OXO-BIODEGRADABLE PLASTICS ASSOCIATION

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OPA RESPONSE TO EU COMMISSION'S GREEN PAPER[1] ON PLASTIC WASTE IN THE ENVIRONMENT

1. The Commission have again failed to understand the difference between bio-based plastics and oxo-biodegradable plastics. They have failed to grasp the fundamental point about oxo-biodegradable technology ie that **it does not just cause fragmentation, but actually changes the molecular structure of the material so that it ceases to be a plastic and becomes biodegradable.** No scientist would describe a material with a molecular-weight of 10,000 Daltons or less as a plastic or a polymer.

2. The Commission seem reluctant to use the term "oxo-biodegradation" even though it is defined[2] by CEN (the European Standards Organisation) and prefer instead the term "oxo-degradation" or "oxo-fragmentation," which is misleading, as it describes only the first phase of the degradation process.

3. The Commission appear to be influenced by anti plastic-bag campaigns, and they have failed to understand the environmental benefits of oxo-biodegradable plastic.

4. Policy in Europe seems to be based on the unrealistic proposition that all the plastic waste can be collected and prevented from getting into the ocean.

5. The OPA is willing to work with the Commission, with NGOs, with commercial users, and with all other stakeholders to address the problem of plastic waste in the environment.

6. The OPA is surprised by the description of oxo-biodegradable technology in Section 2.21 of the EuPC[3] "Answers to the EU Green Paper on plastic waste in the environment," and a full response by the OPA to their paper is Annexed, and is at

[1] Com (2013) 123 final
[2] Oxo-biodegradation is defined in TR15351 as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."
[3] European Plastic Converters' Association

http://biodeg.org/files/uploaded/biodeg/Draft%20reply%20to%20EuPC%20comment%204.6.13.pdf

7. Their now familiar description of the technology as *oxo-fragmentation* demonstrates both a failure to understand the technology and to appreciate that oxo-biodegradable technology has been understood and accepted since the 1970's.

8. The European Normalisation Organisation (CEN) has defined the oxo-biodegradation process (in TR13531) as *degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively,* but EuPC seem not to have appreciated the role of cell-mediated phenomena - ie biodegradation by micro-organisms.

THE BENEFITS OF PLASTIC

9. The Commission say[4] "Plastic is relatively cheap and versatile with many industrial applications, leading to exponential growth over the past century; a trend that is set to continue."

10. This is true. Plastic is a wonder of modern technology, and product-design is improving every day. Plastic carrier bags for example can be made very thin, with minimal raw material, but are still strong enough to carry a full load of heavy shopping. No other shopping-container can carry 2,500 times its own weight and stay strong when wet. A typical plastic carrier bag uses 70% less plastic today than 20 years ago, and no other industry has a better track record for material reduction.

11. Plastic packaging will protect food and other goods from damage and contamination, it is hygienic and can be made in an almost unlimited number of colours and designs. Despite all these attributes it is inexpensive, and is by far the most cost-effective and functional solution available. Much better than paper bags, or "bags for life"[5] The Commission accepts[6] that "modern life is unthinkable without it."

12. Some plastic goods should be designed to maximize durability, but others – eg sandwich triangles and food-bags are not going to be cleaned and re-used, and should continue to be designed for a limited life. Most of the products for which oxo-biodegradability is suitable would fall into that category.

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[4] P3
[5] http://www.biodeg.org/position-papers/alternatives/?domain=biodeg.org
[6] Page 4

13. The case for banning plastic bags is based more on emotion than on a hard analysis of the facts, and there is really no case for banning them.[7] An example of this emotional approach is the Commission's statement[8] that it "is emblematic of modern consumer society." There is nothing intrinsically wrong with a modern consumer society, and when articles are no longer useful they will and should be disposed of. Of course they should be re-used and recycled where it is practical to do so, and the Commission makes some suggestions on which we comment below.

14. Plastic bags can be re-used many times for shopping, and are compact enough to be put in a pocket or handbag. They are also put to many other uses in the home, and for other uses such as clearing dog-waste from the streets, and most of them will eventually serve as a bin-liner to safely collect and dispose of household waste. A Life Cycle Assessment in 2011 by Intertek[9] puts the environmental credentials of plastic bags ahead of paper, and in a further report in 2012[10] Intertek points out that they should not be described as "single-use" bags.

15. Much is made of the Irish experience, but their bag tax has simply transferred plastic consumption from carrier bags (which the supermarkets used to pay for) to bin-liners and other plastic products (which the consumer is now expected to pay for).

16. On 5th August 2011 an OPA member-company commented in detail on the EU Commission's consultation paper on plastic bags.[11]

17. Campaigns against plastic carrier bags are driven by three mistaken beliefs:

    1. That plastic bags take hundreds of years to degrade if they escape into the open environment, which some of them surely will. However, they can and should now be made from controlled-life oxo-biodegradable plastic, which will degrade much more quickly and become invisible and incapable of entangling wildlife or blocking drains. It will then proceed to biodegrade. Controlled-life

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[7] See eg. http://www.incpen.org/docs/CarrierBagsFacts17August2012.pdf and http://www.biodeg.org/position-papers/Plastic-bag-bans/?domain=biodeg.org

[8] Page 15

[9] http://www.biodeg.org/files/uploaded/Sym_response_to_EA_LCA(6).pdf

[10] http://www.biodeg.org/files/uploaded/Intertek_Final_Report_15.5.12(9).pdf para. 70

[11] http://degradable.net/files/uploaded/environmental/press_releases/Sym_Response_to_EU_CONSULTATION.pdf

plastic bags have to pass eco-toxicity tests in the relevant standards (eg BS8472, ASTM D6954) so as to ensure that they are not toxic. Currently the EU has no policy for plastic waste that may escape into the environment and cannot realistically be collected. The Packaging Waste Directive needs to be amended to require all plastic packaging to be made from Controlled-life plastic.

2. That oil is being extracted to make plastic. However, the polymers from which plastic bags are made are usually derived from naphtha, an inevitable by-product of oil refining, which used to be wasted. Using the naphtha to make plastic does not therefore reduce the fuel available for transport or power-generation, nor does it increase oil extraction or imports. By contrast the consumption of fossil fuels in the agricultural production of bio-based plastics does impact upon fossil resources. Oil-based plastics can actually reduce the amount of oil and gas imported because they can be incinerated after their useful life to release the stored energy, which can be used to generate electricity or to heat buildings.

3. That the landfills are filling up with plastic bags. However, plastic carrier bags account for a very small proportion of the space in landfills, and as the Commission has indicated,[12] no plastic of any kind should in future be sent to landfill, and should be incinerated as a fuel if unsuitable for recycling.

18. In the Social Science Research Network article "Grocery Bag Bans and Foodborne Illnesses"[13] by Joshua D. Wright and Jonathan Klick, evidence is presented that carrier- bag bans promoting reusable bags that become contaminated, are bad for your health. Klick of the University of Pennsylvania and Wright of George Mason University, examined emergency-room admission records related to bacterial intestinal infections, especially those related to E. coli, following San Francisco's ban on plastic bags.

19. Klick and Wright found that “the San Francisco City ban is associated with a 46% increase in deaths from food-borne illnesses.”

20. It is often said that degradable plastic encourages littering, but there is no evidence in the Intertek LCA’s or anywhere else, that degradable plastics of any kind encourage

[12] Page 8
[13] http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2196481

littering. A litter-lout would not know that oxo-bio products were biodegradable unless they were so labelled, because they look and feel the same as normal plastic, and such a person would be unlikely to examine a label before deciding to discard litter. In any event a lot of litter is accidentally discarded, without any conscious decision by anyone.

DURABILITY

21. The Commission note[14] that “66.5 million tonnes of plastic will be placed on the EU market by 2020 and that global plastic production could triple by 2020” and point out[15] that “plastic is a very durable material which outlives the products made of it. As a result, the generation of plastic waste is growing worldwide. The durability of plastic also means that uncontrolled disposal is problematic as plastic can persist in the environment for a very long time.”

22. This is true, but it does not need to be true, because science and technology have created oxo-biodegradable plastic, the use of which is now compulsory in the Middle East, Asia, and Africa. There is a full description of this technology on the OPA website[16] but in short, a small amount of a special masterbatch is added to normal polyethylene, polypropylene, and polystyrene, and the formulation can be varied to cause degradation in whatever approximate timescale is desired. The masterbatch does not contain heavy metals and is not eco-toxic.

23. This is not introducing a new product or process. Using oxo-biodegradable technology merely improves the existing product by making it predictable and thus intelligent. So in the same way that producers would use a masterbatch to lengthen the life of plastics, they would use an oxo-biodegradable masterbatch to control its life when left exposed in the open environment.

24. Oxo-degradation is defined by CEN[17] (the European Standards Organisation) as “degradation resulting from oxidative cleavage of macromolecules.” And oxo-biodegradation as “degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively.”

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[14] Page 4
[15] Page 3
[16] http://biodeg.org/files/uploaded/biodeg/briefing_notes/Briefing_Note_OPA_14.03.13.pdf
[17] in TR15351

25. It is important to note that oxo-biodegradable plastic does not just fragment, as is commonly believed. This is because the formulation changes the molecular structure of the plastic and converts it at the end of its useful life into a biodegradable material. No scientist would describe a material with a molecular-weight of 10,000 Daltons or less as a plastic or as a polymer.

26. The Commission say[18] that "Existing manufacturing chains, used to petro-plastics, may need costly adaptation to function with biodegradable plastics." This is true of compostable plastics but not of oxo-biodegradable plastics, because the same machinery and the same raw materials are used as for normal plastics. In most cases the cost of oxo-biodegradable technology is minimal or zero as the cost of the masterbatch can often be absorbed in the manufacturing process. By contrast, "compostable" plastic can cost up to 400% more than normal plastic.

27. Oxo-biodegradable plastic can be recycled[19] or incinerated for energy recovery if collected during its useful life, but it is also designed to degrade then biodegrade if it gets into the open environment as litter. The OPA supports the Commission's efforts to reduce litter, but it is unlikely even in Europe that 100% of the plastic waste will be collected. Of course litter is not an authorised disposal route, and of course litter is a behavioural issue, but the potential of degradable plastic cannot be ignored for those reasons. As the Commission points out[20] around 80% of marine plastic waste is coming from land, but if the plastic were oxo-biodegradable much of it would degrade and cease to be a plastic before it reached the sea.

28. Oxo-biodegradable plastic is not designed to EN13432 because that is a standard for biodegradation in the special conditions found in industrial composting, and has no application to oxo-biodegradable plastic, which degrades in the open environment, by a completely different mechanism. A lot of confusion has been caused by use of the term "biodegradable plastic" (including by the Commission[21]). In future we should speak either of oxo-biodegradable plastic or hydro-biodegradable (ie bio-based "compostable") plastic.

[18] Page 17
[19] http://www.biodeg.org/position-papers/recycling/?domain=biodeg.org
[20] Page 6
[21] Page 16

29. The Commission say[22] “Although plastic is a fully recyclable material, only a small fraction of plastic waste is at present recycled. Enhanced recycling would contribute to the aims of the Roadmap to a Resource Efficient Europe adopted in 2011.”

30. This is a compelling argument against bio-based “compostable” plastics, or plastics containing “enzymatic” additives, which cannot be recycled with ordinary plastic waste - but oxo-biodegradable plastics can. [23] The Commission say[24] “The presence of oxidising agents in the plastic waste streams may also make plastic recycling more difficult” but this is incorrect.

31. Mechanical recycling (ie grinding up the plastic, melting it down, and using it to make new plastic products) makes sense where there is a clean and verifiable supply of plastic waste eg from factory offcuts. It also makes sense for PET bottles which are relatively easy to collect and have a high intrinsic value, and which recycle well.

32. However it is unlikely to be cost-effective in environmental or economic terms to carry out mechanical recycling of much of the contaminated mixed-plastic post-consumer waste. It would be necessary to factor into the equation the cost of collecting, sorting, cleansing, and transporting the waste – sometimes for great distances, and the water used and hydrocarbons burned in the transportation, sorting, cleansing, and pelletising process, in addition of course to the capital and maintenance costs of the land and machinery used in the process. By contrast, virgin polymer is cheap and in abundant supply.

33. Oil is extracted to make petrol, diesel, and other fuels, and will continue to be extracted for that purpose until someone invents a different way to propel motor vehicles, ships and aircraft and to drive and lubricate machinery. Plastics, and other products, are made from a by-product of oil refining which used to be wasted, and do not therefore contribute to the depletion of fossil resources.

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[22] Page 3
[23] http://www.biodeg.org/position-papers/recycling/?domain=biodeg.org
[24] Page 17

34. It is not necessary to recycle in order to dispose usefully of the waste plastic or to reduce dependence on oil because, as the Commission accepts[25], it can instead be used as a fuel for modern thermal-recycling systems, as its calorific value is the same as the oil from which it was made. Energy extracted by those systems can be used to generate electricity or for space-heating, thus reducing the need to import oil for those purposes.

35. The Commission note[26] that "the Framework Directive on Waste[27] sets a general recycling target for household waste which covers, among other materials, plastic waste. ….The Directive also sets out the waste hierarchy giving precedence to waste prevention, reuse and recycling over recovery, including energy recovery, and disposal. There persists, however, a sharp contrast between legislative requirements and actual waste management practice."

36. This is true, and the Commission point out[28] that in Germany 60% of the plastic waste is incinerated. There is a case for putting energy recovery on the same level in the waste-hierarchy as recycling, and above recycling for the types of mixed post-consumers plastics which are uneconomic to recycle. The Commission accepts[29] that under a life cycle perspective not all plastic waste may be suitable for recycling.

LANDFILLING

37. The OPA agrees with the Commission that it is important to prevent landfilling of plastic waste, and the Association would support a tax or a ban. Plastic waste which has been collected should not be put into a hole in the ground, but should be thermally or mechanically recycled.

38. If all the plastic waste were collected there would be no need for oxo-biodegradable plastic, but it is not all collected and probably never will be, even in Europe. Oxo-biodegradable plastic is however designed to have a long enough life to be recycled or incinerated if collected. If sent to landfill it will not (unlike "compostable" plastic) generate methane – a dangerous greenhouse gas.

[25] Page 4
[26] Page 6
[27] 2008/98/EC
[28] Page 9
[29] Page 10

ADDITIVES

39. The Commission suggest[30] that “conventional plastic contains a large number, and sometimes a large proportion, of chemical additives which can be endocrine disruptors, carcinogenic, or provoke other toxic reactions and can, in principle, migrate into the environment, though in small quantities.” There is a case for the Commission to work with the plastics industry to reduce or remove these additives if it can be established that harm has ever been caused by plastic products which contain them.

40. Oxo-biodegradable plastic does not contain heavy metals and it complies with EU and US regulations for direct contact with food. Oxo-biodegradable plastics have to pass the same tests[31] as “compostable” plastics to prove that they are not eco-toxic.

MARINE LITTER

41. Policy in Europe seems to be based on the unrealistic proposition that all the plastic waste can be collected and prevented from getting into the ocean. Other countries, in Africa, Asia, and the Middle East understand that this is indeed unrealistic, and have legislated to require short-life plastic products to be oxo-biodegradable so that it they do get into the ocean (as some of them surely will) they will degrade and will not float around for decades. They will become incapable much more quickly than ordinary plastic, of entangling wildlife.

42. Of course we must reduce the generation of litter and educate people not to litter, and we must also recycle where it makes sense to do so in economic and environmental and terms. However, in every country some of the plastic will always escape the preferred disposal routes and find its way into the open landscape or the ocean, from which it cannot realistically be collected.

43. The characteristic of plastic which causes so much concern for the marine environment is that it can lie or float around for decades before bio-degrading. The plastics industry needs to deal with this by adopting oxo-biodegradable technology for all its short-life products. It is now unnecessary and unacceptable to make short-life plastic products which can lie or float around in the environment for 50 years or more.

[30] Page 5
[31] Eg EN13432 Annex E

44. Oxo-biodegradable plastic is no more a solution to plastic litter than catalytic converters are to air pollution, but both have a role to play.

45. The Commission say[32]"Small and fine particles (so called micro plastics), result from decades of photo degradation and mechanical abrasion and are of particular concern. They are ubiquitous and reach even the most remote areas with a concentration in water sometimes higher than that of plankton. These micro plastics, and the chemical additives they contain, if ingested in large quantities by marine fauna may have a high potential for contaminating the food chain through predatorprey interaction."

46. Plastic products made with oxo-biodegradable technology are of the type which will float on or near the surface, where they will degrade much more quickly than ordinary plastic. They will not therefore be floating around for decades, being ingested by marine creatures and attracting pollutants, and there is no evidence that any marine creature has ever been harmed by fragments of an oxo-biodegradable product. As already explained, after the abiotic degradation process the fragments are no longer fragments of plastic and have become biodegradable. They are no more likely to attract pollutants than fragments of seaweed and other naturally-occurring fragments.

47. The Commission note[33] that "plastic bags accounted for 73% of the waste collected by trawlers along the Tuscany coast." However, most of them would not have been floating around if they had been made with oxo-biodegradable technology. Perversely the Italian government is trying to force manufacturers to use plastic made with "compostable" technology, which is designed to biodegrade in the special conditions found in industrial composting. They would therefore need to collect the litter, and if they could collect the litter it would be better to use it for recycling or energy-recovery. As the Commission has said, "compostable" plastic has no nutritive value for plants.

BIODEGRADABILITY and COMPOSTABLIITY

48. The Commission have been provided with ample information about biodegradable plastics of all types, but still fail to understand the difference between oxo-biodegradable and "compostable" plastics, both of which are degraded by micro-organisms into water, Co2, and biomass.

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[32] http://www.biodeg.org/files/uploaded/Intertek_Final_Report_15.5.12(9).pdf
[33] Page 15

49. They have failed to grasp the fundamental point about oxo-biodegradable technology ie that it does not just cause fragmentation, but actually changes the molecular structure of the material so that it ceases to be a plastic and becomes biodegradable.

50. The Commission seem reluctant to use the term "oxo-biodegradation" even though it is defined[34] by CEN (the European Standards Organisation) and prefer instead the term "oxo-degradation" or "oxo-fragmentation," which misleads as it describes only the first phase of the degradation process.

51. The Commission say[35] "in reality, the large majority of biodegradable plastics can only biodegrade under very specific conditions of constantly high temperature and humidity in industrial composting installations and are neither fit for home composting nor do they decompose in reasonable time when littered." This is true of "compostable" plastics, but it is not true of oxo-biodegradable plastics, which are designed to degrade in a normal open environment in the presence of oxygen, and to degrade much more quickly than ordinary plastic if littered. They are not marketed for composting.

52. The Commission are in error when they say[36] of oxo-biodegradable plastics that "fragmentation of plastic enhanced with an oxidising agent (usually a metal salt) in the presence of oxygen, heat and UV light results in microscopic plastic fragments with similar properties as the bulk plastic." They have failed to appreciate, or do not wish to appreciate, that once the molecular weight of oxo-biodegradable plastic has descended to 10,000 Daltons or less the material is no longer a plastic, and has become a non-toxic biodegradable residue. They have ignored the published science, and in particular research conducted in Sweden[37] in 2010 which shows not only degradation, but 91% biodegradation, within 24 months.

53. The carbon content of oxo-biodegradable plastic is ultimately shared with living organisms in the environment which is not the case with conventional plastic where the carbon is locked in useless hibernation, potentially for centuries.

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[34] Oxo-biodegradation is defined in TR15351 as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively."
[35] Page 16
[36] Page 16
[37] 96 *Polymer Degradation & Stability* (2011) 919

54. The 2012 Intertek Report[38] showed that oxo-biodegradable plastic bags have a better LCA than conventional plastic and bio-based plastic, and as the Commission point out[39] some bio-based polymers, such as polyethylene (PE) from bio-ethanol are not biodegradable at all.

55. The Commission seem to think[40] that bio-based plastics are made from renewable resources. However, they are not "renewable" if you consider the fossil fuels consumed and CO2 emitted by the machines used to clear the land, plough the land, harrow the land, sow the seed, make the fertilisers and pesticides and bring them to the farm, spray the crops, harvest the crops, take the crops to a polymerisation factory, and operate the autoclaves.

56. Further, it is not desirable to use scarce land and water resources to grow crops to make plastic and to increase the cost of food. Those resources should be used to produce food for the many people in the world who do not have enough to eat. The Commission point out[41] that "A link between the rises in corn prices subsequent to the rise in [bio] ethanol production 2008 in the US has been documented" and that if bio-based plastics are encouraged as a replacement for conventional plastics "an increase in land use and raw material prices might result, as well as a loss of biodiversity through transformation of idle land and forests into fields, increasing agricultural consumption of water and fertilizers."

57. It is in fact difficult to see the purpose of bio-based or "compostable" plastics. As a 2013 Report for the German Government has said:[42]
    a. "One can certainly say that a high percentage of bioplastic packaging was recovered in one way or another, but predominantly via waste incineration plants with energy recovery and in part by thermal recycling, most of all in cement works. Composting did not gain a relevant share as a disposal route for used bioplastic packagings, which was in contrast to expectations initially raised."

    b. "[Pladerer et al. 2008] also makes some statements on anaerobic treatment. According to them, various operators of fermentation plants refuse to treat PLA materials in their plants. They also point out that the fermentation of PLA

[39] Page 18
[40] Page 17
[41] Page 18
[42] See http://www.biodeg.org/files/uploaded/biodeg/Compostable%20plastic-German%20study.pdf

materials would probably not yield more favourable results than incineration in a LCA because that would require high-quality use of the compost in addition to utilizing the biogas."

c. "According to [Pladerer et al. 2008], PLA material does not contain any plant-available nutrients and does not contribute to building a soil structure. Composting PLA would therefore have to be considered as disposal only. According to the LCA calculations, composting shows less favourable results than waste incineration.

58. What is the point of bio-based "compostable" plastics if they cannot be made into compost (because they are required by EN13432 to convert to CO2 gas within 180 days), if they should not be sent to landfill (because they can generate methane in anaerobic conditions), if they cannot be recycled with ordinary plastic, if they are not really renewable (because fossil fuels are used in the agricultural and polymerisation process, and some of them actually contain oil-derived materials), if they use scarce land and water resources, and if they are more expensive and less versatile?

QUESTIONS

The OPA responds as follows to specific questions asked by the Commission:

Q(17) Should market-based instruments be introduced in order to more accurately reflect environmental costs from plastic production to final disposal?

Q(18) How can the waste burden posed by short-lived and single-use disposable plastic products best be addressed?

A(17&18) A tax should be put on short-life items which are not oxo-biodegradable, so as to reduce the environmental burden by encouraging plastics which will not lie or float around for decades if they get into the environment.

Q(19) What are the applications for which biodegradable plastics deserve to be promoted, what framework conditions should apply?

A(19) There is no case for promoting bio-based plastics - see 47-54 above. Oxo-biodegradable plastics should be promoted for all short-life items made from

PE, PP, or PS. They should be tested for degradability, biodegradability, and eco-toxicity according to test methods prescribed by BS8472 or ASTM D6954.

Q(20) Would it be appropriate to reinforce existing legal requirements by making a clear distinction between naturally compostable and technically biodegradable plastics, and should such a distinction be subject to mandatory information?

A(20) A clear distinction should be made between oxo-biodegradable and hydro-biodegradable plastics, and CEN should be required to develop a Standard for oxo-biodegradable plastics comparable to BS 8472 and ASTM D6954. There are no "naturally compostable" plastics because they cannot be made into useful compost – only into CO_2 gas. Composting is disposal, not recovery.

Q(21) Would the use of oxo-degradable plastic require any kind of intervention with a view to safeguarding recycling processes, and if so, on which level?

A(21) No, but recycling does need to be safeguarded against bio-based plastics - See 26-32 above.

Q(22) How should bio-based plastics be considered in relation to plastic waste management and resource conservation? Should the use of bio based plastics be promoted?

A(22) There is no case for promoting bio-based "compostable" plastics. They cannot be made into compost (because they are required by EN13432 to convert to CO_2 gas within 180 days), they should not be sent to landfill (because they can generate methane in anaerobic conditions), they cannot be recycled with ordinary plastic, they are not really renewable (because fossil fuels are used in the agricultural and polymerisation process, and some of them actually contain oil-derived materials), they use scarce land and water resources, and they are more expensive and less versatile.

Q(23) What actions other than those described in this Green Paper could be envisaged to reduce marine litter? Should some marine litter related actions be coordinated at EU level (e.g. by setting up a coordinated European Coastal Clean-up Day to raise awareness)?

A(23) **Efforts to reduce marine litter should of course continue, but it is unrealistic to expect that they will ever prevent all the plastic from getting into the oceans. The EU seems to be in denial about this. The EU should do what other countries have done in Asia, Africa, and the Middle East and require all short-life plastic products to be oxo-biodegradable. If they do get into the oceans they will not float around for decades. The Packaging Waste Directive needs to be amended to require all plastic packaging to be made from Controlled-life oxo-biodegradable plastic.**

ANNEX

<u>Response to "EuPC Answers to the EU Green Paper on plastic waste in the environment."</u>

The Oxobiodegradable Plastics Association was surprised by the description of oxo-biodegradable technology in Section 2.21 of the EuPC Answers to the EU Green Paper on plastic waste in the environment. Their now familiar description of the technology as *oxo-fragmentation* demonstrates both an ignorance of the complex degradation process and of the fact that oxo-biodegradable technology has been understood and accepted since the 1970’s.

The European Normalisation Organisation (CEN) has defined the oxo-biodegradation process (in TR13531) as *degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively,* but EuPC seem not to have appreciated the role of cell-mediated phenomena - ie consumption by micro-organisms.

It is difficult to understand how the negative attitude of the leadership of EuPC toward oxo-biodegradable plastic can serve their members, whose factories make products from plastic film. Oxo-bio can easily be used by them with their existing machinery and workforce, and it defends them against the often-heard criticism that they are making products which will lie or float around in the environment for decades if they escape into the open environment. Plastics converters in Europe and around the world are already using oxo-bio technology, and it is very much in the interests of EuPC members that they engage with the oxo-bio industry for their mutual benefit and the benefit of the environment.

Respected Standards Institutions such as ASTM (ASTM 6954-04), BSi (BSi 8472) and AFNOR (N503-T54U and T51-808) have written standard test methodology to measure oxo-biodegradation and confirm that it does degrade and biodegrade and that it is non-toxic.

Independent testing of commercial samples of OXO'-TECHNOLOGY plastics has also routinely shown that these materials can be formulated to degrade rapidly to molecular-weight (Mw) values of well below 10,000. As an example, Fig. 1 shows the reduction of Mw for a commercial PE film aged according to the requirements of ASTM D6954.

The requirements of ASTM D6954 Tier 1 (Mw <5000) and the UAE Standard 5009/2009 (Mw<5000 in no more than 4 weeks) are achieved within 360 h of exposure, with the Mw falling from an initial value of 139,000 to 970 in 1392 hours. It is notable that the initial polydispersity index (Mw/Mn) fell from 8.6 to 2.3, consistent with completely random scission of the polymer chains.

A plastic is defined by ASTM D883 as "a material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight…." Accordingly, no scientist would describe a material with a molecular weight as low as 5,000 as a fragment of plastic.

For EuPC to make unsubstantiated claims related to " *risks of micro-plastics entering the environment, leaching of additives in the environment etc"* when referring to oxo-biodegradability is irresponsible. The environment is much more likely to be polluted by fragments of the conventional plastic products produced by members of EuPC, which will lie or float around as fragmented pieces of plastic for decades before they finally degrade.

The governments of the following countries carefully considered oxo-biodegradable technology as an option for dealing with the problem of plastic waste which escapes into the open environment. They then passed legislation which makes it mandatory to use the technology :- Pakistan, United Arab Emirates, Morocco, Mauritania, DR Congo, Mali, Togo, Cameroun, Yemen, Iran, Slovenia, Serbia, Montenegro, Albania, Ecuador, Brazil (part) and Argentina (part). Other countries will be following their example.

Plastics converters in Europe will not be able to export to those countries unless their products contain oxo-bio technology.

All polymers derive their mechanical properties, especially toughness, from the entanglement of their long molecular chains. Polymer chains long enough to confer useful mechanical properties are usually too large to be able to cross the cell walls of bacteria, algae, or fungi.

All polymer biodegradation thus requires that there be some extra-cellular chemical process to cleave the chains and to release them from the entangled mass as components small enough to be transported into the microbial cell and metabolised. Also to add oxygen as organic functional groups and to shift from a non-polar to a polar behaviour.

There are two well-recognised biodegradation pathways for plastics, hydro-biodegradation, and oxo-biodegradation. The hydro- and oxo- prefixes are inserted to emphasise that biodegradation of a plastic always involves two stages, and both mechanisms are influenced by the environments to which the materials are exposed. There is nothing in nature to exclude oxidative scission as a precursor to biodegradation, and it is in fact the way nature disposes of both natural rubber latexes and the lignin fractions of wood, straw, and other plant matter.

Oxo v Hydro

Apart from the basic distinction between hydrolytic and oxidative cleavage, the main differences between Oxo' and hydro' technologies are;

a) The lifetime of an Oxo' polymer, before biodegradation starts, can be regulated by varying the stabiliser/ pro-oxidant ratio. However, hydro' polymers begin to degrade as soon as they are exposed to moisture. Premature failure of hydro' plastics in moist conditions has been a common problem for the industry, especially in food packaging.
b) Because of the induction-period required for oxidation to produce biodegradable materials, biodegradation of an Oxo' material is inevitably slower than that of a hydro' material. Although this excludes Oxo' plastics from applications requiring, or merely specifying, very rapid bio-assimilation, there are also many applications where the rapid and uncontrolled biodegradation of hydro' plastics is a problem.

In summary, the basic technology of an Oxo' material involves:

a) An induction period during which oxidation catalysis by the pro-oxidant(s) is prevented by the stabilisation package. *During this period there is no change in the structure, properties, or performance of the polymer but the stabilisers are being consumed.*
b) A rapid oxidation of the polymer during which chain-scission produces low molecular-weight materials, which are oxidised, hydrophilic, denser and polar.
c) A period of bioassimilation of the oxidised materials, leading to mineralisation to CO2 and biomass.

It is important to emphasise that these are overlapping processes. Once significant oxidation starts, it is faster in biotic than in abiotic environments, so that predictions from laboratory testing will tend to under-estimate the speed of degradation in natural environments. In nature the degradation and biodegradation act synergistically and enhance the overall process speed, as enzymes released by microbial activity will accelerate the oxidation process of the polymer.

The mechanism of oxidation has been the subject of innumerable studies since the pioneering work of Bolland and Gee in the 1940s on oxidation of rubbers. The peer-reviewed work of Ohtake's group in particular [1-4] has shown that "biodegradation of thin LDPE film in soil was unexpectedly fast because of the synergistic action of oxidative degradation on biological activity, which is probably due to the increasing hydrophilicity of the film surface."

Figure 1 also shows data for a commercial PP film. The requirement of Mw <5000 is achieved within 960 h of exposure, with the Mw falling from an initial value of 360,000 to 4290. The initial polydispersity index (Mw/Mn) fell from 7 to 2, again consistent with completely random scission of the polymer chains. Other independent studies are available and are appended as Annex 2 #3, and #4. All show the same behaviour; the initially high Mw of PE or PP is rapidly reduced to below 5000 by aerobic oxidation.

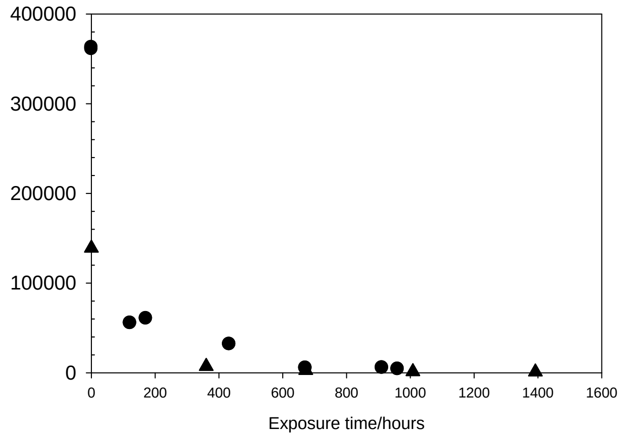

Fig. 1: Mw v time data for commercial Oxo'technology films aged as required by ASTM D6954 (▲= polyethylene; ●= polypropylene)

It is important to recognise that the breakdown of a polyolefin to oxidation-induced embrittlement is not simply scission in the sense of breaking the film into pieces. It happens because the molecular-weight of the polymer is reduced to the point where it is no longer sufficiently entangled to be able to impart any strength. Because this molecular- weight reduction is caused by oxidative chain-scission it leads to materials which not only have low molecular-weights but are also significantly polar.

In their original study [7], Chiellini et al., studied oxidation of a commercial oxo' film, without any pre-treatment. The LDPE film was thermally degraded in air in an oven at 55 °C for 44 days. As shown in Fig. 2, the weight of the sample increased due to oxygen absorption, but, more significantly, at the end of oxidation the weight fraction soluble in acetone had risen to over 25%;

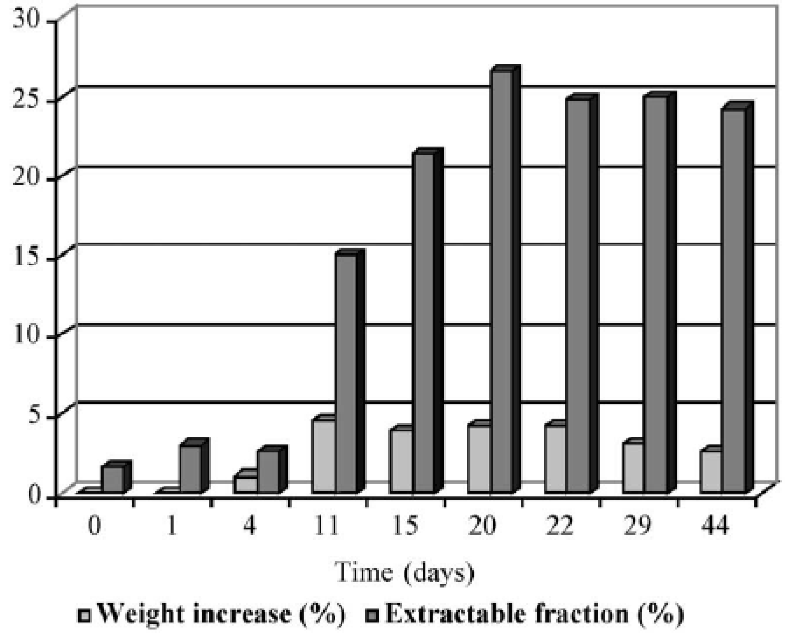

Fig. 2: Increase of dry weight and acetone extractable fraction of LDPE film with thermal degradation at 55°C [7].

Similar results were obtained by the same authors [8] in a study of thermal oxidation of several commercial oxo'technology films of LDPE at different temperatures (Table 1); acetone soluble fractions of up to ca. 30% were recorded.

Sample	CO_i[a]	Acetone extract		
		(%)	Mw[b] (kDa)	ID[b]
FCB-ZSK10	0.453	6.5	1.52	1.49
	0.534	7.7	1.47	1.46
	3.583	17.9	1.30	1.39
	6.816	27.1	0.92	1.32
FCB-ZSK15	0.212	5.9	1.58	1.46
	2.864	9.2	1.67	1.52
	5.193	23.8	1.27	1.43
	7.256	22.6	1.03	1.36
LDPE-DCP540	0.627	5.5	1.08	1.27
	2.243	11.3	1.49	1.41
	4.818	21.1	1.08	1.37
	5.441	27.7	0.89	1.33

[a] Evaluated by FT-IR as $D_{B1640-1840}/D_{B1435}$.
[b] Determined by HT-GPC.

Table 1: Relationship between carbonyl index (COi) and percentage extractable with acetone from original and thermally treated LDPE film [8].

PE is insoluble in acetone and these high weight fractions of extractable material, coupled with their low molecular weights and high carbonyl content as measured by FTIR, show that this material is no longer in any real sense PE; it is a highly oxidised and polar material.

These highly oxidised fractions are highly biodegradable. Fig. 3 shows mineralisation data obtained in soil burial experiments at 25 ^{o}C [7, 9]. They clearly show that these polar, oxidised fractions are as biodegradable as cellulose, the material used as a positive standard in biodegradation testing.

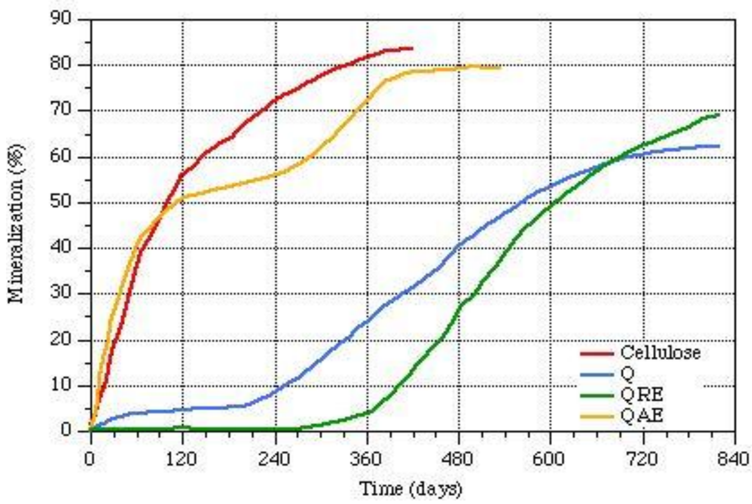

Fig. 3: Mineralisation in soil burial at 25 ^{o}C. QAE is the acetone extract from an oxidised LDPE film. [9]

Timescale of oxidative breakdown;-

There is robust peer-reviewed evidence that:

a) Commercial oxo'technology films do degrade by oxidative chain scission to produce low molecular weight products.
b) The products of oxidation are highly biodegradable.

The remaining issues are:

a) What is the timescale of the oxidation in real-world applications? and;
b) What is the evidence for completeness of biodegradation?

The paper by Jakubowicz et al., [10] used the Arrhenius approach to predict that their Mn-activated samples would have degraded to the point of biodegradability in between 2.5 and 4.5 years. It is important to recognise that the oxidative lifetime of any oxo'technology material depends upon the amounts of antioxidant and of pro-oxidant incorporated, and that lifetimes can be variable depending upon the formulation. This is a major strength of oxo' technology; it allows a sensible period of storage and useful life without degradation and it allows the material to be recycled with normal plastics during that period of time.

There are good reasons for believing that oxo' materials can be made to degrade in shorter times. In one recent paper [11], Ojeda et al studied degradation of a commercial HDPE/LLDPE blend containing a pro-oxidant additive and taken from the market as a supermarket bag. They showed that oxidation reduced the weight-average molecular weight from its initial value of 183,000 to 8300 after only 280 days of outdoor exposure.

Jakubowicz [12] recently presented data derived from testing of some commercial oxo' films using Mn-based pro-oxidant. As in previous work, they aged the samples thermally, in the dark at slightly elevated (40 to 75 ^{o}C) temperatures and used the Arrhenius equation to predict lifetimes to oxidative failure at 25 ^{o}C ranging from 65 to 330 days (Fig 4).

It should be noted that:

a) This data was produced at SP laboratories in Sweden, a Government-accredited independent testing body with no connection to commercial producers of oxo'technology products.

b) the samples used were commercial products, and

c) the predictions of lifetime are in agreement with actual test data in soil exposure (discussed below).

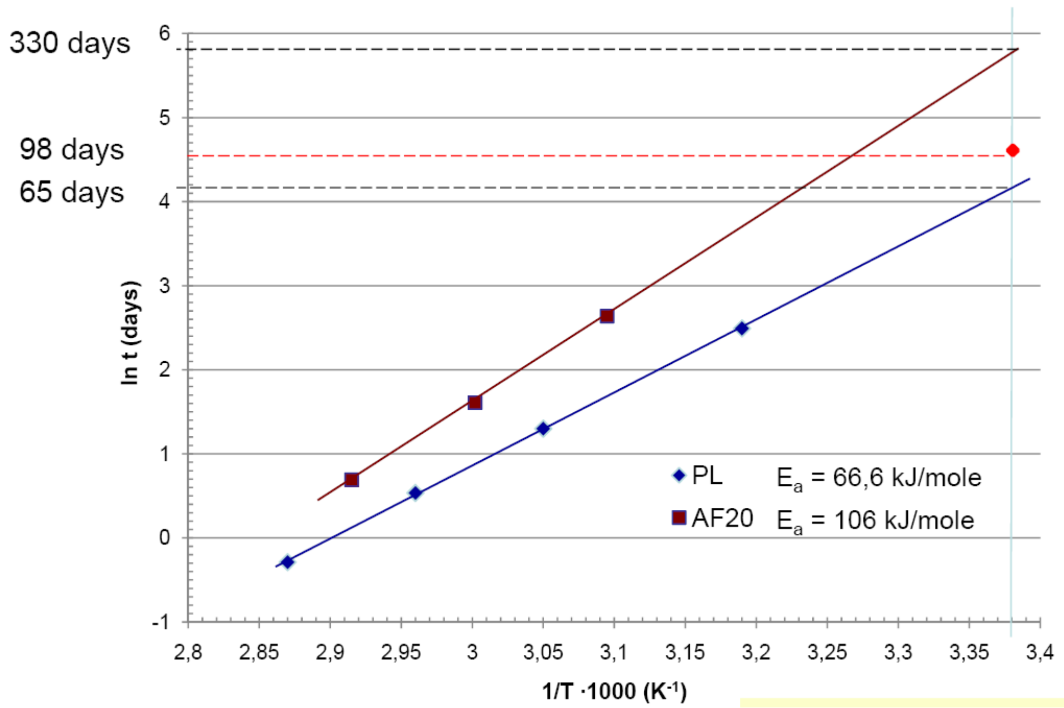

Fig. 4: Arrhenius plots for degradation of commercial oxo'technology films. Reproduced with permission from [12].

Corti et al. [6] showed that once a commercial mulch-film sample exposed to light began to oxidise, subsequent oxidation was significantly faster in a biotic than an abiotic environment at 23 ^{o}C. They suggest that abiotic oxidation of the polymer's carbon backbone produced metabolites which supported metabolic activities in fungal cells leading to further biotically-mediated polymer degradation. Thus, the combined impact of abiotic and biotic factors accelerated the oxidation/biodegradation of the films.

A similar study formed part of an evaluation of commercial materials, conducted by Chiellini's laboratory at the University of Pisa in Italy. FTIR measurements of oxidation in an oxidised oxo' film which had been incubated in the presence of an organism (*S. griseus*) capable of secreting oxidising enzymes showed that the material underwent significant oxidation as compared to the same film without exposure to the micro-organism.

These results clearly show that oxo'technology materials can be degraded by oxidation to the point of total embrittlement at ambient temperatures in periods of less than a year if formulated for that purpose.

Biodegradation and Composting

One false impression is that biodegradability and compostability are the same thing. This is far from true. The environment of an industrial composting facility is quite different from that to which oxo' polymers are expected to be exposed in the open environment for which they are designed. The temperatures, the moisture, and the likely microbiological activity are quite different.

EN 13432, ASTM D6400, and other composting standards were developed to place a very high barrier to the entry of any plastic into industrial composting and, as far as we are aware, no reputable manufacturer makes claims of compostability for oxo' plastics.

It is important to note the "compostable" plastics conforming to EN 13432 or ASTM D6400 cannot be made into compost. This is because those standards require them to convert rapidly to CO2 gas, which is emitted as a greenhouse gas to atmosphere, leaving nothing of any value for the soil.

The most likely disposal routes for oxo' plastics are recycling, landfill and soil surface exposure/burial (litter and Agricultural, horticultural and soil remediation applications), so that degradation in soil-contact is much more relevant.

Because of market requirements, commercial oxo' materials have been independently tested in several countries. For example, there is a report from the Chemical Industry Institute of

Shihezi University, China, on the performance of a PE mulching film. The material was recovered from a field after one growing-season and tested according to ISO 14855:1999 in a controlled composting environment; it was shown to reach 77% conversion of carbon to CO_2 in 45 days. Another report is from the China National Centre for Quality Supervision and Testing of Plastics Products, on the testing of oxo-biodegradable polypropylene lunch boxes, again to ISO 14855:1999, after pre-oxidation in a controlled composting environment. The requirement was for 30% conversion of carbon to CO_2, hence the test was stopped when this was achieved. This material achieved 33% conversion in 126 days.

In the work of Chiellini et. al. on a commercial material, presented in Annex 2 #5, respirometric measurements of CO_2 production from an oxidised oxo' film which had been incubated in the presence of a micro-organism (*S. griseus*) showed that biodegradation was very much faster than that of the same film without exposure to the micro-organism, reaching 80% of the theoretical CO_2 yield in 130 days of soil exposure at 28 ^oC. This result was attributed to the demonstrable increase of oxidation by the biological attack by the micro-organisms once the oxidation had been initiated by thermal ageing.

Jakubowicz [13] has also shown that some oxo' plastics may degrade more slowly in active composting than in air. The published studies by Chiellini et. al. show *faster* bioassimilation of OXO'-TECHNOLOGY plastic in soil at 25 ^oC than in compost at 58 ^oC and the most recent work of Jakubowicz, reported below has confirmed this.

Studies by Jakubowicz et al in soil according to ISO 17556 support the results of Chiellini about faster bioassimilation in soil than in compost; when the same samples were tested in soil at 25 ^oC (Fig. 5), they had an induction time of around 300 days then achieved 80% mineralisation in a further 300 days. *The final mineralisation after 700 days was 91%.*

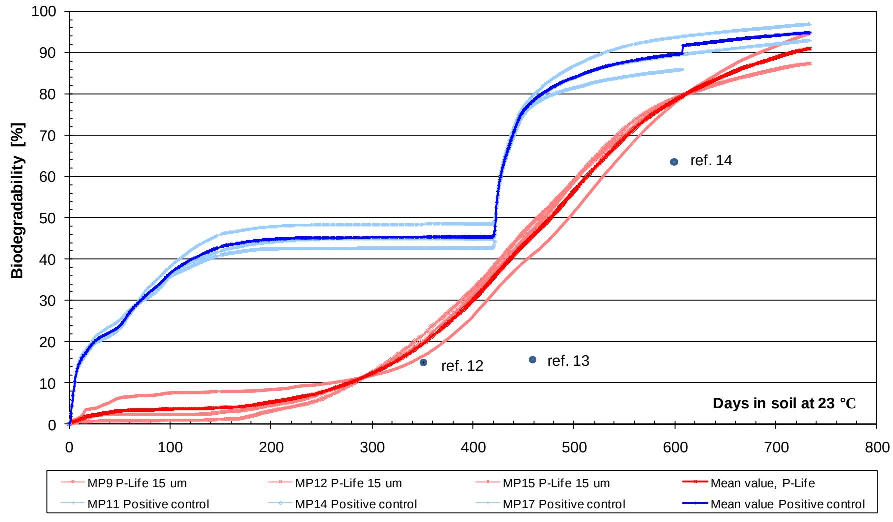

Fig. 5: Compost mineralisation of commercial oxo'technology films. Reproduced with permission from [12, 14].

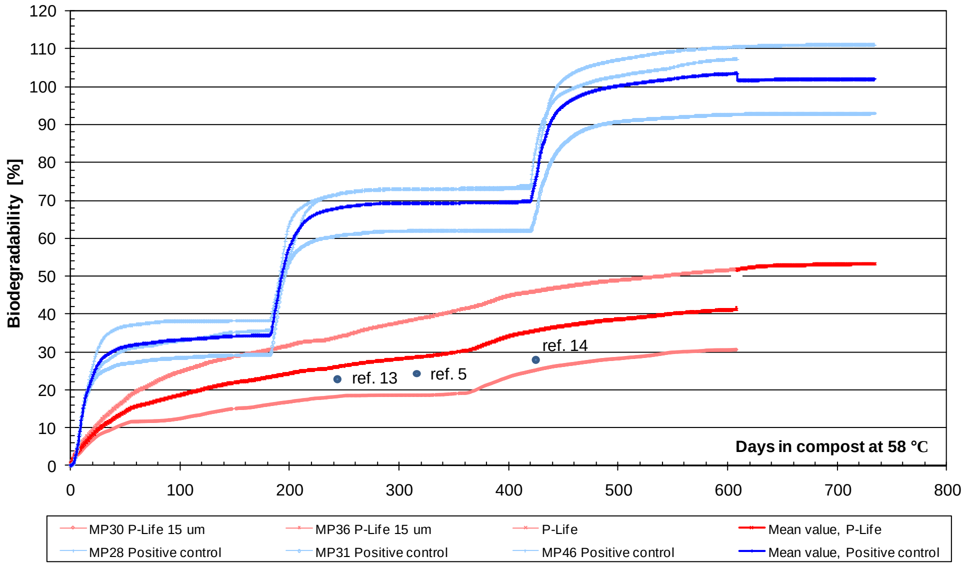

Fig. 6: Soil burial mineralisation of commercial oxo'technology films. Reproduced with permission from [12, 14].

A study of the bacterial and fungal populations of the soil and compost suggested that there were distinct differences which accounted for the ability of the soil microbes and fungi to metabolise the plastic more rapidly than in compost.

Given that these results were obtained by a wholly independent Government accredited Laboratory of the highest reputation, using commercially sourced samples, it is worth quoting from the conclusions in ref. [14]:

"After two years in the soil mineralization experiment, 91% biodegradability was achieved without reaching a plateau phase. *This result has two important implications. The most important one is that it is possible to create LDPE based materials that will almost completely biodegrade in soil within two years. It also indicates that the risk of plastic fragments remaining in soil indefinitely is very low*.

Recyclability

With regard to recycling, mentioned at para. 2.12 of the EuPC paper, it is well known that if oxo-biodegradable materials are collected for recycling during their useful life, they will not interfere with the process. See http://www.biodeg.org/position-papers/recycling/?domain=biodeg.org There is no need to keep them separate from normal plastics in the waste stream.

It is equally well established that bio-based “compostable” plastics can not be recycled with ordinary plastics and EuPc are correct that even a 2% contamination can affect the quality of the recycled plastic.

In the UK shopper bags produced in oxo-biodegradable material for Tesco and Co-Op were successfully recycled. The influence of anti-oxidants and stabilisers in polyolefin is a highly significant aspect of the processability and final performance of finished plastic products, and a full understanding of their relevance will inform an observer of the real-life performance of oxo-biodegradable materials in the recycling stream.

The length of the useful life of an oxo’ plastic product is determined by the ratio of the concentrations of the antioxidants and of the pro-oxidants contained in the particular formulation, which can be modified so that the plastic product degrades according to whatever approximate timescale is required.

It is important to recognise exactly what is happening in an oxo’technology plastic in the early stages of its life. As in all plastics, the presence of traces of peroxides initiates radical reactions in the material and this is accelerated by the pro-oxidant catalyst in an oxo’technology material. The main effect of the antioxidants is to trap these radicals and prevent their attack on the polymer. *Until the antioxidants are consumed and oxidation of the polymer starts, there is no change in the polymer.*

Obviously if *any* plastic is to be recycled it must be collected and processed before it has become degraded. Oxo’technology products will normally have a useful life before embrittlement of at least 18 months, and if they have not been collected and recycled by then, they probably never will be.

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