INTERNATIONAL STANDARD

ISO 5148

First edition
2022-06

Plastics — Determination of specific aerobic biodegradation rate of solid plastic materials and disappearance time (DT50) under mesophilic laboratory test conditions

Plastiques — Détermination du taux de biodégradation aérobie spécifique des matières plastiques solides et du temps de disparition (DT50) dans des conditions d'essai de laboratoire mésophile

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Reference number
ISO 5148:2022(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 14, *Environmental aspects*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Several test methods have been developed by ISO to measure the biodegradation degree of plastics. Under aerobic conditions, the biodegradation reaction of a material is described by the following reaction:

$$C_M + O_2 \rightarrow C_{CO_2} + H_2O + C_B$$

where

C_M is the organic carbon present in the test material (e.g. a polymer or a plastic material);

C_{CO_2} is the carbon evolved as carbon dioxide;

C_B is the carbon assimilated by microorganism and incorporated in the microbial biochemistry.

The test methods follow the biodegradation reaction by measuring either the oxygen uptake (disappearance of the reactant) or the CO_2 evolution (formation of the product). The test methods return a biodegradation percentage (which, strictly speaking, is a "mineralization" percentage). This value is the reaction yield percentage, i.e. the mass of carbon oxidised to CO_2 during the reaction (actual yield) in comparison with the maximum possible yield (theoretical yield). This is expressed as evolved CO_2/theoretical CO_2, the latter value being the amount of CO_2 obtained in case of total oxidation of the original carbon present in the test substance.

A reliable test method for the determination of the C_B, i.e. the amount of C_M that has been assimilated in the biomass is not available at the date of publication.

The test methods are suitable for measuring the final degree of biodegradation but are not suitable for measuring the biodegradation rate, because they do not take into account the surface area of the tested sample. On the other hand, this document provides a guidance on how to measure the biodegradation rate using existing test methods.

Biodegradation of solid, non-water soluble polymers and plastics is a heterogeneous reaction because the polymer is in the solid state while microbes and enzymes are in the liquid phase. Even when the tested material is exposed to solid matrices (e.g. compost, soil, marine sediment) the microbes are in the liquid phase present within the solid matrix (e.g. micropores, macropores). Thus, the reaction of biodegradation happens in the liquid/solid interphase and the available surface area can become a limiting factor. It is a common knowledge that milling increases the biodegradation rate of a plastic sample. The biodegradation speed, i.e. the CO_2 evolution and the O_2 uptake rates, is controlled by the surface area of the tested sample. Therefore, biodegradation rate must be expressed as a function of the available surface area, otherwise the information is pointless and paradoxical results can be obtained.

There is an increasing interest in determining the biodegradation rate and related parameters (such as the disappearance time 50, DT50, i.e. the time within which the initial concentration of the test substance is reduced by 50 %) in order to assess the risk in the case of accidental or deliberate leakage of biodegradable plastics into the environment. Degradation of organic substances in the environment influences exposure and, hence, it is a key parameter for estimating the risk of long-term adverse effects on biota.

This document enables to determine the specific aerobic biodegradation rate i.e. the amount of carbon mineralized per unit time per unit surface area, under the conditions defined by the applied test method.

The approach showed in this document is aimed to measure mineralization rate. It differs from ISO 23832 that describes a test method for the determination of the physical degradation rate and disintegration degree of plastic materials. On the other hand, ISO 22403 identifies the plastic materials that show intrinsic biodegradability when exposed to marine inocula under mesophilic aerobic laboratory conditions.

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1 Scope

This document specifies a method to determine the specific aerobic biodegradation rate of solid, non-water soluble plastic materials under mesophilic conditions.

NOTE The specific aerobic biodegradation rate (which, strictly speaking, is a specific mineralization rate, implying the assessment of the conversion of organic carbon into CO_2 but neglecting biomass formation) is expressed as amount of carbon mineralized into CO_2, per unit time, per unit area.

The method described in this document does not provide information on the ultimate aerobic biodegradability of the tested samples. Biodegradability criteria for plastic materials under mesophilic conditions are provided for example by ISO 23517, and ISO 22403. The method described in this document shall be used to determine the DT50 only when the plastic material is proven to be intrinsically biodegradable using suitable standard specifications such as ISO 23517 and ISO 22403. Furthermore, the biodegradation rate determined on plastic materials whose ultimate biodegradation has not been proven, shall not be considered as a specific characteristic of the whole material.

This document only considers the evolution of CO_2 as direct measurement of mineralization of the tested sample.

The method described in this document may be applied also to solid materials used as a reference.

This document is not applicable for "marine, soil and freshwater biodegradable" claims of biodegradable plastic materials. For such purposes, see relevant product standards if available.

NOTE Although results can indicate that the tested plastic materials and polymers will biodegrade under the specified test conditions at a certain specific aerobic biodegradation rate or DT50, the results of any laboratory exposure are not directly applicable to environmental compartments including soil, marine environments and limnic areas at the actual site of use or leakage.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4591, *Plastics — Film and sheeting — Determination of average thickness of a sample, and average thickness and yield of a roll, by gravimetric techniques (gravimetric thickness)*

ISO 4593, *Plastics — Film and sheeting — Determination of thickness by mechanical scanning*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

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