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EVIDENCE IN RESPONSE TO THE UK GOVERNMENT'S JULY 2019 CALL FOR EVIDENCE ON STANDARDS FOR BIO-BASED, BIODEGRADABLE, AND COMPOSTABLE PLASTICS

My evidence relates to oxo-biodegradable technology and the significance of testing protocols, particularly ASTM D 6954, for testing plastics that degrade sequentially in the open environment by abiotic and biotic degradation. I was one of the authors of ASTM D 6954, and I am vice-chairman of D20:96, which is the relevant Technical Sub-committee at ASTM.

My comments also reflect many years of experience with this particular type of biodegradable plastic which includes:

- Observing the invention and development of the technology
- Extensive involvement in field testing of oxo-biodegradable plastics
- Co-author of several publications on the environmental degradation of oxo-biodegradable plastics.

Oxo-biodegradable Plastics

Oxo-biodegradable plastics have been known and used commercially for over half a century. They were developed by the scientists who had developed conventional plastics, who found a way to render ordinary plastic susceptible to controlled oxidative degradation, by using catalysis to produce simple hydrophilic compounds, many known and recognized as biodegradable in widely disparate aerobic environments.

This abiotic process mimics Nature which utilizes enzymes containing metals, such as Mn, and Fe, to oxidatively break down hydrophobic natural materials such as lignin to facilitate biodegradation. To oxidatively degrade synthetic and hydrophobic polyolefins, similar transition metals, are used at levels selected to produce the degradation kinetics required for a particular application.

Environmental Degradation Pathway:

Degradation occurs in two stages. The abiotic first stage is oxidation.

Oxo-biodegradable plastics + O2 > oxygen containing oligomers / chemicals > biodegradation

As the degradation progresses, the hydrophobic polymeric substrate is converted into low molecular weight oxygenated, hydrophilic species suitable for biodegradation by most microbial species in most aerobic environments, and particles of plastic are not left behind.

Note: oxygen is always needed for oxidation, but moisture is not, and once initiated, oxidation will continue even at low temperature or if the material is occluded from UV light. Heat and UV radiation merely enhance the rate of degradation.

Applications

Shopping bags, packaging film, wrappers, land coverage, bread wrappers, dog-poop bags, and many other everyday applications.

As the markets developed, the need for a standard testing methodology became apparent

Testing Standard for Oxo-biodegradable Plastics

We wrote D 6954 at ASTM to guide the user and developer of these plastics in testing the sequential degradation process to be expected in the open environment, using existing ASTM and

other certified standard methods at each stage. We called it a Standard Guide, because we reserve the title "Specification" for protocols for testing in a controlled environment eg. ASTM D 6400.

ASTM D 6954 is designed for testing plastics which degrade and biodegrade in uncontrolled conditions in the open environment, but it is nevertheless a detailed protocol for proving degradation, biodegradation, and non-toxicity under the conditions expected to be found in the open environment. Biodegradation in industrial composting or anaerobic digestion is not relevant here, and is dealt with in a separate Standard - ASTM D6400.

ASTM D6954 contains six pass/fail tests 1.for the abiotic phase of the test (6.3 - 5% e-o-b and 5,000DA) 2. the tests for metal content and other elements (6.9.6), 3. Gel content (6.6.1), 4.Ecotoxicity (6.9.6 -6.9.10), 5. PH value (6.9.6) and 6. for the biodegradation phase, (for unless 60 % of the organic carbon is converted to carbon dioxide the test cannot be considered completed and has therefore failed).

Of course, conditions in the open environment are variable but there is no need for a standard for each of these conditions. Provided that oxygen is present, a plastic complying with ASTM D6954 will become biodegradable much more quickly than ordinary plastic, and that is its purpose. Oxygen is ubiquitous, and most of the plastic litter is found lying or floating around with abundant access to oxygen, but it is possible to imagine a piece of plastic in anaerobic conditions where abiotic degradation cannot proceed. However if this is in a landfill it does not matter, because the plastic has already been properly disposed of.

It is also possible for a piece of oxo-biodegradable plastic to find itself in anaerobic conditions outside a landfill but this would be very unusual and does not invalidate the general proposition. It is for example possible for plastic to be deprived of oxygen by being heavily bio-fouled in the ocean or buried in sediment, but this is unlikely to happen quickly enough to prevent sufficient exposure to oxygen for abiotic degradation. If it did, then that small proportion of the global burden of plastic litter would perform in the same way as ordinary plastic – no better and no

worse.

ASTM D6954 provides for testing in three stages:

STAGE 1. Artificial weathering with heat and UV irradiation, where oxidation is followed by loss of physical properties and incorporation of oxidation functionality, as seen by IR spectroscopy. Molecular weight is crucial here, and is required by section 7.2.5 to be reported. This is because plastic with a high molecular weight is not amenable to biodegradation, and the purpose of oxidation is to reduce it.

The material can be aged in the natural environment, and this is sometimes done eg by Station d'essais de Vieillissement Naturel de Bandol in France. However, this is a long and expensive process. Artificial ageing is therefore done simply to reduce the time and cost of testing, and does not invalidate the results. If it did it would obviously not be used, and would not have been permitted by ASTM D6954.

Once abiotic degradation has commenced, there is no reason for it to stop save in the unlikely event that it is deprived of oxygen.

STAGE 2. Once the molecular weight has reduced to 5,000 Daltons or less, the material would be in very small particles and would be lost if testing were continued in the open environment. At this level of molecular weight we would expect the material to have become biodegradable, and this is confirmed by testing residue from Stage 1 for biodegradation.

Once the material has become biodegradable, it can be expected to fully biodegrade, save in the unlikely event that it is deprived of bacteria.

Stage 2 testing is done in the laboratory in a microbial consortium by measuring the rate and extent of carbon dioxide evolution (relative to theoretical). The microbial consortium chosen will be relevant to disposal in the open environment. The amount of biodegradation required in order to pass the test is specified in sections 6.6.1 and 6.6.2. Similar carbon-evolution testing is done in the laboratory for compostable plastic according to ASTM D6400 and EN13432, and this method is widely accepted.

STAGE 3. Residue from Stage 2 is evaluated for environmental toxicity in soil and water. An oxo-biodegradable product will not pass the test if these toxicity requirements are not satisfied.

Microparticle Formation

The potential for microparticle formation and persistence in the environment is a very real concern when ordinary plastic materials are littered and allowed to erode and degrade as a result of environmental forces, and this is why oxo-biodegradable plastics were invented. Microplastic formation is highly unlikely in the case of oxo-biodegradable plastics, given their oxygen reactivity and degradation into low molecular weight oxygenated hydrophilic materials. To my knowledge over 40 years there has never been an environmental contamination problem caused by oxo-biodegradable plastic.

Control of Oxidative Degradation Stage

It is not necessary or practicable to specify a precise timescale for degradation, because conditions in the open environment (unlike those in a composting environment) are variable. The key point is that in any given place at any given time in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item, and will not therefore contribute to the long-term pollution of the environment.

Oxidation is particularly relevant to the chemistry of oxo-biodegradable plastics since it influences the commencement and degree of biodegradation.

In research and development, when an oxo-biodegradable plastic is required to have a performance life span of several weeks or several months, a manufacturer adjusts the catalysts and anti-oxidant concentrations having regard to a laboratory test, using ASTM D6954, and correlates the degradation characteristics with real world experience to identify the formulation needed to meet the intended degradation criteria.

ASTM D6954 contains a standard caveat, recognising that

laboratory environments are isolated, unlike the dynamic natural environment - in which degradation and therefore biodegradation is likely to proceed more quickly. However, ASTM D6954 has been devised by myself and other specialists working in the field over many years to provide practical guidance as to how the product is likely to perform in commercial use.

It has been my experience that results from laboratory testing are very likely to be reproduced in the real world. I can see no cause for concern that they would not, and have seen no evidence that they have not. In particular I do not consider that persistent plastic fragments and smaller, microplastics would be left behind which could have any harmful effect on the open environment, and in particular marine life.

There is no need for degradation if the product has not been left in the open environment. In landfills, there is sufficient oxygen initially for oxidation to continue and the plastic is likely to disintegrate, but this is not the main purpose.

I am aware that standards similar to ASTM D6954 for testing oxo-biodegradable plastics have also been written in the UK, France, Sweden, Saudi Arabia and the UAE, but there is really no need for separate standards for every country, as the principles are the same. It is true that abiotic degradation may proceed more quickly in a hot, sunny, country than in a cold, dark country, but that is not a difference in principle. Legislators in any country of the world need only specify that material claiming oxo-biodegradability must be tested according to ASTMD6954, and may not be marketed as oxo-biodegradable unless a satisfactory test report from a reputable laboratory is produced.

Please confirm that you received my evidence before 14th October.

Graham Swift

GRAHAM SWIFT PH. D. (London)

October 8 2019

October 7th 2019