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‘Blue’ paper

Fact-checking plastic biodegradability in the marine environment

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Executive summary

Fishing gear and ALDFG (abandoned, lost, or otherwise discarded fishing gear), commonly called ‘ghost gear’, largely contributes to marine plastic pollution. They directly and indirectly harm marine wildlife, impact maritime traffic, and ultimately threaten human health.

Biodegradable materials have been promoted as suitable or promising alternatives without consideration of their full impacts on the marine environment.

This paper debunks the myths surrounding the biodegradability of plastics under marine conditions, and highlights their potential negative effects on marine life and human activities.

We call for a comprehensive international framework under the Global Plastic Treaty to address the full lifecycle of plastics in marine ecosystems, including those labelled as biodegradable.

The production and use of plastic globally has increased exponentially since the 1950s. In just 20 years, production has doubled and in 2019 alone 460 million tonnes (Mt) of plastics were produced.[1] Unfortunately, plastic waste has more than doubled during this period, increasing from 156 to 353 Mt.

Over **eight million tonnes of plastic enter the ocean every year**.[2] Approximately 10% of this plastic comes from fishing gear[3] and as much as **70% of floating macroplastic debris** (by weight) is so-called **'ghost gear'** (or ALDFG - abandoned, lost, or discarded fishing gear).[4]

More recent studies suggest **fishing and aquaculture equipment** are the second most common plastic items in the sea, accounting for 26% of hard plastic debris by count and 8% by mass.[5]

Due to their toxic nature[i] and resilience to degradation[ii][6], plastics heavily impact marine fauna and flora for long periods[7], making these numbers even more concerning.

- Marine species can suffer injuries, asphyxiation, and death due to ingestion or entanglement in plastic debris.
- Microorganisms, potentially including pathogens, can accumulate on plastic surfaces in what is known as the *plastisphere*.
- Degradation processes occur slowly in the ocean. While they can be accelerated by salinity, temperature, sand abrasion, interactions with rocks, and intense ultraviolet radiation on sea surfaces - the lower temperatures and low dissolved oxygen concentrations can actually slow the process. This is especially true for plastic debris that sinks into the ocean.

It is estimated that 30 million tonnes of plastics have accumulated in the ocean.[8]

- Plastic debris with a lower density than seawater floats **and accumulates in vortex areas**, e.g. the 'Great Pacific Garbage Patch' or it ends up in the 'plastic cloud' formed in the deep sea.[9]
- Plastic debris denser than seawater **sinks to the seafloor**, even in deep sea areas. Over time, it undergoes degradation, fragmentation, and fouling, breaking down into micro- and nanoplastics. As a result, plastic wastes sink even further and are eventually buried in sediment. This process increases the toxicity of plastic debris, as microplastics act as sponges for pollutants.[10]

Biodegradable plastics are often promoted as alternatives to conventional ones in the marine environment, especially for 'ghost gear'. However, **no material can truly biodegrade under marine conditions within a timeframe that would prevent environmental damage.** This is a significant concern since biodegradable fishing nets can cause entanglement, harm wildlife and even damage human activities, such as propellers at sea.

'Biodegradable plastics' are not a viable solution to plastic pollution caused by plastic fishing and aquaculture gear. We need a comprehensive, international framework in the Global Plastic Treaty to address the entire lifecycle of plastics in marine ecosystems. This framework will prevent plastic waste and improve plastic design, production, use, and end-of-life treatment.

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[i] Plastics cause intestinal injuries, leach chemical additives, e.g. plasticizers, flame retardants, antioxidants, other stabilizers, pro-oxidants, surfactants, inorganic fillers, pigments and transfer pathogenic microorganisms. Leistenschneider, et al. 2023.

ii As an example, single-use plastic (HDPE) bottles could have half-lives of approximately 58 years in marine environments, and pipes 1,200 years.

Myth 1: "Biodegradable plastics fully degrade in the marine environment"

FALSE – Plastics are not readily biodegradable in the marine environment

Biodegradable plastics are designed to fragment (physical disintegration) and achieve mineralisation (chemical degradation) through the action of microorganisms, such as bacteria, fungi, and actinomycetes. These plastics are converted into carbon dioxide and biomass in controlled reactor conditions that support a biologically active environment. The biodegradation process mainly involves a community of microorganisms that use plastics as a carbon source.[11]

Several test methods are available based on international ISO standards to determine plastic biodegradation in seawater or marine sediments (Annex I). These methods are limited, however, as they do not accurately represent real-life conditions. They provide an assessment made in laboratory or reactor conditions[iii] and oversimplify the real-world conditions in marine sediment, seawater, sediment interface, and freshwater[iv].[12] During these tests:

- Temperatures are warmer than in marine real life, e.g. tests at 15-25°C (or even at 30°C in the tests of TÜV Austria for the 'OK biodegradable MARINE' certification scheme). This poses a high risk of persistency in cold (deep) sea environments.
- **Conditions are more conducive to microbial activity**, hence biodegradation, compared to ocean conditions due to higher concentrations of ammonia, nitrogen, or phosphorus.
- **Tests are typically conducted in aerobic conditions**, while plastic surfaces in the ocean may be exposed to lower oxygen levels or even anoxic environments such as sediments.
- Tests used to assess product biodegradability do not always evaluate individual constituents, such as **additives and leachates**, and the final product's biodegradability (Annex I). This is a significant gap since it is essential that each organic constituent and the final product meet the biodegradation criteria in the marine environment, including coatings and finishes. For example, plastics can be tested **without additives**, even though these additives can be toxic to microorganisms, reducing or preventing biodegradation.
- The biodegradation of materials in the marine environment is impacted by **micro- and macro-organism fouling**. When plastics are present in the ocean, they quickly become covered by a 'biofilm' made up of inorganic and organic matter, rapidly colonised by bacteria[13]. This colonisation process reduces the surface's accessibility to microorganisms involved in biodegradation. Plastic debris and microplastics sink in the water, leading to lower ultraviolet radiation, oxygen presence, temperature, etc. As a result, biodegradation is slower than in standard tests, but this factor is not considered in standard protocols.

Studies have also demonstrated that there are '**biases associated with the preparation of experimental inocula[v] and test conditions themselves**, including the use of preselected and pre-conditioned strains[vi], artificially modified inocula, powdered test materials, nutrient-rich synthetic media[vii] and test temperatures that are frequently higher than those encountered within the environment.'[14]

[iii] A reactor is a sealed box filled with a test matrix and test item that allows gas exchange between the inner atmosphere and the outside environment to ensure aerobic conditions.

[iv] For instance, the degradation rate of Poly(lactic acid) (PLA) is much lower in the marine environment than under composting conditions (maximum 10% in a year).

[v] Microorganisms or other materials that are introduced in a culture medium to start a biological process.

[vi] The test microorganisms that are provided by a culture collection centre.

[vii] The material used as a substrate for microbial growth.

Researchers also emphasise 'the lack of clear guidelines for analysing **different polymer types**, including composite materials and plastics that contain additives.'[14] This can significantly affect biodegradation rates.

The commonly used method for determining biodegradability involves measuring the conversion of organic carbon to carbon dioxide (CO_2). This method is reproducible, and laboratory experts consider it reliable as a blank reactor is used to correct the background activity of the microorganisms. Other experts consider this method can be influenced by the biodegradation of marine microbial life on plastics, also known as the **plastisphere**. It may 'lead to either underestimation or overestimation of the plastic biodegradation due to other processes.[11]

Regarding chemical additives, the wide range of biodegradable plastics and their varying physical and chemical characteristics result in very different biodegradation pathways. Many of these additives are patented and their information is unavailable for public evaluation but it is challenging to establish a generic protocol for determining their biodegradation.

In conclusion, **no plastic can be considered readily or totally biodegradable in the marine environment**,[14] resulting in their persistence for a long time.

Myth 2: "Biodegradable plastics do not impact marine fauna and flora"

FALSE – Biodegradable plastics seriously injure & kill marine animals

'Ghost gear' is derelict fishing gear that continues to fish and is currently **the deadliest form of marine debris**, mainly due to entanglement[15] and starvation[16] in marine animals. These problems still exist with biodegradable fishing gear, potentially leaving hundreds of animals from various species trapped or dead. The exact amount of **time that biodegradable plastics last in the marine environment is uncertain**, with estimates ranging several days, months, years or even centuries.[12] The length of time depends on the size, type of polymer, and other original material characteristics.

Until conclusive scientific peer-reviewed studies are available, marine life will continue to suffer from entanglement, injuries, or ingestion of biodegradable plastics. The long-lasting degradation of these materials harm and kill marine wildlife, especially turtles, whales, dolphins, and porpoises. It also poses a threat to seabirds and corals.

Biodegradable plastics have the same impacts on marine wildlife as conventional plastics. This is because plastic biodegradability tests are usually conducted over two years[viii], which is relatively short compared to the average lifetime of conventional plastics. During this time, marine animals can become entangled, and in severe cases they can die trapped in nets or by ingesting plastic debris that is available on the water surface, water column, or seabed.

[viii] For example, 2 years in EN ISO 22403:2021 'Plastics - Assessment of the intrinsic biodegradability of materials exposed to marine inocula under mesophilic aerobic laboratory conditions - Test methods and requirements', or in EN ISO 18830:2017 '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'. Some plastics, such as PHB (polyhydroxybutyrate), can degrade more quickly in the marine environment, reaching above 60% absolute biodegradation after about 40 test days. Still, a plateau is reached after about 2 months at about 70% absolute biodegradation.

Seabirds are one of the most affected animal groups, mainly through ingestion, and because they carry plastics back to their nests, sometimes feeding them to their chicks.[17] Plastic additives have even been found in the oil that seabirds produce to keep their feathers resistant to water.[18]

Zooplankton, filter feeders, and benthic organisms can quickly ingest biodegradable microplastics in the same way as conventional plastics. This can harm marine animals by blocking their digestive system or by adsorbing plastic additives and bioaccumulated pollutants.[19]

Abiotic degradation is the physical or chemical breakdown of plastics caused by mechanical forces or UV lights. This process produces carbonyl groups, which increases the polymer's hydrophilicity and makes small plastic fragments more available to organisms. Nanoplastics can act as a “Trojan horse”, passing through cellular membranes of aquatic organisms and entering organisms’ bodies throughout the food chain.[20] No documented evidence suggests that plastic biodegradation can occur within microorganisms once nanoplastics have been adsorbed.

Myth 3: “Biodegradable plastics do not pose a risk to the marine environment”

FALSE – Biodegradable plastics contaminate the marine environment

Biodegradability alone does not guarantee a lack of negative environmental impact. Even biodegradable plastics can pose an ecotoxicity risk to marine life due to the presence of harmful substances including metals, per- and poly-fluorinated substances (PFAS), fluorine, substances of very high concern (SHVC)[21], and other hazardous substances. Plastic additives, such as ultraviolet stabilisers and substituted diphenylamine antioxidants (endocrine disruptors), have been found in Arctic seabirds and seals.[22]

When biodegradable plastics deteriorate, they release more microplastics, nanoplastics, and additives than conventional plastics.[23] This is especially true during weathering.[24] Biodegradable plastics can pose environmental and health risks as potent vectors of microorganisms and pollutants, causing a severe impact on aquatic organisms.[25]

Conventional and biodegradable plastics share a common issue – their additives are not covalently bonded to the polymer. This means that additives can leach out from plastics when they degrade in the marine environment.[26] This is particularly alarming for fishing gear - **surface coatings can peel off and release harmful chemicals into seawater** such as phthalates, ultraviolet stabilisers, antioxidants, bisphenol A, and even flame retardants, which negatively impact aquatic organisms.[27] Bisphenol A, for example, ‘increases abnormalities, alters behaviour and hampers the cardiovascular system development, growth and survival.’[28] Another example, PFAS exposure causes ‘swim bladder defects and hyperactivity.’[29] This is particularly concerning as ocean currents can carry debris over long distances, which act as **vehicles for hazardous chemicals from plastics.** Most marine plastic debris comes from fishing nets and ropes, especially in areas like ‘the Great Pacific Garbage Patch’[5] and the North-East Atlantic islands.[30]

Biodegradable microplastics, similar to conventional microplastics, have a high sorption capacity of pollutants in the environment. They concentrate chemicals, such as hydrophobic persistent organic pollutants (POPs) and metals.[31] Over the long term, **biodegradable plastics can also** harm marine ecosystems by promoting the growth of certain bacteria or wiping out other species.

Biodegradable plastic test standards, e.g. EN ISO 22403 do not assess the plastic additives, such as regulated metals or substances hazardous to the environment, nor do they assess the potential ecotoxic effects – just the intrinsic biodegradability. These are considered in specific standards.[ix] Conventional plastics, however, can be used in marine environments without toxicity tests.

No umbrella standard considers all these relevant aspects together. Certification schemes rely on several standards, e.g. limits on heavy metals and hazardous substances from industrial composting standards and add additional requirements, e.g. cobalt.[x] These certification schemes do not comprehensively consider **contamination risks for the marine environment**. They also **risk encouraging the discarding of plastic items or parts in the marine environment.**

Standards typically do not cover the biodegradation of plastics buried in marine sediments under anaerobic conditions (see Annex I for an overview of relevant standards).[xi]

In conclusion, preventing plastics from ending up in the marine environment should always be prioritised. **Biodegradable plastics in the marine environment are not more "environmentally friendly" than conventional plastics** that do not degrade. They ultimately threaten human health, food security, and livelihoods.

Myth 4: "Biodegradable plastics are essential for certain marine applications"

FALSE – Alternative designs that prevent and mitigate marine losses are available

Biodegradable plastics with abrasion-resistance properties have been developed for various marine applications, including dolly ropes and seine ropes that help protect fishing gears from abrasion caused by the seabed.[xii] These plastics are seen as a potential solution to the problem of 'ghost gear', the most commonly found waste item on beaches.[32] It is essential, however, to note that the many shortcomings of biodegradable plastics listed in this paper, as well as physical and chemical risks to the marine ecosystem, have not been addressed.

Alternative design options that don't require dolly ropes should be promoted to reduce the net contact with the seabed beaches. **It is also essential to explore alternative fishing practices that can be more sustainable.** Gear designs with active and passive buoyancy, for example, can be used at the rear of the net to help lift it and prevent it from scraping the sea floor.[33]. Notably, most German shrimp fishermen have voluntarily stopped using dolly ropes.

[ix] e.g. ISO 5430:2023 'Plastics — Ecotoxicity testing scheme for soluble decomposition intermediates from biodegradable plastic materials and products used in the marine environment — Test methods and requirements' specifically define non-ecotoxicity test protocols for copepods, marine algae and bacteria.
x e.g. in the 'OK biodegradable MARINE' certification scheme from TÜV Austria.
[xi] e.g. EN ISO 18830:2017 and EN ISO 19679:2020 'Plastics - Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sediment interface - Method by analysis of evolved carbon dioxide'
[xii] Dolly ropes are wear and tear items made of small plastic threads of polyethylene, of about 1-2m long (often orange or blue), that are attached to the bottom of the trawl nets. 10-20% of dolly ropes are lost during their first weeks of use.

In addition to avoiding plastic release, we should end bottom trawl fishing. This will protect ecosystems, conserve species, and prevent seabed damage and the negative impacts on bycatches caused by bottom trawling.

Design modifications can also help prevent the loss of gear due to storms and poor quality. Semi-automated oyster growing systems, for example, can permanently attach oyster baskets to a backbone, which controls fouling and reduces the spread of pathogenic microorganisms and predators[xiii]. Other developments, like **alert systems, track and monitor deployed gear.** Flotation buoys with programmable electronic release mechanisms fixed to lobster traps and pots can help retrieve the buoy within a predetermined number of days. This system enables wildlife to escape and alerts fishers to the location of lost gear without releasing plastics into the ocean.[xiv]

Progress towards **circular design to prevent and mitigate plastic losses in the marine environment is promising** but fragmented and needs support. [xv] Plastics are used for various socio-economic activities, but their complex composition makes it difficult to repurpose them. To address plastic pollution, initiatives like 'Fishing for Litter' can help retrieve plastic waste and assess its potential for recycling.

There are several factors to consider in aquaculture, including the ropes where sessile organisms grow and the potential exposure to microplastics during growth. Most impacts can be significantly reduced during depuration, but transport boxes (especially made of expanded polystyrene), could lead to new sources of plastic release. **Alternatives to polystyrene should therefore be considered** throughout the value chain to minimise the release of (micro)plastics or. Plenty of market-based instrument examples can be used to minimise the impacts of ALDFG and improve the circularity and economic feasibility of small and large aquaculture production.

Conclusion: We need a comprehensive lifecycle approach

Biodegradable plastics are not a quick fix to marine plastic pollution. They are end-of-life alternatives to conventional plastics that still have major negative impacts on marine life and human activities. TMarine plastic pollution from fishing and aquaculture gear requires **a comprehensive approach throughout its lifecycle,** starting with preventing plastics from entering our seas and reducing resource use.

This should be promoted under the **Global Plastic Treat**y and include the production, design, use, right to repair, and end-of-life treatment of plastic products – to prevent the release of plastics in the marine environment. Market-based instruments and product traceability methods should also be considered to ensure that the lifecycle analysis incentivises the active reduction of plastic emissions to the marine environment, particularly biodegradable materials coated with or containing toxic additives.

This approach is echoed by other stakeholders who want to see this reflected in the Global Plastics Treaty negotiations: *"A dedicated programme* [of work on plastic fishing gear in the Treaty] *will allow coordination and expansion of existing initiatives while promoting integration with adopted guidance and supporting policy development and implementation at the regional and national level."*[34]

[xiii] FlipFarm Systems won the Global Seafood Alliance's 2021 Global Aquaculture Innovation Award.
[xiv] RESQUNIT is a gear loss prevention tool with programmable electronic release mechanism.
[xv] The new European standard FprEN 17988:2024 should support the sector's effort to reduce its marine impacts.

Annex I: Relevant ISO standards on marine biodegradability and their test limits

There is currently no international umbrella standard specification for biodegradable plastics in the marine environment. An umbrella standard specification for biodegradable plastics normally contains criteria related to the following aspects [xvi]:

- Control of constituents (= limit values for heavy metals, fluorine, absence of hazardous substances, etc.)
- Biodegradation.
- Disintegration.
- Toxicity.

On the international (ISO) level, two standard specifications [xvii] for biodegradable plastics that end up in the marine environment are available:

- *ISO 22403:2020, Plastics - Assessment of the intrinsic biodegradability of materials exposed to marine inocula under mesophilic aerobic laboratory conditions - Test methods and requirements*, defines biodegradation criteria.
- *ISO 5430:2023, Plastics - Ecotoxicity testing scheme for soluble decomposition intermediates from biodegradable plastic materials and products used in the marine environment - Test methods and requirements*, defines toxicity criteria.

ISO standard for assessing plastic intrinsic biodegradability in labs

ISO 22403:2020 prescribes that the final product or each individual constituent should reach at least 90% absolute or relative biodegradation within two years in the marine environment. Moreover, it requires that each organic constituent that is present in a concentration between 1% and 15% (by dry mass) is readily biodegradable or reaches at least 90% absolute or relative biodegradation within two years. Biodegradability should be tested in the marine environment, but different testing methods are allowed.

ISO 22403:2020 includes three marine environments. Table 1 lists the allowed test methods per marine environment.

[xvi] For example, ISO 17088:2021, *Plastics – Organic recycling, Specifications for compostable plastics*, specifies procedures and requirements for plastics, and products made from plastics, that are suitable for recovery through organic recycling and addresses four aspects: a) disintegration during composting; b) ultimate aerobic biodegradation; c) no adverse effects of compost on terrestrial organisms; d) control of constituents.
[xvii] A standard specification is a document that specifies which pass level should be used when using a certain test method.

Table 1. Summary of principles of international marine biodegradation test methods

Aspect	ISO 18830	ISO 19679	ISO 22404	ISO 23977-1	ISO 23977-2
Marine environment	Interface between seawater and seafloor (Sublittoral zone)		Marine sediment (Eulittoral zone)	Seawater from coastal area without or with a low amount of sediment: (1) pelagic seawater test (inoculum = seawater only) and (2) suspended sediment seawater test (inoculum = seawater to which a low amount of sediment has been added)	
Measuring technique		Determination of CO_2 production	Determination of CO_2 production	Determination of CO_2 production	Determination of O_2 consumption
Inoculum	Sandy sediment (30 g) and seawater (natural or artificial) (70 ml) in a flask of 250 ml (Remark: sandy sediment and seawater both from beneath the low-water line)		Wet sediment (400 g) in a test flask of 3 L	Natural seawater (90 ml) (Pelagic seawater test) Natural seawater (90 ml) + 0.1 – 1.0 g/l sediment (Suspended sediment seawater test) in a flask of 300 ml (+ KH_2PO_4 (0.1 g/l) and NH_4Cl (0.05 g/l))	
Temperature	Preferably between 15°C to 25°C, but not exceeding 28°C				
Replicates	Triplicate				
Sample preparation	20 mg film or sheet (At least 100 mg/l seawater + sediment)		100 mg powder (alternatively film or sheet) (At least 25 mg/100 g sediment)	20 mg powder or film per test flask (At least 100 mg/l seawater)	
Reference material	Positive control (mandatory, ashless cellulose filters) Negative control (optional, non-biodegradable polymer e.g. PE)	Positive control (mandatory, ashless cellulose filters) Negative control (mandatory, non-biodegradable polymer e.g. PE)	Positive control (mandatory, microcrystalline cellulose or ashless cellulose filters) Negative control (recommended, non-biodegradable polymer e.g. PE)	Positive control (mandatory, microcrystalline cellulose or ashless cellulose filters) Negative control (recommended if biodegradation is expected to take longer than 6 months, non-biodegradable polymer e.g. PE)	
Validity criterion for reference materials	Positive reference > 60% after 180 days	Positive reference > 60% after 180 days Negative reference < 10% at end of test	Positive reference > 60% after 180 days	Positive reference > 60% after 180 days	Positive reference > 60% after 180 days

For the organic constituents that are present in a concentration between 1% and 15% (by dry mass), the following freshwater testing methods are also allowed:

- OECD Test No. 301: Ready Biodegradability.
- OECD Test No. 310: Ready Biodegradability - CO_2 in sealed vessels (Headspace Test).

If these two test methods are used, the organic constituents need to demonstrate that they are "ready biodegradable".[xviii]

ISO standard for assessing plastic ecotoxicity in the marine environment

ISO 5430:2023 prescribes that soluble decomposition intermediates from biodegradable plastic materials and products used in the marine environment may not be toxic towards:

- Primary producers (algae).
- Primary consumers (invertebrate).
- Decomposers (microorganisms).

It consequently assesses adverse effects on organisms representing different trophic levels. This standard specification prescribes that the following test methods should be used in order to evaluate the toxicity:

Table 2. Summary of principles of international marine toxicity test methods (based on the requirements of ISO 5430)

Test method	Organism	Test duration	Pass criteria defined by ISO 5430
Marine algal growth inhibition test (ISO 10253)	Skeletonema sp. Phaeodactylum tricornutum	72 hours	The percentage inhibition in a test sample shall be ≤ 10% of those from the control sample.
Acute lethal toxicity test to marine copepods (ISO 14669)	Acartia tonsa Dana Tisbe battagliai Volkmann-Rocco Nitocra spinipes Boeck	48 hours	The mortality/immobilisation in the test sample shall be ≤10% of those from the control sample.
Determination of inhibitory effect on light emission of luminescent bacteria (ISO 11348 (all parts))	Aliivibrio fischeri	30 minutes	The bioluminescence in a test sample shall be ≥ 90% of those from the control sample.

ISO standards for determining plastic marine disintegration

Besides international marine biodegradation and marine toxicity test methods, marine disintegration test methods have also been developed. Both real-life and laboratory disintegration methods exist.

[xviii] The pass levels for "ready biodegradability" are 70% removal of DOC and 60% of ThOD or ThCO2 production for respirometric methods. They are lower in the respirometric methods since, as some of the carbon from the test chemical is incorporated into new cells, the percentage of CO_2 produced is lower than the percentage of carbon being used. These pass values have to be reached in a 10-day window within the 28-day period of the test, except where mentioned below. The 10-day window begins when the degree of biodegradation has reached 10% DOC, ThOD or ThCO2 and must end before day 28 of the test. Chemicals which reach the pass levels after the 28-day period are not deemed to be readily biodegradable. The 10-day window concept does not apply to the MITI method.

The international test method **ISO 23832:2021**, *Plastics – Test methods for determination of degradation rate and disintegration degree of plastic materials exposed to marine environmental matrices under laboratory conditions*, specifies test methods for the measurement of the physical degradation of samples made with plastic materials when exposed to following three marine environmental matrixes **under aerobic conditions at laboratory scale**:

- Method A: Sand burial degradation test (= a condition similar to the sandy shoreline where the beach is maintained wet by the waves and tides),
- Method B: Sediment/seawater interface degradation test (= a condition similar to the seabed where most debris sinks, accumulates and undergoes degradation),
- Method C: Seawater degradation test.

Degradation can be measured as (1) mass loss and/or (2) erosion and/or (3) decay of tensile properties. Moreover, the time for disintegration can also be determined. This ISO method only prescribes how testing should be performed. **It does not specify pass levels.**

The international test method **ISO 22766:2020**, *Plastics - Determination of the degree of disintegration of plastic materials in marine habitats under real field conditions*, specifies test methods for the determination of the degree of disintegration of plastic materials exposed to marine habitats **under real field conditions**. The marine areas under investigation are the sandy sublittoral and the sandy littoral zone, where plastic materials can either be placed intentionally, e.g. biodegradable fishing nets, or end up as litter due to irresponsible human behaviour.

European certification schemes for plastic marine biodegradability

Even though no international umbrella standard specifications have been developed, "umbrella certification schemes" have been developed by certification agencies. The following certification schemes exist in Europe:

- OK biodegradable MARINE of TÜV AUSTRIA Belgium.
- DIN Geprüft BIODEGRADABLE IN MARINE ENVIRONMENT of DIN CERTCO.
- DIN plus BIODEGRADABLE IN MARINE ENVIRONMENT of DIN CERTCO.

Table 3 compares the criteria of these three certification schemes.

Table 3. Comparison of the criteria of the certification schemes for the marine environment

<table>
<tr><th>Parameter</th><th>OK biodegradable MARINE (TÜV AUSTRIA Belgium)</th><th>DIN Geprüft BIODEGRADABLE IN MARINE ENVIRONMENT (DIN CERTCO)</th><th>DIN plus BIODEGRADABLE IN MARINE ENVIRONMENT (DIN CERTCO)</th></tr>
<tr><td>Chemical characteristics</td><td>Limit values for heavy metals and other toxic and hazardous substances (Table A.1 of annex A of the EN 13432 + max. 38 ppm Co)</td><td colspan="2">1. Limit values for heavy metals and fluorine (similar to Table A.1 of EN 13432, but with a lower limit value for F of 50 ppm and an additional maximum Co level of 38 ppm)
2. PFAS shall not be intentionally added
3. Each substance of very high concern (SVHC) that exceeds a concentration limit of 0.1% (by dry weight) and appears on the Candidate List of substances of very high concern for Authorization shall not be applied.</td></tr>
<tr><td>Biodegradation</td><td>Minimum 90% biodegradation (absolute or relative) within 6 months in a marine biodegradation test performed in line with ASTM D6691</td><td colspan="2">1. Minimum 90% biodegradation (absolute or relative) within 2 years in marine biodegradation test performed in line with ASTM D6691, ISO 23977-1, ISO 23977-2, ISO 18830, ISO 19679 or ISO 22404 (positive and negative reference material shall be included in testing).
2. For all organic constituents which are present in the manufactured item at a concentration between 1% and 15% (by dry mass) the level of biodegradation shall be determined separately (OECD 301 or OECD 306 or OECD 310 testing is also allowed).</td></tr>
<tr><td>Disintegration (lab-scale)</td><td>Minimum 90% disintegration within 84 days in a marine disintegration test (same testing conditions as ASTM D6691)</td><td colspan="2">The rate of disintegration shall be determined in order to give an indication of the lifetimes of the final product, intermediate or material under optimal conditions in marine environment according to test method ISO 23832 (method A, method B and method C are allowed, but for the final product the method shall be chosen dependant on the application).</td></tr>
<tr><td>Disintegration (field-scale)</td><td>-</td><td>-</td><td>At least 90% disintegration (determined by means of sieving or by means of image analysis) in two different coastal regions (eulittoral and sublittoral zone) after maximum 3 years according to test method ISO 22766.</td></tr>
<tr><td>Environmental safety</td><td>Minimum 90% mobile Daphnia after 48 hours in a medium to which the test item was added in a 0.1% concentration (on dry weight basis) (incubated for maximum 6 months)</td><td colspan="2">Toxicity criteria of ISO 5430 need to be fulfilled (= 3 organisms).
Marine algae: The percentage inhibition in a test sample shall be ≤ 10% of those from the control sample for both algae Skeletonema sp. and Phaeodactylum tricornutum (test method ISO 10253).
Marine invertebrates: The mortality/immobilisation in the test sample shall be ≤ 10% of those from the control sample (test method ISO 14669).
Marine micro-organisms: The bioluminescence in the test sample shall be ≥ 90% of those from the control sample. (test method ISO 11348).</td></tr>
</table>

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