About TDPA™ - An Additive for Oxo-biodegradable Plastics

Because traditional plastics are very stable and not readily degradable and biodegradable in the environment, discarded plastics represent a significant environmental problem, both as litter and as solid waste in landfills. As litter, disposable plastic products (in particular, plastic bags) are a visible and widespread pollutant, and a threat to animal and marine species and to human health. In landfills, they add to landfill volume, hinder landfill compaction and delay the biodegradation of discarded organic materials, thereby fostering the formation of methane, a harmful greenhouse gas. Plastics that would degrade and biodegrade relatively quickly to non-toxic end products in these disposal environments would be a welcome step in managing these issues.

Over the last two to three decades, companies in the plastics industry have developed various approaches to make degradable and biodegradable plastic products that process and perform equivalently to inexpensive and widely-used commodity plastics. The intent has been to develop a degradable and biodegradable plastic that is as functional as commodity plastics, but that would degrade and biodegrade relatively quickly in a disposal environment (litter, landfill, compost, water soil). EPI's proven TDPA™ technology is the most practical and economical way available today to accomplish these objectives.

TDPA™, when added in small quantities to the most common and widely used commodity resins during the manufacture of finished plastic products, causes the modified plastic to degrade at a controlled rate. The degradation, which involves the reaction of the plastic with oxygen in the air, is initiated by exposure to ultraviolet light (sunlight), elevated temperatures and/or mechanical stress. It is "programmed" to start degradation on disposal after the product has fulfilled the required shelf and service lives as defined by end users. Products made with polyethylene (such as grocery, shopping and garbage bags), have been shown to subsequently be biodegradable into non-toxic end products.

Biodegradable plastics incorporating TDPA™ is processed, performs and are visually indistinguishable from conventional non-degradable plastic materials. They are cost-competitive. They are also compatible with existing recycling operations and can be safely co-mingled with conventional plastic inputs prior to the onset of degradation.

TDPA™ products are food contact compliant and meet applicable US, Canadian and European standards. The compliance is supported by scientific testing and published test reports that enable EPI to provide legitimate environmental claim statements. Published work has also demonstrated that composts made from plastics incorporating TDPA™ has no toxic effect on sensitive plant or animal life.

How It Works?

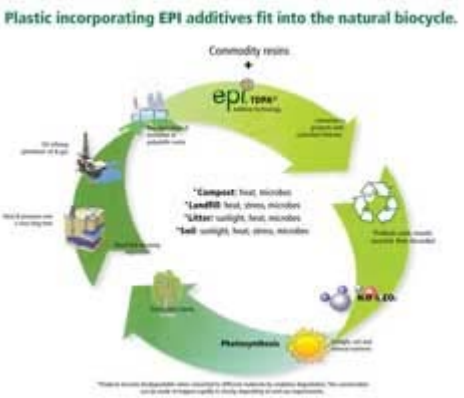
The chemical degradation process involves the reaction of very large polymer molecules of plastics, which contain only carbon and hydrogen, with oxygen in the air. This reaction occurs even without prodegradant additives but at a very slow rate. That is why conventional plastics, when discarded, persist for a long time in the environment. EPI's TDPA™ formulations catalyze or accelerate this reaction and increase the rate of the degradation by several orders of magnitude – i.e. 100's to 1000's of times faster, making TDPA™ incorporated products degrade and physically disintegrate within a few weeks to 1-2 years, depending on the formulation and the disposal environment. To illustrate, a TDPA™ incorporated plastic bag and a conventional plastic bag were hung on the fence and the difference in degradation rates was observed in the degradation test.

Illustration of photo and thermal degradation of a shopping bag incorporating EPI's TDPA® Additive (top row) vs. a bag without EPI's TDPA™ Additive (bottom row). Test procedures follow ASTM D5272 "Outdoor Exposure Testing of Photo Degradable Plastics" Guidelines

Degradation Test

These lower molecular weight fragments are known to, and have been shown, in laboratory simulated composts, to biodegrade into carbon dioxide, water and biomass (cell structure of micro-organisms), which are materials found in nature and part of the biocycle. Commercially available LDPE films incorporating TDPA™ have been shown to convert 60% of their carbon backbone into carbon dioxide in 1.5-2 years with most of the balance of the carbon remaining as micro-organism cells. Unmodified films would take much longer to achieve this.

The chemistry described above has been well known to polymer scientists for years. Indeed manufacturers of polymer resins routinely add antioxidant chemicals to their products to prevent any oxidation during thermal processing into products. EPI's contribution lies in its ability to manage these processes in a predictable way – to balance the effect of its catalytic additives with the effect of contained antioxidants in order to make products that satisfy needs for adequate shelf and service lives while providing degradation/biodegradation rates suitable for the final disposal environment.



Natural Biocycle

A useful feature of catalyzed oxo-degradation chemistry is that, as long as there is any residual antioxidant in the plastic, the catalytic additive has absolutely no effect. These antioxidants are slowly consumed as they do their job. This fact is important in designing shelf and service life of TDPA™ incorporated products and allow these products to be safely recycled in existing recycle streams prior to them exhibiting visual signs of degradation – brittleness or disintegration. Other practical features of the technology are that it is applied to the most common commercially available and used polymers and does not affect the processability or the other properties of these polymers.

The overall process, from polymer to water, carbon dioxide and biomass is called oxo-biodegradation. EPI is the pioneer and world's leading practitioner of oxo-biodegradable technology and has the experience and technical knowledge to design additive systems for polyethylene, polypropylene and polystyrene to meet widely varying needs for shelf and service life and degradation performance in a range of disposal medium and situations.

Benefits & Features of Degradable and Biodegradable Plastics

a. Controlled Lifetime

The shelf life and service life of degradable and biodegradable plastic products incorporating TDPA™ can be customized based on customer requirements ranging from a few months to years depending on the type and amount of TDPA™ added to the plastic resin.

b. Processability

EPI's degradable plastic additive technology is applied to conventional commodity plastics and is processed using almost identical conditions as is required for the unmodified resins.

c. Performance

Degradable products incorporating TDPA™ have similar physical properties and are indistinguishable in look and performance from regular products prior to the onset of degradation.

d. Cost

The cost of TDPA™ incorporated products is only a few percentage higher than the unmodified ones and far less expensive than products using other degradable and biodegradable technologies.

e. Reusable & Recyclable

Products incorporating TDPA™ additives, prior to the onset of degradation, can be reused and are compatible with existing recycling streams during post production or at post consumer level.

f. Degradable & Biodegradable

Test results and proven scientific studies have verified that TDPA™ incorporated products degrade, disintegrate and biodegrade.

g. Non-toxic

Degradable products made using EPI technology are non-toxic and safe for food contact applications.

h. Non-ecotoxic

TDPA™ incorporated products produce no harmful residue after biodegradation.

i. Commercialized

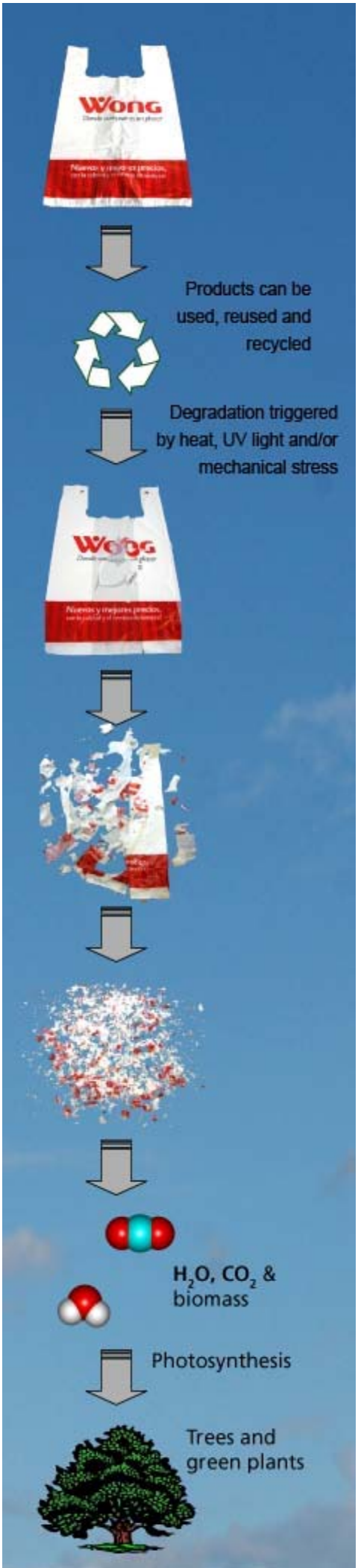
TDPA™ incorporated plastic products are used by international brand names in Europe, USA, Asia, Australia and New Zealand to make carrier bags, cling film, BOPP films etc. Please visit our TDPA™ products page for details.

j. Availability

TDPA™ is readily available worldwide.

k. Pioneer & World Leader

EPI is the pioneer and world leader of oxo-biodegradable plastics technology.



Frequently Asked Questions

1. Why use degradable?

By far the largest proportion of single use plastics such as those used in disposable packaging end their lives in landfills or, unfortunately, as litter. Conventional plastics can persist unchanged for many years in such environments. The same items made from plastics utilizing EPI's proprietary TDPA™ technology safely degrade and biodegrade within a few months to 2 - 3 years in these environments. In landfills, they reduce landfill volume and help maximize capacity utilization and they aid in landfill compression. While not a solution to littering, degradable plastics help in its management by avoiding accumulation of litter. There are also niche markets for example in agricultural mulch films and as landfill covers where products using EPI technology bring large economic and environmental benefits.

2. What are degradable and biodegradable plastics?

Degradable and biodegradable plastics are defined by ASTM D883-99 as follows:

Degradable Plastic: 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.

Biodegradable Plastic: A degradable plastic in which the degradation results from the action of naturally-occurring micro-organisms such as bacteria, fungi, and algae.

3. What is oxo-biodegradation?

Oxo-biodegradation is a two-stage process in which a plastic is first converted by reaction with oxygen to molecular fragments that are water- wettable. Secondly, these smaller oxidized molecules are biodegraded and converted into carbon dioxide, water and biomass, by microorganisms. The rate at which this happens for conventional plastics is very slow, taking decades or even centuries. EPI's TDPA™ additives are catalysts that accelerate this reaction so that it occurs over a few months to a couple of years.

4. What are the main types of biodegradable plastics and how do they differ?

There are 2 main types of biodegradable plastics: oxo-biodegradable and hydro-biodegradable. Both will first undergo chemical degradation by oxidation and hydrolysis for oxo- and hydro-biodegradable plastics respectively. This results in their physical disintegration and a drastic reduction in their molecular weights. These smaller, lower molecular weight fragments are then amenable to biodegradation.

Hydro-biodegradable plastics tend to degrade and biodegrade somewhat more quickly than oxo-biodegradable ones but the end result is the same – both are converted to carbon dioxide, water and biomass. Oxo-biodegradable plastics are generally less expensive, possess better physical properties and are easier to process on current plastics processing equipment than hydro-biodegradable plastics.

5. What are the main benefits of TDPA™ incorporated plastics?

- Proven technology in the marketplace
- Provide environmental benefits
- Provide large economic benefits in some end uses
- Cost effective
- Claims are scientifically validated
- Easy to convert using conventional equipment, processes and conditions
- Same excellent physical properties as conventional plastics
- Can be reused and recycled in existing recycle streams
- Available immediately
- Enhance a product brand name
- Working with the pioneer and leader in oxo-biodegradable technology

6. What products can be made degradable?

Products made from commodity plastics such as PE, PP and PS can be made degradable by incorporating TDPA™ additives. Some commercial products that have successfully incorporating TDPA™ include singlet carrier bags, garbage bags, Dispenser Bags, Ziplock bags, cling film, shrink-wraps and EPS trays.

7. Can TDPA™ based plastics be recycled?

Yes, in-plant materials (trimmings, scrap, etc.) are normally recycled and commonly practiced amongst EPI's manufacturers. The usual amount of recycled materials used is about 20% for degradable/biodegradable and 5% for non-degradable end products. This will ensure that quality of the end products is not compromised. Additionally, post-consumer plastics can also be recycled in existing recycle streams provided they have not already started to degrade.

8. Does the presence of TDPA™ affect processability, output rate and the quality of the end product?

The presence of TDPA™ does not affect processability, output rate or quality of end product and are processed using the same equipment as plastics without the additive.

9. How does TDPA™ affect product performance?

Prior to the onset of degradation and disposal, products incorporating TDPA™ will have virtually identical performance to those without the additive. Products with TDPA™ are engineered to have a predetermined life and have a designated "use before" date.

10. How does EPI ensure quality?

EPI's operates a specialized laboratory that performs a variety of chemical, physical and mechanical tests using standard ASTM test methods on products manufactured with TDPA™ formulations. This ensures that customers receive optimum formulations that perform as specified. Typically, disposal conditions are simulated in QUV weather accelerating equipment and aging ovens and samples from these are tested using plastometers, tensile testing equipment and Fourier Transform Infrared Spectroscopy (FTIR).

11. What will trigger the breakdown of TDPA™ product?

The breakdown of TDPA™ incorporated products is triggered by heat, UV light and/or mechanical stress or a combination thereof.

12. What are the end products of biodegradation and do they have any harmful effect on the environment?

The end products of biodegradation are carbon dioxide, water and biomass. Extensive studies and tests have been conducted by EPI with internationally recognized laboratories and institutions to confirm that they do not leave harmful or toxic residues to the environment.

13. Can TDPA™ plastics be used for food contact applications?

Yes. TDPA™ additives comply with FDA, EFSA and CFIA requirements in the US, Europe and Canada respectively and are safe for food contact applications.