



# EPI Environmental Products Inc.

8<sup>th</sup> Floor, 1788 West Broadway, Vancouver, BC, V6J 1Y1, Canada  
+1 (604) 738 6281 [www.epi-global.com](http://www.epi-global.com)

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## **CORRECTIONS to the BPI's "Background on Biodegradable Additives"**

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The position statement by the Biodegradable Products Institute (BPI) contains many incorrect statements and misleading implications.

What follows are corrections to some of the more blatant errors as these relate specifically to polyolefin products based on technology developed and utilized by EPI Environmental Products Inc.

It should be remembered that the BPI is NOT an unbiased or neutral arbiter of the characteristics and performance of biodegradable plastics. The BPI is constantly trying to denigrate oxo-biodegradable plastics.

1. There are numerous references in the BPI brochure to landfills as being typically anaerobic. In fact aerobic conditions persist for many months in many landfills, at least 2 meters below the surface (3<sup>rd</sup> party test are available). EPI does not claim that products made using its technology will anaerobically biodegrade completely in a landfill – indeed it is not desirable that they should do so. There is robust evidence that EPI's film products do lose all of their strength in landfills; the ensuing fragmentation is beneficial in allowing rapid equilibration and compaction of the landfill. EPI – PE will not oxidize, however, after air is finally excluded and therefore will not biodegrade anaerobically unlike the hydro-biodegradable materials (as touted by the BPI) which can continue to degrade anaerobically.
2. Apparently the BPI still does not understand the science of EPI – based polyolefins. Chain scission DOES shorten polymer chains to the point where they are biodegradable. This is an accepted fact, supported by significant peer – reviewed literature, not just a theory, as claimed by BPI. In numerous articles, it has been shown that degradation of polyolefins (PE,

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a. Chairman & CEO, EPI Environmental Products Inc.

b. Professor of Chemistry, University of Sussex

c. Professor, Dept. of Chemistry and Industrial Chemistry, University of Pisa

d. Consultant, formerly Senior Fellow – ICI, Rohm and Haas, Assoc. ed. "Biomacromolecules"

e. Consultant, formerly Director-General, Chemistry Division, National Research Council, Canada

PP) does lead to the formation of oxidized fragments, accompanied by a substantial drop in molecular weight [see for instance E. Chiellini et al., *Polym. Degrad. Stab.* **91**, 2739-2747 (2006)] and references therein. In particular, in the cited article, a strict correlation between oxidation level of PE (carbonyl index) and molecular weight of the fragmented PE is reported.

3. Perhaps the silliest notion in the BPI position statement is the incorrect suggestion the oxidized fragments of EPI – based polyolefins will stop degrading/biodegrading and persist indefinitely in soil or water. In the first place, there is no chain length or particle size limit below which oxidation chemistry stops. Conventional polyolefins oxidize relatively slowly in the environment whereas the oxo-biodegradable polyolefins produced using EPI additives oxidize much more rapidly. The products are the same, however, and degradation chemistry proceeds in both cases regardless of the size of the fragments.

Experimental observations [A. Corti et al., *Polym. Degrad. Stab.*, **95**, 1106-1114 (2010)] suggest that, during soil burial tests, pre-oxidized EPI-LDPE samples undergo an ongoing degradation process, mediated by both abiotic and biological factors. This leads to the formation of large amounts of oxidized molecular fragments capable of being assimilated as carbon sources by soil microorganisms. This can account for the two-step biodegradation behaviour that has been observed repeatedly for pre-oxidized PE films in soil. Details are presented in Appendix A.

It is also worthwhile noting that, in the computation of the biotic degradation level of the pre-oxidized fragments, one should also take into account the PE – carbon fixed by the microorganisms as new cell biomass. This aspect is particularly important in the case of the microbial digestion of hydrocarbons. In contrast, the often-noted large extent of conversion to CO<sub>2</sub> of carbon present in hydro-biodegradable “bioplastics” is indicative of substantial biocombustion of the organic carbon without any beneficial effect for the natural environment (soil).

4. There are no data which show that moisture retards the fragmentation process for polyolefins based on EPI technology. There are no data that indicate the accumulation in the environment of oxidized fragments from these oxo-biodegradable plastics. BPI is typically quoting selectively from the literature to make its case. A very small number of studies have shown that oxo materials may degrade more slowly in compost environments than in dry conditions, if the additive package is not carefully designed. Independent studies with EPI materials have shown that oxidation is not retarded by moisture, provided that oxygen is available, and that biodegradation is actually faster in soil burial than in compost testing

because of the different microbial populations. The statement that “a plastic bag that is littered in the desert will probably fragment in a few months” (correct) “yet these fragments will persist for years or longer” (incorrect) is typical of the BPI approach. The mixing of truisms with falsehoods reduces the credibility of many BPI writings to unacceptably low levels. Indeed, both statements by BPI denote a lack of knowledge of available scientific evidence. [See for instance the reference in item 3, above]

5. One false impression that permeates much of the BPI position statement is that biodegradability and compostability are the same thing. They are NOT. The standards writing organizations have separate definitions for these two characteristics. It is NOT claimed that oxo-biodegradable plastics based on EPI technology meet the compostability requirements of ASTM D6400 or EN 13432, for example. Perhaps in view of the BPI’s obsession with compostability, it should be noted that those hydro-biodegradable plastics that do meet these requirements are not recyclable in the existing commercial recycling programs. In contrast, oxo-biodegradable EPI – PE is recyclable in these programs (3<sup>rd</sup> party test data are available).
6. Many of the criticisms made by the BPI of oxo-biodegradable technology are equally applicable to the products of BPI members. Biodegradation of the hydro-biodegradable material promoted by BPI requires molecular weight reduction by hydrolysis and the materials will only biodegrade if water and a microbial population are available and the temperature is high enough to allow hydrolysis at a significant rate. In a desert environment, they are likely to persist for very long periods because of the absence of water. Equally, their degradation in a “cold, dark wet forest” is likely to be exceedingly slow as hydrolysis is strongly retarded at low temperatures (and indeed does not take place at all for some hydro-biodegradables).
7. **Standards Commentary:** ASTM standards are both useful and specific. They need to be used appropriately, of course, and it is improper to invoke their use when it is not responsible to do so. It is deliberately misleading, therefore, for BPI to invoke ASTM standards that deal with composting and compostability when discussing EPI – based polyolefins that do not claim compostability. BPI has done this repeatedly.
8. Standards relating to biodegradation and compostability in the BPI publication “Biodegradable Additives” are either specifications or methods. Specifications are the key to legislation from such government agencies as FDA. These are the most demanding standards for industry as they specify a condition that must be met for labeling which in turn has been sold to the

government bodies. Methods are the simple “do it and see” standards which can eventually lead to specifications if there is sufficient support.

9. A special issue with standard specifications in the context of the BPI position paper is that they all refer back to D 6400 / EN 13432 assuming that that these are the major relevant specifications, but they refer only to compost under a set of conditions that have been pre-assigned. They are not relevant to the marine environment, for example and certainly not to materials that compost slowly.
10. What follows in Appendix B are brief descriptions of some ASTM specifications and standard methods. It will be obvious that those which are referred to in the BPI brochure have nothing to do with oxo-biodegradable polyolefins based on EPI technology. It must be concluded that BPI is referring to such standards in the hope that the reader will continue to confuse biodegradability with compostability. Let's remember that these are NOT the same.

#### **Appendix A**

*(excerpt from a manuscript prepared for the “Handbook of Biodegradable Polymers”)*

Highly reproducible results have been obtained from several biodegradation tests carried out in soil burial biometer flasks aimed at assessing the biodegradation behaviour of thermally-oxidized LDPE film samples, i.e., EPI – PE (1). In all cases, the mineralization in soil of the PE does not show appreciable lag-phases but it tends to a first plateau at about 5-7% conversion in a few weeks. After that, a prolonged stasis (4-6 months) in the microbial conversion to CO<sub>2</sub> of the carbon in the samples has been observed repeatedly before further and markedly exponential increases in the biodegradation rate. Quite high (55-65%) degrees of C mineralization are observed (without considering the significant amount of C fixed as biomass) after an additional 18- 24 months of incubation at room temperature. This two-step biodegradation of thermally oxidized LDPE samples has been observed also in mature compost biodegradation tests.

The first exponential phase, occurring during the early days of incubation in the biodegradation of thermally oxidized LDPE in soil, could be attributed to the fast assimilation by soil microorganisms of low molecular weight oxidized intermediates (2-6). Additional support for this hypothesis is obtained from the FT-IR characterization of the LDPE films exposed for a few months to soil microorganisms during biometric tests. Indeed, a significant reduction of the

absorbance in the carbonyl region with respect to the values recorded at the beginning of the test has been observed repeatedly. In contrast, the amount of double bonds in the carbon-carbon polymer chains was found to increase during the soil burial experiments or in the presence of selected fungal strains (7). These observations suggest that, during the soil burial tests, pre-oxidized LDPE samples undergo an ongoing degradation process, mediated by both abiotic and biological factors and this leads to the formation of large amounts of oxidized molecular fragments capable of being assimilated as carbon sources by soil microorganisms. This might explain the two-step biodegradation behaviour that has been observed repeatedly for pre-oxidized PE films in soil.

- (1) E. Chiellini, A. Corti, G. Swift, *Polym. Degrad. Stab.*, **81**, 341-351 (2003).
- (2) A.-C. Albertsson, C. Barenstedt, S. Karlsson and T. Lindberg, *Polymer* **36**, 3075-3083 (1995).
- (3) A.-C. Albertsson, S. O. Andersson and S. Karlsson. *Polym. Degrad. Stab.*, **18**, 73-87 (1987).
- (4) T. Volke-Sepulveda, G. Saucedo-Casteneda, A. Manzur-Guzman, M. Limon-Gonzalez and G. Trejo-Quintero, *J. Appl. Polym. Sci.*, **73**, 1435-1440 (1999).
- (5) S. Bonhomme, A. Cuer, A.-M. Delort, J. Lemaire, M. Sancelme and G. Scott, *Polym. Degrad. Stab.*, **81**, 4421-452 (2003).
- (6) S. Fontanella, S. Bonhomme, M. Koutny, L. Husarova, J.-M. Brusson, J.-P. Courdavault, S. Pitteri, G. Samuel, G. Pichon, J. Lemaire and A.-M. Delort, *Polym. Degrad. Stab.* **95**, 1011-1021 (2010).
- (7) A. Corti, S. Muniyasami, M. Vitali, S.H. Imam and E. Chiellini, *Polym. Degrad. Stab.* **95**, 1106-1114 (2010).

### **Appendix B Standards**

ASTM Standard D 6400-04 is a specification for compostable plastics. It is designed for plastics that are composted in municipal or industrial aerobic composting facilities. It is similar in most respects to EN 13432. It identifies acceptable labeling practice for plastics claimed to be compostable. Rate and extent of composting must be similar to a selected natural standard; the extent of biodegradation is expected to be 60% in 90 days (as compared to 60 days for 60% conversion in EN 13432. For land application of the compost product, the metals analysis should meet all accepted norms and the compost must pass standard ecotoxicity tests.

ASTM Standard D 6868 – 03 is a specification for Biodegradable Plastics used as Coatings on Paper or Compostable Substrates. This is a minor modification of D 6400 that was written to accommodate Metabolix's venture into paper coatings

ASTM Standard D 7081-05 is a specification for Non-floating Biodegradable Plastics in the marine environment. It is based on D 6400 for meeting an acceptable degree of biodegradation under marine conditions, water and sediment, but not composting.

ASTM D 5338-98 is a Standard Test Method for Determining Aerobic Biodegradation of Plastic under controlled composting conditions in a laboratory approximation. The rate and degree of biodegradation are recorded. It is the basis for D 6400 Specification standard.

ASTM D 5511 is a Standard Test Method for Determining Anaerobic biodegradation of plastics under high-solids (30%) anaerobic digestion conditions. It is a simulation of anaerobic composting in an industrial or municipal facility, very similar to D 5526. The method compares plastics relative to a standard for rate and degree of biodegradation using gas evolution measurements.

ASTM D 5526-94 is a Standard Test Method for determining the anaerobic biodegradation of plastics under accelerated landfill conditions – but only after anaerobic conditions prevail. It is a laboratory test in which the evolution of gas with time is used to compare and contrast different plastics. No specification has been set.

ASTM D 5988-03 is a Standard Test Method for determining aerobic biodegradation of plastic in soil or of residual plastic in a compost after composting. This is not a specification but simply a method showing how to test and record the rate and degree of biodegradation relative to similar materials and standards.

ASTM D 6776-02 is a Standard Test Method for determining anaerobic biodegradation of radio-labeled materials in a laboratory-scale simulated landfill. This is a minor modification of D 5526 (above) where radiolabels allow greater accuracy in gas measurements.

***What do all these ASTM standards have in common?***

Other than part of D 5988, they have **virtually no relevance** to the evaluation of polyolefins based on EPI technology.