Information in support of the use of oxo-biodegradable technology.

FOREWORD

The **OXO-BIODEGRADABLE PLASTICS FEDERATION (OBPF),** is an industry wide, global collaboration group (see Board membership list) to promote the appropriate use of oxo-biodegradable products through participation in the development of standards, regulations, material guides and positive community interaction.

The OBPF has been founded by a group of leading manufacturers and technologists and is supported by scientific, economic and social research into the development of products, applications, and systems deriving from and using oxo-biodegradable products. It is intended to help educate and further public awareness of oxo-biodegradable products as an available alternative to existing products and to promote the use of these products without any anti-competitive activities in relation to other relevant industry and academic associations.

Dr Gary Ogden FIMMM CSci
Chairman, OBPF

Mr Ray Loflin
Secretary, OBPF

1st May 2018

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

1. INTRODUCTION

Plastic packaging is essential to modern life, supermarket shopping would be impossible without packaging, and food waste would increase dramatically if we were not able to deliver appropriate amounts of prepared foodstuff to the public. Some mock the concept of an individual cucumber being wrapped in plastic shrink-wrap, but that simple action permits a shelf life of 14 days in comparison to 3 days without wrapping.

Polyolefins in particular have been an enormous success in packaging and agricultural applications requiring mechanically tough films, because they are cheap, easy to process and tough, and offer excellent barrier properties against moisture, micro-organisms and oxygen. They have come to dominate a highly competitive market simply because they are the best solution.

The OBPF advocates for the collection and recycling of plastic products (oxo-biodegradable plastics being fully compatible with recycling systems). However, where waste management is problematic or in the case of any plastic which misses the correct disposal routes, e.g. by becoming litter, then oxo-biodegradable plastics provide a safe, non-toxic solution to the plastic litter in the environment.

Oxo-biodegradable plastics work through an additive system that is incorporated into the polymeric product through the inclusion at the manufacturing stage of a small percentage (typically 1-3% dependant upon the additive system) of a concentrated additive masterbatch, that renders conventional polyolefins, amongst other common polymers, ultimately bio-degradable.

The opportunity to convert oil-derived and bio-based (such as polyethylene derived from sugar cane) packaging into a biodegradable material, while maintaining all the advantages of economical production and safe, hygienic packaging, has been recognised in Central and Latin America, Africa, the Middle East, Pakistan and India with regional and national legislation recognising and, in some cases, stipulating the use of oxo-biodegradable technology.

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

2. RELEVANT DOCUMENTS

ASTM D883 Terminology Relating to Plastics.

ASTM D3826: Practice for Determining Degradation End-point in Degradable Polyethylene and Polypropylene Using a Tensile Test

ASTM D5208: Practice for Fluorescent Ultraviolet (UV) Exposure of Photodegradable Plastics.

ASTM D5576: Practice for Determination of Structural Features in Polyolefins and Polyolefin Copolymers by Infrared Spectrophotometry (FT-IR).

ASTM D6954-18: Standard Guide for Exposing and Testing Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation.

CEN TR 15351:2006 Plastics—Guide for vocabulary in the field of degradable and biodegradable polymers and plastic items

EC/10/2011: COMMISSION REGULATION on plastic materials and articles intended to come into contact with food.

EN13432 (2000): Requirements for packaging recoverable through composting and biodegradation.

ISO 9001:2008 Quality management systems — Requirements

ISO 17025 General requirements for the competence of testing and calibration laboratories

U.S. Food and Drug Administration (FDA) Title 21 of the *U.S. Code of Federal Regulations* (21CFR).

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

3. TERMINOLOGY

The oxo-biodegradation process and oxo-biodegradable materials have been defined using several standards globally. Accepted and applicable definitions, drawn form these standards listed above, are provided below for use in the following report:

Degradation (of plastic), *n* - a deleterious change in the chemical structure, physical properties, or appearance of a plastic. (D883-11)

degradable (of plastic) *n* –a plastic designed to undergo a significant change in its chemical structure under specific environmental conditions resulting in a loss of some properties that may vary as measured by standard test methods appropriate to the plastic and the application in a period of time that determines its classification. (D883 – 11)

Degradability *n* – the quality of being degradable

biodegradation (of plastic), *n* - degradation of a polymeric item as a result of cell-mediated phenomena. (CEN TR 15351)

Biodegradable, *n* – capable of biodegradation

Biodegradability, *n* - the quality of being biodegradable

Oxidation, *n* - process promoted thermally or by ultraviolet (UV) radiation or both in the presence of oxygen. (CEN TR 15351)

Oxo-degradation, *n* - degradation resulting from oxidative cleavage of macromolecules. (CEN TR 15351)

Oxidatively degradable plastic, *n* - a degradable plastic in which the degradation results from oxidation (D883-11).

Oxo-biodegradation, *n* - degradation resulting from oxidative and cell-mediated phenomena either simultaneously or successively. (CEN TR 15351)

Oxo-biodegradable, *n* – capable of oxo-biodegradation

Oxo-biodegradable additive *n* – a single or synergistic blend of additives which induce oxo-biodegradable characteristics into plastics

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

Oxo-biodegradable additive masterbatch *n* – a material containing a concentrated amount of oxo-biodegradable additive in a carrier suitable to be diluted into the final product

Oxo-biodegradable plastic *n* - a polymer capable of oxo-biodegradation

Oxo-biodegradability, *n* - the quality of being oxo-biodegradable

plastic(s), *n* **-** material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or processing into finished articles, can be shaped by flow. (ASTM D883)

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

4. OXO-BIODEGRADATION

All polymers derive their mechanical properties, especially toughness, from the entanglement of their long chains. Polymer chains long enough to confer useful mechanical properties are usually too large to be able to cross the cell walls of bacteria or fungi. All polymer biodegradation requires is that there be some extra-cellular chemical process to change the molecular structure, both chemically through oxidation in the case of oxo-biodegradable plastics (or hydrolysis for compostable materials) and structurally through a process of molecular weight reduction by molecular chain cleavage. Thus, releasing them from the entangled mass such that they are no longer polymeric in nature and therefore small enough to be transported into the cell and metabolised.

As alluded to above, there are two well-recognised biodegradation pathways for plastics, hydro- 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.

In natural hydro-biodegradable (HBD) polymers, chain scission occurs by hydrolysis, as in the case of polyesters like the poly(hydroxyalkanoates). In naturally oxo-biodegradable (OBD) polymers, scission is by oxidation, as in the case of natural rubber and lignin.

In either case, this initial degradation may be purely chemical or it may be mediated by enzymes released from the cell. Both hydrolytic enzymes (typically esterases) and oxidising enzymes (e.g. cytochrome systems) are well known. There is certainly nothing in nature to exclude oxidative scission as a precursor to biodegradation; it is the way nature disposes of both natural rubber latexes and the lignin fractions of wood and other plant matter.

Aside from the basic distinction between hydrolytic and oxidative cleavage, the main differences between OBD and HBD technologies are;

a) The lifetime of an OBD polymer, before biodegradation starts, can be regulated by varying the antioxidant:pro-oxidant ratio.

b) Because of the induction period required for oxidation to produce biodegradable materials, biodegradation of an OBD material is inevitably slower than that of an HBD. Although this excludes OBD plastics from applications requiring, or merely specifying, very rapid bio-assimilation such as industrial (municipal) composting, there are equally many applications where the rapid and uncontrolled biodegradation of HBD plastics is a problem.

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

In summary, the basic technology of an OBD material involves:

a) An induction period during which oxidation catalysis by the pro-oxidant(s) is prevented by the antioxidant(s). *During this period there is no change in the polymer but the antioxidants are consumed.*

b) A rapid oxidation of the polymer during which chain scission produces low molecular weight entities, which are oxidised, hydrophilic and polar.

c) A period of bio-assimilation of the oxidised fragments leading to mineralisation to CO2.

It is important to emphasise that these are overlapping processes. In particular, once significant oxidation starts, it is faster in biotic than in abiotic environments, so that lifetime predictions from simple oven ageing or light exposure testing will tend to predict over-long breakdown times in natural exposure.

The important points to consider from the above mechanism, is that the material molecular weight is continually reduced through a catalytic oxidative process and will continue to decrease while aerobic conditions prevail. Therefore, the material degrades and is able to become assimilated into the environment, due to the loss in mechanical integrity caused by the oxidative reduction in Mw of the material. This produces low Mw oxidised molecular species which become evermore hydrophilic and available as carbonaceous food sources for microbes. Microbes then digest these species to not only produce CO_2 but to use a material for cell growth and conversion to humus in a similar manner to wood and leaf matter.

The oxo-biodegradable process is in contrast to compostable bio-based polymers which essentially use an industrial composting system at high temperature to firstly breakdown the material through hydrolytic processes to produce fragmented polymeric material and then to incinerate at least 90% of the polymer over a period of up to 6 months to form CO2, a problematic greenhouse gas.

It is worth noting here that while compostable standards such as EN13432 and ASTM D6400 (currently under urgent review at ASTM) allow for a period of 26 weeks at 58°C for completion of the biodegradation process in municipal composting facilities, it is very rare that these facilities operate at this standard temperature and turn compost around in 6-11 weeks, as such, an ever increasing number of municipal composting (and anaerobic digestion) facilities do not permit the inclusion of polymers certified to these standards to be present in the feedstock.

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom

5. OXO-BIODEGRADATION STANDARDS & TESTING

Oxo-biodegradable polymers can be tested and characterised according to:

"ASTM D6954-18: Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation"

Other national standards such as BS8472, UAE S 5009, SASO 2879 are similar to ASTM 6954-18, all utilising a 3-Tier sequential methodology:

Tier 1 – Oxo-degradability
Tier 2 – Biodegradability
Tier 3 - Ecotoxicity

In Tier 1 testing, the structural and chemical metamorphosis of the polymer chains due to the oxidation and reduction in molecular weight can be followed through techniques such as FT-IR, HT-GPC and change in mechanical properties.

In Tier 2, the abiotically degraded material generated in Tier 1 can be tested for ultimate biodegradation in various standard methods common to all laboratory biodegradation testing.

In Tier 3, the residue from biodegradation can be tested for ecotoxicity properties through common standard methods such as those prescribed in OECD 207 & 208, amongst others. Additionally, the materials can be tested for compliance to the requirements of a number of toxic substances lists.

In addition to the requirements of ASTM D6954-18, oxo-biodegradable additive masterbatch and the products produced from them may be tested for compliance to the requirements of ROHS2, CONEG, REACH and direct and indirect food contact regulations such as EU/10/2011 and FDA Title 21.

Address for communications: Dr Gary Ogden FIMMM, CSci, Chairman, Oxo-Biodegradable Plastics Federation
c/o 9 School Road, West Felton, Oswestry, Shropshire. SY11 4HH United Kingdom