EPI Environmental Products Inc.

8th Floor, 1788 West Broadway, Vancouver, BC, V6J 1Y1, Canada
+1 (604) 738 6281 www.epi-global.com

EPI's Response to DEFRA/Loughborough Report on Oxo-Biodegradable Plastics

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NOTE: All of the discussion of specific materials below refers to oxo-biodegradable PE films based on EPI technology, here denoted OBPE-EPI.

The recent report commissioned by Defra from a group at Loughborough University is extremely disappointing. Given that it carries the logo of a UK Government department, comments on a significant business both in the UK and worldwide and can be expected to have significant impact, it was surely incumbent upon Defra to produce the best possible analysis of the performance and impact of OBP materials. Instead, they chose to contract the work to a group with no experience in polyolefins or in biodegradation and to limit discussion with people with real expertise. The result is a document which shows significant failures to understand the technology, contains significant numbers of wrong and misleading statements and fails to acknowledge some significant contributions.

In producing the report, Defra chose not to allow any comment or review by those who are most affected by it. Instead, it was peer reviewed by people who have significant commitment to bioplastics and could not be expected to review it in an unbiased manner. This is a great pity because it would have been easy to produce a much better report without significantly more effort or cost; any of the many stakeholders could have corrected some of the errors and omission and provided more data. As it is, we can only conclude that this is a politically-biased exercise rather than one designed to be a disinterested analysis of the benefits of the technology.

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a. Chairman & CEO, EPI Environmental Products Inc.
b. Emeritus Professor of Chemistry, University of Sussex (UK)
c. Professor, Dept. of Chemistry and Industrial Chemistry, University of Pisa (Italy)
d. Consultant, formerly Senior Fellow – ICI, Rohm and Haas, Assoc. ed. "Biomacromolecules" (USA)
e. Consultant, formerly Director-General, Chemistry Division, National Research Council, (Canada)
f. Director of Research at the Institute of Physical Chemistry of the National Centre of Scientific Research Demokritos and Director of Graduate Studies at the same Institute (Greece)

Some of the many errors and omissions in the report include:

Abiotic degradation of OBPs in the outdoor environment

The authors clearly acknowledge that OBPs do degrade to embrittlement in the outdoor environment though they confuse embrittlement and biodegradation. They criticize OBP materials on the basis that "The length of time to degradation cannot be predicted accurately because it depends so much on environmental conditions". This is a truism for all materials; scientists have been attempting for decades to make lifetime predictions for materials exposed outdoors and have largely failed. It is equally true for any attempt to make lifetime predictions for bioplastics in outdoor exposure.

It is actually easier to make predictions for OBP materials than for conventional polymers because the lifetime is so much shorter that it can be estimated under controlled conditions by extrapolation from much less accelerating conditions than are needed for long-life products. The statement that "it is likely that oxo-biodegradable plastics will start to degrade between 2-5 years in the UK" is simply wrong; even in the landfill studies quoted, OBPE-EPI materials were degraded to complete embrittlement in less than a year under cool, burial conditions. The peer-reviewed work of Chiellini on OBPE-EPI material showed total embrittlement in less than 10 days at 55^{o}C in the dark, at which point the material was so degraded that 25% of its mass was soluble in acetone and as biodegradable as cellulose; no PE which performs like this in the laboratory could possibly survive for 5 years in the outdoors in typical UK exposure. Equally, the authors seem to be unaware of the published data for the Envirocare™ products marketed by Ciba (now BASF) which show times to complete embrittlement variable between 30 and 300 days in outdoor exposure in soil contact in Italy depending on the additive formulation.

Bio-accumulation of Residues in the Environment

The authors of the report claim that "there is any lack of evidence on the fate of oxo-biodegradable plastics in the environment" and that "No evidence was found in this study that oxo-degradable fragments have a harmful bio-accumulative effect but neither was there evidence that they do not".

This is simply not consistent with extensive experience. OBP films are not new technology; they have been in continuous use since the mid 1970s and one of their major applications has been as agricultural mulching films. It is only recently that the use of these materials has become controversial due to their wider market penetration and a sustained attack by producers of more expensive products.

Although EPI does not market its own additives in this area, we are fully aware of the many studies which have been performed on OBP materials in agricultural applications, and which have been published in peer-reviewed articles. Mulching films have been used continuously and successfully since 1975 in many countries and no evidence of bio-accumulation, "plastic dust", ecotoxicity or reduced soil fertility has ever been found.

Agricultural mulching films produced using EPIs additives and modified EPI formulations have been marketed by Ciba (now BASF) for some years and no evidence of bio-accumulation has been reported. Ciba's Envirocare™ technology received the "*New Technologies in Materials Award"* at the Society of

Plastics Engineers Global Plastics Environmental Conference in 2006. These films are in widespread and successful use.

Oxo-biodegradation of OBP films in Landfill

Evidence for the abiotic oxidative degradation of OBPE – EPI films in operating landfills during the winter in three countries has been published in the peer-reviewed literature. Data from all of these investigations show significant aerobic microbial activity, major oxidation and major decreases in physical properties of the plastics and, in the case of the landfill near Birmingham, proof of a major reduction in molar mass. Although no measurements of biodegradation of the degraded plastics were (or could have been) made, it certainly would have been occurring. The authors/reviewers of the Loughborough report criticize the scatter of data points in the Birmingham study. This is ludicrous in view of the practical difficulties of operating in a working landfill, especially during an unusually wet, cold winter.

There is no justification whatsoever for the statements in the report that there is a "lack of evidence about what actually happens to oxo-biodegradable plastics in a landfill" and "the most likely scenario is that they remain undegraded." These unsupported, incorrect statements do not coincide with the facts. Perhaps they reflect the biases and inadequate expertise of a majority of the authors/reviewers.

In section 6.11 Annex B4 "Results of a landfill trial in Wisconsin…" we are shown a series of photos of a composting site. This has nothing to do with landfill disposal of oxo-biodegradable plastics, nor is the lack of degradation of OBPs in any way surprising as they were never formulated to degrade in that environment.

Compatibility of Oxo-biodegradable PE films with Conventional Recycling

The Loughborough report states that "the uncertainties surrounding the effect of oxo-biodegradable plastics on the conventional plastics recycling process means that the safest solution is to keep oxo-biodegradable plastics out of the mainstream plastics recycling process." This statement is clearly invalid in the case of OBPE – EPI.

The lifetime of any OBP product before the onset of rapid oxidation to embrittlement is controlled by the ratio of the pro-oxidant and antioxidant concentrations. Up to the point where the antioxidant is completely depleted and oxidation of the polymer starts, there is no change to the polymer structure. If the plastic is included in a recyclate stream before degradation starts, it will take with it its pro-oxidant. However, the bulk of the plastic will contain antioxidants but not pro-oxidant. The result is that the pro-oxidant effect is completely swamped by the massive excess of antioxidant.

This effect was unequivocally demonstrated in the third-party study commissioned by the Government of the Province of Quebec, where it was shown that carrier bags made from OBPE – EPI plastic are entirely compatible with conventional plastics recycling, at mixture levels up to 50%. The physical properties of both relatively thick moulded samples and of blown films were equal to those prepared from the normal recycled plastic. In contrast, when the conventional recycled plastics stream was mixed

with either of the commercial bag materials made from hydro-biodegradable plastics (compostable according to ASTM D6400) it was not possible even to prepare a blown film.

Concern is expressed in the Loughborough report about the possibility of including partially degraded oxo-biodegradable PE in the conventional plastics recycling feedstock. This could happen but the result will be equivalent to the inclusion of partially degraded conventional PE, which must have happened already numerous times. As described earlier, the degraded material (oxo-biodegradable PE or ordinary PE) will be significantly diluted by non-degraded PE containing antioxidants. A simple ASTM test measures antioxidant, the presence of which will prevent pro-degradant additive from catalysing oxidative degradation. For short service life products made from recycled plastics, it is most likely that no extra antioxidant will be needed. For products that need to function for some years, antioxidant may need to be added – but this is the case even in the absence of any oxo-biodegradable PE in the recycle feed.

Perhaps the authors/reviewers in doing the required revisions to their Loughborough report should consider adding the recommendation that compostable plastic bags need to carry the warning that they must not be included in conventional plastic recycling collections. This could be placed alongside the warning that these compostable bags are not suitable for home composting.

Composting and Biodegradation

There are two well-recognized biodegradation pathways for plastics, hydro- and oxo-biodegradation. The hydro- and oxo- prefixes are inserted to emphasise that biodegradation of a plastic is always a two-stage process and both mechanisms are influenced by the environments to which the materials are exposed.

Both types of biodegradable plastics are important in being designed to ensure plastics are environmentally benign after their disposal. Hydrobiodegradable plastics generally, but not always, biodegrade completely to CO_2 within a short time and meet ASTM D 6400 and EN 13432 standard specifications for compostable plastics. OBPs, on the other hand, degrade more slowly by oxidation to fragments that biodegrade. A standard testing guide is now available from ASTM in D 6954 for testing these plastics using a battery of standard methods to follow both abiotic degradation and biodegradation.

A fundamental problem of the Defra report is that it uses the D 6400 or EN 13432 compost specification standards as the yardstick to conclude that OBPs are not biodegradable because they do not conform to this specification. The report correctly points out that the biodegradation of any material should always be qualified by rate, time and conditions of exposure. Hence, it is true that compostable plastics are plastics that biodegrade to D 6400 specifications in the time frame of an industrial composting process. However, it is equally true that plastics that do not meet composting standards may be perfectly acceptably biodegradable in other environments.

Industrial composting is a process for rapidly biodegrading organic materials under controlled conditions in a specified short time. The composting industry has been rightly concerned about the possibility of

plastics as contaminants in its products and D 6400 and EN 13432 are both designed to place a very high barrier to the entry of any plastic into industrial composting.

It is perfectly possible to formulate OBPs so that they will embrittle, fragment and vanish during the high-temperature, in-vessel phase required of all industrial composting in the EU. However, current OBPs were not developed to be composted and EPI, fully recognising the concerns of the compost industries, makes no claims for compostability of its products.

Other applications, like carrier bag film, require a longer lifetime before degradation begins and are formulated accordingly. Unfortunately, many people who should know better fail to recognise the distinction. As just one example, the Defra report places significant weight on a study (Annex B1) published from the University of California, which concluded that OBPs were not biodegradable. The report's authors fail to recognise that the OBP film used was never formulated or claimed to degrade under the conditions of open windrow composting and would not have been expected to show any degradation, so that the results are meaningless. Much the same is true of most of the pictures cited in the report as evidence for non degradation. The films used were never formulated or claimed to degrade under the conditions tested; they are intended to have a useful life, to be recyclable and to degrade only on ultimate disposal. A fundamental advantage of OBPs is this ability to delay the onset of degradation to allow a useful service life.

EPI fully recognises the need for proper standards for testing and specifying the performance of OBPs. It is frustrating that the bioplastics industry has consistently opposed the development of such standards both in the EU and the US. The landmark standard for OBPs is ASTM D 6954 which is a Standard Guide for testing plastics that degrade in an environment by multiple steps. It includes toxicity testing at all degradation stages to ensure that partial or slow biodegradation does not introduce toxicity issues. The Standard Guide references existing standards that may be used at each degradation stage to determine extent and rate of degradation, and commits to further standards development or improvements where needed. A standard method is currently in development for landfill environments and will permit quantification of landfill degradation of all plastics. Other standards are anticipated to follow, particularly standard specifications for oxo*(bio)*degradable plastics in a given environment. This will differentiate oxobiodegradable from hydrobiodegradable plastics and set expectations of performance. EPI is fully supporting these efforts.

The authors of the Loughborough report are critical of the work of Prof. Chiellini of the University of Pisa. Prof. Chiellini is an acknowledged world expert on biodegradation and we understand that he intends to comment separately on the misrepresentation of his conclusions in the report. However, it is important to point out that the reproducibility of biodegradation of OBPE-EPI is established in Prof Chiellini's work through multiple experiments. In addition the authors appear to have neglected a key point established in his work, in that the carbon balance with formation of soil microbial cell biomass is not mentioned. This is a very important point in favour of the use of OBPE-EPI, which contrasts with the statement of the reporters on the detrimental effect on soil by the accumulation of oxidized PE fragments; in fact his work clearly shows that the biodegradation of OBPE fragments in soil results in fixation of organic carbon as biomass, exactly opposite to the fast mineralisation of hydro-biodegradable polymers to CO_2 in a form of bio-incineration.

Bio-accumulation of Residues in the Environment

The Loughborough report comments on the presence of plastic wastes in the Pacific Ocean and the alleged accumulation of toxins on discarded polymer pellets. This whole section (6.4.4) of the report is utterly irrelevant and the implication that OBPs could possibly be blamed for the accumulation of waste plastics in the oceans is nonsense. The major source of waste in the oceans is deliberate or accidental dumping from ships and it is highly doubtful if any of this plastic is OBP materials.

Non-validity of the 'Key Findings'

A number of the so-called key findings listed in the Summary of the Loughborough report are wrong, irrelevant or misleading. As an example, let's look at the 1st bullet under 'a', ….."it is likely that oxo-biodegradable plastics will start to degrade between 2 – 5 years in the UK." That time period estimate is much too long. After use, re-use and disposal, the onset of degradation of OBPE – EPI in a landfill, as an example, is much sooner.

The inclusion of the 2nd bullet under 'a' - reference to composting and EN13432 – is gratuitous and irrelevant. The authors seem desperate to include consideration of composting at every turn, which really reduces the credibility of the report.

The third bullet under 'a' again refers to composting. It goes on to say that the term biodegradable in oxo-biodegradable is "meaningless and potentially confusing to consumers" because "all types of plastics are likely to biodegrade given enough time." That is precisely why the correct (non-confusing) term for products like OBPE – EPI is "oxo-biodegradable", so that the consumer will know that such materials are quite different from all other types of plastics.

Oxo-biodegradable plastics provide many environmental benefits compared to ordinary polyolefins. These benefits have been summarized in several articles of which the authors/reviewers are aware.

In summary, the Loughborough report falls well short of its intended goal to provide a thorough review of OBP technology. In the end, it is a biased report that serves only to propagate misconceptions and misinformation about oxo-biodegradable plastics, and provides a disservice to those seeking to understand the benefits of the technology.