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."