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The Identity of Oxo-Degradable Plastics and their Use in Switzerland

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Executive Summary

Oxo-degradable plastics (ODP) are plastics containing pro-oxidant additives that allegedly promote fragmentation and subsequent biodegradation. However, in practice, ODP do not fully biodegrade under environmental or industrial composting conditions, and thus may serve as a source of microplastics in the environment. In addition, ODP can negatively impact recycling processes. Recently, the Single-Use Plastics Directive has been adopted in the European Union, stating that the placing on the market of all plastics containing additives, which through oxidation lead to fragmentation (i.e. ODP), will be prohibited. In this study, we investigate the occurrence of ODP in Switzerland and the feasibility of identifying ODP using handheld XRF. The main lessons learned are as follows:

Finding 1: No wide use of intentional ODP has been identified in Switzerland, with some unknowns. The stakeholders, which due to their size may circulate large amounts of intentional ODP, are aware of the related environmental risks and thus consciously avoid using them. Some smaller users and distributors of intentional ODP products in Switzerland have been identified, and additional users and distributors of the same kind may exist. In the agricultural sector, there is generally no awareness of ODP and related stakeholders do not know whether designated degradable products are made from ODP or not. Europe as a whole is a small market for intentional ODP compared to other regions of the world (e.g. the Middle East and South America).

Finding 2: Information on ODP mass flows is not easily available and accessible. It is challenging to retrieve information from manufacturers and other stakeholders. From trade statistics, it is not possible to derive any information on the import of pro-oxidant additives, ODP, or products made from ODP to Switzerland.

Finding 3: Pro-oxidant additives are broad and complex. The assumption of Fe, Mn and Co salts being the main pro-oxidant additives is based on limited primary literature. A broad variety of substances may be used as commercial pro-oxidants. Substances used as commercial pro-oxidant additives can also provide a variety of other functionalities in a polymer. Due to possible addition of such additives for functionalities other than being pro-oxidant, some conventional plastics may also be unintentional ODP.

Finding 4: It is challenging to differentiate between ODP and conventional plastics using handheld XRF due to the diversity of commercial pro-oxidant additives and lack of differences observed in the currently available samples.

Building on the findings of this study, the following recommendations to address ODP and some of the challenges identified above are summarized and highlighted below:

A. **An unequivocal definition of ODP is needed.**
B. **Simple methods for identifying ODP in practice need to be developed.**
C. **Regulating the labeling of degradable products may contribute to a proper disposal.**
D. **Restrictions on placing ODP on the market may be considered.**

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Abbreviations

ECHA	European Chemicals Agency
EMF	Ellen MacArthur Foundation
LOD	Limit of Detection
OBPF	Oxo-Biodegradable Plastics Federation
ODP	Oxo-Degradable Plastics
OPA	Oxo-Biodegradable Plastics Association
PE	Polyethylene
PP	Polypropylene
RoHS	Restriction of Hazardous Substance Directive (RoHS 2011/65/EU)

1. Introduction

Oxo-degradable plastics (or oxo-biodegradable plastics, oxo-plastics, pro-oxidant additives containing plastics, subsequently called ODP) are conventional polyolefin plastics (e.g. polyethylene (PE) and polypropylene (PP)) formulated to contain certain 'pro-oxidant' additives. The additives are intended to promote oxidation of the polymers under the influence of heat and/or UV radiation to the point that they break and fragment. Due to this specific design, ODP have been claimed to degrade rapidly in the environment and are used for products for which such a property is desired. This includes products that can end up in the environment voluntarily or involuntarily, such as carrier bags, agricultural products, rubbish bags, food packaging and landfill covers (Hann et al. 2016). It is estimated that the European market of ODP amounted to at least 20 000 tonnes in 2016, while it could have been as high as 100 000 tonnes (Hann et al. 2016). A brief overview of the distribution and use of ODP in individual EU Member States is provided in Table 1-1.

However, the (bio)degradability claim has been contested, and the concern of ODP being sources of microplastics in the environment is rising. Other debates have also taken place, e.g. whether pro-oxidant additives would cause harm to the environment and whether the presence of pro-oxidant additives would be problematic to waste treatment processes including plastic recycling and composting. In a recent review study commissioned by the European Commission(Hann et al. 2016), the following conclusions have been reached:

- The compiled evidence suggests that **ODP are inhibited from biodegradation** under conventional environmental conditions. The pro-oxidant additives in ODP will accelerate the fragmentation of plastics, in favorable prevailing conditions. Heat, light and moisture affect how quickly fragmentation occurs. However, biodegradation following the fragmentation will only occur after an initial stage with increased temperature or UV radiation. ODP act similarly to conventional plastics in an open environment including marine environment, i.e. are inhibited from biodegradation, if they are not first exposed to UV radiation (or, to a certain extent, heat). First, contained anti-oxidants (e.g. UV stabilizers) need to be broken down to allow pro-oxidant additives to accelerate the oxidation process. Such an increased exposure to UV radiation or high temperatures cannot be taken for granted under any circumstances.
- The evidence suggests that **ODP are not suitable for any form of composting or anaerobic digestion process** and will not meet current standards for packaging recoverable through composting in the EU (EN 13432:2000). They are designed to degrade in much slower timeframes than required for industrial composting.
- Evidence suggests that oxidized **ODP can significantly impair the physical quality and service life of recycled plastics.** This influence on the secondary material properties is difficult to counteract by including stabilizers because it is impossible to fully control the level of aging experienced by ODP during the product use phase.
  The evidence available does not support the suggestion that ODP can be identified and sorted separately by reprocessors with the technology that is currently available. Furthermore, even given sufficient labelling manual sorting would be time-consuming and is unlikely to be economically viable.

There have been different counter statements and opinion expressions regarding ODP degradability and recyclability; however, it is interesting to note that they are expressed by the industry associations of ODP manufacturers (Oxo-Biodegradable Plastics Association 2013, 2018a, 2018b; Oxo-

Biodegradable Plastics Federation 2017), the pro-oxidant additive manufacturers (EPI Environmental Plastics Inc. 2015; Symphony environmental technologies 2018) and by people associated with such manufacturers (Susman 2018). It is also interesting to note that these counter statements are made without any reference, or are based on scientific studies that do not well represent typical environmental conditions, or are not relevant to the issues mentioned above.

1.1 Recent legal developments in the EU

To date, several European Union (EU) Member States have already either banned the use of ODP or restricted companies from claiming that ODP are biodegradable. An overview of the current legislations on ODP by individual EU Member States can be found in Table 1-1.

On the EU level, the European Commission has been working on restricting the use of ODP in the EU (European Commission 2018). In line with the REACH procedures for restricting substances, the Commission first requested the European Chemicals Agency (ECHA) to review the scientific basis for taking regulatory action on EU level and develop a restriction proposal. ECHA has undertaken a call for evidence in 2018, including specific questions regarding the quantity of ODP manufactured and used in the EU (ECHA 2018). During the call for evidence, ECHA also welcomed views on how ODP should be defined, with a working definition for pro-oxidant additives provided as follows:

"Additives used in plastic that facilitate their oxo-degradation"

Quote 1: *The working definition of 'pro-oxidant additives' used in the ECHA call for evidence for the restriction proposal of oxo-degradable plastics* (European Chemicals Agency 2019)

The call for evidence was concluded, and a publication was planned for July 19th 2019.

In parallel, the Commission prepared a proposal for a 'Directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment' (2018/0172 (COD)) (European Parliament and European Commission 2019). The also called 'Single-Use Plastics Directive' (Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment) has been adopted by the European Parliament on March 27th, 2019 (European Parliament Plenary) and by the European Council on May 21st, 2019. The Directive entered into force on July 2nd, 2019. Member States are required to prohibit the placing on market of, besides certain single-use plastic products, products made from ODP (Article 5). The definition of ODP in Article 3 of the Directive is as follows:

"'Oxo-degradable plastic' means plastic materials that includes additives which through oxidation lead to the fragmentation of the plastic material into micro-fragments or to chemical decomposition".

Quote 2: *The definition of ODP by the European Parliament and Commission in the Directive on certain plastic products (also known as 'Single Use Plastics Directive', European Parliament and European Commission 2019a)*

In light of the newly adopted Single-Use Plastics Directive, the planned restriction proposal by ECHA has been withdrawn as of May 8th 2019. Instead, the EU Member States will have two years, i.e. until July 3rd, 2021, to transpose the legislation into their national law.

1.2 Recent legal developments in Switzerland

In Switzerland, Isabelle Chevalley, member of the National Council for the Canton of Vaud, belonging to the Green Liberal Party, has brought up an Interpellation to the Federal Council regarding deception in the context of oxo-degradable plastic bags on 10 September 2018 (Interpellation 18.3721: "Täuschung rund um die oxo-abbaubaren Säckchen stoppen"; following up on Interpellation de Buman 13.3620: "Oxo-biologisch abbaubare Säckchen. Eine schlechte Idee"). On 26 September 2019, she issued a motion (Motion 19.4182: "Wann werden oxo-abbaubare Kunststoffe verboten?") that aims to require the Federal Council to impose a prohibition on ODP as soon as possible. On 27 November 2019, the Federal Council proposed to adopt the motion. At the time of publication of the present report, the Parliament has not yet decided whether to accept or reject the motion.

1.3 Project aims and scope

To understand whether ODP are a problem in Switzerland and to foster relevant actions (e.g., restriction or ban) if necessary, it is key to first know which ODP are being used in which applications in which quantities in Switzerland. So far such information has not been made available in the public domain. The goal of the present study is to fill in this gap and answer the questions about which ODP can be identified in which products on the Swiss market and their respective use volumes. This study further aims to evaluate the feasibility of using handheld X-ray fluorescence (XRF) equipment to identify pro-oxidant additives in plastics as one method to identify and monitor ODP on the market and in waste streams.

Table 1-1: Distributors of ODP and legislation related to ODP in different EU countries

	Number of distributors of pro-oxidant additives manufacturers identified in Hann et al. (2016) in single EU countries									**Additional information on the use of ODP in the countries**	**Policies related to oxo-degradable plastics on a country level**	
	Sym-phony	Well Plastics (Re-verte)	Green Ready	Add-X	Willow Ridge	EPI	EcoPoly	P-Life	Ener Plastics		According to Hann et al. (2016)	According to European Commission (2018b)
Austria												
Belgium											(Walloon Region) ban proposed	have legislation that forbids oxo-plastics to claim that they are biodegradable
Bulgaria		1		1								have legislation that forbids oxo-plastics to claim that they are biodegradable
Croatia												
Republic of Cyprus		1										
Czech Republic				1								
Denmark												
Estonia												
Finland												
France				1						mentioned as one of biggest consumers by OPA; have test standard for ODP (AC T51- 808)	ban on all lightweight plastic carrier bags, including those from ODP, and excluding bags that are biodegradable in home composting systems, from July 2016	ban on oxo-plastics
Germany												
Greece		1										
Hungary		1		1								have legislation that forbids oxo-plastics to claim that they are biodegradable
Ireland										mentioned as biggest consumer of agricultural foils by OPA		

Italy		1		1						stakeholder which has distributed ODP bags in the past in Italy has been identified, however, at present no information on the product is findable on the internet	ban on all plastic bags, including those from ODP, but with exemption for biodegradable bags under EN 13432	new law will force the oxo-industry to give info on the negative environmental impact of these plastics on the environment; ban on oxo-plastics
Latvia												
Lithuania		1										
Luxem-bourg												
Malta												
Nether-lands		1										
Poland				1								
Portugal												
Romania		1										
Slovenia		1										
Spain		1		1						mentioned as one of biggest consumers by OPA		ban on oxo-plastics
Sweden										have test standard for ODP (SPCR 141)		studying the issue and considering restrictive measures
UK		1								known ODP bag manufacturers from UK *Polybag* and *Reddipak* who also sell their products to the biggest extent or exclusively there; have test standard for ODP (BS 8472)	ban on ploughing degradable mulch films under soil	studying the issue and considering restrictive measures
Notes	no distri-butors net-work dis-played	through out the UK and Europe by Distru-pol	no infor-mation		no EU country was men-tioned	has ware-housing facili-ties in North Ameri-ca, Europe and Asia	no infor-mation	Asia, mostly Hong Kong	no infor-mation			

2. Methods

2.1 Investigation of the occurrence of ODP in Switzerland

The occurrence of ODP in Switzerland was investigated using a combination of different approaches. It should be noted that the investigation here focused only on plastics that have been marketed as 'oxo-degradable'.

First, possible application areas of ODP were retrieved from (Hann et al. 2016), internet research and patent review. Based on the known applications, possibly relevant stakeholders in Switzerland were identified and contacted. These included supermarket chains, a large packaging manufacturer, a large plastic manufacturer, companies sourcing packaging, a provider of a collection system for agricultural wrapping foils and recycling thereof, and agricultural associations. In addition, other experts that are familiar with the topic were contacted. The list of directly contacted stakeholders, contact details and outcomes is available in Table 6-1 in the Appendix. In Table 6-2, additional stakeholders relevant to the use of ODP in Switzerland are listed, who were not directly contacted, but only identified either through stakeholders in Table 6-1 or from literature. In addition to stakeholders from Switzerland, also international stakeholders identified by Hann et al. (2016) were approached, and specifically asked regarding their sales to Switzerland and Europe. These included pro-oxidant additive manufacturers, ODP product manufacturers, and related industry associations. In addition, the European Commission, ECHA, international research institutions, and recycling, agricultural and environmental organizations were contacted regarding available information. Details of these international stakeholders are provided in *Table 6-3* in the Appendix. In addition, the distributor network of the known pro-oxidant additive manufacturers was mapped out to determine whether distributors are situated in Switzerland.

Second, a number of stakeholders were excluded as users of ODP based on their recent commitment to the Oxo Statement initiated by the Ellen McArthur Foundation that ODP packaging is not a solution to plastics pollution and does not fit in a circular economy (Ellen McArthur Foundation 2017). These stakeholders include many major international companies with headquarter or branches in Switzerland, or distributing products in Switzerland.

Third, a search of ODP products from online retailers was conducted: Amazon, Ebay and Alibaba were searched for the names of commercial pro-oxidant additives, the testing standards for oxo-degradability (e.g. ASTM D6954) and other keywords ('oxo-degradable', 'prodegradant additive'). Products were generally marketed as 'degradable' and only in the detailed product description they could be identified as ODP. Building on the search results, 27 ODP products were ordered via Amazon to check on the possibility of online ordering ODP products to Switzerland and were shipped to Switzerland (see *Table 6-5* in the Appendix). These products are primarily bags (e.g. dog excrements, diaper/feminine waste, or generic waste bags), and depending on the producers, they may contain pro-oxidant additives d2w (from Symphony), TDPA, or another pro-oxidant (from EPI).

2.2 Exploring of analytical methods for identifying pro-oxidant additives

A combination of theoretical and chemical analytical approaches was used to explore potential methods to differentiate between ODP and conventional plastics based on the identities of pro-oxidant additives.

It started with the theoretical approach, consisting of literature and patent review of the identities and possible commercial pro-oxidant additives. First, scientific papers cited by the review study commissioned by the European Commission (Hann et al. 2016) and from a SciFinder search (using 'oxo-degradable plastic' as a search term) were used as a starting point. Pro-oxidant additives that were mentioned in these studies were noted and tracked to their original sources. Then, patents mentioned in these scientific papers, patents assigned to the pro-oxidant additive manufacturers known from the stakeholder analysis (see *Table 6-3* under 'Pro-Oxidant Additive Manufacturer', 'ODP Product Manufacturers'), and patents identified on Google Patents and Espacenet (search terms: 'oxo-degradable plastic/polymer', 'degradable polymer/plastic') were reviewed. All patents, similar to or cited by already identified patents, as well as patents within the IPC classification 'Y10S260/43— Promoting degradability of polymers' were also investigated. Assignee names were tracked to the current companies and their products by internet research.

For the analytical approach, 27 samples of ODP products ordered from online retailers were compared with 23 conventional bags collected from Swiss retailers using elemental analysis with a handheld XRF (Thermo Scientific™ Niton™ XL2 Analyzer with a plastic calibration). The equipment calibration was validated using a certified reference material, ERM-EC681m – Polyethylene (high level). The limits of detection (LODs) under ideal conditions for identifiable elements are provided in Table 6-6 in the Appendix. Given the large number of non-detects (i.e. levels below the LODs) in the measurement results, statistical analysis based on Helsel (2005) describing the treatment of left censored data was conducted. In brief, the measurements of individual compounds in ODP and conventional plastics were characterized by a non-detect-ratio, the ratio between measurements below the limit of detection and the total number of measurements. Groups with a non-detect-ratio <0.5 were analyzed by estimating the values below the LOD using the Kaplan Meier Estimation (Python package: Lifelines – Kaplan Meier Fitter). Groups with a ratio between 0.5 and 0.8 were analyzed by estimating measurement values below the LOD using the robust maximum likelihood estimation. For those groups above a non-detect-ratio of 0.8, only the number of samples above the LOD and maximum measured value were reported.

3. Results and Discussion

3.1 The occurrence of intentional ODP in Switzerland

The collected information is mostly qualitative. Therefore, no material flow analysis of intentional ODP is feasible at the current stage. Instead, the following main lessons are learned; for detailed information, see Table 1-1, as well as Table 6-1, *Table 6-2* and *Table 6-3* from the Appendix.

Finding 1: No wide use of intentional ODP has been identified in Switzerland, with some unknowns.

While intentional ODP have been identified in some products by some minor users and distributors in Switzerland, they do not seem to be widely used in Switzerland due to consciousness by some major producers, users and distributors. In the field of agriculture, 'degradable' mulch films are being used; however, due to a lack of detailed information, it cannot be concluded whether or not intentional ODP are being used. This is a major uncertainty of the study, which warrants a future study.

Finding 1.1. The stakeholders, which due to their size may circulate large amounts of intentional ODP, are aware of the related environmental risks and thus consciously avoid using them.

- Coop and Migros do not offer ODP carrier bags and avoid ODP packaging for their own branded goods, and Amcor does not use ODP in packaging manufacturing. All three appeared to be critical of ODP.
- Some other large companies may be excluded as potential producers or users of ODP due to their commitment to the Oxo Statement by the Ellen MacArthur Foundation (EMF) pleading against the use of ODP (Ellen McArthur Foundation 2017). These include Nestlé, Unilever, BASF, Novamont, Danone, Marks & Spencer, L'Oréal, EuPC, Borealis, Flexible Packaging Europe, Veolia, Suez, Industrievereinigung Kunststoffverpackungen, petcore Europe, Henkel, edana, 3M, Andritz, Celanese, Clariant, Covestro, Daikin, Du Pont, Evonik, Freudenberg, Henkel, Voith, Johnson&Johnson, Kimberly-Clark, LG Chem, rkw and Wacker Chemie.
- No distributors of pro-oxidant additives have been identified in Switzerland.

Finding 1.2. Some smaller users and distributors of intentional ODP products in Switzerland have been identified, and additional users and distributors of the same kind may exist.

- ODP shopper bags are being distributed by some small ecological shops and farmer markets, e.g., in the canton of Vaud[1]. A major reason of using ODP bags is because they are believed by the retailers and their customers to be fully biodegradable within a suitable timeframe.
- Three Swiss companies (Sanpac[2], dietragtasche.ch[3] and Papival) have sold ODP bags in Switzerland. Sanpac commented that they will no longer have oxo-degradable products in their sales assortment as soon as the stock is exhausted[4], whereas dietragtasche.ch produced

[1] Personal communication, 2019-04-11; personal communication, 2019-04-18; for more detailed information see Table 6-2 from the Appendix

[2] Personal communication, 2019-04-18; oxo-degradable bags are listed in Sanpac's product catalogue (Sanpac SA 2019), additionally denoted as non-compostable; more detailed information can be found in Table 6-1 from the Appendix

[3] Personal information, 2018-12-13; Baier et al. (2016); more detailed information can be found in Table 6-1 from the Appendix

[4] Personal communication, 2019-06-14

only once an oxo-degradable product[5] and has ceased its production of ODP products ever since. The Swiss company Papival has stopped their sales of ODP bags after a complaint at the Swiss Commission of Integrity (Schweizerische Lauterkeitskommission).

- The UK-based company Polybags, also a vendor of ODP bags, sold some products to Switzerland in the past (while they sell 90% of their products in the United Kingdom)[6], and it is possible to purchase their bags online and get them delivered to Switzerland (see *Table 6-5*).
- For private persons and small businesses, it is possible to order and get ODP products delivered to Switzerland via Amazon and other online retailers, by searching e.g. for 'ASTM 6954' or 'EPI'. These include mainly different types of bags (e.g. dog/cat excrement bags, diapers bags, household waste bags, shopping bags) and straws. Sales numbers for these products purchased online are not available.

Finding 1.3. In the agricultural sector, there is generally no awareness of ODP and related stakeholders do not know whether designated degradable products are made from ODP or not.

- The Swiss Farmers Association (Schweizer Bauernverband) has no information on the use of ODP in agriculture in Switzerland, nor does InnoRecycling AG, the main company collecting and the only one recycling silo wrapping foils in Switzerland.
- In vegetable farming, degradable foils are being used. The Association of Swiss Vegetable Producers (Verband Schweizer Gemüseproduzenten) does not know whether they are made from ODP or not, nor has information on the quantities used.
- Agroscope has conducted a study on the use of plastics in agriculture in Switzerland (Kalberer et al. 2019), including the amount of degradable mulch foils annually used, the related amount of plastics getting dispersed in the environment and their environmental consequences. The study consulted Swiss distributors of agricultural foils, including gvz-rossat, and found that these distributors do not have any detailed material information for the foils they sell beyond that they are claimed as being 'degradable'.[7]

Finding 1.4. Europe as a whole is a small market for intentional ODP compared to other regions of the world (e.g. the Middle East and South America).

- A general consensus by the contacted pro-oxidant additive manufacturers (mainly through the Oxo-Biodegradable Plastics Association, with Symphony as a member) and ODP product manufacturers (mainly through Willow Ridge Plastics) is that Europe is a small market in international comparison, which matches information on their websites and distributor locations. Some European countries (e.g. Spain, France, Ireland, Hungary, Italy, Bulgaria) have been mentioned as main sales markets, or determined as such via the distribution network of the pro-oxidant additive manufacturers (see Table 1-1). Switzerland is not part of these main markets. France and Spain, mentioned by the OPA as the biggest consumers of intentional ODP in Europe, are estimated by the same to each consume around 3 000 tonnes of ODP annually (see *Table 6-3*)

[5] Personal communication, 2019-06-13

[6] Personal communication Polybags (contact number from website), 2018-11-12

[7] Personal communication, 2018-12-18

- To put this in perspective, Hann et al. (2017b) estimated that worldwide 155 000 – 700 000 t/a of ODP are consumed, which is in line with the estimation of 600 000 t/a by the OPA (with 1% additive content[8]), and of 750 000 t/a by Tullo (2011). The total plastic consumption of the world amounts to around 400 million t/a (Geyer et al. 2017), which gives a calculated share of less than 0.2% of intentional ODP to all plastics. For Switzerland, the total plastic consumption amounts to roughly 1 million t/a (Schelker et al. 2011). Applying the same share of intentional ODP to all plastics, it would give an amount of 2 000 t/a of intentional ODP use in Switzerland. However, as outlined, the ODP market share in Switzerland seems to be much smaller than in other parts of the world, and thus, the actual amounts are likely to be smaller.

Finding 2: Information on ODP mass flows is not easily available and accessible.

Finding 2.1. It is a challenge to retrieve information from manufacturers and other stakeholders.

- Most of the pro-oxidant additive or ODP product manufacturers that have been contacted replied that the requested information is confidential, or were not reachable for our requests. The association of the plastic industry in Switzerland, SwissPlastics, does not have information on ODP, neither do two relevant environmental NGOs in Switzerland.
- International recycling organizations have no information on ODP. Some other international organizations, including international farming associations, did not reply to our request.
- Hann et al. (2016) were asked for the list of the 61 ODP product manufacturers in Europe mentioned in their study. Also the EU commission and ECHA were contacted regarding the same matter. No information was retrieved due to confidentiality.

Finding 2.2. From international trade statistics, it is not possible to derive any information on the import of pro-oxidant additives, ODP, or products made from ODP to Switzerland.

- Pro-oxidant additives, often salts of transition metals, are compounds that can be used for a number of purposes, for example as catalysts, pigments or stabilizers in different plastics and other products (for more details, see Section 3.2 below). Thus, the import of respective substances cannot be solely attributed to the use in ODP manufacturing.
- As a common practice, the import of ODP in primary forms such as granulates, if any, would be registered based on the polymer type (e.g. PE, or PP) under the codes 3901–3914 of the Harmonized Commodity Description and Coding System. This means that imported ODP would be classified identically to other PE, PP or PET granulate, with no indication on the presence of pro-oxidant additives.
- The same applies to products made from ODP. They are classified according to the product type, in the best case including a distinction according to main material and polymer type. No information about the exact material (going beyond polymer type) is publically available.

[8] Personal communication OPA, 2018-11-12, also see Table 6-3

3.2 Identification and characterization of commercial pro-oxidant additives and ODP

Finding 3: Pro-oxidant additives are broad and complex.

A variety of substances are identified to have been used as commercial pro-oxidant additives, comprising not only transition metal salts (e.g., the commonly referenced Fe, Mn and Co salts), but also other broad substance categories such as unsaturated organic compounds. Many of the identified substances may be used for other functionalities in polymers as well, and thus a much larger fraction of plastics might unintentionally oxo-degrade. The behavior of intentional and unintentional ODP, especially their degradation/fragmentation, in the environment and during recycling might be determined by the ratios of pro-oxidants and antioxidants present (Scott 2013).

Finding 3.1. The assumption of Fe, Mn and Co salts as main pro-oxidant additives is based on limited primary literature.

- A majority of papers have named manganese, iron and cobalt salts or complexes as the 'typical' pro-oxidant additives (see *Table 6-4* in the Appendix). However, it is interesting to note that some papers just assumed the typical pro-oxidant additives composition, whereas others cited secondary literature, whose information can be traced back to only two patents (see Figure 3-1).

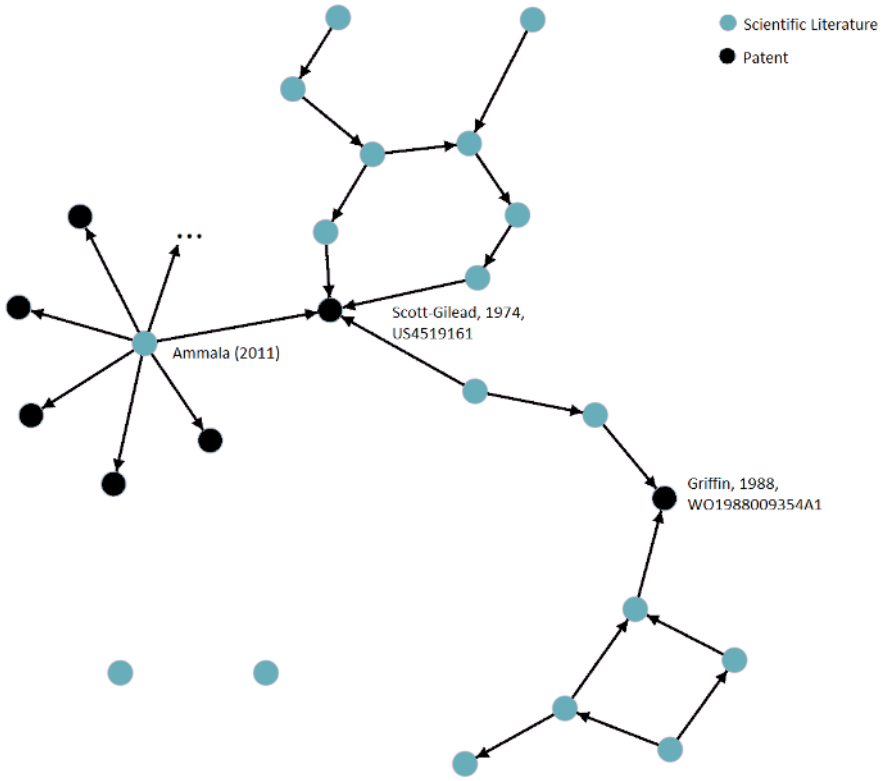

Figure 3-1: Citation network for composition of pro-oxidant additives (see Table 6-4 for detailed references).

- Ammala et al. (2011) reviewed a number of other patents and described other pro-oxidant additives. Also ketone copolymers, unsaturated alcohols and esters, β-diketones, benzophenones and other photosensitizers were mentioned as pro-oxidant additives.

- The lack of original sources cited in the scientific literature casts doubt on the limitation to manganese, iron and cobalt salts as commercially important pro-oxidant additives. However, the commercial relevance of the variety of substances mentioned by Ammala et al. (2011) is not clear. To investigate the commercial relevance of all potential pro-oxidant additives a detailed patent review was conducted.

Finding 3.2. A broad variety of substances may be used as commercial pro-oxidants.

- Some information[9] on the chemical compositions of commercial pro-oxidant additives and the used concentrations in ODP is retrieved by identifying and linking relevant patents via their assignees to the companies producing pro-oxidant additives. For about half of all the commercially available pro-oxidant additives identified, their related patents are identified, from which the composition information was retrieved (see Table 3-1).

- The most commonly cited pro-oxidant additives are transition metal salts and complexes (Forsberg et al. 2007; Brackman 1974; Rahman 2012; Baciu and Gho 2009; Scott 2004; Garcia and Gho 1996, 1998; Chapman et al. 2018; Wallis et al. 2018; Downie 2002; Barclay 2011; Schulman Plastics 2006). However, no limitation to Mn, Co and Fe as mentioned in the literature is found. In other words, Mg, Ti, V, Ni, Cu and Ce are likely also commercially relevant as pro-oxidant additives, while any other transition metal salt may also be used. Other pro-oxidant additives identified are co-polymers (Willett 1992), unsaturated organic compounds (Taylor and Haffner 1994), and broad functional groups such as photosensitizers (Downie 2002), pigments or dyes (Schulman Plastics 2006). Recommended concentrations for most pro-oxidant additives ranged from 0.01 % to 10 % by mass of the final polymer.

- This list of commercial pro-oxidant additives may still be incomplete: The compositions of some frequently mentioned and used pro-oxidant additives (e.g. Symphony's d2w or EcoLogic's EcoOne) remain unknown, as no related patents were found. In addition, pro-oxidant additives and masterbatches might contain a different formulation than mentioned in the patents. This increases uncertainty about which substances are being used as pro-oxidant additives and also which plastics are being ODP, intentionally or unintentionally.

Table 3-1: Chemical composition of commercial pro-oxidant additives and masterbatches, relevant patents and related manufacturing companies. Commercial pro-oxidant additives of unknown composition are marked in orange.

Company	Additive Name	Pro-oxidant Additive	Relevant Patent	Webpage
Add-X	*Addiflex*	**Transition metal salt**: Mn, Fe, Cu, Co, and Ni	Forsberg et al. 2007	http://www.add-xbiotech.com/company.aspx
Adpast; A. Schulman	*PDEG275, PDEG555, PDEG222*	**Transition metal compound/pigments:** TiO_2, ZnO, $ZnSO_4$, lithopone, Fe/Sb/Pb/Cr oxides, cobalt blue, iron blue, ultramarines, manganese violet	Schulman Plastics 2006	http://www.adplast.pt/products/oxo-degradation-masterbatches/ http://www.adplast.pt/products/photo-degradable-masterbatches/

[9] Many patents are written in a way to cover a broad range of modifications to the invention; e.g., broad ranges of concentrations, at which oxo-degradability can be observed, are provided, and thus may not necessarily be representative for the actual practice.

AkzoNobel	*EvCote*	**Transition metal salt:** Ti, V, Cr, Mn, Fe, Co, Ni, Cu – carboxylic acid salt	Brackman 1974	https://www.akzonobel.com/en/for-media/media-releases-and-features/akzonobel-creates-worlds-first-fully-compostable-and
Archer Daniels Midland			None found	https://www.scopus.com/record/display.uri?eid=2-s2.0-0027629984&origin=inward&txGid=e6600d1cd918c334b384eb87fdb76941
Bhavin industries	*Coraplast Degradable PD1001, PD1002*		None found	https://www.coraplast.co.in/products/additivemasterbatch.htm
Bio-TEC	*EcoPure*	**Furanones:** 2(3*H*)-Furanone dihydro-4,5-dimethyl; 4,5-dimethyl-5*H*-furan-2-one; 3,4,5-trimethyl-5*H*-furan-2-one	Lake and Adams 2008	http://www.goecopure.com/how-ecopure-biodegrades-plastic-products-in-landfills.aspx
EcoLogic	*Eco-One*		None found	http://ecologic-llc.com/
EcoPoly Solutions	*OxoElite*		None found	http://www.ecopolysolutions.com/
EnerPlastic LCC	*EP OBD*	**Transition metal stearates**: Co, Mn, Fe stearates	Rahman 2012	http://www.enerplastics.com/products/oxo-biodegradable/
ENSO Plastics	*Restore*		None found	https://www.ensoplastics.com/Products/Products.html
EPI	*TDPA*[10]	**Transition metal stearates:** Co, Ce, Fe stearates	Garcia and Gho 1998	http://www.epi-global.com/
EPI	*epi*[10]	**Transition metal carboxylate**: Ce, Co, Fe, Mg, Al, Sb, Ba, Bi, Cd, Cr, Cu, Ga, La, Pb, Li, Mg, Hg, Mo, Ni, K, Ag, Na, Sr, Sn, W, V, Y, Zn, Zr, rare earths **Preferred:** stearate	Garcia and Gho 1996, 1995	http://www.epi-global.com/
EPI	*epi*[10]	**Transition metal complexes**: Mn, Ce, Cr, Cu, Ni, Co , Fe, Mo, W, V with carboxylates: stearates, laurates and synthetic branched-chain C_4–C_{18} carboxylates Preferred: Co, O/N-coordinated complexes	Scott 2004	http://www.epi-global.com/
EPI	*epi10*	**Transition metal carboxylate**: Al, Sb, Ba, Bi, Cd, Ce, Cr, Co, Cu, Ga, Fe, La, Pb, Li, Mg, Mn, Hg, Mb, Ni, K, Ag, Na, Sr, Sn, W, V, Y, Zn, Zr, rare earths. **Preferred:** Fe/Co/Mn/V stearate, Ferric 12-hydroxy-stearate	Baciu and Gho 2009	http://www.epi-global.com/
Lifeline Technologies	*OX1014*		None found	http://www.lifelinetechnologies.in/oxo_photobiodegradable.html
Maskom	*M 85701*		None found	http://www.maskom.com.tr/en/?page=katki-masterbatch

[10] Many ODP claim to contain "epi" additives. It is unclear whether all ODP and patents refer to Epi's TDPA additives or to other formerly sold "epi" additives.

Perf Go Green	*GoGreen*		None found	
Phoenix Plastics	*Gaia Element Oxo 480*		None found	http://phoenixplastics.com/products/
Poly-materia	*'Biotransformation'*	**Transition metal complexes:** Fe, Mn, Cu, Co, Ce	Wallis et al. 2018; Chapman et al. 2018	https://polymateria.com/
Program-mable Life Inc.	*P-Life*	**Photodegradant**: aliphatic or aromatic ketones, quinones, peroxides, hydroperoxides, azo compounds, organic dyes, latent sensitizers, aromatic hydrocarbons Chemical degradent: **transition metal complex**	Downie 2002	http://www.p-life.com.hk/en/page/WsPage.php?news_id=1
Symphony Environ-mental	*d2w*		None found	https://www.symphonyenvironmental.com/solutions/oxo-biodegradable-plastic/
Techmer PM		**Unsaturated organic compounds**: alkoxylated ethylenically unsaturated natural oils, alkoxylated ethylenically unsaturated fatty-acids, alkoxylated ethylenically unsaturated fatty-acid esters, alkoxylated ethylenically unsaturated fatty-alcohols, alkoxylated ethylenically unsaturated fatty-alcohol esters	Taylor and Haffner 1994	https://www.techmerpm.com/industries/agriculture/
Trioplast	*Actimais, Actigreen M7*		None found	https://www.trioplast.com/en/products-solutions/horticulture-film/
Wells Plastics	*Reverte*	**Transition metal salt**: with tartrate, stearate, oleate, citrate, and chloride	Barclay 2011	https://wellsplastics.com/Products/biodegradables/
Willow Ridge Plastics	*WRP*	**Copolymer**: from olefin and acrylate/acetate monomers	Willett 1992	http://www.willowridgeplastics.com/

Finding 3.3. Substances used as commercial pro-oxidant additives can also provide a variety of other functionalities in a polymer.

None of the pro-oxidant additives identified is used exclusively for pro-oxidation. They may also be used, inter alia, as colorants, lubricants, polymerization catalysts or modifiers (see Table 3-2). For example, TiO_2 is a commonly used opacifier and white pigment (SpecialChem 2019; Charvat 2004).

Table 3-2: Other functions of the substances used as commercial pro-oxidant additives in polymers

Category	Other Function	Examples	Source
Transition metal salts	Catalyst	Ti, V, Mg chloride Cr oxides Ti, Zr, Hf metallocenes Al, Ni, Pd, Co, Fe, V complexes	(Kissin 2008)
Transition metal salts	Colorant	Ti, Zn, Fe, Sb, Pb, Cr oxides ZnSO4, Mixed metal oxide, lithopone, cobalt blue, iron blue, ultramarines, manganese violet, mercury cadmium reds,	(Gardner 2005; Sheftel 2000; SpecialChem 2019; Charvat 2004; Schulman Plastics 2006)
Transition metal stearates	Acid scavenger / Catalyst capture	Al, Ca, Mg, Cu, Zn stearates	(SpecialChem 2019)
Transition metal stearates	Lubricant / Release Agent	Al, Ba, Mg, Zn, Pb, Ca, Cd, (Ni, Fe, Mn, Co, Cr,Cu) stearates	(SpecialChem 2019)
Unsaturated organic compounds	Modifier	Peroxides, hydroperoxides	(Arkema 2019)
Unsaturated organic compounds	Colorant	Quinones, Azo compounds, Organic dyes, Latent sensitizers	(Abetz 2005; Downie 2002)
Unsaturated organic compounds	Degradation product of other additives	Quinones (TP from phenol antioxidants)	(Pospíšil 1988)

Finding 3.4. Some conventional plastics may be unintentional ODP.

- Conventional plastics may contain pro-oxidant additives that were added for different intended functionalities (see above). Moura et al. (1997) described that colorants in general can act as pro-oxidants. If they partake in the creation of radicals or reactive oxygen species, such as singlet oxygen ($^1\Delta g$), they can trigger photo-degradation of the polymer matrix. According to Moura et al. (1997) and Scott (2013), the balance between pro-oxidants and antioxidants (such as UV-absorbers, quenchers, radical and peroxide scavengers) determines the photo-degradation rate of a polymer.
- Thus, a potentially much higher number of plastics on the market may match the current legal definition of ODP (see Quote 1 and Quote 2 on Page 2), without being advertised or intended as such, i.e. unintentional ODP.
- The economic shares of unintentional ODP and the effects on the environment and recycling remain unknown and warrant further investigations.

Finding 4: ODP and conventional plastics cannot be distinguished using handheld XRF.

- From the 27 ODP samples, all contained Fe, a majority (>50%) contained Ba, Ti, Zn, Cu and V, several (23%) also contained Cr, and individual samples (<20 %) contained Cd, Bi, Pb and Ni (see Figure 3-2 and Figure 3-3, and for raw data, see *Table 6-7* in the appendix). Also,

conventional plastic products (n = 23) were found to regularly contain Fe, Ba, Ti, Zn, Cu and V (see Figure 3-2). Some individual conventional plastic bag samples also contained Cr and Pb with maximum levels lower than the maximum levels in ODP.

- Sb, Sn, Se, As, Hg and Au were not found in any of the samples (all measurements below the limit of detection). For Cd, Bi, Pb, Br, and Ni more than 80% of the measurements were below the limit of detection (see Figure 3-2), thus no statistical comparison between ODP and conventional plastics could be conducted (Helsel 2005). However, outliers from ODP had higher levels of Cd, Bi, Pb, Pb and Ni than those from conventional plastics.

- For Cr, Ba and Cl between 50% and 80% of measurements were below the limit of detection, while for Ti, Zn, Fe and V only the minority (<50%) of measurements showed results below the limit of detection. ODP outliers generally had higher levels of Cr than outliers from conventional plastics, however, due to the limited sample size and large variance of the data, no statistically significant difference could be found. Overall, for none of the elements significant differences (based on independent two-sided t-test, significance level=95%) between ODP and conventional plastics could be found (see Figure 3-3).

- One potential explanation for the lack of observed differences might be that ODP are made up of separate groups characterized by their typical pro-oxidant additives. Each group might exceed the levels of specific elements in conventional plastic, while on average ODP do not exceed it. A correlation between Ti and V across the ODP samples (see Figure 3-4 and Figure 3-5) was found, suggesting there might be separable groups of ODP. However, the small sample size (n = 27) does not permit principal component analysis of the data.

- Overall, it is suggested that the differences between ODPs and conventional plastics cannot easily be determined by XRF. The inability to observe significant differences between ODP and conventional plastic products in this study and the suspected use of non-transition-metal-based pro-oxidant additives suggests that handheld XRF is not a feasible method for identifying ODP. However, grouping ODP by their contained pro-oxidants additives might enable using handheld XRF for distinguishing some ODP and conventional plastics. Generally, the broad variety of commercial pro-oxidant additives make chemical analytical methods to distinguish between ODP and conventional plastics intricate.

- The measured heavy metal concentrations were compared with the existing criteria in the Annexes 2.9 (for all plastics) and 2.18 (for electrical and electronic equipment)[11] of the Swiss Chemical Risk Reduction Ordinance (ORRChem) to provide further insights on their hazards. From all of the samples measured (27 ODP samples and 23 conventional plastic bag samples), two ODP exceeded the metal thresholds, another ODP sample contained highly elevated levels of cadmium but without exceeding the thresholds. More specifically, a green 'degradable' kitchen waste bag from GoGreen (USA, produced in Indonesia) was found to contain 30±60 ppm cadmium (threshold: 100 ppm; Annexes 2.9 and 2.18) and 3240±110 ppm lead (threshold: 1000 ppm; Annex 2.18), and thus exceeded the ORRChem threshold of lead that would be permitted in electrical and electronic equipment. An orange 'degradable' waste bag for feminine hygiene products from Bey Bee (USA, produced in India) contained 6200±1400 ppm lead and 1100±200 ppm chromium. The feminine hygiene waste bag exceeds the threshold of 1000 ppm lead in the Annex 2.18 by a large margin. When assuming all

[11] In Switzerland, the restrictions on hazardous in electrical and electronic equipment are identical to those specified in Directive 2011/65/EU (RoHS2) in terms of type of regulated heavy metals and flame retardants, involved appliance categories, exemptions from bans on substances and dates of entry into effect.

contained chromium to be hexavalent, then also the threshold of hexavalent chromium in the Annex 2.18 is exceeded. A black waste bag from Polybags Limited (UK) contained 40±20 ppm cadmium, which is below the threshold (100 ppm) in the Annexes 2.9 and 2.18, whereas the six other samples from Polybags Limited did not contain any of the investigated hazardous elements above the limits of detection.

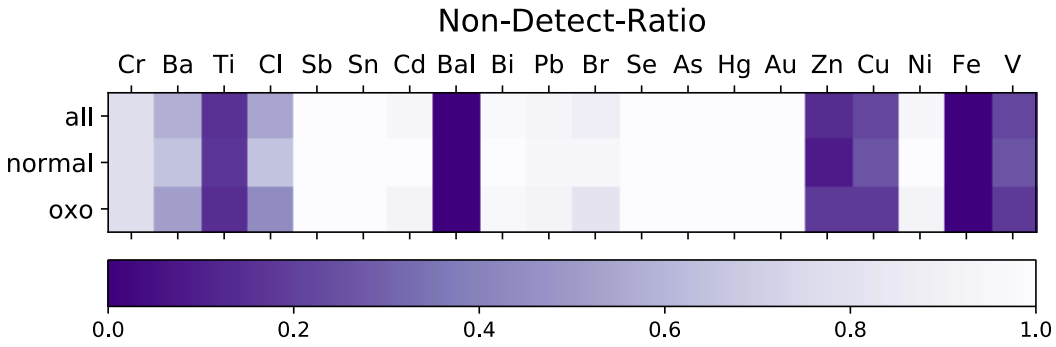

Figure 3-2: Ratio of samples below the limit of detection per element for different groups based on their source and the considered element. Groups with a ratio <0.5 were analyzed by Kaplan-Meier estimation for the values below the limit of detection. Groups with a ratio between 0.5-0.8 were analyzed with MLE estimation. For those groups above 0.8 only the number of samples above the LOD and maximum measured value was reported (Helsel 2005).

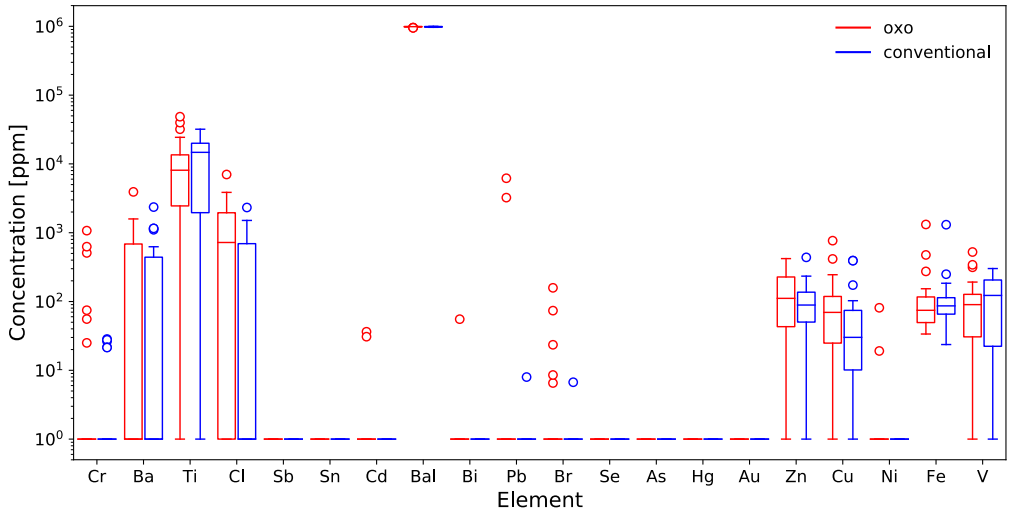

Figure 3-3: Boxplot of the observed concentrations of transition metals in the ordered ODP products (red), plastic bags not advertised as oxo-degradable (blue) and HDPE recycling material (green). Circles mark outliers, each box represent 50% of the measured data points, the whiskers show the extremes, the line within each box represents the median. All measured values can be found in Table 6-7.

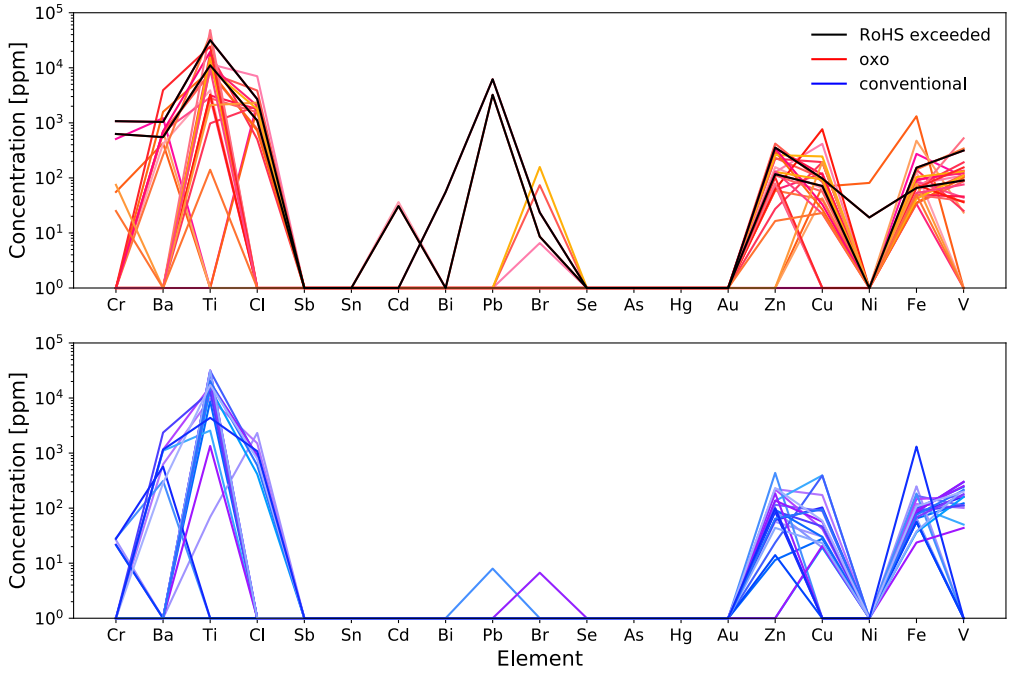

Figure 3-4: Observed concentrations of transition metals in the ordered ODP (top) and conventional plastic (bottom) products in ppm by individual samples (separate lines). Each individual line represents measurements of different elements from the same product.

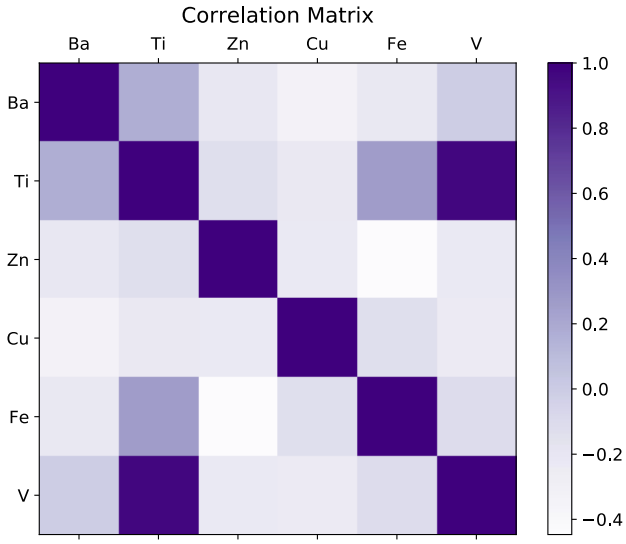

Figure 3-5: Correlation matrix between selected transition metal concentrations from ODP samples. Only transition metals with less than <50% of values below the limit of detection are depicted, for other elements statistical artifacts dominate.

4. Recommendations

Building on the findings of this study, the following recommendations to address ODP and some of the challenges identified above are summarized and highlighted below.

A. An unequivocal definition of ODP is needed.

The definitions of ODP employed in the Single-Use Plastics Directive (see **Quote 2**) and used by ECHA in their call for evidence (see **Quote 1**) would cover a large range of 'unintentional' ODP. These plastic products are not traditionally considered ODP, and are not advertised as such either. Currently, it is unclear if these 'unintentional' ODP may results in similar issues as 'intentional' ODP (i.e. fragmentation to yield microplastics) in the environment and during mechanical recycling, due to factors such as the presence of large quantities of anti-oxidants. Thus, it is unclear whether such 'unintentional' ODP are covered by the restriction of ODP in the Single-Use Plastics Directive of the EU. Hence, it would be advisable to clarify the definition of ODP which are within the scope of regulatory actions, including pro-oxidant additives.

B. Simple methods for identifying ODP in practice need to be developed.

Monitoring and enforcement are only possible, if ODP products can be identified in the market. Any method for identification of ODP must be based on the clear definition of ODP. For the current definition in the Single-Use Plastics Directive (EU) 2019/904 (European Parliament and European Commission 2019) (see **Quote 2**), it is challenging to identify ODP in practice due to the variety of substances that have pro-oxidant properties (e.g. co-polymers, organic compounds, transition metal compounds) and the time-constraint per sample. Product-based approaches, such as testing for fragmentation or chemical decomposing of plastic articles, are lengthy and not feasible for a large number of samples.

C. Regulating the labeling of degradable products may contribute to a proper disposal.

The term 'degradable' may refer to a wide range of different processes causing the decomposition of a material within different timeframes, at different temperature levels, and in different media. It is difficult for consumers without specific knowledge in the concerned field to distinguish between different degradable products. In order to trigger proper consumer behavior, it would be important to label products clearly and consistently. However, this is often not the case at the moment. For example, regarding 'compostability', it is often not clearly denoted whether a product is suitable only for industrial composting, or for home composting as well. Similarly, for ODP, the (mis-)labeling of being '(bio)degradable' may mislead consumers to think that the product can be disposed of in the environment without causing harm, possibly resulting in incorrect disposal and littering.

Hence, the related labeling of plastic products (e.g. 'degradable', 'biodegradable', 'compostable in industrial/home composting') needs to be linked to a unique and clear definition and related testing requirements and enforced with clear empirical evidence, showing fulfillment of the respective requirements. Table 6-8 in the Appendix and the accompanying Excel spreadsheets provide an overview of different internationally recognized standards related to the degradability of plastics, as well as specified test conditions and evaluation criteria. Such international standards may sometimes be tricky with regard to their representativeness of conditions in practice. For example, there is an internationally recognized standard including pass/fail criteria for packaging compostable in industrial composting facilities – EN 13432:2000. However, the test conditions required in the standards do not necessarily well represent the real conditions in practice (Baier et al. 2016). Therefore, it is important to evaluate the suitability of the standards for the intended purposes (e.g., complete mineralization in soil). In general, it is recommended that the test conditions be adapted to the conditions prevailing

in reality as well as possible. Also, it is very important that the requirements for a certain designation are matched with the purpose, i.e. the target way of disposal. Such labeling may also be helpful to prevent the labeling and thus use of ODP, as ODP will not pass the testing for such standards. It will also likely contribute to solving the challenges in identifying and monitoring ODP.

In this context, it should be noted that degradability is not an environmentally favorable property for every kind of product, but rather for certain specific applications. Examples for such could be products which are hard to be prevented from (partially) ending up in the environment (e.g. pieces of mulch foils and fireworks, shotgun cartridges; see Figure 5 in Kawecki and Nowack 2019), or products which are likely to be disposed of when having residues of a substance containing nutrients attached (e.g. food packaging; Ellen McArthur Foundation 2016).

D. Restrictions on placing ODP on the market may be considered.

Current scientific evidence does not support the claim that ODP degrade in the environment within a reasonable timeframe and being completely mineralized (Hann et al. 2017). ODP may also pose significant challenges on the current plastic recycling system. Although intentional use of ODP does currently not seem to be wide-spread in Switzerland, a precautionary approach to regulate the manufacture, import and placing on the market of ODP and products made from ODP in Switzerland may be considered. This would protect the environment and plastic recycling systems in Switzerland from (potentially) disruptive ODP and ensure that Swiss regulation being harmonized with the existing regulation of ODP within the territory of the most important trade partner of Switzerland, the European Union. Such a restriction may cover products that are marketed as being 'oxo-degradable', products that contain specific types of pro-oxidant additives, and/or products that may show significant oxo-degradation in practice.

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6. Appendix

Table 6-1: Contacted stakeholders related to ODP in Switzerland and information on ODP use. Names of individuals were redacted.

Area / Activity	Association / Company / Institution	Contacted by	Form of Contact	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
				Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
retailer	Coop	Melanie Haupt → Magdalena Klotz	email → phone call	N/A	No	N/A	No*	No*	considers ODP not sensible, mentions self-commitment of "Runder Tisch Biologisch Abbaubarer Werkstoffe Schweiz" not to use ODP, of which besides Coop also Migros and Manor are part
	Migros	Melanie Haupt → Magdalena Klotz	email	N/A	No	N/A	No*	No*	consider ODP not sensible
agriculture	Schweizer Bauernverband	Magdalena Klotz	email	has no information	N/A	N/A	N/A	N/A	
	Verband Schweizer Gemüseproduzenten	Magdalena Klotz	email	has no information	N/A	N/A	N/A	N/A	degradable foils are used for vegetable cultivation, does not know whether they are oxo-degradable; does not have information on quantities used; topic gained importance, are currently considering of more specific investigations with partners;
	ADI Valor (FR)	Magdalena Klotz	email	has no information	N/A	N/A	N/A	N/A	
recycler	InnoRecycling	Melanie Haupt → Magdalena Klotz	email → phone call	has no information (but no problem with recyclate from silo wrapping foils reported)	N/A	N/A	N/A	N/A	
packaging producer	Amcor	Stefanie Hellweg	email	N/A	N/A	N/A	No	No	considers ODP not sensible

Area / Activity	Association / Company / Institution	Contacted by	Form of Contact	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
				Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
sourcing packaging for manufactured products	Jowa	Magdalena Klotz	email	N/A	N/A	N/A	No	N/A	considers ODP not sensible, Jowa uses packaging containing as few additives as possible due to possible migration into food
sourcing packaging for manufactured products	Nestlé	Magdalena Klotz	email	N/A	N/A	N/A	No	N/A	no reply to email
plastic manufacturer	BASF	Melanie Haupt	personal meeting; email	No	No	N/A	No	N/A	BASF did research on ODP in the early stage of their development, but decided not to follow this path; focus on bio-degradable materials instead
distributor bags	dietragtasche.ch	Magdalena Klotz	email	N/A	Yes	N/A	N/A	N/A	have only once produced ODP product
distributor packaging	Sanpac	Magdalena Klotz	email	N/A	Yes	no infor-mation	no infor-mation	no infor-mation	sell bags to La Ferme Vaudoise; will not have oxo-degradable products in their assortment any longer as soon as stocks are finished
product manufacturer	Polybags (UK)	Magdalena Klotz	phone call → email	N/A	Possibly	Possibly	N/A	N/A	produce rubbish and carrier bags, sold sometimes in past to Switzerland, sell 90% in UK; possible to order their products via Amazon to Switzerland; no answer to email

Area / Activity	Association / Company / Institution	Contacted by	Form of Contact	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
				Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
institutions	Agroscope	Magdalena Klotz	email, phone call	N/A	N/A	N/A	N/A	N/A	conducted project investigating use of plastics in agriculture which has been finalized, report available (Kalberer et al. 2019); Agroscope has been in contact with distributors of foils and other agricultural products in Switzerland (incl. gvz-rossat), which are almost exclusively imported, and they do not know further details on degradable foils
	EMPA	Magdalena Klotz	email	N/A	N/A	N/A	N/A	N/A	according to company Add-X Biotech, their pro-oxidant additive AddiFlex® has been tested by EMPA, use of logo is according to current knowledge status not compliant to rules; according to scientific publication (Jakubowicz 2003), mineralization tests in soil columns have been conducted at EMPA, EMPA is mentioned only under acknowledgements in publication; publication contains test method and result of mineralization test, result does not confirm that the product is biodegradable, because test was not conducted according to any widely-recognized standard for the determination of biodegradability (it contained a pre-oxidation step); test report not stored at EMPA anymore; test reports regarding ecotoxicity and plant growth effects not available, only mentioned in document "Certificate regarding the additive AddiFlex®": "The plant growth test and the ecotoxicity effects have been studied with positive results above 100% according the EN 13432 (Requirements for packaging recoverable through composting and biodegradation) and the Standard OECD 208 (Terrestrial plants, growth test). Evidence: EMPA test report Nr. 422809."
	ETH	Melanie Haupt	email	N/A	N/A	N/A	N/A	N/A	no reply to email
experts	quantis	Magdalena Klotz	phone call	N/A	N/A	N/A	N/A	N/A	see Table 6-2
	member of the National Council (CH)	Magdalena Klotz	email	N/A	N/A	N/A	N/A	N/A	see Table 6-2

Area / Activity	Association / Company / Institution	Contacted by	Form of Contact	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
				Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
environ-mental organizations	Ocean Care (CH)	Magdalena Klotz	contact form	N/A	N/A	N/A	N/A	N/A	no information available; refer to SwissPlastics; interested in project results;
	WWF (CH)	Magdalena Klotz	contact form	N/A	N/A	N/A	N/A	N/A	no information available; refer to EMPA, HSR and ZHAW;

Legend

* No for own brands, for products from suppliers probably No, but not known with 100% certainty

** landfill covers are assumed not to be used in Switzerland due to the prohibition of landfills

names in brackets: forwarded email or were CC in email

Yes

Possibly

No

N/A or not enough information available to authors

Table 6-2: Identified, not contacted stakeholders related to ODP in Switzerland and related information. Names of individuals were redacted.

Area / Activity	Association / Company / Institution	Source	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
			Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
retailer	Manor	part of "Runder Tisch Biologisch Abbaubarer Werkstoffe", members of which have committed themselves not to use ODP	N/A	No	N/A	No*	No*	
packaging producer and distributor	Papier Mettler AG	information from Baier et al. (2016)	N/A	N/A	N/A	Possibly***	Possibly***	
small retailers	La Ferme Vaudoise, Place de la Palud 5, 1003 Lausanne		N/A	Yes	N/A	no information	no information	distributes oxo-degradable shopping bags; small "green, local" food shop; also other such besides La Ferme Vaudoise distribute oxo-degradable products; retailers believe that bags are biodegradable.
	retailers in small village Marchissy, Canton de Vaud; pharmacies		N/A	Yes	no information	no information	no information	retailers believe that bags are biodegradable.
farmer markets	farmer market Lausanne, Saturday morning;		N/A	Yes	N/A	no information	N/A	distribute oxo-degradable shopper bags;
	market in an onion fair in Oron (Canton de Vaud)		N/A	Yes	N/A	no information	N/A	retailers believe that bags are biodegradable.
vegetable box scheme (Biokiste)	specific association not known		Yes (not discussed in which form)					
distributor packaging	Papival, Canton du Valais		in the past					stopped sales of oxo-degradable products following a complaint brought before the Swiss Commission of Integrity (Commission Suisse pour la Loyauté / Schweizerische Lauterkeitskommission)
online order to Switzerland via Amazon	different distributors via Amazon	acquisitions via Amazon by Helene Wiesinger	N/A	N/A	Yes	N/A	N/A	possible to order and get delivered oxo-degradable products to Switzerland (Amazon search for ASTM 6954, EPI), including dog / cat excrement bags, diapers bags, household waste bags, straws

Area / Activity	Association / Company / Institution	Source / Relevant person	Use / Sale of Oxo-Degradable Plastics in Switzerland **					Statement
			Agriculture	Carrier Bags	Other Bags	Food Packaging	Other Packaging	
institutions	ETH		N/A	N/A	N/A	N/A	N/A	Referred to by a researcher at Agroscope, working on bio-degradable mulch foils and might thus have information.
	Kantonales Labor Zürich		N/A	N/A	N/A	N/A	N/A	Referred to by a researcher at Agroscope, working on bio-degradable mulch foils and might thus have information.
association, company	BiomasseSuisse, Leureko		N/A	N/A	N/A	N/A	N/A	Referred to by a researcher at Agroscope, working on bio-degradable mulch foils and might thus have information.

Legend
* No for own brands, not known for products from suppliers
** landfill covers are assumed not to be used in Switzerland due to the prohibition of landfills
*** according to "BAW vergären & kompostieren?", company produces ODP packaging foils (under the label natureStep) and has a branch in Switzerland, however, no ODP products are produced or distributed in Switzerland

Yes
Possibly
No
N/A or not enough information available to authors

Table 6-3: International stakeholders related to ODP and information from contact. Names of individuals were redacted.

Association / Company	***Contacted by***	***Form of Contact***	***Statement***
European Chemicals Agency (ECHA)	Zhanyun Wang	email	ECHA does not make results of calls for evidence public, responses are partly or wholly confidential, when ECHA produces restriction proposal (current status: due for July 2019), summarized information will be made publically available
Directorate-General for Environment (DG ENV), European Commission (EC)	Zhanyun Wang	email	no answer
European Environment Agency (EEA)	Zhanyun Wang	email	refers to relevant staff members of the European Commission
Directorate-General for Research and Innovation (DG RTD), European Commission (EC) (previously working at EMF)	Zhanyun Wang	email	refers to Commission Staff Working Document accompanying the EU Plastics Strategy (SWD/2018/016 final. Document 52018SC0016. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2018%3A16%3AFIN);
Technical University of Denmark (DTU)	Zhanyun Wang	email	no answer
Department for Environment, Food & Rural Affairs (DEFRA), UK	Magdalena Klotz	email	DEFRA does not hold data specifically on oxo-degradable plastic products; refers to Waste and Resources Action Programme (WRAP)

Association / Company	*Contacted by*	*Form of Contact*	*Statement*
Oxo-biodegradable Plastics Association (OPA)	Yaqi Zhao Magdalena Klotz	email phone call (2018-11-12)	members of OPA are: - Symphony - ODP product manufacturers market numbers (estimated via turnover devided by price, no exact studies available): - globally annually in total 6.000 t pro-oxidant additives produced => 600.000 t ODP (1% additive) - 250.000 t ODP globally annually attributable to Symphony (incl. d2w additive) - mainly sold to South-East Asia (China, Malasia), South America, Middle East (UAE, Saudiarabia) - little sold to Europe (because of competition with bio-degradable plastics) - main countries consumption Europe: □ France and Spain: each 30 t additives / year => 3000 t ODP / year (first statement: this is consumption; then: this is production and lot of export from there; then: again consumption. anyways, in opinion of contact person, those two countries are the biggest consumers in Europe) mainly packaging applications, amount used for agricultural film would come on top of that (not included in numbers) □ agricultural film mainly used in Ireland □ UK: ~ 2000 t ODP / year consumption for films, food packaging, garbage bags, binliner; additionally some agricultural film □ (Turkey) - nothing exported to Switzerland no information available on how much ends up in the environment BASF (making bio-degradable plastic) financed study by Hann et al. (2017) acc. to contact person
Oxo-Biodegradable Plastics Federation (OBPF)	Yaqi Zhao Magdalena Klotz	email email	no phone number online; no answer to email
European Bioplastics	Yaqi Zhao	email	distance themselves from ODP
Swiss Plastics	Melanie Haupt Zhanyun Wang	meeting 2018-07-02	no numbers on use amounts available, working on definition
Symphony (UK)	Yaqi Zhao Magdalena Klotz	email phone call to OPA (2018-11-12)	answer to email Yaqi Zhao: not able to provide data; information from OPA call: Symphony makes up for 250,000 t ODP globally (see below in line OPA); just some distributors mentioned on website, among which not CH
Add-X (SE)	Yaqi Zhao Magdalena Klotz	email	no phone number online; no answer to email; no distributor in CH

Association / Company	*Contacted by*	*Form of Contact*	*Statement*
EPI (Canada)	Yaqi Zhao Magdalena Klotz	email phone call	answer to email Yaqi Zhao: information confidential; branch in Europe reached via call, contact person does not seem willing to give information ("need to look into accounts", "in the middle of something urgent", refers to office in Canada); call Canada not answered; no list of distributors found
Wells Plastics (UK)	Yaqi Zhao Magdalena Klotz	email phone call → email	answer to email Magdalena Klotz: information strictly private and confidential
Willow Ridge Plastics (USA)	Yaqi Zhao Magdalena Klotz	email phone call (2018-11-13)	answer to Yaqi Zhao: ODP make up 0.6% of total plastics; information from call: - sales to Europe: extremely low single digit figure - contact person names competition with PLA and companies like BASF and Novamont in Europe and USA as reason for low sales; - countries they sell to in Europe: Southern Europe (Italy, maybe Balkans), Eastern Europe, not really France and Spain (being asked specifically for that, based on information from OPA); mention a list of distributors on website among which not Europe (incl. CH);
EcoPoly Solutions (Canada)	Yaqi Zhao Magdalena Klotz	email phone call	no answer to email; called: number did not work
GreenReady Plastic (NO)	Yaqi Zhao Magdalena Klotz	email (eak@nor-x.no) phone call (+47 91119684)	not reached by phone; no distributor list; website does not exist anymore, seems that now the company is NOR-X/Normors (providing oxo-degradable chin collars), acc. to the website of which products purchasable in Switzerland via https://www.nangeroni.ch/ (company providing funeral supplies);
P-Life (USA /Japan)	Yaqi Zhao Magdalena Klotz	email phone call	phone number did not work; part of Evive (USA); distributor in Hong Kong with list of product manufacturers (mainly in China); list of countries "backing" oxos: from Europe only Albania, Montenegro, Serbia, Slovenia;
EnerPlastics LCC (UAE)	Yaqi Zhao Magdalena Klotz	email phone call	not reached by phone; based in Dubai (UAE), "servicing the ever-growing plastic converting industry in the region" acc. to website information;

Association / Company	*Contacted by*	*Form of Contact*	*Statement*
BEOLOGIC (BE)	Magdalena Klotz	Fakuma fair in Friedrichshafen	sell "sustainable" compounds: from natural, eco-friendly materials, biodegradable, from recycled material, reduced weight; used to sell ODP, but acc. to conversation partner they decompose to microplastics and have been expensive; such plastics are not sold anymore
Polybags (rubbish & carrier bags)	Magdalena Klotz	phone call (2018-11-12) → email	short call: 90% sold in UK, sold to CH sometimes; no answer to email;
Richmond plastics (rubbish & carrier bags)	Magdalena Klotz	phone call email	could be called (not reached repeatedly); no answer to email;
Reddipak (rubbish & carrier bags)	Magdalena Klotz	phone call (2018-11-12)	sell only in UK; 20 t/a ODP sold in UK (they are a small company according to contact person);
Plastic Recyclers Europe (PRE)	Yaqi Zhao Magdalena Klotz	email phone call → email	in short call refered to email contact; no answer to email
European Association of Plastics Recycling & Recovery Organisations (EPRO)	Magdalena Klotz	email	have no statistics on ODP, volumes are small and they have never tried to quantify them; interested in project result; refers to member organizations (for CH acc. to website: PRS); also refers to a person, who has been working at PRE, now EUPR
EUPR (European Certification of Plastics Recyclers)	Magdalena Klotz	email	no answer
COPA-COGECA	Magdalena Klotz	email	no answer
World Farmers Organization	Magdalena Klotz	email	no answer
Ellen MacArthur Foundation (EMF)	Magdalena Klotz	email	Position paper against ODP taken down from website based on third party queries as precautionary measure while concluding own investigations; EMF recommends precautionary approach, i.e. ban, until further detailed research has been conducted

Table 6-4: Chemical composition of pro-oxidant additives according to the scientific literature

Number	Author	Year	Title	prooxidant additives	Reference
1	Albertsson	1991	Susceptibility of enhanced environmentally degradable polyethylene to thermal and photo-oxidation	transition metal salts	WO1988009354A1
2	Ammala	2011	An overview of degradable and biodegradable polyolefins	Transition metal salts, Chromophoric groups, photosensitizers, Oxo-hydroxy group additives, Ketone copolymers	US3454510, US4121025, US4519161, US5854304, WO2008020752, BE816647, …
3	Bonhomme	2003	Environmental biodegradation of polyethylene	transition metal (notably iron complexes)	US4519161
4	Briassoulis	2004	An Overview on the Mechanical Behaviour of Biodegradable Agricultural Films	ferric and nickel dibutyldithiocarbamates, substituted benzophenones, titanium zirconium chelates	3, 5
5	Chiellini	2006	Oxo-biodegradable carbon backbone polymers e Oxidative degradation of polyethylene under accelerated test conditions	transition metal compounds such as dithiocarbamates; copolymerisation with monomers containing carbonyl groups	16
6	EC	2016	The Impact of the Use of 'Oxo-degradable' Plastic on the Environment	salts of manganese, iron or cobalt	5, personal communication
7	Fontanella	2010	Comparison of the biodegradability of various polyethylene films containing pro-oxidant additives	Mn, Fe, Co	no reference
8	Fontanella	2013	Comparison of biodegradability of various polypropylene films containing pro-oxidant additives based on Mn, Mn/Fe or Co	Mn, Fe, Co	no reference
9	Griffin	1976	Degradation of polyethylene in compost burial	not given	WO1988009354A1
10	Jakubowicz	2003	Evaluation of degradability of biodegradable polyethylene (PE)	transition metal complexes	1
11	Khabbaz	1999	Chemical and morphological changes of environmentally degradable polyethylene films exposed to thermo-oxidation	iron dimethyl dithiocarbamate; iron dimethyl dithiocarbamate + carbon black; iron dimethyl dithiocarbamate + nickel dibutyldithiocaramate;	9, US4519161
12	Koutny	2006	Biodegradation of polyethylene films with prooxidant additives	transition metal complexes (Fe, Co, Mn) (+ biodegradable fillers (starch,…))	19, 10

13	Kyrikou	2007	Biodegradation of Agricultural Plastic Films: A Critical Review	Transition Metal Complexes	4
14	Pometto	1993	Pure-culture and enzymatic assay for starch-polyethylene degradable plastic biodegradation with Streptomyces species	not given	no reference
15	Scott	1990	Photo-biodegradable Plastics: Their Role in the Protection of the Environment	Iron salts (Fe stearate), Fe-thiolates	US4519161
16	Scott	1994	Environmental Biodegradation of Hydrocarbon Polymers Initiation and Control	transition metal compounds, notably, iron, cobalt, manganese and copper, (as stearates, dithiocarbamates) iron/manganese/cobalt/vanadium/cerium dithiocarbamates	15
17	Snyder	2016	The effect of exposure to Pyrinex 480 on the degradation of clearoxodegradable polyethylene agriculturalfilms	transition metal (iron and manganese) carboxylates offatty acids	13
18	Song	2009	Biodegradable and compostable alternatives to conventional plastics	n.a.	no reference
19	Weiland	1995	Biodegradation of thermally oxidized PE	Cobalt-(acac)-complex	14, 1

Table 6-5: Brand names of ODP products

Use	Producer	Product	Additive	Source	URL	Availability
Agricultural Applications	Cimic	Greenhouse Film, Mulch Film, Silage Film		Alibaba	https://www.alibaba.com/product-detail/plastic-agricultural-biodegradable-reflective-Mulch-film_60788090194.html?spm=a2700.7724838.2017115.1.9f8530650Rwrj1	Available - Large quantities only
Agricultural Applications	Cysy, Henan, China	Mulchfilm		Alibaba	https://www.alibaba.com/product-detail/Biodegradable-agricultural-plastic-mulch-film-ground_60299929719.html?spm=a2700.7724838.2017115.21.2ac720e4ruhJSU&s=p	Available - Large quantities only
Agricultural Applications	EcoPoly	Muchlfilm (DegriFilm)	OxoElite	(Hann et al. 2016)	http://www.ecopolysolutions.com/degrifilm-6/	Not available
Agricultural Applications	Solplast	Mulchfilm (Acosol)	Acosol OD	(Hann et al. 2016)	https://www.solplast.com/EN/acosol-od-ng-mf.html	Not available
Agricultural Applications	EcoLogic	Several	Eco-one	(Hann et al. 2016)	https://ecologic-llc.com/about/eco-one-video-tour	Not available
Agricultural Applications	Ciba Speciality Chem/BASF	Mulchfilm	Envirocare	(Hann et al. 2016)	https://www.heinwillemleeraar.nl/wp-content/uploads/2016/08/presentatie-Olivier-de-Beaurepaire-afbreekbaarheid-van-folie.pdf	Not available - Out of market
Bags	P-Life, Pro-link Asia	Bags	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Oxo-Biodegradable-newspaper_217171746.html?spm=a2700.galleryofferlist.normalList.43.72c857a28SzOTT	Available, but no response to our order
Bags	Weifang Kangle Plastics Co.	Shopping bags	epi	Alibaba	https://www.alibaba.com/product-detail/Eco-friendly-EPI-degradable-T-shirt_60806188449.html?spm=a2700.galleryofferlist.normalList.21.4d862550lzVQ5D&s=p	Available, but no response to our order
Bags	Xiamen Richer Plastic Co., Ltd	Shopping bags	epi	Alibaba	https://www.alibaba.com/product-detail/Good-quality-Degradable-epi-Polyethylene-plastic_873634458.html?spm=a2700.galleryofferlist.normalList.13.1d5e2550DPQYWe	Available, but no response to our order
Bags	Cangnan Plastic Packaging Printing Factory	Sealing bags	epi	Alibaba	https://caiyin.en.alibaba.com/product/60779859228-805758197/Free_sample_Heat_Seal_Plastic_Bag_Epi_Biodegradable_Plastic_Bag.html?spm=a2700.7803241/a.0.0.51613e5fgE0X3F	Available, but no response to our order
Bags	Xiamen Richer Plastic Co., Ltd.	Shopping bags	epi	Alibaba	https://cnricher.en.alibaba.com/product/859519564-209817150/Degradable_epi_HDPE_LDPE_die_cut_punch_handle_door_knob_hanger.html?spm=a2700.7803241/a.0.0.2c863e5fFGPmrP	Available, but no response to our order

Bags	Hong Jin Group (H.K.) Ltd	Shopping bags	epi, d2w	Alibaba	https://hk108488706.fm.alibaba.com/product/115042443-0/Eco_friendly_EPI_D2W_oxo_biodegradable_nonwoven_bag_degradable_nonwoven_shopping_bag_promotion_nonwoven_fabric_merchandise_bag.html?spm=a2700.7803241/a.0.0.3d733e5fQ6fe6I	Available, but no response to our order
Bags	Hong Jin Group (H.K.) Ltd	Shopping bags	epi, d2w	Alibaba	https://www.alibaba.com/product-detail/Eco-friendly-EPI-D2W-oxo-biodegradable_115042373.html?spm=a2700.7724838.2017115.196.10822550qYOYYe	Available, but no response to our order
Bags	Hong Jin Group (H.K.) Ltd	Waste bags	epi	Alibaba	https://www.alibaba.com/product-detail/EPI-oxo-biodegradable-newspaper-bag-D2W_114903340.html?spm=a2700.7724838.2017115.331.10822550qYOYYe	Available, but no response to our order
Bags	Jiangsu Shang Hai International Trage Co.	Shopping bags		Alibaba	https://www.alibaba.com/product-detail/Factory-outlet-disposable-plastic-t-shirt_60826634514.html?spm=a2700.7724838.2017115.372.57c67c0fHWa8YY	Available, but no response to our order
Bags	Ka Lee Bags	Bags	P-life	Internet Market Review	http://www.kaleebags.com.hk/en/index-1.html http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Bags	Chun-Hing	Bags	P-life	Internet Market Review	http://www.chun-hing.com/ContactUs.php?lang=eng http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Bags	Kann Lun Polybags	Bags	P-life	Internet Market Review	http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Bags	Polybags Limited, UK	Bags	epi	(Hann et al. 2016)	https://www.polybags.co.uk/hm_biodegradable.htm	Available - Shipped
Bags	99% good	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B07CPR5N96/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	Houndscoop	Dog waste bags	epi, TDPA	Amazon	https://www.amazon.com/gp/product/B06VSY8L96/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped

Bags	Pobby	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B07999QX4K/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	PetNPet	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B074DTXCLL/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	Yankee Merchandise	Shopping bags	n.a.	Amazon	https://www.amazon.com/gp/product/B01ESD2GBA/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	Go Green	Kitchen garbage bags	GoGreen	Amazon	https://www.amazon.com/gp/product/B001F0REJE/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	Green Nature	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B07GKY2YRK/ref=od_aui_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	Bey Bee	Feminine hygiene product bags	epi	Amazon	https://www.amazon.com/gp/product/B0744F3JVS/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1	Available - Shipped
Bags	PM Company	Money deposit bags	epi	Amazon	https://www.amazon.com/gp/product/B003X0V04E/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1	Available - Shipped
Bags	RangerRob	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B07JF21NFQ/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1	Available - Shipped
Bags	Goobi Baby	Diaper bags	epi	Amazon	https://www.amazon.com/gp/product/B01MZYEFSB/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1	Available - Shipped
Bags	PetLoft	Dog waste bags	epi	Amazon	https://www.amazon.com/gp/product/B075WPN7QB/ref=ppx_od_dt_b_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	PetNPet	Cat litter box liners	epi	Amazon	https://www.amazon.com/gp/product/B019FBOY1A/ref=ppx_od_dt_b_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	MomEasy	Diaper bags	epi	Amazon	https://www.amazon.com/gp/product/B01DDS3J1W/ref=ppx_od_dt_b_detailpages00?ie=UTF8&th=1	Available - Shipped
Bags	HyperCat	Cat litter box liners	epi	Amazon	https://www.amazon.com/gp/product/B01G3RVOSU/ref=ppx_od_dt_b_detailpages00?ie=UTF8&psc=1	Available - Shipped
Bags	WVSCM	Garbage bags	epi	Alibaba	https://www.alibaba.com/product-detail/ECO-biodegradable-compostable-plastic-garbage-bags_60094839676.html?spm=a2700.galleryofferlist.normalList.170.72c857a28SzOTT	Available - Shipped
Bags	D2W	Garbage bags	d2w	E-Bay	https://www.ebay.com/itm/D2W-Degradable-Swing-Bin-Liners-6-x-15-bags/182650147978?hash=item2a86cc148a:g:yO0AAOSwi8VZW33M:rk:1:pf:0	Available - Shipped
Bags	D2W	Freezer bags	d2w	E-Bay	https://www.ebay.com/itm/D2W-Degradable-Large-Freezer-Bags-8-x-100-bag/183117407366	Available - Shipped

Bags	Dongguan Fangije Printing and Packaging Co., Ltd	Shopping bags	epi	Alibaba	https://www.alibaba.com/product-detail/EPI-oxo-biodegradable-plastic-carry-bag_678088107.html?spm=a2700.8443308.0.0.4aa63e5fnsMySV	Available - Shipped
Bags	Richmond plastics	Rubbish Bags, Lightweight Bags, Dog waste bags	TDPA	(Hann et al. 2016)	http://www.richmondplastics.com/green-initiative/	Not available
Bags	Reddipak	Rubbish Bags, Lightweight Bags	epi	(Hann et al. 2016)	https://www.reddipak.co.uk/environment/	Not available
Bags	Evive Europe Ltd	Rubbish Bags, Lightweight Bags	P-life	(Hann et al. 2016)	http://www.evive.com/disposables	Not available
Bags	Reli	Trash bags (Biostar Biodegradable)	epi	Ebay	https://www.ebay.com/itm/Reli-Biostar-Biodegradable-Trash-Bags-6-10-Gallon-Wholesale-1000-Count-/143010965732	Not available - Does not ship to CH
Food contact materials	P-Life, Green Production Ltd.	Cutlery	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Oxo-Biodegradable-Plastic_11893600.html?spm=a2700.galleryofferlist.normalList.11.547c57a2OFhZZC	Available, but no response to our order
Food contact materials	P-Life, Green Production Ltd.	Food containers	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Totally-Oxo-Biodegradable_101463274.html?spm=a2700.galleryofferlist.normalList.18.547c57a2OFhZZC	Available, but no response to our order
Food contact materials	P-Life, Green Production Ltd.	Straws	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Oxo-Biodegradable-Plastic_101463304.html?spm=a2700.galleryofferlist.normalList.221.72c857a28SzOTT	Available, but no response to our order
Food contact materials	P-Life, Green Production Ltd.	Cups	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Oxo-Biodegradable-Plastic_218325922.html?spm=a2700.galleryofferlist.normalList.272.72c857a28SzOTT	Available, but no response to our order
Food contact materials	P-Life, Green Production Ltd.	Water bottles	P-life	Alibaba	https://www.alibaba.com/product-detail/P-Life-USA-Oxo-Biodegradable-Drink_218325690.html?spm=a2700.galleryofferlist.normalList.237.8d9057a2ICY2Bq	Available, but no response to our order
Food contact materials	Green Production Ltd	Cutlery	P-life	Internet Market Review	http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered

Food contact materials	Palron Food Packaging Company	Food Containers, Cups	P-life	Internet Market Review	http://www.palron.com/ http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Food contact materials	Symphony - d2w	Straws	d2w	Internet Market Review	https://www.symphonyenvironmental.com/solutions/oxo-biodegradable-plastic/	Available in large quantities only (>500 kg), therefore not ordered
Food contact materials	Upper Midland Products	Straws	Eco-pure	E-Bay	https://www.ebay.com/itm/Eco-Friendly-Green-Straws-Bulk-Pack-of-200-Jumbo-Plastic-Green- Environment-by/323539298654?ssPageName=STRK%3AMEBIDX%3AIT&_trksid=p2057872.m2749.l2649	Available - Shipped
Landfill Cover	EPI	Landfill Cover	epi	(Hann et al. 2016)	https://www.envirocoversystem.com/products/	Not available
Packaging	CPS Flexible Ltd	Packaging films (Oxolife)	d2w	(Hann et al. 2016)	http://www.cps-flexible.co.uk/customers-marketing.html	Not available
Several	Kwong Wah Chemical & Plastics Co	Several	P-life	Internet Market Review	http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Several	Nan Sing Plastic Ltd	Bags	P-life	Internet Market Review	http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in Large quantities only (>500 kg), therefore not ordered
Several	Universal Plastic and Metal Manufacturing	Bags, Seat covers, Ponchos	P-life	Internet Market Review	http://www.upmplastic.com/ http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered

Several	Wai Kwong Polyethylene Products	Bags	P-life	Internet Market Review	http://www.wkpolybag.com/ http://www.p-life.com.hk/en/page/WsPage.php?news_id=6	Available in large quantities only (>500 kg), therefore not ordered
Several	EPI - TDPA	Several	TDPA	Internet Market Review	http://www.epi-global.com/en/about-tdpa.php	Not available
Several	Willow Ridge Plastics	Additive manufacturer only	BDA, PDQ-H, PDQ-M	Internet Market Review	http://www.willowridgeplastics.com/products-and-services/	Not available - Additive manufacturer only
Several	Ener Plastics	Additive manufacturer only	EP OBD	Internet Market Review	http://www.enerplastics.com/products/oxo-biodegradable/	Not available - Additive manufacturer only

Legend

Product was successfully shipped to Switzerland

Product can be shipped to Switzerland

Product cannot be shipped to Switzerland

Table 6-6: Limits of detection (LODs) and expected concentration ranges for transition-metal-based pro-oxidant additives according to patents in ppm (mg/kg). LODs are for the Niton XL2 XRF for polymer matrices under ideal conditions and are calculated as three standard deviations (99.7% confidence interval) for each element for a 30-second total analysis time. Elements not detected in regular 'Polymer mode' are stored as others. (Thermo Scientific 2010)

Elements	LOD [ppm]		Expected conc. [ppm]	
	PE	PVC	Min	Max
Ba	150	N/A	20	41 500
Sb	30	35	13	41 800
Sn	30	35	17	17 300
Cd	16	20	17	16 500
Bi	8	25	20	19 700
Pb	8	20	27	92 800
Br	5	25	N/A	N/A
Se	5	25	N/A	N/A
As	5	25	N/A	N/A
Hg	8	40	26	26 100

Elements	LOD [ppm]		Expected conc. [ppm]	
	PE	PVC	Min	Max
Au	8	40	26	25 800
Zn	12	80	10	80 000
Cu	15	80	10	10 100
Ni	15	80	9	9 400
Fe	20	125	9	9 000
Cr	30	110	8	8 400
V	200	1 200	8	8 200
Ti	150	1 500	8	60 000
Cl	50	N/A	N/A	N/A

Legend
- Detectable
- Not used
- Not detectable

Table 6-7: Elemental concentrations in different plastic samples (ODP 'oxo', conventional plastics and recycling material) in ppm (mg/kg) measured using a handheld XRF. For elements that are not explicitly measured by the XRF, the machine provides a sum of all these elements (hereafter referred to as 'sum of the rest elements').

Cat.	Sample Name	Producer / User	Color	Cr	Ba	Ti	Cl	Sb	Sn	Cd	Bi	Pb	Br	Se	As	Hg	Au	Zn	Cu	Ni	Fe	V	Sum of the rest elements
oxo	7-CBECOC5-clear shopper bag	Polybags Limited (UK)	transparent	< LOD (19)	< LOD (235)	< LOD (29)	< LOD (450)	< LOD (48)	< LOD (34)	< LOD (27)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (3)	< LOD (3)	< LOD (8)	< LOD (9)	< LOD (6)	< LOD (16)	< LOD (12)	34 ± 16	< LOD (12)	999883 ± 1
oxo	7-POLYCHIPBIO_ packaging foam	Polybags Limited (UK)	white	509 ± 61	1221 ± 456	< LOD (124)	2308 ± 1251	< LOD (134)	< LOD (101)	< LOD (77)	< LOD (34)	< LOD (24)	< LOD (16)	< LOD (26)	< LOD (15)	< LOD (50)	< LOD (75)	< LOD (32)	< LOD (109)	< LOD (94)	274 ± 90	105 ± 40	995172 ± 128
oxo	7-BOBCOMPOST_ compost bag	Polybags Limited (UK)	white, green	56 ± 15	426 ± 279	< LOD (44)	1871 ± 731	< LOD (84)	< LOD (61)	< LOD (46)	< LOD (13)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (13)	< LOD (16)	< LOD (13)	69 ± 18	81 ± 19	1318 ± 69	< LOD (15)	996137 ± 45
oxo	7-BIOREFUSE-waste bag	Polybags Limited (UK)	white, green	< LOD (17)	693 ± 307	< LOD (40)	< LOD (933)	< LOD (91)	< LOD (65)	< LOD (50)	< LOD (12)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (11)	< LOD (13)	< LOD (12)	43 ± 16	< LOD (21)	475 ± 45	23 ± 10	998184 ± 20
oxo	7-CBECOW5-shopper bag blue	Polybags Limited (UK)	blue	< LOD (22)	< LOD (197)	18389 ± 245	503 ± 270	< LOD (42)	< LOD (31)	< LOD (24)	< LOD (9)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (13)	223 ± 13	193 ± 18	< LOD (16)	68 ± 21	191 ± 41	980421 ± 148
oxo	7-BOB16OBIOB-waste bag black	Polybags Limited (UK)	black	< LOD (22)	416 ± 206	3908 ± 138	< LOD (875)	< LOD (63)	< LOD (45)	36 ± 23	< LOD (11)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (15)	157 ± 13	64 ± 16	< LOD (18)	129 ± 27	< LOD (37)	995148 ± 48
oxo	7-dog waste bag	Polybags Limited (UK)	green	< LOD (23)	< LOD (245)	11678 ± 228	7013 ± 664	< LOD (52)	< LOD (37)	< LOD (30)	< LOD (10)	< LOD (7)	7 ± 3	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	127 ± 13	416 ± 25	< LOD (19)	77 ± 25	111 ± 39	980469 ± 167
oxo	28-dog waste bag	99% good (US)	green, black	< LOD (20)	684 ± 187	8096 ± 183	3860 ± 568	< LOD (56)	< LOD (41)	< LOD (32)	< LOD (11)	< LOD (6)	74 ± 4	< LOD (5)	< LOD (4)	< LOD (9)	< LOD (14)	231 ± 14	99 ± 15	< LOD (17)	46 ± 22	113 ± 33	986796 ± 114
oxo	29-dog waste bag	Houndscoop (US)	black	< LOD (19)	689 ± 262	2898 ± 126	< LOD (1080)	< LOD (78)	< LOD (56)	< LOD (43)	< LOD (11)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	72 ± 11	< LOD (22)	< LOD (20)	86 ± 28	44 ± 23	995227 ± 48
oxo	30-dog waste bag	Pobby (US)	green, black	< LOD (21)	< LOD (278)	11003 ± 214	2047 ± 511	< LOD (57)	< LOD (42)	< LOD (32)	< LOD (10)	< LOD (7)	< LOD (3)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (13)	60 ± 10	122 ± 17	< LOD (19)	94 ± 26	123 ± 37	986319 ± 120
oxo	31-dog waste bag	PetNPet (US)	blue, turquois	< LOD (17)	579 ± 158	7585 ± 150	548 ± 291	< LOD (47)	< LOD (34)	< LOD (27)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (13)	434 ± 16	86 ± 13	< LOD (13)	33 ± 17	88 ± 27	990643 ± 72
oxo	31-dog waste bag	PetNPet (US)	blue, turquois, black	< LOD (18)	594 ± 157	8113 ± 155	942 ± 314	< LOD (47)	< LOD (34)	< LOD (27)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (13)	440 ± 16	82 ± 13	< LOD (13)	36 ± 18	91 ± 28	989685 ± 79
oxo	31-dog waste bag blue	PetNPet (US)	blue, turquois	< LOD (17)	742 ± 156	8284 ± 157	830 ± 307	< LOD (47)	< LOD (34)	< LOD (26)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (13)	388 ± 16	86 ± 13	< LOD (13)	< LOD (26)	80 ± 28	989536 ± 80
oxo	31-dog waste bag red	PetNPet (US)	red	< LOD (20)	1584 ± 201	8920 ± 189	721 ± 427	< LOD (58)	< LOD (42)	< LOD (33)	< LOD (10)	< LOD (6)	< LOD (3)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	303 ± 16	27 ± 13	< LOD (18)	36 ± 23	101 ± 33	988281 ± 100
oxo	31-dog waste bag-green	PetNPet (US)	green, black	< LOD (16)	< LOD (269)	3143 ± 103	1770 ± 431	< LOD (54)	< LOD (39)	< LOD (30)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (8)	< LOD (13)	348 ± 15	115 ± 14	< LOD (13)	49 ± 19	46 ± 19	994258 ± 48
oxo	32-shopper bags	Yankee Merchandise (US)	green, transparent	< LOD (18)	< LOD (345)	979 ± 75	2025 ± 704	< LOD (70)	< LOD (50)	< LOD (38)	< LOD (10)	< LOD (7)	< LOD (3)	< LOD (5)	< LOD (4)	< LOD (9)	< LOD (12)	27 ± 8	192 ± 18	< LOD (18)	141 ± 27	25 ± 15	996340 ± 36
oxo	33-kitchen bags	Go Green (US)	green	570 ± 24	637 ± 154	10588 ± 189	689 ± 314	< LOD (49)	< LOD (36)	31 ± 19	< LOD (29)	3279 ± 53	7 ± 4	< LOD (7)	< LOD (41)	< LOD (12)	< LOD (14)	357 ± 16	120 ± 17	< LOD (16)	59 ± 21	74 ± 32	983551 ± 133
oxo	33-kitchen bags	Go Green (US)	green	637 ± 25	573 ± 158	10999 ± 196	960 ± 335	< LOD (50)	< LOD (36)	< LOD (29)	< LOD (29)	3314 ± 54	< LOD (7)	< LOD (7)	< LOD (42)	< LOD (12)	< LOD (15)	370 ± 16	91 ± 17	19 ± 11	47 ± 21	74 ± 33	982908 ± 143

Cat.	Sample Name	Producer / User	Color	Cr	Ba	Ti	Cl	Sb	Sn	Cd	Bi	Pb	Br	Se	As	Hg	Au	Zn	Cu	Ni	Fe	V	Sum of the rest elements
oxo	33-kitchen bags	Go Green (US)	green	666 ± 30	529 ± 178	11432 ± 230	1500 ± 425	< LOD (56)	< LOD (41)	< LOD (33)	< LOD (32)	3113 ± 59	< LOD (8)	< LOD (8)	< LOD (47)	< LOD (14)	< LOD (17)	338 ± 18	91 ± 21	< LOD (21)	79 ± 26	101 ± 39	982119 ± 165
oxo	33-kitchenbags-single	Go Green (US)	green	634 ± 29	463 ± 150	11412 ± 222	1257 ± 403	< LOD (48)	< LOD (35)	< LOD (28)	< LOD (30)	3248 ± 55	10 ± 5	< LOD (7)	< LOD (44)	< LOD (13)	< LOD (15)	357 ± 17	89 ± 18	< LOD (18)	79 ± 24	112 ± 39	982283 ± 153
oxo	34-dog waste bag	Green Nature (US)	green, black	< LOD (16)	< LOD (269)	2804 ± 102	1554 ± 433	< LOD (55)	< LOD (39)	< LOD (30)	< LOD (8)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (8)	< LOD (10)	111 ± 9	56 ± 12	< LOD (13)	49 ± 19	38 ± 19	995082 ± 41
oxo	35-feminine hygiene bag	Bey Bee (US)	orange, white, black	1125 ± 47	1367 ± 184	36116 ± 529	2732 ± 511	< LOD (59)	< LOD (44)	< LOD (35)	< LOD (53)	6894 ± 117	29 ± 7	< LOD (11)	< LOD (79)	< LOD (18)	< LOD (21)	134 ± 15	72 ± 26	< LOD (28)	156 ± 40	348 ± 72	950958 ± 504
oxo	35-feminine hygiene bag	Bey Bee (US)	orange, white, black	1250 ± 49	1102 ± 172	36853 ± 540	2622 ± 508	< LOD (56)	< LOD (42)	< LOD (34)	55 ± 36	7094 ± 120	26 ± 7	< LOD (12)	< LOD (80)	< LOD (18)	< LOD (20)	119 ± 15	88 ± 26	< LOD (27)	180 ± 40	331 ± 73	950235 ± 525
oxo	35-feminine hygiene bag	Bey Bee (US)	orange, white, black	1108 ± 47	1077 ± 167	38054 ± 547	2661 ± 512	< LOD (54)	< LOD (41)	< LOD (33)	< LOD (51)	6572 ± 112	24 ± 7	< LOD (11)	< LOD (77)	< LOD (19)	< LOD (19)	137 ± 15	75 ± 25	< LOD (27)	144 ± 39	408 ± 75	949681 ± 504
oxo	35-feminine hygiene bags-single	Bey Bee (US)	orange, white, black	804 ± 35	602 ± 187	16754 ± 307	2767 ± 502	< LOD (60)	< LOD (44)	< LOD (36)	< LOD (43)	4182 ± 83	15 ± 6	< LOD (9)	< LOD (62)	< LOD (17)	< LOD (18)	79 ± 12	50 ± 24	< LOD (26)	133 ± 35	169 ± 47	974385 ± 278
oxo	36-money bag	PM Company (US)	white, green	< LOD (32)	260 ± 156	39838 ± 480	< LOD (491)	< LOD (51)	< LOD (37)	< LOD (30)	< LOD (12)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (13)	< LOD (16)	59 ± 12	41 ± 19	< LOD (24)	142 ± 34	342 ± 67	958839 ± 370
oxo	37-dog waste bags	RangerRob (US)	blue	< LOD (21)	< LOD (302)	3262 ± 128	< LOD (930)	< LOD (62)	< LOD (45)	< LOD (35)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (11)	< LOD (14)	62 ± 11	766 ± 32	< LOD (18)	75 ± 23	36 ± 23	995024 ± 50
oxo	38-diaper bag	Goobi Baby (US)	blue, turquois	< LOD (17)	< LOD (204)	9453 ± 165	1779 ± 331	< LOD (43)	< LOD (31)	< LOD (24)	< LOD (10)	< LOD (6)	158 ± 5	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (11)	259 ± 12	245 ± 16	< LOD (13)	42 ± 17	110 ± 29	987950 ± 88
oxo	39-dog waste bag	PetLoft (US)	violet	< LOD (30)	707 ± 153	19528 ± 306	< LOD (631)	< LOD (47)	< LOD (34)	< LOD (27)	< LOD (11)	< LOD (7)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (11)	< LOD (18)	341 ± 18	33 ± 17	< LOD (21)	91 ± 27	135 ± 51	978570 ± 194
oxo	40-cat litter liners	PetNPet (US)	white, green	< LOD (39)	< LOD (174)	48568 ± 539	< LOD (376)	< LOD (39)	< LOD (29)	< LOD (24)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (12)	< LOD (16)	79 ± 11	< LOD (27)	< LOD (22)	52 ± 27	524 ± 76	950635 ± 420
oxo	41-diaper bags	MomEasy (US)	blue	< LOD (20)	< LOD (217)	15373 ± 227	< LOD (358)	< LOD (46)	< LOD (33)	< LOD (26)	< LOD (9)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (8)	< LOD (12)	129 ± 11	93 ± 14	< LOD (15)	104 ± 23	132 ± 39	983894 ± 125
oxo	42-cat litter liners	HyperCat (US)	white, green	< LOD (31)	3919 ± 168	24338 ± 308	< LOD (356)	< LOD (42)	< LOD (31)	< LOD (25)	< LOD (10)	< LOD (7)	< LOD (3)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (13)	102 ± 11	< LOD (21)	< LOD (19)	65 ± 25	154 ± 52	971094 ± 229
oxo	61-straws	Upper Midland Products (US)	green	75 ± 20	< LOD (265)	2100 ± 103	2326 ± 552	< LOD (55)	< LOD (40)	< LOD (31)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (5)	< LOD (11)	< LOD (15)	< LOD (10)	195 ± 22	< LOD (19)	79 ± 24	< LOD (31)	995053 ± 51
oxo	62-oxo-shopper bag	Dongguan Fangije Printing and Packaging Co., Ltd (China)	red	< LOD (24)	< LOD (205)	9484 ± 190	< LOD (491)	< LOD (43)	< LOD (31)	< LOD (25)	< LOD (9)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (12)	131 ± 10	22 ± 13	< LOD (15)	53 ± 19	76 ± 34	989854 ± 84
oxo	62-bio-shopper bag	Dongguan Fangije Printing and Packaging Co., Ltd (China)	transparent, white, green	25 ± 12	< LOD (265)	141 ± 30	< LOD (449)	< LOD (54)	< LOD (39)	< LOD (30)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (9)	16 ± 5	23 ± 10	< LOD (13)	49 ± 17	< LOD (14)	999473 ± 5
conven-tional	bio1-postage-ETH	ETH (CH)	transparent	< LOD (28)	< LOD (209)	8816 ± 190	< LOD (502)	< LOD (44)	< LOD (31)	< LOD (25)	< LOD (10)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (12)	11 ± 6	28 ± 14	< LOD (16)	65 ± 21	122 ± 35	990551 ± 81
conven-tional	n1-dog waste bag-yellow	n.a. (CH)	yellow	26 ± 15	< LOD (315)	69 ± 41	2325 ± 665	< LOD (63)	< LOD (46)	< LOD (36)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (11)	< LOD (14)	57 ± 9	30 ± 16	< LOD (19)	249 ± 33	< LOD (19)	996998 ± 32

Cat.	Sample Name	Producer / User	Color	Cr	Ba	Ti	Cl	Sb	Sn	Cd	Bi	Pb	Br	Se	As	Hg	Au	Zn	Cu	Ni	Fe	V	Sum of the rest elements
conventional	n10-vegetable bag-transparent	Migros (CH)	transparent	< LOD (22)	< LOD (228)	< LOD (35)	< LOD (521)	< LOD (46)	< LOD (33)	< LOD (26)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (10)	88 ± 8	19 ± 11	< LOD (12)	66 ± 17	< LOD (14)	999542 ± 4
conventional	n11-shopper bag-drinks ot world	Drinks of the World (CH)	blue, mixed	< LOD (23)	693 ± 194	11436 ± 227	1642 ± 523	< LOD (59)	< LOD (43)	< LOD (33)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (11)	< LOD (16)	249 ± 16	213 ± 21	< LOD (19)	129 ± 29	131 ± 39	985471 ± 130
conventional	n11-shopper bag-drinks ot world	Drinks of the World (CH)	blue, mixed	< LOD (21)	685 ± 206	9900 ± 207	1371 ± 490	< LOD (62)	< LOD (45)	< LOD (35)	< LOD (10)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (5)	< LOD (11)	< LOD (15)	227 ± 16	178 ± 20	< LOD (21)	119 ± 29	114 ± 35	987371 ± 112
conventional	n11-shopper bag-drinks ot world	Drinks of the World (CH)	blue, mixed	< LOD (22)	498 ± 188	7994 ± 180	1511 ± 472	< LOD (57)	< LOD (41)	< LOD (32)	< LOD (10)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	190 ± 13	128 ± 17	< LOD (17)	109 ± 26	57 ± 31	989477 ± 94
conventional	n12-shopper bag-pharmacy	Pharmacy Birmensdorferstr. (CH)	grey, green	< LOD (24)	< LOD (234)	20221 ± 294	< LOD (534)	< LOD (50)	< LOD (36)	< LOD (29)	< LOD (10)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	61 ± 10	103 ± 18	< LOD (19)	81 ± 26	162 ± 47	979037 ± 181
conventional	n13-shopper bag-coop rec	Coop – recycling bag	white, orange	< LOD (24)	< LOD (285)	14741 ± 266	< LOD (785)	< LOD (59)	< LOD (43)	< LOD (34)	< LOD (12)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (5)	< LOD (11)	< LOD (15)	115 ± 13	89 ± 19	< LOD (21)	168 ± 33	111 ± 43	983812 ± 154
conventional	n14-shopper bag-migros rec	Migros – recycling bag	white, orange	< LOD (27)	1155 ± 207	16166 ± 294	< LOD (827)	< LOD (62)	< LOD (45)	< LOD (35)	< LOD (13)	< LOD (9)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (12)	< LOD (18)	220 ± 17	42 ± 19	< LOD (24)	146 ± 34	163 ± 48	981736 ± 173
conventional	n15-shopper bag-blue	n.a. (CH)	blue	< LOD (31)	1274 ± 369	2512 ± 156	< LOD (2007)	< LOD (109)	< LOD (78)	< LOD (59)	< LOD (17)	< LOD (11)	< LOD (6)	< LOD (9)	< LOD (7)	< LOD (17)	< LOD (25)	133 ± 19	404 ± 37	< LOD (33)	89 ± 41	50 ± 29	994372 ± 78
conventional	n15-shopper bag-blue	n.a. (CH)	blue	< LOD (30)	933 ± 358	2617 ± 164	< LOD (2146)	< LOD (107)	< LOD (77)	< LOD (58)	< LOD (15)	< LOD (10)	< LOD (6)	< LOD (8)	< LOD (6)	< LOD (16)	< LOD (23)	137 ± 19	384 ± 34	< LOD (31)	126 ± 41	< LOD (44)	995290 ± 63
conventional	n16-shopper bag-MAVI-epi	MAVI ((TR)	blue	< LOD (31)	< LOD (190)	33415 ± 408	< LOD (458)	< LOD (42)	< LOD (31)	< LOD (25)	< LOD (11)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (5)	< LOD (11)	< LOD (15)	27 ± 10	449 ± 28	< LOD (22)	89 ± 28	302 ± 62	965431 ± 296
conventional	n16-shopper bag-MAVI-epi	MAVI ((TR)	blue	< LOD (28)	< LOD (190)	29459 ± 360	< LOD (429)	< LOD (41)	< LOD (30)	< LOD (25)	< LOD (11)	< LOD (8)	< LOD (3)	< LOD (5)	< LOD (5)	< LOD (10)	< LOD (13)	27 ± 9	375 ± 24	< LOD (20)	93 ± 26	312 ± 57	969482 ± 247
conventional	n16-shopper bag-MAVI-epi	MAVI ((TR)	blue	< LOD (29)	< LOD (200)	30433 ± 373	830 ± 326	< LOD (44)	< LOD (32)	< LOD (26)	< LOD (10)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (10)	< LOD (14)	17 ± 9	351 ± 24	< LOD (21)	76 ± 26	277 ± 57	967846 ± 268
conventional	n17-vegetable bag-transparent	Coop (CH(	transparent	28 ± 16	312 ± 164	< LOD (41)	< LOD (565)	< LOD (50)	< LOD (36)	< LOD (28)	< LOD (10)	8 ± 5	< LOD (3)	< LOD (5)	< LOD (4)	< LOD (9)	< LOD (15)	438 ± 17	< LOD (20)	< LOD (15)	184 ± 25	< LOD (16)	998772 ± 12
conventional	n18-shopper bag-white	n.a. (CH)	white	< LOD (21)	< LOD (207)	15143 ± 225	416 ± 255	< LOD (44)	< LOD (32)	< LOD (25)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (8)	< LOD (10)	< LOD (9)	19 ± 12	< LOD (14)	36 ± 19	159 ± 39	984089 ± 122
conventional	n19-shopper bag-coop II	Coop	white, orange	< LOD (26)	2359 ± 222	13047 ± 257	< LOD (795)	< LOD (62)	< LOD (45)	< LOD (35)	< LOD (12)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (12)	< LOD (16)	89 ± 13	47 ± 17	< LOD (22)	88 ± 31	112 ± 43	984020 ± 151
conventional	n2-packaging electronics-transp	Packaging Mixer (CH)	transparent, red	28 ± 15	569 ± 162	< LOD (66)	< LOD (519)	< LOD (48)	< LOD (35)	< LOD (27)	< LOD (10)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (8)	< LOD (11)	87 ± 8	< LOD (17)	< LOD (13)	56 ± 18	< LOD (22)	999084 ± 8
conventional	n20-freezer bag	Migros (CH)	transparent	22 ± 11	< LOD (219)	1346 ± 67	< LOD (392)	< LOD (45)	< LOD (32)	< LOD (25)	< LOD (8)	< LOD (6)	< LOD (2)	< LOD (3)	< LOD (3)	< LOD (7)	< LOD (8)	< LOD (6)	21 ± 9	< LOD (11)	24 ± 15	44 ± 14	998146 ± 15
conventional	n21-shopper bag-H&M	H&M (CH)	white, grey	< LOD (29)	< LOD (227)	30070 ± 390	< LOD (555)	< LOD (49)	< LOD (36)	< LOD (29)	< LOD (12)	< LOD (7)	< LOD (4)	< LOD (5)	< LOD (4)	< LOD (11)	< LOD (15)	94 ± 12	30 ± 17	< LOD (21)	100 ± 30	244 ± 59	968969 ± 266
conventional	n22-shopper bag-thin-white-MDPE	n.a. (CH)	white	< LOD (28)	< LOD (247)	19248 ± 301	918 ± 348	< LOD (53)	< LOD (38)	< LOD (30)	< LOD (12)	< LOD (9)	7 ± 3	< LOD (6)	< LOD (5)	< LOD (12)	< LOD (18)	186 ± 16	< LOD (29)	< LOD (24)	93 ± 29	253 ± 48	979217 ± 201
conventional	n3-waste bag-zurich	Züri-Sack (CH)	white	< LOD (30)	< LOD (199)	31953 ± 393	< LOD (442)	< LOD (43)	< LOD (32)	< LOD (26)	< LOD (11)	< LOD (8)	< LOD (4)	< LOD (5)	< LOD (5)	< LOD (12)	< LOD (16)	138 ± 13	57 ± 17	< LOD (21)	86 ± 27	301 ± 60	967243 ± 279
conventional	n4-shopper bag-white	n.a. (CH)	white	< LOD (27)	< LOD (280)	19829 ± 317	< LOD (709)	< LOD (59)	< LOD (43)	< LOD (34)	< LOD (12)	< LOD (8)	< LOD (4)	< LOD (6)	< LOD (5)	< LOD (13)	< LOD (17)	100 ± 13	< LOD (27)	< LOD (24)	68 ± 30	180 ± 50	979020 ± 204

Cat.	Sample Name	Producer / User	Color	Cr	Ba	Ti	Cl	Sb	Sn	Cd	Bi	Pb	Br	Se	As	Hg	Au	Zn	Cu	Ni	Fe	V	Sum of the rest elements
conventional	n5-shopper bag-black	n.a. (CH)	black	21 ± 13	< LOD (244)	< LOD (32)	< LOD (500)	< LOD (50)	< LOD (36)	< LOD (28)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (3)	< LOD (3)	< LOD (8)	< LOD (9)	14 ± 5	< LOD (16)	< LOD (13)	56 ± 17	< LOD (13)	999861 ± 1
conventional	n6-shopper bag-coop	Coop	white, orange	< LOD (24)	< LOD (175)	31542 ± 336	< LOD (303)	< LOD (38)	< LOD (28)	< LOD (23)	< LOD (9)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (11)	44 ± 8	23 ± 13	< LOD (17)	38 ± 21	220 ± 50	968022 ± 237
conventional	n7-shopper bag-grey	Point Cadre (FR)	white, grey	< LOD (25)	< LOD (186)	20102 ± 275	600 ± 287	< LOD (40)	< LOD (29)	< LOD (23)	< LOD (10)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (12)	64 ± 9	95 ± 16	< LOD (16)	76 ± 22	212 ± 47	978804 ± 165
conventional	n8-shopper bag-FCW	Franz Carl Weber (CH)	blue, mixed	< LOD (25)	286 ± 173	17339 ± 280	786 ± 468	< LOD (54)	< LOD (40)	< LOD (31)	< LOD (11)	< LOD (7)	< LOD (4)	< LOD (6)	< LOD (4)	< LOD (10)	< LOD (16)	233 ± 16	59 ± 17	< LOD (20)	108 ± 28	199 ± 47	980983 ± 168
conventional	n9-shopper bag-red-ESPRIT	Esprit (CH)	red	< LOD (22)	1155 ± 152	4366 ± 136	1081 ± 360	< LOD (44)	< LOD (32)	< LOD (25)	< LOD (9)	< LOD (7)	< LOD (3)	< LOD (4)	< LOD (4)	< LOD (9)	< LOD (11)	99 ± 9	< LOD (18)	< LOD (14)	1308 ± 52	< LOD (41)	991920 ± 65
recycling	rec1-foils	Inno Recycling	mixed	129 ± 34	< LOD (292)	18805 ± 373	< LOD (752)	< LOD (62)	< LOD (46)	< LOD (36)	< LOD (18)	< LOD (13)	< LOD (7)	< LOD (10)	< LOD (8)	< LOD (21)	< LOD (31)	146 ± 19	64 ± 34	47 ± 28	535 ± 66	261 ± 58	979364 ± 273
recycling	recinno190301-blue	Inno Recycling	blue	< LOD (16)	< LOD (224)	738 ± 51	< LOD (354)	< LOD (46)	< LOD (33)	< LOD (25)	< LOD (8)	< LOD (6)	< LOD (2)	< LOD (3)	< LOD (3)	< LOD (7)	< LOD (8)	16 ± 5	152 ± 13	< LOD (11)	55 ± 16	< LOD (15)	999013 ± 8
recycling	recM18-grey	Inno Recycling	grey	21 ± 11	< LOD (227)	60 ± 23	< LOD (423)	< LOD (46)	< LOD (33)	< LOD (26)	< LOD (8)	< LOD (5)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (7)	< LOD (11)	295 ± 12	< LOD (15)	< LOD (11)	130 ± 19	< LOD (11)	998993 ± 8
recycling	recM19-grey	Inno Recycling	grey	< LOD (16)	< LOD (224)	63 ± 22	< LOD (430)	< LOD (45)	< LOD (33)	< LOD (25)	< LOD (8)	< LOD (5)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (7)	< LOD (10)	226 ± 10	15 ± 10	< LOD (11)	77 ± 17	< LOD (11)	999073 ± 7
recycling	recM20-grey	Inno Recycling	grey	< LOD (15)	< LOD (226)	57 ± 22	462 ± 286	< LOD (46)	< LOD (33)	< LOD (26)	< LOD (9)	< LOD (6)	< LOD (3)	< LOD (4)	< LOD (3)	< LOD (7)	< LOD (11)	233 ± 11	< LOD (15)	< LOD (11)	77 ± 17	< LOD (10)	999016 ± 8

Legend

- <100 ppm
- 100 – 1000 ppm
- 1000 – 100000 ppm
- >100000 ppm

Table 6-8: Compilation of relevant EN, ISO and ASTM standards, as well as OECD guidelines, related to plastics degradability (This table is of purely informative character. The exact specifications shall be taken from the standards themselves.)

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
DIN EN 17033	2018	Plastics - Biodegradable mulch films for use in agriculture and horticulture - Requirements and test methods	standard	mulch films ICS 83.140.10	plastics ICS 83.140.10	-	biodegradability	for basis material without additives: information on constituents of mulch foil material; maximum limits for regulated metals and other substances; concentration of substances of very high concern: <0.1%; ignition loss >60%;	specified within standard
EN ISO 17556	(2012) draft 2018	Plastics - Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved	test standard	general	plastics ICS 83.080.01	-	ultimate aerobic biodegradability	N/A	N/A
ASTM D5988	2018	Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials in Soil	test standard	general	plastics	-	biodegradability	N/A	N/A
DIN EN 13432	2000 (corrections 2005 and 2007)	Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging	standard	packaging ICS 55.020	general	wastes - other standards related to wastes * Including waste prevention ICS 13.030.99	composting biodegradation	yes: identification and characterization of the components of the packaging; limits for heavy metals content; determination of organic carbon content and total dry matter, ignition loss min. 50%;	specified within standard
DIN EN 14995	2006	Plastics - Evaluation of compostability - Test scheme and specifications	standard	general	plastics ICS 83.080.01	wastes - other standards related to wastes * Including waste prevention ICS 13.030.99	composting	yes: identification and characterization of the components of the packaging; limits for heavy metals content; determination of organic carbon content and total dry matter, ignition loss min. 50%;	specified within standard

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
DIN EN 17033	not allowed	EN ISO 17556; for basis material (without additives);	natural soil or standard soil (blend of 70% industrial silica sand, 10% clay, 16% natural soil and 4% mature, well aerated compost)	20 - 28 ± 2 °C preferably 25°C	24 months	conversion of 90% of organic carbon (absolute or compared to reference material)	aerobic	no
EN ISO 17556	N/A	specified within standard	natural soil or standard soil (blend of 70% industrial silica sand, 10% clay, 16% natural soil and 4% mature, well aerated compost)	20 - 28 ± 2 °C preferably 25°C	should typically not exceed six months; max. 2 years	N/A	aerobic	no
ASTM D5988	no	specified within standard	natural, fertile soil collected from the surface layers of fields and forests	20 - 28 ± 2 °C	-	N/A	aerobic	no
DIN EN 13432	no	ISO 14855 (ISO/TR 15462, ISO 14851, ISO 14852); optionally anaerobic (ISO 14853, EN ISO 11734)	stabilized, mature compost [stabilisierter, ausgereifter Kompost]	58 ± 2 °C	1. 6 months (2. 2 months)	1. 90% degradation (or 90% of reference material) (2. 50% degradation of the theoretical value for the test material, based on biogas production)	1. aerobic (2. anaerobic)	aerobic: 90% disintegration into parts <2mm in 12 weeks; anaerobic + aerobic (total max 5 weeks): 90% disintegration into parts <2mm; test material in form of final product; test in pilot-scale plant or real composting facility;
DIN EN 14995	no	ISO 14855 (ISO/TR 15462, ISO 14851, ISO 14852); optionally anaerobic (ISO 14853, EN ISO 11734)	stabilized, mature compost [stabilisierter, ausgereifter Kompost]	58 ± 2 °C	1. 6 months (2. 2 months)	1. 90% degradation (or 90% of reference material) (2. 50% degradation of the theoretical value for the test material, based on biogas production)	1. aerobic (2. anaerobic)	aerob: 90% disintegration into parts <2mm in 12 weeks; anaerob + aerob (total max 5 weeks): 90% disintegration into parts <2mm; test material in form of final product; pilot-scale test according to ISO 16929;

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
DIN EN 17033	for polymeric base material (without additives): Seedling Emergence and Seedling Growth Test according to OECD 208 (germination rate and plant biomass >90% of value for blank soil); Acute or Chronical Toxicity to Earthworms Tests (difference to blank soil in mortality rate and biomass of surviving adults < 10%); Inhibition of Soil Microorganisms Nitrification Test (nitrite formation >80% compared to blank soil);	for foil: requirements regarding thickness, mechanical and optical properties, appearance, designation on packaging or label (optionally on foil); directions on label regarding installations and use must be followed; label must be preserved until end of use;	for thermoplastic mulch foils; base material for test in primary form (pellets, powder); mulch foil made from tested base material is considered as compliant with standard if addition of masterbatch or additives does not lead to a foil which is contrary to the requirements from section 5;
EN ISO 17556	N/A	no	valid among others for polymeric materials containing additives like plasticizers or coloring agents;
ASTM D5988	N/A	no	plastic materials, including formulation additives; "This ASTM test method is equivalent to ISO 17556."
DIN EN 13432	yes: physico-chemical properties (density, total dry matter, ignition loss, salt content, pH value, total nitrogen, ammonium nitrogen, phosphate, magnesium and calcium content); germination rate and plant biomass of two species of higher plants, that have grown on the compost with test substance, have to amount to more than 90% of the value for the blank value compost - based on OECD 208 (OECD Guidelines for the Testing of Chemicals — Guideline 208: Terrestrial Plants, Growth Test);	no negative consequences on the biological treatment process (determined via disintegration test); recognizability as compostable or biodegradable by the end user;	meant to give information on the behavior of packaging in waste treatment facilities; DIN EN 13432 and 14995 have the same requirements;
DIN EN 14995	yes: physico-chemical properties (density, total dry matter, ignition loss, salt content, pH value, total nitrogen, ammonium nitrogen, phosphate, magnesium and calcium content); germination rate and plant biomass of two species of higher plants, that have grown on the compost with test substance, have to amount to more than 90% of the value for the blank value compost - based on OECD 208 (OECD Guidelines for the Testing of Chemicals — Guideline 208: Terrestrial Plants, Growth Test);	no negative consequences on the biological treatment process (determined via disintegration test); recognizability as compostable or biodegradable by the end user;	DIN EN 13432 and 14995 have the same requirements;

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
ISO 17088	2012	Specifications for compostable plastics	standard	general	plastics	-	"compostable", "compostable in municipal and commercial facilities", "biodegradable during composting"	yes: concentrations of regulated metals and other toxic substances in the plastic product or material <50 % of those prescribed for sludges, fertilizers and composts in the country where the final product will be placed on the market or disposed of; > 50 % of volatile solids in plastic product or material;	not specified
ASTM D6400	2012	Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities	standard	general	plastic	-	composting	yes: regulated metals less than 50 % of those prescribed for sludges or composts in the country where the product is sold; for the United States, the regulated metal concentrations are given; (heavy metals limits: least strict, then EN 13432, then DIN V 54900, but the last has less substances regulated than EN 13432)	partly acc. to ASTM D6400, otherwise regulations for other countries
ISO 18606	2013	Packaging and the environment — Organic recycling	standard	packaging	general	-	organic recycling (carried out in industrial composting plants or anaerobic digesters); composting; biodegradability	yes: limits for metals and hazardous substances; additionally: constituents known to be, or expected to become, hazardous to the environment during the biological treatment process shall not be deliberately introduced; information on, and identification of, the constituents of the packaging materials; determination of the organic carbon content, total dry solids, and volatile solids (>50%);	specified within standard

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
ISO 17088	not allowed	ISO 14855-1 or -2, or ASTM D5338	stabilized, mature compost [stabilisierter, ausgereifter Kompost]	58 ± 2 °C	test is terminated when the plateau phase of the biodegradation has been attained; standard time 45 days; max. 6 months	>90 % of the organic carbon - absolutely or compared to reference - converted	aerobic	yes: >90% of original dry mass disintegrated into pieces <2mm after 84 days in a controlled composting test, according to ISO 16929, ISO 20200, ISO 14855-1 or ASTM D5338 (thermophilic composting conditions without the CO2-trapping equipment)
ASTM D6400	not allowed	ASTM D 5338-98 (Testmethode) ISO 14855-1 ISO 14855-2	stabilized, mature compost	58 ± 2 °C (applies for both test methods)	6 months	90% of organic carbon converted to CO2	aerobic	yes: 90% (of original dry weight) disintegration into parts <2mm in 12 weeks in controlled composting test acc. to ISO 16929
ISO 18606	no	aerobic: ISO 14855-1 or -2 (if necessary, an internationally standardized biodegradability test method, esp. ISO 14851 or 14852 can be used); anaerobic: ISO 14853 or ISO 15985	aerobic: stabilized, mature compost; anaerobic: digested sludge;	aerobic: 58 ± 2°C; anaerobic: 35 ± 2°C	6 months	90% conversion of organic carbon (absolute or relative); anaerobic: none (because normally followed by aerobic composting)	aerobic; anaerobic	90% disintegration into parts <2mm in 12 weeks; tested acc. to ISO 16929 or ISO 20200;

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
ISO 17088	yes: Based on the relevant national and/or regional regulations, the plastic product or material shall not, upon decomposition, release unacceptably high levels of regulated metals or other toxic substances into the environment. seedling germination rate of the finished compost and the plant biomass in the compost > 90 % of that of corresponding blank composts (determined in accordance with OECD Guideline 208 with the modifications specified in Annex E of EN 13432:2000)		Products meeting the requirements outlined are appropriate for labelling as “compostable”, “compostable in municipal and commercial facilities” or “biodegradable during composting”. The term “biodegradable” shall not be used to describe the performance of plastics which meet this specification unless the conditions typically found in composting and described in ISO 14855-1 and ISO 14855-2 are included (for example “biodegradable during composting”). The name of the country where the plastic product or material is to be marketed or recycled by composting shall be indicated. When testing finished articles and products, testing shall be conducted starting with the articles and products in the same form as they are intended to be used. If the products or materials under test include fillers, the fillers shall be present when the products or materials are tested as described in 6.2, 6.3 and 6.4. However, their inorganic carbon content shall be excluded from the mineralization calculations in 6.3. Products or materials to which catalysts are subsequently added, or in which the content of the catalyst is changed, shall be retested to demonstrate that the new material meets the criteria specified in 6.2, 6.3 and 6.4.
ASTM D6400	yes: physico-chemical properties (density, total dry matter, ignition loss, salt content, pH value, total nitrogen, ammonium nitrogen, phosphate, magnesium and calcium content); germination rate and plant biomass of two species of higher plants, that have grown on the compost with test substance, have to amount to more than 90% of the value for the blank value compost - based on OECD 208 (OECD Guidelines for the Testing of Chemicals — Guideline 208: Terrestrial Plants, Growth Test);	no	ASTM D6400 has similar requirements to DIN EN 13432 and 14995
ISO 18606	seedling germination rate of the finished compost and the plant biomass in the compost > 90 % of that of corresponding blank composts (determined in accordance with OECD Guideline 208 with the modifications); compost preparation acc. to ISO 16929, 10 % sample input concentration.	The packaging or packaging component which is intended for entering the biological waste stream shall be recognizable as organically recyclable by the end user by appropriate means.	same as DIN EN 13432, but choise between aerobic and anaerobic free, some small difference regarding anaerobic;

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
DIN V 54900	1998	Testing of the compostability of plastics	standard *(withdrawn)*	general	plastics		composting	yes	DIN V 54900-1
DIN EN ISO 14855 -1 -2	2012 2018	Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions - Method by analysis of evolved carbon dioxide - Part 1: General method Part 2: Gravimetric measurement of carbon dioxide evolved in a laboratory-scale test	test standard	general	plastics ICS 83.080.01	wastes - other standards related to wastes * Including waste prevention ICS 13.030.99 (only for -1)	composting biodegradation	N/A	N/A
DIN EN 14046	2003	Packaging - Evaluation of the ultimate aerobic biodegradability of packaging materials under controlled composting conditions - Method by analysis of released carbon dioxide	test standard	packaging ICS 55.040	general	wastes - other standards related to wastes * Including waste prevention ICS 13.030.99	composting biodegradation	N/A	N/A
ASTM D5338	2015	Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions, Incorporating Thermophilic Temperatures	test standard [standard test method]	general	plastics	plastic materials, which are intended to be composted in facilities that achieve thermophilic temperatures	composting biodegradation	N/A	N/A
ISO 13975	2019	Plastics — Determination of the ultimate anaerobic biodegradation of plastic materials in controlled slurry digestion systems — Method by measurement of biogas production	test standard	general	plastics	-	biodegradability	N/A	N/A

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
DIN V 54900		DIN V 54900-2	aqueous medium, compost	20-25 ± 1 °C	6 months	60% for homopolymers 90% for co-polymers	aerobic	yes
DIN EN ISO 14855 ***-1*** ***-2***	N/A	specified within standard	stabilized, mature compost [stabilisierter, ausgereifter Kompost]	58 ± 2 °C	6 months (just for -1)	N/A	aerobic	no
DIN EN 14046	N/A	specified within standard	stabilized, mature compost	58 ± 2 °C	should not exceed 6 months	N/A	aerobic	documentation of visual impression
ASTM D5338	N/A	specified within standard	stabilized, mature compost [stabilisierter, ausgereifter Kompost]	58 ± 2 °C	45 days	N/A	aerobic	no
ISO 13975	N/A	specified within standard	digested sludge, or organic waste such as livestock faeces or garbage	55 ± 5 °C or 35 ± 3 °C	60 days, may be shortened or extended, but shall not exceed 90 days	N/A	anaerobic	no

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
DIN V 54900	yes: DIN 54900-4 Testing of the ecotoxicity of the composts	DIN V 54900-3 Testing under practice-relevant conditions and testing of quality of the composts	only secondary sources available
DIN EN ISO 14855 ***-1*** ***-2***	N/A	no	test material not in form of final product
DIN EN 14046	N/A	no	not referred to by any of the standards mentioned here (only by a withdrawn VDI Technische Regel: VDI 4424:2005)
ASTM D5338	N/A	no	"test method equivalent to ISO 14855" The test material may be in the form of films, formed articles such as dog bones, granules, or powder. The maximum surface area of a compact test material used should be about 2 by 2 cm.
ISO 13975	N/A	no	

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
DIN EN ISO 14853	2018	Plastics - Determination of the ultimate anaerobic biodegradation of plastic materials in an aqueous system - Method by measurement of biogas production	test standard	general	plastics ICS 83.080.01	-	biodegradability	N/A	N/A
EN ISO 11734	1998	Water quality — Evaluation of the „ultimate“ anaerobic biodegradability of organic compounds in digested sludge — Method by measurement of the biogas production	test standard	compounds	organic	-	biodegradability	N/A	N/A
DIN EN ISO 15985	2018	Plastics - Determination of the ultimate anaerobic biodegradation under high-solids anaerobic-digestion conditions - Method by analysis of released biogas	test standard	general	plastics ICS 83.140.10	-	biodegradability	N/A	N/A
DIN EN 14987	2007	Plastics – Evaluation of disposability in waste water treatment plants – Test scheme for final acceptance and specifications	standard	general	plastics	water quality - sewage water ICS 13.060.30	disposability in waste water treatment plants	no	no

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
DIN EN ISO 14853	N/A	specified within standard	digested sludge	35 ± 2 °C	normally 60 days, can be terminated if plateau is reached or extended until plateau is reached, but shall not exceed 90 days	N/A	anaerobic	no
EN ISO 11734	N/A	specified within standard	digested sludge	35 ± 2 °C	around 60 days	N/A	anaerobic	N/A (see Comments)
DIN EN ISO 15985	N/A	specified within standard	digested sludge from treated municipal waste, preferrably only organic fraction, more than 20% solids	52 °C ± 2 °C	normally 15 days or until plateau is reached	N/A	anaerobic	N/A
DIN EN 14987	no	DIN EIN ISO 14852 or 14851	municipal or industrial sewage sludge (NOT solution from soil or compost)	20 - 25 ± 1 °C (NOT thermophilic)	56 days	90% mineralisation degree (absolutly or of reference material)	aerobic	dispersibility (in water easily decomposed to particles <10mm)

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
DIN EN ISO 14853	N/A	no	
EN ISO 11734	no	no	test material needs to dissolve in water or mineral medium at beginning of test -> seems not suitable for biodegradable plastics
DIN EN ISO 15985	N/A	no	conditions from this standard do not necessarily represent the optimum conditions for reaching a maximum degree of biodegradation
DIN EN 14987	no	degree of solubility/dispersibility in cold or warm water	

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
DIN EN ISO 14851	(2004) draft 2016	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium - Method by measuring the oxygen demand in a closed respirometer	test standard	general	plastics ICS 83.080.01	-	biodegradability	N/A	N/A
DIN EN ISO 14852	2018	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium - Method by analysis of evolved carbon dioxide	test standard	general	plastics ICS 83.080.01	-	biodegradability	N/A	N/A
DIN EN 14047	2002	Packaging – Determination of the ultimate aerobic biodegradability of packaging materials in an aqueous medium - Method by analysis of evolved carbon dioxide	test standard	packaging ICS 55.040	general	-	biodegradability	N/A	N/A
DIN EN 14048	2003	Packaging - Determination of the ultimate aerobic biodegradability of packaging materials in an aqueous medium - Method by measuring the oxygen demand in a closed respirometer	test standard	packaging ICS 55.040	general	-	biodegradability	N/A	N/A

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
DIN EN ISO 14851	N/A	specified within standard	acqueous solution of activated sludge	preferrably 20-25 ± 1 °C	6 months (draft: 2 months)	N/A	aerobic	no
DIN EN ISO 14852	N/A	specified within standard	acqueous solution of activated sludge or suspension from nutrient-rich soil or compost	preferrably 20-25 ± 1 °C	6 months	N/A	aerobic	no
DIN EN 14047	N/A	DIN EN ISO 14852	acqueous solution of activated sludge or suspension from nutrient-rich soil or compost	preferrably 20-25 ± 1 °C	6 months	N/A	aerobic	no
DIN EN 14048	N/A	DIN EN ISO 14851	acqueous solution of activated sludge	preferrably 20-25 ± 1 °C	6 months (draft: 2 months)	N/A	aerobic	no

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
DIN EN ISO 14851	N/A	no	plastics incl. additives explicitly mentioned; meant to give information on the behavior of packaging in waste treatment facilities;
DIN EN ISO 14852	N/A	no	plastics incl. additives explicitly mentioned; meant to give information on the behavior of packaging in waste treatment facilities;
DIN EN 14047	N/A	no	not referred to by any of the standards mentioned here (only by a withdrawn VDI Technische Regel: VDI 4424:2005)
DIN EN 14048	N/A	no	not referred to by any of the standards mentioned here (only by a withdrawn VDI Technische Regel: VDI 4424:2005)

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
ISO 18830	2016	Plastics -- Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sandy sediment interface -- Method by measuring the oxygen demand in closed respirometer	test standard	general	plastics ICS 83.080.01	-	biodegradability	chemical composition and properties like TOC should be stated	N/A
DIN EN ISO 19679	2018	Plastics – Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sediment interface – Method by analysis of evolved carbon dioxide	test standard	general	plastics ICS: 83.080.01	-	biodegradability	chemical composition and properties like TOC should be stated	N/A
ASTM D7081	2005	Standard Specification for Non-Floating Biodegradable Plastics in the Marine Environment	standard *(withdrawn)*	general	plastics	-	"biodegradable in marine waters and sediments"		
ASTM D6691	2009	Standard test method for determining aerobic biodegradation of plastic materials in the marine environment by a defined microbial consortium or natural sea water inoculum	test standard	general	plastics	-	biodegradability	characterization of polymeric material (carbon content, molecular weight)	N/A

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
ISO 18830	N/A	based on ISO 14851	artificial or natural sea water on natural sandy sea sediment	if possible 15 - 25 °C, not above 28 °C, ±2 °C	until plateau is reached, maximum 24 months	N/A	aerobic	no
DIN EN ISO 19679	N/A	based on ISO 14852	artificial or natural sea water on natural sandy sea sediment	if possible 15 - 25 °C, not above 28 °C, ±2 °C	until plateau is reached, maximum 24 months	N/A	aerobic	no
ASTM D7081			marine waters or sediments (e.g. shallow or deep salt water or brackish water)	30±2 °C	6 months	30% conversion	aerobic	70% disintegration based on original dry weight into pieces <2mm in 12 weeks
ASTM D6691	N/A	specified within standard	artificial (with isolated marine microorganisms) or natural sea water (with inorganic nutrients)	30 ± 1°C	10-90 days, shorter if plateau is reached or longer if no biodegradation within respective time;	N/A	aerobic	no

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
ISO 18830	N/A	visual inspection	preferrably foil as test medium, placed on surface of sediment
DIN EN ISO 19679	N/A	visual inspection	preferrably foil as test medium, placed on surface of sediment
ASTM D7081			
ASTM D6691	N/A	no	test specimen in powders, films, pieces, fragments, formed articles or aqueous solutions; for plastic materials (including formulation additives)

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
ASTM D7473	2012	Standard test method for weight attrition of plastic materials in the marine environment by open system aquarium incubations	test standard	general	plastics	-	weight attrition	characterizing of plastic films for testing (formulation, carbon content, molecular weight, film thickness and uniformity)	N/A
OECD 306	1992	OECD Guideline for the testing of chemicals. Biodegradability in seawater	guideline for testing	compounds	chemicals	-	biodegradability (distinction from ready biodegradability)	requirements on organic carbon content, volatility, solubility in water, absorption onto glass surfaces; toxicity to bacteria can be tested	no
ISO 16221	2001	Water quality -- Guidance for determination of biodegradability in the marine environment					biodegradability		
ASTM D6692	2001	Standard test method for determining the biodegradability of radiolabel polymeric plastic materials in seawater	standard *(withdrawn)*						

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
ASTM D7473	N/A	specified within standard	natural flowing seawater or sediment (preferably muddy as opposed to sand) surfaces under natural flowing seawater in open tray incubation in marine aquarium	seasonally varying water temperatures	maximum 180 days	N/A	aerobic	no
OECD 306	no	specified within standard: shake flask or closed bottle method	natural sea water, nutrients added	normally 15-20°C ± 1 or 2°C, may be beyond	60 days (shake flask); 28 days recommended, but can be prolonged (closed bottle);	>70% DOC (dissolved organic carbon) removal; >60% ThOD (theoretical oxygen demand)	aerobic	no
ISO 16221								
ASTM D6692								

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
ASTM D7473	N/A	determination of loss due to soluble components (e.g. plasticizers)	for non-floating plastic materials (including formulation additives); representative of aquatic environments near the coasts and near the bottom of a body of water in the absence of sunlight, particularly UV and visible portions of the spectrum; The goal of this test is to obtain data that will predict real world experiences based on the extent and rate of biodegradation data of the same materials obtained from the laboratory Test Method D6691. If Test Method D6691 achieves 30 % mineralization, then apply this Aquarium test and perform it. If the results from Test Method D6691 do not achieve 30 % mineralization, then aquarium incubation testing need not be done and the material shall be considered non-biodegradable in the marine environment. The standard addresses weight loss of the plastics in a marine environment and cannot be used for demonstrating biodegradation for which Specification D7081 needs to be used. [ASTM D7081 has been withdrawn] test specimen: plastic film pieces of known size and thickness; "This test by itself shall not be used as the basis for claims, such as "Biodegradable in Marine Environments" since it is only a weight loss test method."
OECD 306	no	no	If the result is positive, it may be concluded that there is a potential for biodegradation in the marine environment. However, a negative result does not preclude such a potential but indicates that further study is necessary, for example, using as low a concentration of the test compound as possible.
ISO 16221			not available via https://ethz.eresearchcenter.eu/
ASTM D6692			

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
OECD 309	2004	OECD Guideline for the testing of chemicals. Aerobic Mineralisation in Surface Water – Simulation Biodegradation Test	guideline for testing	compounds	chemicals	-	mineralization	selected chemical properties should be available	no
ASTM D5526	2018	Standard Test Method for Determining Anaerobic Biodegradation of Plastic Materials Under Accelerated Landfill Conditions	test standard	general	plastics	-	biodegradability	N/A	N/A
DIN EN ISO 7827	2013	Water quality -- Evaluation of the "ready", "ultimate" aerobic biodegradability of organic compounds in an aqueous medium -- Method by analysis of dissolved organic carbon (DOC)	test standard	compounds	organic	-	biodegradability	N/A	N/A
DIN EN ISO 9439	2000	Water quality - Evaluation of ultimate aerobic biodegradability of organic compounds in aqueous medium - Carbon dioxide evolution test	test standard	compounds	organic	-	biodegradability	N/A	N/A

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
OECD 309	no	shake flask	natural surface water (fresh, brackish or marine) alone or with suspended sediment	field temperature or 20-25 ± 2 °C	should normally not exceed 60 days, but may be extended to maximum 90 days (semi-continuous even longer)	no	aerobic	no
ASTM D5526	no	specified within standard	pretreated municipal solid waste fraction with inoculum from anaerobic digester for organic household waste	35 ± 2 °C	4 months, possible to extend until reference has degraded >70% or there is no significant gas production for one week	no	anaerobic	no
DIN EN ISO 7827	N/A	specified within standard	acqueous solution of outflow of waste water treatment plant, activated sludge or surface water	22 ± 2 °C	28 days, or can be prolongued by 1-2 weeks, or degradation >80% and constant degradation level	N/A	aerobic	N/A (see Comments)
DIN EN ISO 9439	N/A	specified within standard	acqueous solution of outflow of waste water treatment plant, activated sludge or surface water	preferrably 20-25 ± 2 °C	should not exceed 28 days, but can be prolongued for 1-2 weeks if degradation noticable	N/A	aerobic	N/A (see Comments)

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
OECD 309	no	determination of different chemical parameters	based on ISO 14592 and includes elements from OECD Guidelines 307 and 308; different concentrations of test substance should be used; incubation in dark or diffuse light
ASTM D5526	no	no	It is acceptable for the test specimen to be in the form of films, powder, pellets, or formed articles, or in the form of a dog bone.
DIN EN ISO 7827	N/A	no	test material needs to dissolve in water or mineral medium at beginning of test -> seems not suitable for biodegradable plastics
DIN EN ISO 9439	N/A	no	test material needs to dissolve in water or mineral medium at beginning of test -> seems not suitable for biodegradable plastics

Designation	Year	Title	Type of document	Product category	Material	Stage in life cycle / purpose	Process designation	Chemical test (composition, harmful substances, nutrients)	
								required?	Test method
DIN EN ISO 9408 ***DIN EN ISO 9887*** ***DIN EN ISO 9888*** ***DIN EN ISO 10707*** ***ISO 14592*** ***ISO 14593***	1999 1994 1999 1998 2005	Water quality - *other standards*							
ISO/TR 15462	2006	Water quality -- Selection of tests for biodegradability							
DIN EN 14045	2003	Packaging – Evaluation of the disintegration of packaging materials in practical oriented tests under defined composting conditions;	test standard	packaging ICS 55.040		wastes - other standards related to wastes * Including waste prevention ICS 13.030.99	composting disintegration		
ISO 16929 ***DIN EN ISO 16929***	2013 2018	Plastics — Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test	standard standard (draft)	general	plastics ICS: 83.080.01		disintegration		
DIN EN ISO 20200	2016	Plastics — Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test	standard	general	plastics ICS: 83.080.01		disintegration		
ASTM 6954		Standard Guide for Exposing and Testing Plastics that Degrade in the Environment by a Combination of Oxidation and Biodegradation	test standard	general	plastics ICS: 83.080.01	-	oxo-biodegradation	no	N/A

Designation	Abiotic degradation step	Biotic degradation test						Disintegration requirement
		Test method	Medium	Test temperature[1]	Test duration	Pass-fail criterion	Atmosphere	
DIN EN ISO 9408 ***DIN EN ISO 9887*** ***DIN EN ISO 9888*** ***DIN EN ISO 10707*** ***ISO 14592*** ***ISO 14593***								
ISO/TR 15462			acquatic environment					
DIN EN 14045								
ISO 16929 ***DIN EN ISO 16929***								
DIN EN ISO 20200								
ASTM 6954	20 - 70°C for films: until elongation at break max. 5% and molecular weight < 5000 no maximum timeframe	ASTM D5988, ASTM D5338 or ASTM D5526	soil, compost or landfill (or water)	20 - 28 ± 2 °C 58°C ± 2 °C 35 ± 2 °C	no requirement	no (60 / 90 % conversion for homopolymers / co-polymers, but no timeframe requirement)	aerobic or anaerobic	(molecular weight, polydispersity index or tensile elongation should be determined)

Designation	Ecotoxicity test (of degradation products)	Other additional tests / requirements	Comments
DIN EN ISO 9408 ***DIN EN ISO 9887*** ***DIN EN ISO 9888*** ***DIN EN ISO 10707*** ***ISO 14592*** ***ISO 14593***			
ISO/TR 15462			relevant tests have been included in this list
DIN EN 14045			not referred to by any of the standards mentioned here (only by a withdrawn VDI Technische Regel: VDI 4424:2005)
ISO 16929 ***DIN EN ISO 16929***			
DIN EN ISO 20200			
ASTM 6954	terrestrial and aquatic ecotoxicity tests suggested: Aquatic toxicity test with Rotifer brachionus Plant germination: cress seed test Plant growth test according to OECD 208 Earthworm test according to OECD 207	no	"If composting is the designated disposal route, Specification D6400 is the only ultimate and definitive applicable specification for measuring biodegradation or compostability. Oxidation followed by biodegradation under the conditions found in this guide does not confer the designation "compostable" or any connotation that the applications are acceptable for composting in a commercial or municipal composting facility." "The correlation of results from this guide to actual disposal environments (for example, agricultural mulch films, composting, or landfill applications) has not been determined, and as such, the results should be used only for comparative and ranking purposes."

Footnote

[1] highest allowed test temperature

Legend

withdrawn standards or standards for test objects such that not relevant for plastics

General comments

for some standards, only German version was available; in such case, translation has been done
table sorted by medium of degradation test
color coding used for different temperature ranges for allowing faster readability

Relevant OECD guidelines

for degradation, accumulation

OECD Guidelines for the Testing of Chemicals, Section 3: Environmental fate and behaviour
(https://www.oecd-ilibrary.org/environment/test-no-309-aerobic-mineralisation-in-surface-water-simulation-biodegradation-test_9789264070547-en)
include a number of test guidelines, e.g.:
Test No. 301: Ready Biodegradability
Test No. 304A: Inherent Biodegradability in Soil
Test No. 306: Biodegradability in seawater [see table]
Test No. 307: Aerobic and Anaerobic Transformation in Soil
Test No. 309: Aerobic Mineralisation in Surface Water – Simulation Biodegradation Test [see table]
Test No. 311: Anaerobic Biodegradability of Organic Compounds in Digested Sludge: by Measurement of Gas Production
Test No. 305: Bioaccumulation in Fish: Aqueous and Dietary Exposure
Test No. 317: Bioaccumulation in Terrestrial Oligochaetes

for ecotoxicity tests

OECD Guidelines for the Testing of Chemicals, Section 2: Effects on Biotic Systems
(https://www.oecd-ilibrary.org/environment/oecd-guidelines-for-the-testing-of-chemicals-section-2-effects-on-biotic-systems_20745761)
collection of about 150 of the most relevant internationally agreed testing methods used by government, industry and independent laboratories to identify and characterise potential hazards of chemicals
include a number of test guidelines, e.g.:
Test No. 208: Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test
Test No. 227: Terrestrial Plant Test: Vegetative Vigour Test
tests on bird toxicity, earthworm reproduction toxicity, toxicity to sediment inhabitants