Oxo-Biodegradable
Plastics Association

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The New Plastics Economy

Rethinking the future of plastics

Smart "oxo-biodegradable" plastic (OBP) should be seen as part of an overall strategy to improve the Environment, and it is fully consistent with the principles of "Reduce" "Re-use" "Redesign" and "Recycle."

EXECUTIVE SUMMARY

- Plastic waste is a serious environmental problem.
- Microplastics are caused by the embrittlement and erosion of ordinary plastic, and these fragments of plastic can lie or float around for decades adsorbing toxins.
- Bag taxes, and incentives to reduce and recycle are not enough, because thousands of tons of ordinary plastic will still get into the environment every day, where they will create microplastics.
- We therefore need to stop using ordinary plastic for everyday items.
- Everyday plastic items should urgently be upgraded with OBP technology so that they will safely degrade and then biodegrade in a much shorter time, if they get into the open environment.
- **It is essential to understand that OBP does not simply fragment into pieces of plastic – it converts at the end of its useful life into materials with a low molecular-weight which are no longer plastic, and will be recycled back into nature by naturally-occurring bacteria and fungi.**
- OBP is designed to biodegrade in the open environment, and requires no special conditions.
- The Oxomar report[1] has proved beyond doubt that OBP biodegrades even in the oceans much more efficiently than ordinary plastic. The scientists have also proved, by using a carbon 13 tracer, that the material is actually bioassimilated by the bacteria.[2]
- The European Chemicals Agency has studied OBP, and said on 30th October 2018 that it is not convinced that it creates microplastics.
- OBP costs little or no more than ordinary plastics. It can be made by the same factories with the same machinery, so there are no job-losses.
- OBP can contain a tracer so that they can be identified by waste-sorting equipment, but this is not necessary, because they can be recycled with ordinary plastics if collected during their useful life. Crop-based plastics cannot.
- OBP is made from a by-product of oil refining, so almost the same amount of oil would be extracted from the ground even if plastics did not exist. There is no need to switch to expensive vegetable-based alternatives, which consume land and water resources as well as fossil-fuels, and are themselves made with up to 70% petroleum components.

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[1] https://www.biodeg.org/subjects-of-interest/agriculture-and-horticulture/the-marine-environment/
[2] Report as yet unpublished

- Vegetable-based plastics are in any event the wrong choice if we are concerned about litter - because they are tested to biodegrade in an industrial composting unit – not in the open environment. [3]Nor do they convert to compost – they convert into CO_2.
- **It is important to understand that oxo-biodegradable plastic is not a completely new product – it is ordinary plastic, upgraded so that it will not lie or float around in the environment for hundreds of years.**

  For an audio-visual introduction to OBP and other plastic innovations see https://youtu.be/rc-YWqQ_HHY

This Association fully supports the idea of a circular economy for plastics, and (OBP) is entirely consistent with those principles. We support the redesign of plastics, we support re-use of plastics, and we support recycling of plastic where it makes sense.

At the present time, and for most applications, plastic is the best option for protecting our food and other goods from damage and contamination. It is waterproof, strong and flexible; it can be adapted for a variety of products, it is not expensive, and is made from raw materials which are readily available

A Life-cycle Assessment by Intertek for the UK Government in 2011[4] put plastic ahead of all the other materials used to make shopping bags. Intertek performed another LCA for shopping bags in 2012 which included the litter metric, and they put the environmental credentials of OBP ahead of bio-based and conventional plastic. A report by the Denkstatt Environmental Consultancy of Germany[5] shows that it would be a serious mistake to ban plastic packaging and use other materials instead.

The conclusions of the Denkstatt report were that:

• Plastics applied in the packaging sector today, are mostly used as a very energy efficient material. Plastics enable resource-efficient packaging solutions, which result in significant savings of energy and GHG emissions. This is due to the fact that plastic packaging facilitates significantly reduced material consumption which results in less energy consumption for the same functional unit.

• In addition many plastic packaging products save significant amounts of energy and GHG emissions during the use phase. These benefits are especially significant, when plastic packaging can be used to increase the shelf-life of food resulting in reduction of food wastage.

• Vice versa the substitution of plastic packaging by other materials would in most cases increase energy consumption and GHG emissions.

• Finally a "carbon balance" for plastic packaging shows that the estimated use benefits are at least 5 times higher than the emissions from production & recovery.

Further, there is a January 2020 Report by the Green Alliance[6] who had interviewed representatives from five of the UK's major supermarkets as well as from major consumer goods and beverage companies. One of them had received many complaints saying that "plastic is evil and has no place, regardless of any positives it might have in addressing food waste and what not… It's been ferocious."

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[3] EN13432 para 1. Provides that "This European standard makes provision for obtaining information on the processing of packaging in controlled waste treatment plants, but does not take into account packaging waste which may end up in the environment through uncontrolled means, i.e. as litter."

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

[5] https://denkstatt.eu/portrait/?lang=de

[6] https://www.green-alliance.org.uk/plastic_promises

The Report says that some decisions have been taken knowing it could actually increase environmental burdens. One supermarket representative was frank: “We are aware that [by switching from plastic to other materials] we may, in some cases, be increasing our carbon footprint.” A brand representative bluntly complained about misinformation being spread about the environmental credentials of non-plastic single use packaging formats: “The past year has just really annoyed me no end with companies boasting about not using plastic, even when they’re in single use glass, and their carbon emissions are going to be off the scale.”

PAPER

Isn’t it better to use paper bags instead of plastic bags?

No. A statement from Exeter City Council in January 2020 said Paper “is often touted as the solution to all our plastic woes, but it just isn’t. This is just another example of making a problem worse by trying to make it better…or trying to look like you’re trying to make it better. Paper production and transportation is incredibly fuel- and energy- and water-intensive – much more so than thin plastic. It tends to result in the deforestation of old wood that is often replaced by a non-native monoculture, severely inhibiting the biodiversity essential for life on earth.”

Planting trees is a really good thing; but cutting down forests is a different matter. We need more trees, not more new ones and fewer old ones. Why do they use old wood? Because it has nice long fibres. Think about all the fuel used in cutting down trees and hauling them. All the water and energy and chemicals used in pulping, bleaching, drying, cutting, and transporting.

The embedded carbon and environmental damage in a paper bag is significant. So paper is not a solution to plastic. It may rot quicker in nature, but the harm it does before it gets there can be considerably higher than that caused by plastic.

The Life-cycle Assessment by Intertek, published by the UK Government in February 2011[7] found that “The paper bag has to be used four or more times to reduce its global warming potential to below that of the conventional HDPE plastic bag, but was significantly worse than the conventional HDPE bag for human toxicity and terrestrial ecotoxicity due to the effect of paper production. However, it is unlikely the paper bag can be regularly reused the required number of times due to its low durability.

- The process of making paper bags causes 70% more atmospheric pollution than plastic bags.
- Paper bags use 300% more energy to produce, and the process uses huge amounts of water and creates very unpleasant organic waste. When they degrade they emit methane and carbon dioxide.
- If you compare the use of resources in manufacturing paper compared with plastic, in water usage alone, the cost is much higher given that fresh water is a resource that is in short supply in many regions of the world.
- A stack of 1000 new plastic carrier bags would be around 2 inches high, but a stack of 1000 new paper grocery bags could be around 2 feet high. For every seven trucks to deliver paper bags, only one truck is needed for the same amount of plastic bags, creating much less transport pollution and road congestion. 2,000 plastic retail bags weigh 30 pounds, while 2,000 paper grocery bags weigh 280 pounds. Additionally it takes 91% less energy to recycle a pound of plastic than it takes to recycle a pound of paper. Plastic bags generate 80% less waste than paper bags.
- Also, because paper bags are not as strong as plastic, people may use two or three bags inside each other. Paper bags cannot normally be re-used, and will disintegrate if wet.

A study published on 19th July 2017 in “Science Advances” by researchers at the University of California, Santa Barbara, the University of Georgia, and the Law of the Sea Education Association in Woods Hole, Mass., said that “***The same properties that make plastics so versatile — durability and resistance to degradation — make these materials difficult or impossible for nature to assimilate.” The researchers concluded that “humans are conducting an uncontrolled experiment on a global scale, in which***

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

***billions of metric tons of material will accumulate across all major terrestrial and aquatic ecosystems on the planet*"**

This is the very reason why OBP has been invented. It performs in exactly the same way as normal plastic, but it protects the environment from the accumulation of plastic waste by converting at the end of its useful life into biodegradable materials which are no longer plastic. The micro-organisms then return the material to nature.

Urgent action is therefore necessary. Governments must stop dithering and make it mandatory for all short-life products made from polyethylene or polypropylene to be made with OBP. This has already been done in Saudi Arabia, the UAE, and other countries, and it is time that the rest of the world followed their example. The EU is moving in the opposite direction due to pressure from vested-interests,[8] and as a result the EU is being charged in its own courts with misuse of legislative power.[9]

These countries in the Middle East recognise that upgrading the plastic is preferable to trying to ban it. They do not want to leave plastic waste in the environment as a problem for future generations, so they sent experts to England to study OBP technology. They are now convinced that OBP offers an "insurance policy" if all else fails, and **factories and brand-owners are not allowed to export to those countries unless their plastic products and plastic packaging are made with OBP technology.**[10]

Whilst the amount of plastic waste and leakage into the environment can be reduced by suitable policies, the only way to prevent plastic fragments getting into the environment entirely is to ban all plastics, which is clearly disproportionate and not desirable. Nobody doubts that all plastics will fragment as they degrade, but OBP has been designed to convert rapidly at the end of its useful life into low molecular-weight biodegradable materials in the outdoor environment with access to oxygen. Nobody doubts that this does occur. Sunlight and heat will accelerate the process but they are not essential.

Similarly, nobody doubts that the length of time that this process takes will depend on conditions in the environment. Equally, nobody doubts that under the same environmental conditions OBP will become biodegradable much more quickly than conventional or crop-based plastic. However, questions are asked as to whether the whole of the plastic will convert to low-molecular-weight materials, but this is well understood and the industry standards for OBP place limits on the formation of non-degradable fractions.

If OBP merely fragmented without biodegrading, CEN would not have defined oxo-biodegradability[11], and the American and British and French Standards authorities would not have included tests for biodegradability in ASTM D6954, BS8472 and AC T51-808

The Eunomia Report (2016) to the EU Commission concluded that *"The debate around the biodegradability of OBP plastic is not finalised, but* ***should move forward from the assertion that OBP plastics merely fragment, towards confirming whether the timeframes observed for total biodegradation are acceptable from an environmental point of view and whether this is likely to take place in natural environments****."* As to these issues see below. There is therefore no longer any justification for anyone to refer to OBP as "oxo-degradable" or "oxo-fragmentable."

THE SCIENCE

The scientists who invented plastic soon realised that the durability which they had worked so hard to achieve would cause a serious problem if the plastic escaped into the open environment as litter. They therefore

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[8] https://bioplasticsnews.com/2021/12/06/history-anti-oxo-biodegradable-plastics-history/
[9] https://www.symphonyenvironmental.com/eu-court-case-update/
[10] See http://www.symphonyenvironmental.com/exporting-plastic-products-saudi-arabia/
[11] TR 15351 "degradation identified as resulting from oxidative and cell-mediated phenomena, either simultaneously or Successively."

found a way to make the molecular structure of the plastic dismantle automatically in the open environment so that it becomes biodegradable, and they called it "oxo-biodegradable."

The biodegradability of oxo-biodegradable polymers has been extensively studied and reviewed in scientific articles over more than 40 years. In 2018 the scientific evidence was reviewed by a former Judge in England.[12] He concluded, in a 14-page written Report, that oxo-biodegradable technology:

- does facilitate the ultimate biodegradation of plastics in air or seawater by bacteria, fungi or algae, within a reasonable time, so as to cause the plastic to cease to exist as such, far sooner than ordinary plastics, without causing any toxicity;
- that "the benefit is obvious of reducing future contributions to the scourge of plastic pollution of land and sea";
- that oxo-biodegradable technology is compatible with composting and recycling; and
- "the criticism alleging that oxo-biodegradable plastic technology would materially encourage littering [can only be regarded] as fanciful and unrealistic."

In 2019 a Report by Queen Mary University London[13] showed that:

- Molecular-weight reduction is a critical factor in rate and extent of biodegradability
- The use of a prodegradant catalyst caused rapid molecular-weight reduction;
- The degraded polymer was then biodegraded by bacteria commonly found in soil and marine environments
- Oxo-Biodegradable plastic demonstrated up to 90 times more mineralisation than ordinary plastic
- There is similar biodegradation whether the polymer is degraded in the laboratory or under real-life conditions.

In 2015 Gewert et al[14] found that "Abiotic degradation produces carbonyl groups that increase the hydrophilicity of the polymer and thus increase its availability for biodegradation"

Dussud et al[15] compared three polyethylene-based polymers, with similar surface roughness, and observed increase in oxidation and hydrophilicity brought about by the inclusion of a prodegradant additive and then by oxidative degradation, which is a clear factor in the ability of organisms to colonize the material. During these experiments, the degree of colonisation (cell count) is not only an indication of the ability of microorganisms to physically populate the surface of the material, but is also influenced by each material's ability to act as a source of nutrients for the microorganisms.

Eyheraguibel et al[16] identified the products of degradation facilitated by a prodegradant additive in an OBP as oxidised oligomers. The characterisation of the oligomers, before and after exposure to the bacterial strain R. rhodochorus, provides insight into the oligomeric products of polyolefin degradation and their biodegradability. The paper demonstrates that after sufficient molecular weight reduction, the oligomers are soluble in water and that the most and undergo near-total biodegradation: 60% biodegradation after only four days, up to 95% after 240 days.

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[12] https://www.biodeg.org/uk-judge-find-the-case-for-oxo-biodegradable-plastic-proven/
[13] https://www.biodeg.org/wp-content/uploads/2019/12/qmu-press-release.pdf
[14] Gewert, B., Plassmann, M. and MacLeod, M. (2015). Pathways for degradation of plastic polymers floating in the marine environment. Environmental Science: Processes & Impacts pp.1515.
[15] "Colonization of Non-biodegradable and Biodegradable Plastics by Marine Microorganisms" Frontiers in Microbiology, (2018). 9.
[16] "Characterization of oxidized oligomers from polyethylene films by mass spectrometry and NMR spectroscopy before and after biodegradation by a Rhodococcus rhodochrous strain" 184 Chemosphere (2017) 366-374.

Arraez et al[17] say "The design of materials with the ability to degrade once their service life has finished is one of the industrial approaches to face the problems of accumulation of plastic wastes in the environment. The purpose of such process is to generate chemical changes in the polymer structure as a result of oxidation in air. This is achieved by using special additives called pro-oxidant/pro-degradants (oxo additives) consisting of organic salts of metals …. The degradation process induced by the incorporation of oxo additives in polymers is called oxo-biodegradation and is defined as the process of transforming complex molecules into simpler elements from oxidation reactions that promote the cleavage of the chemical bonds, the incorporation of polar groups, and the reduction in molecular weight in polymer chains favouring their interaction with micro-organisms in the environment, transforming them into bio-assimilable materials. ….. Micro-organisms such as bacteria fungi and algae use the oxidation products of the polymer chains as carbon sources resulting in the formation of carbon dioxide, water, and bio-mass."

See also Ammala et al., 2011; Koutny et al., 2006a; Singh and Sharma, 2008). (Albertsson and Karlsson, 1980; Chiellini et al., 2006; Jakubowicz et al., 2006; Ojeda et al., 2011(Albertsson et al., 1987; Bonhomme et al., 2003; Corti et al., 2010; Jakubowicz et al., 2011).

The EU Commission report[18] accepts at para. 3.1 that the plastic does not simply fragment into small pieces. It says that "This first stage of degradation prepares the oxo-degradable plastic for biodegradation by reducing the molecular weight of the plastic to the point where it may be consumed by biological organisms,"

A report was issued by the Ellen MacArthur Foundation in 2017 and endorsed by some of the world's largest producers of the very plastic packaging which is polluting the oceans. It was also financially supported by the producers of vegetable-based plastics who see oxo-biodegradable plastics as a threat to their market-share.

It said that "oxo-degradable" plastics simply fragmented but having engaged with our scientists they no longer say that. They now admit in their May 2019 report that "oxo-degradable" plastics are manufactured so that they can degrade faster than conventional plastics and that they do become biodegradable, but they say that "it is not yet possible accurately to predict the duration of the biodegradation for such plastics."

For that reason a broad indication only can be given as to timescale. It is however possible to say with certainty that at any given time and place in the open environment an oxo-biodegradable plastic item will become biodegradable significantly more quickly than an ordinary plastic item. That is the point. - Do we want ordinary plastic which can lie or float around for decades, or oxo-biodegradable plastic which will be recycled back into nature much more quickly? Of course, we don't want plastic in the sea at all, but that is not the present reality.

We discovered that the author of the MacArthur Report is not a polymer scientist, nor even qualified in chemistry.

A draft of the 2017 MacArthur report had been submitted to Prof. Ignacy Jakubowicz, one of the world's leading polymer scientists, who replied that it did not accord with his understanding, nor the science in this field.[19]

He also explained to them that "The degradation process is not only a fragmentation, but is an entire change of the material from a high molecular weight polymer, to monomeric and oligomeric fragments, and from hydrocarbon molecules to oxygen-containing molecules which can be bioassimilated." They are then recycled back into nature by the naturally-occurring micro-organisms. This point is absolutely crucial to an

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[17] "Thermal and UV degradation of polypropylene with pro-oxidant. Abiotic characterization" Applied Journal of Polymer Science (2017) 135, 46088

[18] 16th January 2018

[19] http://www.biodeg.org/Reply%20to%20Ellen%20MacArthur%20Foundation%20from%20Prof%20Ignacy%20Jakubowicz%20-%2021-8-17.pdf.

understanding of (OBP) but the MacArthur researchers have failed to understand it. The same mistake was made by the authors of the January 2018 EU Commission report on oxo-biodegradable plastic.

For the OPA response to the MacArthur report see https://www.biodeg.org/wp-content/uploads/2019/11/emf-report-2-2.pdf

For the OPA response to the EU Commission report see http://www.biodeg.org/OPA%20responds%20to%20European%20Commission%20%20-%20%20%2019%20January%202018.pdf

Oxo-biodegradable or Hydro-biodegradable?

The term "biodegradable plastic" should not be used, as it immediately begs the question whether you mean oxo-biodegradable or hydro-biodegradable. These two are completely different technologies, with different purposes:

- Oxo-biodegradable – is made from polymers such as PE, and PP, and contains special ingredients (which do not include any metals exceeding the prescribed limits.[20] OBP products are tested according to ASTM D6954[21] to prove that they are biodegradable and non-toxic. They can also be recycled during their useful life, and independent reports proving this are publicly available on the OPA website.[22] Starch is not used in OBP.
- Crop-based hydro-biodegradable plastics (HBP) - (also loosely known as "bio-based plastics" or "bioplastics" or "compostable plastics"). These contain a high proportion of oil-based material, and are tested according to EN 13432 or ASTM D6400 to biodegrade in the special conditions found in industrial composting. For more detail about that type of plastic see the Annex to this briefing note.

Polymers made from crops such as sugar-cane, would benefit from the inclusion of oxo-biodegradable technology because they are not otherwise biodegradable. There are in addition some additives marketed as "enzymatic" or "microbiological" but these are not oxo-biodegradable, and it is doubtful whether the plastic (as distinct from the additive) will degrade at all.

For OBP generally see www.biodeg.org

Oxo-biodegradation was studied by the Eurofins laboratory in Spain in 2016, who tested specimens of plastic made with Symphony's d2w[23] masterbatch according to ASTM D6954 and found that the prodegradant additive reduced the molecular weight of the plastic to the point where it became a low molecular weight material accessible by bacteria as a food-source, and no longer a plastic.

At that point they tested for presence of metals and found that there were none exceeding the limits prescribed in Annex A.1.2 of EN13432. The specimen also passed the test for gel content.

They then subjected the degraded material to biodegradation testing and found that the bacteria generated a quantity of CO_2 which showed that they had consumed the residual material to the extent of **88.9%, at a rate which produced that consumption in 121 days.** They then proved compliance with the eco-toxicity tests prescribed by OECD 207 and 208.

[20] EU Packaging Waste Directive 94/62/EC Art. 11 and Annex A.1.2 of EN13432.
[21] https://www.astm.org/catalogsearch/result/?q=D6954
[22] For definition of plastic see ASTM D883
[23] www.d2w.net

Specimens of plastic made with Symphony's d2w[24] masterbatch were also tested according to ASTM D6954 by Intertek in December 2021. They found **92.74% biodegradation in 180 days**. The specimen also passed the test for ecotoxicity, prescribed metals, and gel content.

Oxo-biodegradation has also been proved in France[25] by an entirely different methodology set out in AFNOR AC T51-808, which also uses bacteria which are found in soil and in marine environments.

Work has also been done at the Technical Research Institute of Sweden and the Swedish University of Agricultural Sciences, and a peer-reviewed report, was published in Vol 96 of the journal of Polymer Degradation & Stability (2011) 919-928. **They found 91% biodegradation within 24 months**. French academics at the Institut de Chimie de Clermont-Ferrand have also found that fragmentation of polymer led to the formation of a complex mix of small compounds that are readily water-soluble and totally assimilated by bacteria.

None of these tests mentioned above were designed to prove biodegradation in the laboratory only, but were designed to show what would be likely to happen under real-world conditions, just as tests done on "compostable" plastic are done in a laboratory according to EN13432 or ASTM D6400.

OBP has the same tensile strength as ordinary plastic, but it automatically converts in the presence of oxygen into $C0_2$, water, and biomass if discarded into the open environment. It does not therefore leave microplastics behind - and the particles of plastic which have been found in the oceans by NGOs and scientists are particles of *ordinary* plastic. Light and elevated temperatures are not necessary for the conversion process, but they will accelerate it. Nor is moisture necessary.

The first (abiotic) phase of oxo-biodegradation can be as short as a few months depending on the heat, UV light, and stress in the disposal location, as compared with 50 years or more for old-fashioned plastics. The residues are harmless, as proved by the OECD eco-toxicity tests, and the material has also become hydrophilic and polar - so it will stick to the earth and will be much less likely to blow around as dust than would fragments of conventional plastic.

Materials such as twigs and straw, which are obviously biodegradable, will take much longer than OBP to biodegrade. After the molecular reduction has occurred, the oxo-biodegradable material will be converted into water and humus by naturally-occurring bacteria and fungi, **thus completing the cycle from oil, back to nature.**

When anything degrades in aerobic conditions CO_2 is released, and in the case of bio-based plastic this has to occur very rapidly in an industrial composting unit to satisfy EN13432 or ASTM D6400. By contrast, OBPs release CO_2 much more slowly, and it can be absorbed by the surrounding vegetation and used by micro-organisms as a food-source.

There are four issues of particular concern:

- MICROPLASTICS AND LITTER
- RESOURCE DEPLETION
- RECYCLING
- COMPOSTING AND FOOD WASTE

MICROPLASTICS AND LITTER

Microplastics are a serious environmental problem. They are caused mainly by the embrittlement and erosion of conventional plastic, and these fragments can lie or float around for decades, adsorbing toxins.

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[24] www.d2w.net
[25] CNEP R2014-222- May 2014

The European Chemicals Agency has studied OBP, and said on 30th October 2018 that it is not convinced that it creates microplastics.

It is well known that millions of tonnes of plastic waste end up in the environment every year. Plastic packaging is estimated to represent the highest share, as its weight, size and low-value make it prone to uncontrolled disposal.

Plastic pollution of the open environment is a worldwide problem, and that is the reason why campaigners around the world are wanting to ban or tax plastic bags[26]. The level of pollution by plastic litter, including microplastics, is alarming, and almost all of it is conventional plastic, which can persist in the environment for decades. It is necessary to stop using conventional plastic as a matter of urgency.

A public-opinion poll by You Gov in the UK in July 2015 showed that 85% of people thought that all plastic carrier bags should be both recyclable and biodegradable [i.e. oxo-biodegradable] in case they accidentally get into the open environment. A similar result was found in Mexico.

In an ideal world, all the used plastics would be collected, but we don't live in an ideal world. In some countries government strategy aims at improving the economics, quality and uptake of plastic recycling and reuse, and reducing plastic leakage into the environment, and we agree with this. However, there is nothing in this strategy for dealing with the thousands of tons of plastic which (despite the strategy) will for the foreseeable future still escape into the open environment, endangering wildlife and clogging up waterways. Somehow, we have to make sure that it does not lie or float around for decades.

To meet this challenge OBP was developed by polymer scientists.

It is important to stress that OBP is consistent with a circular economy. This is because OBP items can be redesigned, they can be re-used unless and until they get into the open environment as litter, and they can be recycled[27] without the need for separation if collected during the useful life of the product. OBP is not designed to be deliberately lost to the economy – but it is there to protect the environment if all else fails.

Micro-beads – used in products such as cosmetics and made from PE or PP, and some small plastic goods such as drinking straws and stirring sticks have attracted a lot of attention recently, but they are a minor source of microplastics, and they too could be made oxo-biodegradable.

The problem which OBP is designed to address has nothing to do with landfill. Biodegradation is not desirable in landfill, because most landfills are not sealed whilst in use, and biodegradation in anaerobic conditions generates methane, which is a dangerous greenhouse gas, more powerful than CO_2.

Plastic should not be landfilled at all, and soon it will not be allowed in Europe - because plastic which has been collected is useful for its calorific value and for recycling.

A vegetable-based "compostable" plastic will generate methane in anaerobic conditions in landfill, but OBP will not. Some landfills are designed to capture methane but how do you know at the point of manufacture whether your plastic item will end up in one of them?

Nobody doubts that any type of plastic which has converted to low molecular-weight materials has become accessible to micro-organisms, who can use it as a food source, and that these micro-organisms exist on land and in the sea. The dispute is about how quickly they will bioassimilate the material, and whether they will bioassimilate all of it.

Once the material has become biodegradable in the open environment it really does not matter how long it takes to biodegrade completely if it has been proved to be non-toxic. This would matter only in the unlikely situation that large quantities of plastic residues had been discarded in the same place, and this is not likely

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[26] http://www.biodeg.org/bagbansandtaxes.html
[27] http://ww.biodeg.org/reycling.html

in the case of carrier bags or packaging. **One thing is certain – that under any conditions in the open environment OBP will have biodegraded much more quickly than old-fashioned plastic in the same place.**

If we are concerned about litter on land and sea which cannot realistically be collected, there is no point in choosing 'compostable' plastics, which obviously have to be collected before they can be put into a composting unit, and no point in choosing the type of crop-based plastic (sometimes called 'drop-in plastic') which is no more biodegradable than conventional plastic (See "Fossil Resources" below). By contrast, OBPs can be re-used and recycled during their useful life, and only if they do not get collected would they degrade and biodegrade in the open environment.

OBP can be used to make **mulch films for agriculture**, but it is a bespoke product. A reputable supplier will formulate the polymer and additive having regard to the type of crop and its growing-season. Allowance will be made for exposure to UV light on the surface of the field during the growing season, and trials will be done in situ with a range of formulations before an OBP mulch-film is supplied to a farmer in commercial quantity. For a report of successful tests in Wales see chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.symphonyenvironmental.com%2Fwp-content%2Fuploads%2F2021%2F06%2FPembroke-Mulch-Film-Trial-Report-30.09.13V1.pdf&clen=695628&chunk=true

Vegetable-based plastic is not as useful for this purpose, because the time for degradation cannot be controlled.

As to whether the micro-organisms will bioassimilate the whole of the low molecular-weight material, biodegradation of 91% has been proved as noted above, at the Technical Research Institute of Sweden and the Swedish University of Agricultural Sciences, and of 88.9% in the Eurofins laboratory in Spain. This is complete biodegradation for all practical purposes (the limit specified for "compostable" plastic in EN13432 is 90% of the maximum degradation of a suitable reference material, and this could be less than 90% of the actual material).

Evaluation of degradation can be done in the open environment, as was done in seawater at Bandol [28] but the evaluation of biodegradation has to be done under laboratory conditions (as is also the case with plastics marketed as "compostable") – it cannot be done in a field or an ocean or a compost heap. These tests are very expensive and are not done for the amusement of scientists. They are designed to replicate conditions in the real world, and there is no reason to think that in the open environment the micro-organisms will stop before they have consumed all of the available material. It is for those who think so to provide credible reasons, and they have not produced any.

When comparing the performance of OBP with conventional plastic, the conventional plastic will not biodegrade at all until it has acquired biodegradability after exposure for very many years, and then its performance will be much the same as the degraded residues of OBP. The purpose of OBP is therefore to reduce very significantly the period of time that the plastic is lying or floating around, and accumulating in the environment and adsorbing toxins before it becomes biodegradable.

PROPENSITY TO LITTER

It is often claimed that biodegradable plastics are likely to encourage littering, but this is rarely advanced as an objection to bio-based plastics. The Eunomia Report says*, "rather than speculation, objective behavioural research is required to move this topic forward in a constructive manner."*

In our view, even if there were a label describing a product as oxo-biodegradable, it is unlikely that the people who cause litter will look for the label before deciding to throw a plastic item out of a car or train window. Further, even if it were true that biodegradability encourages littering, and supposing that there would be 10%

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[28] See note 16 below

more litter - is it preferable to have 110 plastic items in the environment which will degrade and biodegrade in a few years or even months, or 100 plastic items which will lie or float around for decades?

It is not acceptable to continue debating this speculative proposition any longer, while thousands of tonnes of conventional plastic are getting into the environment every day, which will accumulate and pollute the environment for decades into the future.

A Life-cycle Assessment by Intertek shows that when the litter metric is included OBP is actually the best material for making carrier bags.[29]

RESOURCE DEPLETION

We find it hard to understand the trend towards replacing conventional oil-based plastics with plastics derived partly or fully from crops.

Oil-based plastics, including OBP, do not cause fossil resource-depletion. This is because they are made from ethylene – a by-product of oil-refining which used to be wasted. The oil is extracted to make fuels and lubricants, and the same amount would be extracted even if oil-based plastics did not exist. Therefore, until other fuels and lubricants are found for vehicles, ships, aircraft, buildings, and factories, it makes sense to use this by-product instead of consuming large amounts of fossil fuel in the agricultural production, transport, and polymerisation of "crop-based" plastics. See http://www.biodeg.org/biobased.html

It would therefore be deceptive to describe crop-based plastics as "renewable."

RECYCLING

Plastic is often deemed officially 'recycled' if it is recovered for recycling, no matter what ultimately happens to it. However, whilst almost all pre-consumer waste (eg factory offcuts) is recycled or reused, almost all post-consumer waste plastic is not. There are reasons for this, one of which is that a great deal of water is needed to wash post-consumer waste to make it useable, so the amount of waste-water generated is enormous. Moreover, this process leaves prodigious quantities of dirty solid waste, including biological waste that is hazardous and highly undesirable.

Similarly, the recycling charity RECOUP says that "where plastic products are particularly lightweight and contaminated with other materials, the energy and resources used in a recycling process may be more than those required for producing new plastics. In such cases recycling may not be the most environmentally sound option." It is too costly in financial and environmental terms to collect it, transport it, sort it, bail it, store it, and then reprocess it. This is why it was being dumped in Malaysia.

These are the very products in which OBP technology is commonly used and they are not plastics in high-value use. OBP technology is not suitable for PET.

Recycling is sometimes used as an objection to biodegradable plastic, on the basis that it will contaminate a post-consumer waste stream, but this is clearly irrelevant unless the waste plastic is going to be mechanically recycled.

d2w biodegradable plastic is normally used for low-value items which are not worth recycling, but experts in Austria and South Africa have found it to be compatible with recycling if anyone still wants to recycle it.[30] They also found that bio-based plastics are not recyclable.

Separation of the different types of polymer is a problem with all types of plastic film, and is another reason why post-consumer plastic film is not attractive to recyclers.

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[29] See http://www.biodeg.org/New%20LCA%20by%20Intertek%20%20-%20Final%20Report%2015.5.12(1)%20(1).pdf
[30] https://www.biodeg.org/recycling/

It is sometimes said that oxo-biodegradable plastic cannot be separated from ordinary plastic in the waste stream by the existing equipment, and that it could compromise the quality of recycled products. This is easily remedied by the inclusion of a tracer in the OBP at manufacture which the equipment can recognise, but it is not necessary because as noted above oxo-biodegradable plastic can be safely recycled without separation.

It is clear from these expert reports that it is not necessary to add stabilisers unless the recyclate is being used to make long-life products, in which case the manufacturer of those products would be adding stabilisers anyway. These stabilisers are in a quantity and with a chemistry which he would normally use, and no special arrangements are necessary for recyclate containing OBP.

Most conventional waste plastics will have been exposed to UV radiation, in particular agricultural film, and may have oxidised to some extent, but not enough to become biodegradable. Recyclers of mixed plastic wastes have no way of knowing which have been exposed and for how long, and it is also known that printing inks, and other chemicals will affect the recycling process.

Therefore, the industry already has the problem of identification when dealing with post-consumer plastic films and deals with it by using those materials for low-value/short-life applications such as carrier bags and garbage sacks. If an OBP carrier bag is going to be collected for recycling at all it is likely to be collected during its useful life, and during that time, it will be unlikely to have oxidised to any significant extent.

The position of the OBP industry is therefore based on scientific reports by specialist researchers. Our experience is entirely consistent with the specialist reports, that oxo-bio plastic can be safely recycled, and recyclers have presented no technical evidence and no actual experience, to the contrary.

In the last four years alone, enough masterbatch has been sold by one OPA member to make 600,000 tonnes of OBP products from polyethylene and polypropylene. We know that OBP products have been successfully recycled for the past 15 years by OPA members and their customers around the world, and in those 15 years we have heard no reports of any difficulty encountered.

It is time for a much better dialogue between the recyclers and the OBP industry. If we can combine oxo-biodegradable technology with the three R's of 'Reduce, Reuse and Recycle', we can all help win the battle against plastic waste - for the lasting benefit of future generations.

The specialist researchers also confirmed that crop-based 'compostable' plastics cannot be safely recycled with oil-based plastics. Anyone who wants to promote recycling should certainly be concerned about vegetable-based plastic. Some of it will get into the plastic waste recycling stream – especially as it is being promoted for carrier bags and packaging.

Actually, the best way to deal with contaminated post-consumer waste plastic is to send it to modern, non-polluting, thermal recycling facilities and to use the energy released from the plastic to generate electricity.

COMPOSTING AND FOOD WASTE

In the first place, we need to protect food from wastage by damage and contamination, and for this purpose plastic is necessary. In today's fast-moving society, it is inconceivable that enough food could be put on enough tables within the required timescale without using plastic. For the reasons given above this should be OBP.

Second, we need to educate ourselves not to waste food, and not to use agricultural land and water resources for producing bio-fuels and bio-plastics, instead of producing food.

The main purpose of plastic marketed as compostable is to make bags which are used to carry compostable material to an industrial composting plant and which do not therefore have to be emptied there.

However, the industrial composters and local authorities do not want it.[31] Epsom & Ewell Borough Council in the UK tells its residents:

> "When you use plastic bags in your food waste caddy you're simply using them to contain the food, and keep your caddy clean. They don't get recycled. In fact, the first thing that happens when your food waste gets to the recycling plant is the plastic bags are all dredged out. They're sent off for burning along with normal refuse to generate electricity. After that, the food waste can be recycled."
>
> "We used to ask you to use bio-liners to line your food waste caddy, but the food waste recycling companies found that bio-liners compost down much more slowly than the food. That slowed the recycling process and made it much more expensive. They tried dredging the bio liners out of the food waste, but the sticky bio-liners got tangled around the dredging equipment. Cleaning them off was very expensive. So they found that using ordinary plastic bags was, overall, much more cost-effective."

The City of Exeter, UK has rejected both "compostable" plastic and paper as alternatives to ordinary plastic.

A "Grocer" magazine survey of more than 1,000 individuals in 2019 found that "consumers think that vegetable-based plastics are the most environmentally friendly packaging materials, ahead of paper, glass, cardboard, conventional plastic and aluminium, in that order." But most consumers don't realise that "compostable" plastic does not convert into compost, and that it is tested to biodegrade in an industrial composting facility – not in the open environment. Nor do they know that it is required by EN13432 and ASTM D6400 to convert rapidly into CO_2 gas, and the last thing the planet needs is more CO2.

EN13432 is a standard written by the bio-based industry representatives on CEN for their particular technology and is not relevant to OBP (except that OBP meets the same non-toxicity criteria). In fact the desirability of this standard and this product must be questioned in an age where great efforts are being made to reduce CO_2 emissions.

"Compostable" plastic is also sometimes used for packaging and carrier bags, in the mistaken belief that it is better to make plastic from crops instead of oil – See "Fossil Resources" above.

People should not be allowed to market plastic as "compostable."

"Compostable" plastic is in any event addressing the wrong problem. The problem is not that there is insufficient plastic being converted to CO_2 in composting facilities – the problem is that there is too much plastic getting into the open environment.

THE MARINE ENVIRONMENT

OPA member, Symphony Environmental wanted to be sure that their oxo-biodegradable plastic would properly biodegrade in the oceans – so they sent samples to the French marine laboratory L'Observatoire Océanologique de Banyuls who studied it for three years. They have concluded that it does properly biodegrade in the oceans much more quickly and efficiently than ordinary plastic. The Oxomar report can be found at https://www.biodeg.org/subjects-of-interest/agriculture-and-horticulture/the-marine-environment/ Further studies (as yet unpublished) by the scientists have used a carbon 13 tracer to find the biodegraded material actually inside the bacteria who have consumed it.

According to Dr. Jean-François Ghiglione[32] *"OBP will float and be at almost all times subjected to UV light, which accelerates the abiotic phase of degradation. This is not always the case on land, where plastic pieces are often covered by soil, leaves etc. and are less exposed to UV light*." He points out that *"there are specific bacteria living in the "seasurface microlayer" (the top millimetre of the ocean surface), where bacteria are different from those further below the surface. The bacteria in the sea-surface microlayer are particularly*

[31] https://www.biodeg.org/subjects-of-interest/composting/

[32] Directeur adjoint de L'Observatoire Océanologique de Banyuls.

adapted to a hydrophobic environment (e.g. where oil materials are floating) and these bacteria are known to present a high capability for hydrocarbon degradation. These bacteria are therefore potential OBP-degraders, and such an environment does not exist at the surface of soil. These bacteria are probably less abundant and less diverse in the ocean than in soil, but probably more effective to degrade OBP."

"Some marine bacteria, such as Alcanivorax borkumensis and R. rhodochorous are noted for their ability to biodegrade hydrocarbons and they are ubiquitous in the oceans. They occur in low concentrations in unpolluted seas but are observed to accumulate in waters polluted by oil spills. When presented with a source of carbon which is recognisable to the microorganisms as food, it seems therefore that they will respond with increased populations. The relatively low concentrations of microorganisms found in unpolluted oceans is not therefore a reason for expecting slow biodegradation of OBP."

Evidence is available - from tests done in real time at Bandol[33] on the coast of France that OBP will degrade to low molecular-weight materials under natural conditions in water, and samples aged under those conditions were studied in 2016 at Queen Mary University London where the abiotically degraded plastic was presented as the only source of carbon available to the bacteria. The samples were proved to be biodegraded by bacteria commonly found in the oceans, and separate samples were biodegraded by bacteria commonly found on land. The degraded plastic was also proved to be non-toxic to those bacteria.

The products of abiotic degradation of OBP are not fragments of plastic. As noted above, the molecular structure has been dismantled and the plastic has converted into a waxy substance which is no longer plastic. By contrast, conventional plastics can be observed to fragment, but will remain in the environment for a long period of time as high molecular-weight microplastics.

Several other studies have been done, including those by Pascall et al, Takada et al, Mato et al and Teuten et al, which demonstrate that conventional polymers such as polyethylene and polypropylene will readily adsorb PCB and other toxins. This is because the polymers are inherently non-polar and hydrophobic in nature, and with a low Tg (glass transition temperature), their nature allows for greater segmental mobility, pore-size, free volume, diffusion and partition coefficients. This means that hydrophobic organic toxins such as PCB can in theory adsorb to the polymers (through Van der Waals attractive forces) from the aqueous environment.

The increased pore-size and free volume also means that if the toxin is adsorbed to the conventional polymer, it will not readily desorb. Over long periods of time the plastic will break down by friction, shear, and weathering, and the potential for the plastic fragments to adsorb toxins increases. Takada et al demonstrated in a field experiment in Tokyo Bay that conventional plastic fragments collected from the bay had adsorbed up to 892 ng/g. This suggests that the plastic had persisted in that area for at least twenty-seven years (assuming a linear uptake).

Under the action of oxygen, UV light, and ambient heat, polyethylene and polypropylene which contains oxo-biodegradable additives will change its molecular structure and break down. Hydroperoxy intermediates are readily formed in the initial phase of degradation, and immediately there is a change in chemical structure and increase in polarity. The formation of these oxygenated species already makes the polymer less susceptible to adsorption of PCB and related hydrophobic toxins.

Lower diffusion and partition coefficients result from increased cohesive forces, thereby reducing segmental mobility and pore-size. The highly polar functional groups that are formed will not interact with the non-polar toxins, either through chemical reaction or intermolecular interaction.

The second stage of degradation is the molecular-weight reduction of the hydroperoxy intermediates (with the vicinal form proceeding more rapidly) to intermediate and short-chain aldehydes, ketones, esters, and hydroxyl and hydrocarbon radicals. These will proceed further to carboxylic acids which will be readily bioassimilated by micro-organisms.

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[33] Station d'essais de Viellissement Natural de Bandol

In summary, the constantly progressing transormation of the oxo-biodegradable polymer, results in species with increased hydrophilic character that will readily solubilise and emulsify in the ocean environment. It would, therefore, not be possible for hydrophobic toxins such as PCB to accumulate on OBP materials

STANDARDS

The main Standards which have been written for testing OBP are ASTM D6954 (USA); BS8472 (UK); AFNOR AC T51-808 (France); and SPCR 141 (Sweden). Variants of these standards have also been adopted in other countries. There is no European standard for OBP because the technical committees of CEN are dominated by representatives of the bio-based plastics industry who do not wish to see a standard which might increase competition from OBP.[34] Accordingly the OBP industry has worked at its own expense in the other standards organisations around the world to assist in developing new and better standards.

ASTM D6954 contains no less than six pass/fail criteria. 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 at least 60% of the organic carbon is converted to carbon dioxide the test cannot be considered completed). It is for customers and governments to decide what timescales are acceptable to them.

NON-TOXICITY

The OBP industry is as much concerned as anyone that its products should not introduce toxicity into the environment, and for this reason the standards for OBP require testing to confirm that the residues are harmless. Essentially OBP is made from the same materials as conventional plastics, with the addition of only 1% of a masterbatch (most of which is ordinary polymer), and they have to pass the same tests in EN 13432 as HDP to ensure that there is no toxicity and no metals exceeding prescribed limits.

Other ingredients which manufacturers may wish to include in plastic products are not the responsibility of the OBP industry, and should be specifically regulated by government.

The Eunomia Report says ***"it does appear that the OBP industry can create products that have minimal toxic impact on flora and fauna. … and it is encouraging that almost all existing test standards for OBP plastic specify some form of toxicity test using established methods (such as germination and earthworm survival tests)."***

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[34] https://bioplasticsnews.com/2021/12/06/history-anti-oxo-biodegradable-plastics-history/