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 <u>much higher degree of degradation</u> 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. <u>This is consistent with the presence of the additive accelerating film degradation and conversion into a wax."</u>*

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. (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

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."

Professor Ignacy Jakubowicz (Sweden) advised the Ellen MacArthur Foundation as follows, but they omitted this 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."

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.