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Oxo-Biodegradable plastics and the micro-plastics issue: towards a logical approach

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1. Intertek has carried out a wide range of work on polymers, including various Life Cycle Assessments (LCAs) and other environmental studies. Intertek produced two LCAs on plastic bags and oxo-biodegradable plastics. The second one, carried out in 2012, included an assessment of oxo-biodegradable plastics and litter [1].

2. Oxo-degradable plastics are conventional plastics which degrade by oxidation but do not become biodegradable for a long period of time. By contrast, oxo-*bio*degradable plastics are plastics which are designed to become biodegradable in a shorter time. Oxo-biodegradation is defined in CEN/TR 15351 as "degradation identified as resulting from oxidative and cell-mediated phenomena, either simultaneously or successively." It is not clear whether the reference to ECHA includes oxo-biodegradable plastics, but this document is concerned with oxo-biodegradable plastics.

3. Oxo-biodegradable plastics are conventional plastics that contain a metal-based catalyst or catalysts that are designed to speed up the breakdown of polymer molecules until they are reduced to a size that is able to be biodegraded. Polymers comprise long molecular chains in the region of 250,000 Daltons in mass (one Dalton is the mass of one hydrogen atom). Polymers need to be broken down into the region of 5000 Daltons before organisms can feed on them and achieve biodegradation. Conventional plastics eventually break down to this size, but oxo-biodegradable plastics are designed to achieve it much faster. Conventional plastics and oxo-biodegradable plastics are the same (apart from the addition of a small amount of catalyst in the case of oxo-biodegradable plastics), and the mechanisms of biodegradation are the same; oxo-biodegradable plastics are simply designed to achieve biodegradability sooner. Conventional plastics may take up to a century to be reduced in size to 5000 Daltons (the rate is highly variable depending on environmental conditions and other factors), whereas oxo-biodegradable plastics are likely to reach 5000 Daltons significantly sooner (again, the rate is variable, but is designed to be faster than conventional plastics).

4. Oxo-biodegradable plastics are made with a plastic masterbatch containing a catalyst that promotes degradation by oxidation in the presence of oxygen, and which reduces molecular weight to the point where biodegradation can occur. The masterbatch typically makes up 1% of the plastic it is used in. The masterbatch is itself mostly polymer, with the catalyst (or catalysts) making up only a small portion of the 1%. Therefore, the amount of catalyst in the plastic product is low – typically lower than other additives in conventional plastic such as colourants, UV inhibitors, stabilisers, extenders and so on.

5. The catalysts used in oxo-biodegradable plastics are metallic catalysts, often based on manganese, iron or cobalt, that are considered safe. They are not on any known toxic lists; for example, they are not among the hazardous substances listed in Art 11 of the Packaging Waste Directive 94/62/EC or in EN13432 Annex A.1.2 (which is the European standard for plastics intended for composting in food-production). Also, oxo-biodegradable plastics are tested according to the same eco-toxicity tests prescribed by EN13432 Annex E for plastics intended for composting (even though oxo-biodegradable plastics are not intended for composting). They are shown to be non-toxic by OECD standard testing. Plastics (whether oxo-biodegradable or not) may contain other less desirable substances – for which there may be evidence of harm, such as Bisphenol A – and authorities are taking appropriate steps to restrict the use of these substances.

6. Various stakeholders offer differing opinions about how much faster degradation of oxo-biodegradable plastics occurs compared to conventional plastics. The somewhat limited research [2] that has been carried out to date shows that the speed range of degradation may be from marginally faster than normal plastics, to very significantly faster, depending on such factors as the formulation of the masterbatch and the extent to which the plastic is exposed to UV light and heat [3].

   "Polyethylenes containing pro-oxidant substances degrade by exposure to the environment, resulting in decreased molar mass and incorporated oxygen in the chain in the form of carboxylic groups. This exposure to natural weathering for a period of 3–4 months decreased the mechanical properties of polyethylene (containing about 80 mg kg-1 of cobalt), causing disintegration of the material. Saturated humidity increased abiotic oxidative degradation and biodegradation, as compared to natural humidity. The polyethylene bags mineralized about 12% of the original carbon in compost at 58 degrees C for three months after being exposed for one year to natural weathering. Exposure periods longer than three months and environmental moisture exert little influence on the degradability of cobalt-activated PE. There was low biodegradation of conventional PE films exposed to natural weathering for one month or longer, and fungi belonging to the genera Aspergillus and Penicillium grew on oxo-biodegradable PE films in environments with saturated humidity." [3]

   "........Oxo-biodegradable plastics are conventional plastics, such as High Density Polyethylene (HDPE), commonly used in carrier bags, which also include additives which are designed to promote the oxidation of the material to the point where it embrittles and fragments. This may then be followed by biodegradation by bacteria and fungi at varying rates depending upon the environment." [4]

   "Extrapolations from a laboratory study on a particular LDPE film engineered with a short service life suggest that almost complete degradation in soil can be achieved within two years." [4]

   "The debate around the biodegradability of PAC plastic is not finalised, but should move forward from the assertion that PAC plastics merely fragment, towards confirming whether the timeframes observed for total biodegradation are acceptable from an environmental point of view and whether this is likely to take place in natural environments." [4]

   "From the information studied, the authors of this Report can believe that it is possible for an OBP plastic to fully mineralise in an open environment, with the prodegradant additives encouraging this action, and thus the polymers and entrained substances can be assimilated into the natural environment." [4]

7. In ideal conditions for degradation, such as where the plastic has been exposed to UVB light [5], heat, humidity, and mechanical stress, there is no doubt that the rate of degradation is significantly faster than that of conventional plastics.

   "While all biomaterials, including plastics, will invariably biodegrade in the marine environment, the rate of this process, even in the benthic sediment, is several orders of magnitude slower compared to light-induced oxidative degradation of plastics." [6]

8. In non-ideal conditions, the degradation rate may be only marginally faster than that of normal plastics. (Oxo-biodegradable plastics are designed this way, so that they do not degrade in storage or use, only after use.) This is why the research shows a wide range of degradation rates. The key point is that the rate is faster. How much faster, and under what scenarios, is a matter of debate.

9. Oceans have high humidity and high UV levels in the surface layers where oxo-biodegradable plastics are likely to be found if they are in the ocean (since they tend to float). This would suggest that the speed of conversion to biodegradable materials may be in the upper part of the speed range. There has not been extensive research on this aspect, and as other reports have pointed out, further research needs to be undertaken. However, the research that does exist appears to show significant degradation for oxo-biodegradable plastics. The crucial timescale is the time it takes for the molecular weight of the polymer to reduce from circa 250,000 Daltons to 5,000 Daltons or less. After the material has reduced to 5000 Daltons or less, it is available for biodegradation, and biodegrades in much the same timescale as other biodegradable material, having regard to environmental conditions. The effectiveness of oxo-biodegradable plastics in oceans has been studied at Bandol in France [7], where oxo-biodegradable plastic was aged in seawater, where it successfully degraded to circa 5000 Daltons in mass.

   "The weathering test on sea water surface, performed to point out the behaviour of samples containing pro-degradant d2w additive in wet environments (films and bags accidentally released in oceans or lakes), points out very promising behaviours. Assuming that there is correlation between oxidation rate and elongation at break, film FA6224 A would present a 50% loss of mechanical properties in three weeks, and a total loss in three months, when exposed in summer period in Mediterranean climate." [7]

   To demonstrate that this material was biodegradable, the residues were exposed at Queen Mary University London to *A. borkumensis* (a bacterium commonly found in oceans) and were seen to be consumed by the bacteria as a food source, indicating biodegradability.

   "Our results show that oxo-biodegradable plastic is biodegradable by bacteria commonly found in the open environment both on land and in the oceans, after the molecular weight of the plastic has been reduced by oxidation promoted by the pro-degradant additive." [8]

10. Perhaps the most important point is this: whatever the speed of degradation, it is faster than that of conventional plastics. The different opinions of various stakeholders concerning the speed of degradation, and the different findings of the limited research that has been carried out to date, are simply a matter of degree.

11. The faster degradation and subsequent biodegradation of oxo-biodegradable plastics means that they enter the eco-system as waste plastic in the same way as conventional plastic, but they degrade, and then ultimately biodegrade to natural materials and are recycled back into nature, in less time than conventional plastics. This means that oxo-biodegradable plastics have a shorter dwell-time in the ecosystem. In the case of micro-plastics [9] 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.

12. Research could be carried out to demonstrate this, but none has been carried out to date, as far as is known. Ideally, research would be designed to arrive at an approximate value for what dwell time or biodegradation rate would result in micro-plastics declining rather than building up in oceans. There would be many challenges to determining such a rate. For example, the rate of arrival of plastics into the oceans appears to be continuing to rise in some parts of the world. This is largely a result of rising consumption and continuing inappropriate waste management in growing economies. Therefore, any figure would have to take account of future trends of inputs of plastics into the marine environment, and such forecasting is bound to have errors. What can be said now, even ahead of such research, is that any shortening of the dwell time must be useful. Any improvement in the speed of degradation must be useful. Considering very approximate order of magnitude figures, if conventional plastics were considered to take say 20 to 200 years to biodegrade in the oceans, and oxo-biodegradable plastics take say 1 to 10 years to biodegrade, already the oxo-biodegradable plastics are showing potential to make a positive, rather than negative, contribution to the issue.

13. Some commentators have suggested that an acceptable biodegradation rate should be faster than this – such as 60 days. Certainly, such fast biodegradation would be ideal once the micro-plastics were in the oceans. However, slower rates would still be fast enough to reduce the micro-plastics population in the oceans (subject to research). The issue with very fast biodegradation rates is that these rates risk compromising the purpose of the plastics. A plastic product that fails in use is a waste of resources. Plastics need to fulfil their function before biodegrading. Therefore a 60 day rate, while perhaps theoretically commendable, is unlikely to ever be viable or even desirable for the majority of plastics.

14. The amount of oxo-biodegradable plastics in the ocean is currently tiny compared to all plastics. Almost all the micro-plastics found in the oceans have come from the fragmentation of conventional plastics. Although conventional plastics can fragment quite quickly on exposure to sunlight and mechanical stress, the fragments remain for years at a molecular mass which is too high for biodegradation. This means that conventional plastics can persist in the ocean for decades before they become biodegradable. This is why the micro-plastics tonnage in the oceans has built up: the inflow and dwell time exceeds the outflow (outflow being disappearance due to biodegradation). If the dwell time were shorter, and/or the inflow lower, build up would not occur and the micro-plastics problem would not exist.

15. Various stakeholders have offered various opinions on oxo-biodegradable plastics, including raising doubts about their efficacy and even doubting the point of them. Oxo-biodegradable plastics have been criticised for:

    a. Increasing the amount of plastics, which is obviously illogical. The presence or not of an oxo-biodegradable additive in a plastic does not change the amount of plastic.

    b. Encouraging a throw-away society, which of course they do not. The littering and inappropriate waste management that leads to the oceanic micro-plastic problem occurs irrespective of any additives in the plastics. Much of the littering is accidental, and the kind of people who deliberately throw litter do not care whether the plastic may be a type of biodegradable plastic.

    c. Being less desirable for re-use and recycling. Oxo-biodegradable plastics are not antagonistic to re-use and recycling [7]. As has been demonstrated by the technical reports, and in practice over years of recycling, the tiny amounts of oxo-biodegradable additive in the system make no difference to recycling or re-use.

d. Not being supportive of the circular economy. There is a clear theoretical benefit to a circular economy. However, that is a different issue from the current harsh reality of micro-plastic pollution. If society wished to eliminate anything that is not supportive of the circular economy, it should first stop burning oil, which is a non-circular threat to sustainability that is orders of magnitude greater than the amount of oil going into making useful products such as plastics. The material used to make plastics is in any event an inevitable by-product of the process of making fuels, and the same amount of oil would be extracted from the ground if plastics did not exist.

e. Increasing micro-plastics. That would be alchemy: the amount of micro-plastics is obviously the same, it is simply that they appear faster and then disappear faster than conventional plastics.

16. Some of the opinions voiced by some parties have led some stakeholders to consider a potential ban on oxo-biodegradable additives. This seems unjustified, unnecessary, and also counterproductive. For the foreseeable future, conventional plastics will continue to be used all over the world, in increasing amounts due to global development, despite the efforts of environmentalists and governments in some countries. Even if oxo-biodegradable technology was no longer available on the European market, large quantities of conventional plastics will continue to enter the ecosystem and will remain there as a problem for future generations. Therefore, a ban would be ineffective because it would have no perceivable impact on the problem.

17. A ban of any product would normally be justified only where there existed proof of significant harm. In the case of oxo-biodegradable plastics, the worst possible case (based on the views of the most sceptical stakeholders) could be that oxo-biodegradable plastics are little different from conventional plastics in terms of environmental impact. The best possible case is that they would be beneficial in relation to the micro-plastics issue. The point is that the range is neutral-to-good, not harmful. Therefore, a ban does not seem to be logical or justified.

References

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