Why Biodegradable?

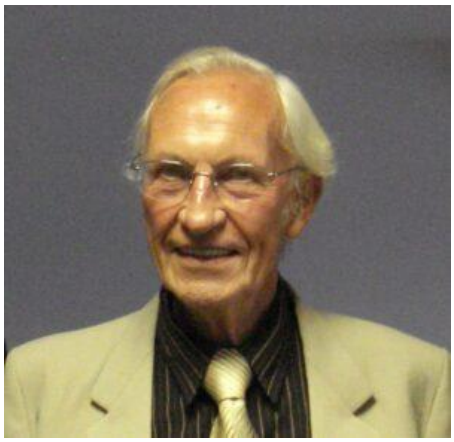
There is one thing on which we can all agree – that it is important to protect the environment, and especially the oceans, from plastic pollution. We would like to explain how d2w oxo-biodegradable plastic technology can help to do this.

Incidentally, some confusion has been caused by use of the term "oxo-degradable." Nobody puts pro-degradant additives into plastic and markets it as "oxo-degradable," and nobody would want it, if all it does is to create fragments of plastic.

"Oxo-degradation" is defined by CEN (the European Standards authority) in TR15351 as "degradation resulting from oxidative cleavage of macromolecules." This describes ordinary plastics, which abiotically degrade by oxidation in the open environment and quickly create fragments, but do not become biodegradable except over a very long period of time.

"Oxo-biodegradation is defined by CEN as "degradation resulting from oxidative and cell-mediated phenomena, either simultaneously or successively". This means that the plastic degrades by oxidation until its molecular weight is low enough to be accessible to bacteria and fungi, who then recycle it back into nature.

So what is oxo-biodegradable plastic and why was it invented?


Professor Gerald Scott

The mechanism of abiotic peroxidation of hydrocarbons has been extensively studied over the past 50 years. Oxo-biodegradable plastic was invented in the 1970s by Professor Scott and other polymer scientists[1] who had realised by then that polyethylene and polypropylene could cause an environmental problem if it escaped from the waste management processes and ended up in the open environment as litter.

So, knowing that most of it would not be collected, they discovered that if they introduced into the normal polyethylene or polypropylene a tiny amount of a catalyst (which is usually a salt of manganese or iron) the plastic would not start to degrade while it is in storage and would perform in exactly the same way as normal plastic whilst in use, but if it was discarded into the open environment it would rapidly

become biodegradable, and be consumed by bacteria in the same way as nature's wastes.

In cricketing terms it is a long-stop, to protect the environment if all else fails.

So their idea was that manufacturers would stop using ordinary plastic, and would upgrade it with their new technology at little or no extra cost. Sadly, this has not been adopted widely enough, so the plastic continues to lie or float around for decades. Professor. Scott said just before he died that if his invention had been more widely adopted the ocean plastic garbage patches would be much reduced.

The reason why ordinary plastic is not biodegradable is that it comprises long entangled chains of molecules, which give it a high molecular-weight, and this is too high for the material to be accessed by microbes. The molecular-weight of ordinary plastic does reduce naturally over time but it takes very many years -some say 100 years – before ordinary plastic ceases to be a plastic and has become biodegradable. So, what the d2w catalyst does is to cause the molecular chains to be dismantled by oxidation so that the material is no longer a plastic and becomes biodegradable. The important thing is not the *size of the fragments*, but the molecular-weight.

Light and heat will accelerate the process, but it will continue even in dark, cold, conditions. Moisture is not necessary for oxidation, and does not prevent it.

It is crucially important to understand how the hydrocarbon polymers degrade in the environment by a combination of peroxidation and bioassimilation and how the free radical chain mechanism can be controlled by antioxidants. It would be possible to make oxo-biodegradable plastic so that it started to degrade immediately, but it would then have no useful life. Sustainability must in practice be a compromise between commercial viability (i.e., cost-performance) and environmental acceptability. Bioassimilation of plastics residues in the environment is an essential but not the only requirement of technologically useful packaging plastic, and in most cases, plastics require a controlled lifetime before physical degradation commences.[2]

Life-cycle assessments by Intertek have shown that oxo-biodegradable plastic has a better LCA than the other materials used for packaging.[3]

So that is what d2w oxo-biodegradable plastic is for – but what is it NOT for?

1. It is NOT a disposal route. The plastic is designed to be reused, recycled, and disposed of like normal plastic, but the d2w technology will make sure that if it gets into the open environment the molecular weight will reduce very rapidly so that it becomes biodegradable
2. It is NOT for Landfill. If the plastic has been taken to landfill, it has been responsibly disposed of and there is no need for it to degrade. Also if anything biodegrades in anaerobic conditions it will generate methane, which is undesirable unless the landfill has been designed to collect the gas. Oxo-biodegradable plastic will not degrade in the absence of oxygen.
3. It is NOT for Composting. Five short points on plastic marketed as "compostable":

- It does not deal with the problem of plastic litter in the environment, because it is designed and tested to biodegrade in a composting facility, not in the open environment.
- It does not convert into compost (EN13432 and ASTMD6400 require it to convert into C02 gas)[4] It is therefore designed for a deliberate linear process and is not circular. The material is intended to be wasted and lost to atmosphere by conversion into CO2.

(c) It cannot be re-used, recycled, or made from recyclate

(d) It leaves microplastics in the compost and in the open environment

(e) Is not wanted by industrial composters and local authorities.

It should not therefore be described as **compostable** or **biodegradable.** It should not be made mandatory, and should instead be banned.

See https://www.biodeg.org/subjects-of-interest/composting/

On 14th November 2022 the UK Environment Minister said "our call for evidence suggests these materials are often stripped out at the start of the process and landfilled or incinerated."

On 2nd December 2022 the Minister said: "Compostable plastics must be treated in industrial composting facilities to be broken down and, when processed incorrectly, can be a source of microplastics and contaminate recycling streams. " "This packaging does not contribute to a circular economy in the same way as packaging that can be reused or recycled into new packaging or products do, as compostable plastic packaging is generally intended to be used only once.

ARGUMENTS AGAINST OXO-BIODEGRADABLE PLASTIC

There are a number of issues which are always raised:

1. **Microplastics**. – Some of the microplastics found in the environment are coming from tyres and man-made fibres, but recycling is also a source of microplastics. A report in Journal of Hazardous Materials Advances[5] says "Raw recycling wash water was estimate to contain microplastic counts between 5.97 106 – 1.12 × 108 MP m−3 (following fluorescence microscopy analysis). The microplastic pollution mitigation (filtration installed) was found to remove the majority of microplastics >5µm, with high removal efficiencies for microplastics >40µm. However, Microplastics <5µm were generally not removed by the filtration and subsequently discharged, with 59-1184 tonnes potentially discharged annually."

However, most of the microplastics found in the environment are caused by the fragmentation of ordinary plastic when exposed to sunlight. These fragments are very persistent because their molecular weight is too high for microbes to consume them, and can remain so for decades.

This is why oxo-biodegradable plastic was invented. The plastic falls apart because the molecular chains have been dismantled and it is no longer a plastic. (When Ellen MacArthur Foundation asked Professor Jakubowicz for his advice He made this point, but they ignored it).[6]

The European Chemicals Agency

The European Chemicals Agency (ECHA) were asked to study oxo-biodegradable plastic in December 2017. They made a Call for Evidence, and they informed us after 10 months that they had not been convinced that it creates microplastics. ECHA have never provided a dossier to support any ban on oxo-biodegradable plastic, and there is no evidence that microplastics from oxo-biodegradable plastic have ever been found in the environment.

It has been used for bread bags for more than ten years by the largest bread producer in the world (Bimbo bakeries) and there have been no problems with microplastics or recycling.

2. that oxo-biodegradable plastic will contaminate a **recycling stream** and is incompatible with a circular economy. That is not correct, but it is correct for "compostable" plastics, which are not recyclable. Five points on recycling:[7]

- Recyclers have to assess the level of degradation of any plastic sent for recycling whether it is oxo-biodegradable or not. They cannot recycle ordinary plastic which has started to degrade after exposure to sunlight.
- If the recyclate is to be used to make short-life products (eg food packaging) it does not matter whether it contains oxo-biodegradable plastic, because biodegradation is actually desirable in case the item becomes litter.
- Stabilisation is therefore necessary only for long-life products, and the producer of long-life products would stabilise them in the same way whether the recyclate contains oxo-biodegradable plastic or not. He does not need to know the proportion of oxo-biodegradable plastic in the feedstock. This normal stabilisation would neutralise any oxo-biodegradable residue.
- It is not necessary to separate oxo-biodegradable PE or PP from conventional PE or PP before recycling, but if so desired oxo-biodegradable masterbatch could be made visible to automatic sorting equipment by including a marker.
- Oxo-biodegradable masterbatch is used in PE and PP, but NOT in PET.

3. that **recycling** is preferable to biodegradation. Yes, but it is not possible to recycle plastic which has escaped into the open environment from which it cannot realistically be collected. The ONLY way to deal with it is biodegradation.

4. has it been shown that oxo-biodegradable plastic **will fully biodegrade?** Yes, tests have been done by Intertek showing biodegradation of 92.74% when tested according to ASTM D6954. (The percentage required by EN13432 for "compostable" plastic is 90%). No reason has been shown why biodegradation should stop before it is complete. You will never find 100% carbon-evolution because some of the material converts into water and biomass. Even if it did not fully biodegrade, it would still be better than ordinary plastic, which would have created persistent microplastics but would not have biodegraded at all.
5. EN13432 for "compostable" plastic requires biodegradation to be **tested in a laboratory** (not in a compost heap) but it is suggested that oxo-biodegradable plastic should be tested only in outdoor conditions See however the statement of Dr. Graham Swift (Vice-chairman of the Technical Committee at ASTM) who says "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." [8]

Further, a four-year interdisciplinary study, known as the Oxomar[9] project, has been sponsored by the French Government. The goal was to evaluate the biodegradation of OXO-bio in marine waters.

In their conclusion the scientists reported that "We have obtained congruent results from our multidisciplinary approach that clearly shows that oxo-biodegradable plastics biodegrade in seawater and do so with a significantly higher efficiency than conventional plastics. The oxidation level obtained due to the d2w prodegradant catalyst was found to be of crucial importance in the degradation process."

See also the report[10] from Queen Mary University London by Rose et. al 11th February 2020. Para 2.6 says "prior to testing, samples of LDPE and oxo-LDPE were surface-weathered in sea water for 82 days, undergoing natural variations in sunlight and UV intensity."

7. that they cannot be sure **how long** the plastic will take to biodegrade in the open environment, but it is not disputed by anyone that it will be many times faster than ordinary plastic when exposed under the same conditions in the open environment. Queen Mary University say (at para. 2.3) up to 90 times faster.


Paper bags

PAPER

It might be thought that paper is more environmentally-friendly than plastic – after all it is made from trees. But it doesn't grow on trees, so the trees have to be destroyed to make the paper. In fact it takes 24 trees on average to make just one ton of paper.

It also takes more than four times as much energy to manufacture a paper bag than a plastic bag. Whole forests are cut down to make paper – forests that could be helping the environment by absorbing greenhouse gases.

Most paper bags are made by heating wood chips under pressure at high temperatures in a chemical solution. The chemicals used in paper production are toxic and contribute to air pollution, including acid rain. They also pollute waterways, and the toxicity of the chemicals is long-term and settles in sediments, where it can work its way into the food chain.

In fact paper bags produce 70% more air-pollutants and 50% more water-pollutants than plastic bags.

But it doesn't end there. In 2005, the Scottish Government[11] issued an environmental impact assessment containing comparisons between a lightweight plastic bag and a paper bag.

Indicator of Environmental Impact	Plastic bag HDPE Lightweight	Paper
Consumption of nonrenewal primary energy	1.0	1.1
Consumption of Water	1.0	4.0
Climate Change (emission of greenhouse gases)	1.0	3.3
Acid Raid (atmospheric acidification)	1.0	1.9
Air quality (ground level ozone formation)	1.0	1.3
Eutrophication of water (algal blooms, dead zones, fish kills)	1.0	14.0
Solid waste production	1.0	2.7
Risk of litter	1.0	0.2

As can be seen from the table above, paper has more adverse environmental impact in almost every category. (A score greater than 1.0 indicates that the paper bag makes more contribution to that environmental problem than a lightweight plastic bag). See also the LCA done by Intertek for the UK Environment Agency[12]

Advocates for paper will say that paper bags are 'green' because they are 100% recyclable, and so they are in theory. In fact paper can be recycled up to 7 times before losing its integrity, but a paper bag would need to be used at least 3 times to offset the environmental impact of its production. Paper bags are not durable

enough to be used 3 times, and they rarely survive a single use, as they tear easily. Also they are much heavier than plastic bags and are nowhere near as strong, so you would need more of them, and they completely lose their strength when wet.

Because paper is a lot heavier than plastic it costs a lot more to transport, and causes more pollution from transportation. According to a briefing paper published by the Northern Ireland Assembly in 2011[13] it would take approximately seven trucks to transport the same number of paper bags as can be transported by a single truck full of plastic bags.

Plastic is made from ethylene, a by-product of oil production which used to be wasted. Therefore, so long as we still need oil for transport and energy production it makes sense to use the by-product to make plastic products.

However, conventional plastic can be a problem as it takes decades to degrade, and it disintegrates into microplastics. Fortunately this problem can be solved by using d_2w biodegradable technology, so that if the bag or packaging escapes collection and ends up in the environment as litter on land or sea it will degrade and biodegrade (be consumed by bacteria and fungi) leaving nothing behind. Just like nature's wastes.

Paper is fantastic, so let's save some trees and use paper for the things that only paper can do. Plastic is not the eco-villain it is made out to be, and when made with d_2w it is much kinder to the planet.[14]

AGRICULTURAL MULCH FILM

Farmers all over the world spread thousands of square kilometres of plastic sheet on their fields to protect their crop from weeds and to reduce the evaporation of water. Essentially, farmers have three options:

1. **Conventional plastic** – after the harvest the farmer has to drag hectares of plastic off his fields. He is not allowed to burn it on the farm, and burying it is not a good idea because it is labour-intensive and effectively puts the site out of cultivation, so he has to pay for it to be taken away. Some farmers send their plastic for recycling but it is usually contaminated with mud and other contaminants, so recycling does not make a lot of sense in economic or environmental terms when you consider the cost of hauling the plastic off the field, loading a large truck, and driving it along country roads to a recycling facility often hundreds of miles away – using fossil fuels, causing congestion, and emitting pollution. The plastic then has to be washed and the contamination has to be disposed of – and then the plastic has to be processed into recyclate.

Also, having lain on the fields exposed to sunlight it is likely to have degraded to the point that it is not fit for recycling, and fragments will have been scattered by the wind whilst being removed. The UK Environment Minister said on 25th May 2023 that "the government does not hold data on the amount of agri-plastic film collected or recycled."

2. **Bio-based Plastic** – this is expensive and may not be strong enough to resist tearing. The timescale for degradation cannot be programmed.
3. **Oxo-biodegradable plastic** – successful field-trials have been run in Wales.[15] The next time the field is ploughed, the biodegradable material will be returned to the soil, where it will be bioassimilated by the bacteria and will provide a source of carbon for next year's plants.

By taking note of the climatic conditions in the area, and using the correct formulation, it is possible to make the plastic last for as long or short a time the farmer requires.

It is no more difficult to spread d2w plastic on the fields than ordinary plastic, and a company in Ireland called SAMCO have invented a machine for laying the mulch film.

Oxo-biodegradable mulch films have been studied by scientists for more than 20 years. At page 47 of Degradable Polymers, Principles and Applications[16] Professor Scott says "The degradation products formed by oxo-biodegradation are of benefit to the agricultural environment as biomass and ultimately in the form of humus. Carbon is retained in the soil during oxo-biodegradation in a form accessible to growing plants, rather than by being emitted to the environment as carbon dioxide, as is the case with hydro-biodegradable polymers (e.g. pure cellulose and starch) ….. Time control of biodegradation of the synthetic carbon-chain polymers is achieved by antioxidants that behave similarly to naturally occurring antioxidants present in lignin and tannin."

See also "Polymers and the Environment"[17]

With regard to the edges of the mulch film which are buried to hold it in place. They will still biodegrade because, unlike photo-degradable plastic, an oxo-biodegradable plastic does not need constant exposure to sunlight. It is also possible to make a mulch film in which the buried sides of the film incorporate a different biodegradable masterbatch as compared to the middle part of the film.

EUROPEAN UNION

The BPA were not entirely surprised to see in December 2022 that the homes and hotels of 18 MEPs and officials had been searched by the police, yielding suitcases stuffed with banknotes.

The reason we were not surprised is that we have never been able to understand how it was possible for them to impose a ban on “oxo-degradable plastic”[18] without any dossier from the European Chemicals Agency (ECHA) showing any justification for any such ban. To make matters worse, the Commission had actually asked ECHA (under Art 69 of the REACH Regulation) to study whether these products created microplastics. ECHA received hundreds of pages of evidence but they informed the BPA in October 2018 that they were not convinced that microplastics were formed. They were instructed by the Commission to terminate the study.

The Commission’s draft Directive did not include any ban on oxo-degradable or oxo-biodegradable plastic, but the Parliament proceeded to legislate, and circumvented all the safeguards against arbitrary legislation provided by Arts. 69-73 of REACH. Could it be that there was some improper influence?

This Directive has been challenged in the European Court in Luxembourg and the case was heard by five judges on 20th March 2023. Their decision is awaited.[19]

The loser here is the environment, because ordinary plastic is still being used to make products which get into the open environment every day, where thousands of tons will lie or float around for decades. They should urgently be made with d2w oxo-biodegradable technology, so that they will biodegrade much more quickly and will not leave harmful residues.

d2w technology is supplied to plastics manufacturers as a masterbatch in pellet form, so that they can upgrade their products with the same machinery and workforce, at little or no extra cost. It is a “drop-in” technology.

For a pdf version of this text – Click Here

Portuguese translation – Click Here

[1] www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf Scott, “Degradable Polymers, Principles and Applications” (ISBN 1-4020-0790-6) and Scott, “Polymers and the Environment” (ISBN 10: 0-85404-578-3).

[2] www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf page 617-9

[3] https://www.biodeg.org/subjects-of-interest/life-cycle-assessments/

[4] See also www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf page 621 ““Rapid mineralisation is not ideal for polymers in compost where the carbon in the original plastic should be converted over a longer period of time to biomass and only slowly to carbon dioxide. The oxo-biodegradable polymers (e.g. the polyolefins) are ideal for this purpose since controlled peroxidation is the rate-determining step in the overall process. Furthermore they cannot give toxic or otherwise objectionable by-products during bioassimilation”

[5] https://www.sciencedirect.com/science/article/pii/S2772416623000803

[6] https://www.biodeg.org/wp-content/uploads/2019/11/emf-report-1.pdf

[7] https://www.biodeg.org/subjects-of-interest/recycling-2/

[8] https://www.biodeg.org/wp-content/uploads/2021/02/Swift-evidence-to-BEIS.pdf See also www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf at page 620

[9] https://www.biodeg.org/wp-content/uploads/2021/07/Final-report-OXOMAR-10032021.pdf

[10] https://www.biodeg.org/wp-content/uploads/2022/10/QM-published-report-11.2.20-1.pdf

[11] http://www.scotland.gov.uk/Resource/Doc/57346/0016899.pdf

[12] https://www.biodeg.org/wp-content/uploads/2021/04/uk-ea-publishes-lca-of-supermarket-carrier-bags-.pdf

[13] https://www.biodeg.org/wp-content/uploads/2023/07/Northern-Ireland-comparison-of-bags-Feb-2011.pdf

[14] https://www.biodeg.org/wp-content/uploads/2021/04/intertek-final-report-15.5.121.pdf

[15] – See https://www.biodeg.org/wp-content/uploads/2020/09/Pembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf.

[16] (ISBN 1-4020-0790-6)

[17] (ISBN 10: 0-85404-578-3) pages 109-118 and 461-466, and www.biodeg.org/wp-content/uploads/2023/07/Scott-Wiles-paper-June-2001.pdf page 618.

[18] (by Art. 5 of the Single-use plastics Directive 2019/904)

[19] As at 1st August 2023