to increase crop yields. This process has been used since the late 1930s and can bring clear societal benefit in terms of food production and food security*[38] However, *“In specific applications, where plastics are used directly in the open environment, these can present a source of*

[36] See also para. 11.25 below
[37] https://www.biodeg.org/scientific-evidence-to-echa/
[38] 3.3.1

contamination if collection (e.g. for reuse, recycling or other forms of managed disposal) is either not cost-effective (e.g. agricultural mulch films), incomplete or not possible. In such applications, ***biodegradable plastics*** *could convey benefits over conventional polymers if they reach an open environment in which they are able to biodegrade adequately within appropriate timescales, as confirmed by suitable testing."* The key question is whether they should be oxo-biodegradable or hydro-biodegradable.

6.2 *"Mulch film is difficult to recycle when it is contaminated with soil, vegetation and chemicals, and poses risks to the environment if landfilled or left on the field."*[39] *Biodegradable mulch films are promising alternatives to PE films as they offer the same qualities and purpose, while their biodegradability in soil suggests reduced concern of accumulation.*

6.3 *The application of biodegradable mulch offers the possibility of ploughing them into the soil after use. By this practice, biodegradable mulch may influence the soil in two ways; firstly, as a physical barrier affecting soil microclimate and atmosphere (similar to conventional mulch film); and secondly, by adding carbon, additives and adherent chemicals and microorganisms to the soil."*

6.4 *"Mulches made from conventional plastics present challenges once they have reached the end of their life. The cost of removal and disposal is high and for thin (<20µm) films this is not feasible. Hence, end-of-life films can accumulate in the environment, compromising gas exchange and water infiltration. In addition, plastic mulches can fragment into microplastics, leading to reduced soil functioning."*

6.5 *"In this application, biodegradable plastics may offer advantages over conventional plastic because there is a high likelihood that end-of-life products will reach a receiving environment where they are designed to biodegrade, hence there are potential advantages over conventional plastics."*

6.6 After the crop has been harvested many square kilometres of contaminated conventional plastic have to be removed and disposed of from each farm. This is a very expensive process, and creates huge quantities of contaminated waste, which cannot easily and safely be burned or recycled into useful products, and cannot transported on country roads easily or safely.

6.7 This is why oxo-biodegradable mulch films have been invented. They have been successfully used in farm trials in Wales[40] where different formulations were tried in order to demonstrate that the degradation time can be controlled according to the farmer's requirements.

6.8 The SAPEA Report at 6.2.3 says "*Farmers have positive views of biodegradable plastic mulch films, exhibit a great willingness to learn more about the material, and recognise the benefits of reduced pollution and the convenience of not having to remove or dispose of the materials."* Also, "*Farmers need to maintain the functionality of their soils, hence the potential for product information to be followed is relatively high."*[41]

6.9 Oxo-biodegradable plastic sheets can be programmed at manufacture to degrade soon after the harvest. The degraded material can then be ploughed into the soil where it completes the bio-degradation process and becomes a source of carbon for next year's

[39] 6.2.3
[40] https://www.biodeg.org/wp-content/uploads/2020/08/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf
[41] SAPEA 3.3.1

plants. It should be noted that sunlight is not necessary for the continued degradation of this material.

6.10 Oxo-biodegradable plastics have been used in agriculture in many countries (including USA, China, Japan, Israel, and the EU).

6.11 It is suggested in the Report[42] that whilst the main body of an oxo-biodegradable mulch film might degrade and biodegrade as intended, the edges of the film which are buried to anchor the film in the field would not biodegrade. However, the edges of the film can be differently formulated so that they will biodegrade at much the same rate, but it is in any event much easier for the farmer to collect and dispose of strips two or three inches wide than to collect and dispose of many square kilometres of plastic sheet.

6.12 The SAPEA report at 6.4.3 says that "*there is great interest in biodegradable plastic materials from the agricultural sector, yet it is not clear whether farmers are aware that some products labelled as biodegradable may only degrade fully under conditions of industrial composting and that their usage may lead to unintended environmental consequences.*"

6.13 The advantage of oxo-biodegradable over hydro-biodegradable (bio-based) plastics is that they do not need conditions of industrial composting, and also that by adjusting the formulation of the masterbatch it is possible to control the rate of degradation so as to accord with the timescale required for the particular crop.

6.14 SAPEA 6.4.2 notes that lower price points are needed for a transition to biodegradable plastic mulch films. This is another advantage of oxo-biodegradable plastic, as its price is much lower than bio-based film. It does not need subsidy from taxpayers' money.

7.0 OTHER TECHNOLOGIES

7.1 Oxo-biodegradable technology makes plastics which are functional and stable for reuse and recycling – but if they escape into the environment degradation proceeds more rapidly. For each application we must choose whether to prioritize use, reuse and recovery – (but mitigate the decades-long effect in the event of littering, by including a prodegradant catalyst and facilitating degradation leading to simultaneous biodegradation which is completed in a matter of years or even months); or chose "compostable" materials which are designed to be taken to a composting facility and wasted after one use.

7.2 Oxo-biodegradable plastics should not be confused with other technologies which claim biodegradability, including those which are mixed with starch so that the starch biodegrades, leaving the polyethylene or polypropylene behind.

7.3 Nor should oxo-biodegradable plastics be confused with enzymatic plastics. As the SAPEA Report notes at p. 21 *"polyolefins consist of a carbon chain with covalent carbon-carbon bonds, which no natural enzyme can cut directly."* The molecular weight must first be reduced.

8.00 COMPOSTING OF PLASTICS

8.1 There is nothing wrong with composting garden and kitchen waste, but no plastics of any kind should be introduced into the process. **There are at least 21 reasons why "Compostable" plastic is not useful[43]**

42

43 [21 reasons why 22-1-20 by anna v3 (biodeg.org)]

8.2 Plastics marketed as "Compostable" are really an irrelevance, because the main problem facing governments today is plastic waste which has escaped into the open environment, from which it cannot realistically be collected and taken to a composting facility. The SAPEA report notes at 5.4.2 that *"If compostable plastics are introduced into the open environment, their certifications no longer apply."*

8.3 A "Grocer" magazine survey of more than 1,000 individuals in 2019 found that *"consumers think that plant-based compostable plastics are the most environmentally friendly packaging materials,"* but most consumers don't realise that "compostable" plastic **does not convert into compost**, and there should be an immediate ban on marketing such plastic as compostable. It is required by ASTM D6400 and EN13432 to convert rapidly into CO_2 gas, and the last thing the planet needs is more CO_2. If you can collect a plastic product there are better things to do with it than turn it into CO_2. This is not circular.

8.4 Also, many consumers do not know that "compostable" plastic is tested to biodegrade in an industrial composting facility – not in the open environment. In November 2019 the Danish courts ruled in Ellepot v Sungrow that "compostable" PLA plastics **must not be described as biodegradable** – because they are not proved to be biodegradable except in the special conditions found in an industrial composting facility.

8.5 Further, plastics marketed as compostable are far too expensive for everyday use, and there are very few industrial composting facilities available. For this reason the German courts in Güthoff v Deutsche Umwelthilfe (2014) held that it is **deceptive to market plastic as "compostable."**

8.6 Also these plastics are often deceptively marketed as "renewable," but this ignores the fossil fuels consumed in the agricultural production process by the machines which clear the land, plough the land, bring the seeds to the farm and sow them, harrow the land, bring the fertilisers and pesticides to the farm and spread them, harvest the crop and transport it to the factory, and by the machines which polymerise the raw material.

8.7 It also ignores the land and water resources devoted to producing the raw materials, which should be used for growing food. EASAC (March 2020 report) says that *"replacing PE by a bio-PE would require almost all (93.5%) of global wheat production."* This is of course unsustainable.

8.8 Although these plastics are marketed as "bio-based" this is also deceptive, because they can contain up to 60% oil-based material. This is not usually mentioned in the advertising. Also, conversion of organic materials to CO_2 at a rapid rate is not "recovery" or "recycling." Nature's lignocellulosic wastes do not behave in that way, and if they did the products would have little value as soil improvers, having lost most of their substance and their carbon.

8.9 On 11th September 2003 a Report to the Australian Government by the Nolan-ITU Consultancy concluded as follows in relation to hydro-biodegradable polyesters (eg starch-based) "At the end of the commercial composting process, all of the carbon has been converted to CO_2 so there is a contribution to greenhouse gas levels but not to the value of the compost."

8.10 The same Report concluded that "degradable polymers manufactured from renewable resources (e.g., crops) have greater impacts upon eutrophication due to the application of fertilizers to land."

8.11 On 15th July 2020 a report appeared in “Waste Management” Vol. 113, Pages 312-318. The conclusions were:

- In many cases, plastic bags are being replaced with compostable plastic bags.
- Industrial composting processes do not completely remove film fragments.
- Compost is thus a potential source of fragments from compostable plastic bags.
- Compostable plastic fragments are then deteriorated in soil to microplastics.
- Compostable microplastic results in an increase number of aflatoxigenic fungi.

8.12 The SAPEA Report itself notes at 5.4.2 that *“Because of their potential for widespread environmental distribution, the ecological risks of micro- and nano-sized biodegradable plastics should be subjected to special consideration. Compost is one source of compostable and biodegradable micro- and nanoplastics that is expected to increase with increased application of compostable and biodegradable plastic products in the future.”* And at 5.5.3 *“Some biodegradable plastics intended for biodegradation by composting (e.g. PLA) may contribute to microplastic debris if not fully biodegraded in environmental conditions. This concern also applies to microplastic residues in compost used for soil fertilisation and amendment.”*

8.13 There is also concern about toxicity. At 5.5.2 the SAPEA Report says *“In the most recent study, six out of ten samples of the biodegradable polymer PLA, as well as pellets of one type of the biodegradable polymer PHA, induced baseline toxicity, while one PLA product also showed a potent effect on oxidative stress.”*

9.0 USERS REJECT “COMPOSTABLE” PLASTIC

9.1 Even industrial composters and local authorities do not want ”compostable” plastics.

9.2 For example, the website of Epsom & Ewell Borough Council in the UK says[44]

“We used to ask you to use bio-liners to line your food waste caddy, but the food waste recycling companies found that bio-liners compost down much more slowly than the food. That slowed the recycling process and made it much more expensive. They tried dredging the bio-liners out of the food waste, but the sticky bio-liners got tangled around the dredging equipment. Cleaning them off was very expensive. So they found that using [ordinary] plastic bags was, overall, much more cost-effective. They're not recycled but good stuff still happens to them. And you can use old bags like bread-bags or carrier bags if you like.”

- The City of Exeter UK has also rejected it[45]
- And the City of Toronto, Canada[46]
- In January 2020, the industrial composters of Oregon gave 9 reasons why they did not want it[47]
- Then the SUEZ waste-management company[48]

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[44] https://www.epsom-ewell.gov.uk/why-it-ok-put-plastic-bags-food-waste-not-green-recycling-bin
[45] Rejects ‘compostable’ plastic and paper - Biodeg
[46] https://www.cbc.ca/news/technology/plastic-packaging-compostable-plastic-marketplace-1.5487617

[47] https://bioplasticsnews.com/wp-content/uploads/2019/04/Oregon-composters-dont-want-Compostable-Packagine.pdf
[48] https://www.usinenouvelle.com/article/sacs-plastiques-compostables-le-grand-malentendu.N926789

- Then a devastating exposé on Netherlands television[49]

- And another TV exposé in Canada about how compostable plastics are not being composted but instead sent to landfill or incineration.[50]

9.3 Many areas do not have industrial composting plants, and the Welsh Government has refused to invest in them.[51] Plant-based compostable plastics are going to landfill rather than recycling because so many local authorities are unable to deal with them.

9.4 "Compostable" resins are worse than conventional or oxo-biodegradable plastics when it comes to oxygen transmission-rate or moisture vapour transmission-rate. These resins are also water sensitive, and their physical, optical, mechanical, and chemical properties are inferior.

9.5 SAPEA 6.3.3 *"Bio-based plastics that use first-generation feedstock (i.e. crops suitable for human or animal consumption) do not necessarily present a more sustainable alternative to fossil-based plastics particularly when the environmental impacts of land use changes are accounted for."*

9.6 SAPEA 6.6 "One of the key challenges is to ensure that plastics that only biodegrade in industrial facilities do not end up in the open environment."

9.7 One of the objectives of the European Strategy for Plastics in a Circular Economy is to reduce dependence on imported fossil fuels. We agree with this, but it cannot be done by encouraging bio-based plastics. Farmers do not use horses any more, and large amounts of fossil-fuels are consumed and pollutants emitted in the agricultural production and polymerisation processes.

9.8 By contrast, oxo-biodegradable (and conventional) plastic is made from a by-product of oil-refining, which would arise whether plastics were made or not. This resource will be available so long as petroleum is needed for fuel and lubrication, and we should not waste it. In addition, dependence on imported fossil fuels should be reduced by capturing the calorific value in waste plastic in a modern non-polluting waste-to-energy process, instead of sending it to landfill.

10.00 HOME COMPOSTING

10.1 Why would anyone want to buy an expensive plastic bag to transport kitchen waste to a home compost when he could use a bucket?

10.2 A study for the French government at [52]says that *"composting management must be in line with good practices recommended by ADEME (weekly brews for one month and then every 1 to 2 months, humidity control), – the average ambient temperature over the first three months of composting must be close to that of the standard: outside temperature of 25^{o}C – 5^{o}C. It is unlikely that all of these conditions will be met by individuals."*

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[49] The Composting Fairy Tale – Bioplastics News

[50] https://www.cbc.ca/news/technology/plastic-packaging-compostable-plastic-marketplace-1.5487617

[51] https://www.bbc.co.uk/news/uk-wales-47238220

[52] https://www.ademe.fr/sites/default/files/assets/documents/compostage-domestique-industriel-sacs-plastiques-papier_2019.pdf

10.3 Home composting of plastic is therefore dangerous and should not be encouraged. This is because the plastic may have been contaminated by pathogens from putrefying food, and the temperature in a home compost may not be high enough to kill those pathogens.

10.4 The French study also shows that *"plastic bags are poorly disintegrated and biodegraded if good domestic composting practices are not applied."* It also shows that, *"even when good practices are followed, there are still a few pieces of plastic bags of micrometric or even millimetre size in composts beyond the standard year of home composting."*

10.5 In addition, the study says *"it appears that the biodegradation of plastic bags suitable for domestic composting makes little or no contribution to the formation of humus because, in accordance with the biodegradation tests of these materials according to the NF T 51-800 standard, at least 90% of the carbon organic dioxide is converted into carbon dioxide."*

11.00 THE GCSA RECOMMENDATIONS[53]

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

> **11.2** We would agree with the general proposition, but oxo-biodegradable plastics do not need specific environmental conditions. They are designed to biodegrade anywhere that oxygen and bacteria are available.
>
> **11.3** Consumers will think that a product sold as biodegradable will biodegrade in the open environment, so plastic products which are designed to biodegrade in special conditions eg in an industrial composting facility, should not be described as biodegradable. An immediate ban should be placed on that practice.

11.4 Prioritize *reduction, reuse and recycling of plastics before considering biodegradation*

Yes and no.

(a) Reduction must bear in mind that plastic is the best material for protecting ourselves and our food from contamination. It can be made anti-microbial, and it has a better LCA than alternative materials used for packaging. Switching to other forms of packaging could increase risks to climate-change and health.

(b) If you want to use a plastic item many times, and recycle it, and you can be confident that it will not escape into the open environment, the best option is conventional plastic. You cannot however be confident, and must therefore consider the need for biodegradation. Oxo-biodegradable plastic can be re-used and recycled and can be made from recyclate, but "compostable" plastic cannot.

(c) Even if plastic packaging gets collected, separation of this type of plastic from other waste presents a challenge, and recycling of low-value polyethylene and polypropylene packaging is often not feasible in economic or environmental terms. It is not therefore important whether oxo-biodegradable PE and PP plastic packaging is recyclable or not – although it is.[54]

11.5 *Limit the use of Biodegradable Plastics (BDPs) in the open environment to specific applications for which reduction, reuse, and recycling are not feasible.*

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[53] GCSA Report Page 21

[54] https://www.biodeg.org/subjects-of-interest/recycling-2/ .

11.6 The GCSA Report says "*We 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."*

11.7 Collection from the environment is very challenging for plastic packaging which has escaped as litter and may be spread over a wide area on land or sea. This is the specific application for which oxo-biodegradable plastic is designed, and where the environmental benefits are clear. It will biodegrade significantly more quickly than ordinary plastic under the same conditions.

11.8 Do *not consider BDPs as a solution for inappropriate waste management or littering*

11.9 Then what is the solution for inappropriate waste management or littering? We would all agree that waste management should be appropriate and that littering should not occur. However, the authors cannot close their eyes to the failures of waste-management, even in the developed world, and to the fact that accidental and deliberate littering does occur – whether we like it or not.

11.10 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*

11.11 We agree with this, and are ready to cooperate. The OPA already offers a testing and certification service,[55] but this is not mentioned in section 4.5.2 of the SAPEA report *"Available certification programmes, including for the open environment."*

11.12 For the reasons mentioned above the open environment on land and sea is a receiving environment which has to be considered, and in which the conditions at the time and place of disposal cannot be known in advance. The Report says *"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."* We agree with this. Biodegradation is not the primary purpose of oxo-biodegradable plastics. Biodegradability is there to deal with the *failure* of waste management.

11.13 The Report says *"before considering BDPs for certain applications, it is important to consider whether the application should exist in the first place, or if alternative materials could be employed instead."* Plastic is one of the few materials in common use which can be made antimicrobial[56] and Life-cycle Assessments[57] show that is the best material for packaging.

11.14 Require *testing of biodegradation of BDP applications under laboratory and simulated environmental conditions.*

11.15 We agree with this.

[55] https://www.biodeg.org/about/certification-specification-for-oxo-biodegradable-plastics/
[56] www.d2p.net
[57] https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/

11.16 *Require assessment of biodegradation and environmental risk of BDP under the conditions of specific open environments.*

> **11.17** There is no such thing as a specific open environment. The conditions in the open environment are almost infinitely variable. It might be possible to regard agricultural applications as a specific open environment, but even there the conditions are widely variable.

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

> **11.19** We agree with this, subject to 11.17 above

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

> **11.21** We have made this a principal objective of the Oxo-biodegradable Plastics Association, and the Association does not condone anyone who makes false claims of biodegradability. We are critical of the failure – even in official documents – to distinguish between oxo-degradable and oxo-biodegradable, plastic. The SAPEA report itself causes confusion by failing to do this, and by using the term "Biodegradable plastic" without making it clear whether they are referring to oxo-biodegradable or hydro-biodegradable plastic.
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> **11.22** The SAPEA Report says, at 6.2.1 *"Given that most of the currently available biodegradable polymers decompose in a timely manner only in industrial facilities under controlled conditions, and bio-based plastics degrade over long periods just like their fossil-based counterparts, it is perhaps not surprising that there is considerable confusion and scepticism among consumers about products that combine the terms 'bio' and 'plastics.'* The term 'bioplastic' is a source of confusion, because it is used to refer to both bio-based and biodegradable polymers in instances where it is not clear what type of bioplastic it refers to.
>
> **11.23** *Many consumers understand the term 'biodegradable' as something that will break down 'naturally' in the open environment in the same way as something that is considered 'compostable'. While biodegradability and compostability have distinct technical definitions, they are often conflated and used as synonyms by consumers.*[58]
>
> **11.24** The GCSA report is correct[59] that *"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."* Biodeterioration is what happens to ordinary plastic in the open environment – Biodegradation is what happens to oxo-biodegradable plastic.
>
> **11.25** SAPEA 6.4.3 *WRAP found that a majority of British consumers never looked at packaging labels for disposal information*.

11.26 *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*

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[58] SAPEA 6.2.1

[59] 1.4.3

11.27 We agree with this. The SAPEA report says, at 5.5.3 *"a significant reduction in the biodegradation rate of compostable plastics such as PLA is expected in environmental conditions, as compared to composting conditions. Therefore, labelling of plastic items intended for industrial composting should not include 'biodegradable', but only 'compostable' so not to confuse public waste handling."*