# 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** |
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| 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<br><br>However, sending any kind of plastic to a composting facility is not desirable. See |

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| | 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 |
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| 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.<br><br>**"Oxo-degradation"** is defined by CEN as "degradation identified as resulting from oxidative cleavage of macromolecules."<br><br>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]. |

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| | | | **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.<br><br>**"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]<br><br>The material then undergoes biotic processes, known as biodegradation.<br><br>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"<br><br>The studies cited by the author in footnotes 9 and 34 correctly refer to oxo-biodegradable plastic as oxo-biodegradable plastic.<br><br>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.<br><br>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. |

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| | | 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.<br><br>**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.<br><br>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.<br><br>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.<br><br>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<br><br>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.<br><br>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.<br><br>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.<br><br>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.** |

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| | | | 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<br><br>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.<br><br>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).<br><br>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.<br><br>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**.<br><br>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/<br><br>"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. |

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| 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:<br><br>• Prodegradant catalyst / degradation promoter – this may include one or a blend of several organic salts of transition metals. They are not heavy metals.<br>• Stabilizers – to preserve or enhance the stability of finished products during processing, shelf/service-life and to facilitate use, reuse and recycling.<br>• Mineral fillers/extenders (where appropriate)<br>• Carrier resin<br><br>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**."<br><br>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<br><br>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.<br><br>As to definitions see item 1 above.<br><br>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.<br><br>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. |

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| 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.<br><br>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.<br><br>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.<br><br>As to definitions see item 1 above.<br><br>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. |

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| | | about polymer backbone and type of additives.<br><br>*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]<br><br>Recital 15 does not apply to oxo-biodegradable plastic because:<br><br>(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<br>(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.<br><br>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."<br>(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 |

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| | | | 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/<br>(d) It does not negatively affect recycling. https://www.biodeg.org/subjects-of-interest/recycling-2/<br><br>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.<br><br>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.<br>(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.<br><br>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.<br><br>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. |

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| | | 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.<br><br>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].<br><br>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].<br><br>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] |

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| 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**.<br><br>Due to this contamination, post-consumer **recyclability** is also not practical or economically viable. Pre-consumer recycling is more feasible.<br><br>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].<br><br>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.<br><br>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.<br><br>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.<br>https://www.biodeg.org/subjects-of-interest/recycling-2/<br><br>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.<br><br>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.<br><br>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.<br><br>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.<br><br>The author notes that the UK is (correctly) restricting the amount of plastic waste going to landfill. |

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| | | | 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.<br><br>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 .<br><br>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.<br><br>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. |

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| | | 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*<br>• • Not a specification; only a guidance<br>• • *Tested temperature range: 20 °C – 70 °C (not suitable to Scottish weather conditions)*<br>• • *Molecular weight reduction- <5000Daltons; EAB criteria-<5%*<br>• • ≥ 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.<br><br>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<br><br>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."<br><br>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.<br><br>Abiotic degradation has in fact been tested in the real world, but biotic degradation and ecotoxicity can only be tested in the laboratory.<br><br>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 |

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| | | | carbon dioxide the test cannot be considered completed and has therefore failed)<br><br>20-70C refers to accelerated exposure conditions, not conditions in the open environment, which would obviously not be found in Scotland.<br><br>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.<br><br>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*<br>• • 90% of total theoretical carbon dioxide evolution within 6 months<br>• • Disintegration not >10% be >2mm within 12 weeks.<br>• • *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.<br><br>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 |

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| | | 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."<br><br>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<br><br>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).<br><br>Nobody is claiming that oxo-biodegradable plastic will biodegrade to a particular extent within a particular timescale under all conditions in the open environment.<br><br>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.<br><br>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.<br><br>The principal purpose of oxo-biodegradable technology is to reduce the impact of littered plastics by facilitating faster rates of degradation and biodegradation |

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| | | | 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.<br><br>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<br><br>Oxo-biodegradable mulch films should easily pass the tests in EN 17033-2018,.<br><br>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.<br><br>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.<br><br>By contrast crop-based plastics typically degrade via hydrolysis, a reaction with water, which was provided by drip irrigation.<br><br>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.<br><br>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. |

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| 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.<br><br>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.<br><br>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.<br><br>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.<br><br>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.<br><br>As to Thomas et al see https://www.biodeg.org/wp-content/uploads/2020/05/BPA-RESPONSE-TO-LOUGHBOROUGH-REPORT.pdf |

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| | | 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.<br>**(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<br><br>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?<br><br>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."<br><br>"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."<br><br>(b) Re Markowicz et al.<br><br>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." |

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| | | **(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.<br><br>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.<br><br>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.**<br><br>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:<br>• In many cases, plastic bags are being replaced with “compostable” plastic bags.<br>• Industrial composting processes do not completely remove film fragments.<br>• Compost is thus a potential source of fragments from compostable plastic bags.<br>• Compostable plastic fragments are then deteriorated in soil to microplastics.<br>• Compostable microplastic results in an increase number of aflatoxigenic fungi.<br><br>Even industrial composters and local authorities do not want ”compostable” plastics. For example, the website of Epsom & Ewell Borough Council in the UK says:<br><br>“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 |

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| | | | sticky bio-liners got tangled around the dredging equipment. Cleaning them off was very expensive."<br>• The City of Exeter UK has also rejected "compostable" plastic – **Click to read**<br>• And the City of Toronto, Canada – **Click to read**<br>• In January 2020, the industrial composters of Oregon gave 9 reasons why they did not want it – **Click to read it**<br>• Then the SUEZ waste-management company – **Click to read**<br>• Then a devastating exposé on Netherlands television – **Click to read**<br>• 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**<br><br>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.<br><br>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.<br><br>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.<br><br>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. |

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| | | | **(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.<br><br>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.<br><br>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.<br><br>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.<br><br>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 ). |

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| | | | 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.<br><br>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.<br><br>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:<br><br>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.<br><br>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<br><br>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 |

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| | | | 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.<br><br>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].<br><br>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.<br><br>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.<br><br>Excessive concentrations of almost anything eg table-salt, could be toxic, but this is not permitted for oxo-biodegradable plastics.<br><br>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 |

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| | | 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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