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Plastics — Environmental aspects — State of knowledge and methodologies

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 249, *Plastics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

Introduction

Plastics materials are highly flexible and universally applicable. They can be found in a diversity of product areas and application sectors. In order to achieve a sustainable management and exploitation of products, safe and efficient manufacturing processes are compulsory within the value chain. In addition, an environmentally friendly use and handling across diverse applications is necessary during consumption, reuse and disposal. This ensures that an effective and qualified management at the product's end-of-life is addressed through proper performed procedures and evaluations.

If mismanagement happens at any of the above described life cycle stages, the use of plastics and plastics-containing products can create adverse effects to the environment. It has been proven, not least by the United Nations Environment Programme, that discarded products as well as microplastics are found in the environment around the globe, be it on land or water bodies including the sea. There are diverse causes for this such as inappropriate or inefficient waste management infrastructures, improper management of plastics products and their waste reuse or disposal, inefficient wastewater management, etc. Therefore, various types of entries into the environment and diverse constitutions and compositions of the microplastic particles in the environment are to be considered. Littered articles as well as microplastics consists of different kinds of products and come from different waste, e.g. bottles, films, fishing nets, tyres, cosmetics, clothing fibres, etc.

Over extended time in the environment, plastics products and their waste will breakdown into smaller items and finally disintegrate to microparticles. Microplastics also enter the environment directly through its intentional use in some product applications. Microparticles, be it via primary product use or via secondary fragmentation of macro articles, should be considered with special care since they can give rise to adverse environmental impact especially in the aquatic environment and its biota.

This document with its primary focus on plastics, rather than all the other materials, in the environment intends to provide a survey on the international situation of plastics and plastics in the environment with special attention to microplastics in the marine environment, its detection and determination. For this purpose, the document describes the state-of-the art testing methods as well as assessment approaches.

Although this document gives a representative overview of the current knowledge (up to early 2017) and activities about plastics and microplastics around the world, information is predominately generated from the Northern Hemisphere and activities in Europe and North America.

In this way, the document can be recognized as a contribution towards harmonized procedures and measures in order to provide a sound basis for a reliable and verifiable evaluation of the impact of plastics and microplastic in the environment. The document covers the following key items of interest.

— Status of plastics products and plastics in the environment: Facts about plastics use and proven findings about the occurrence of plastics and microplastics in the environmental matrix, be it on land and water bodies including the sea.

— Terminology: The terms "plastic particles", "plastic microparticles", "microplastics", "plastic nanoparticles" or "solid microparticle" are currently not defined in a consistent way and are, especially in an international context, being used differently. This document makes an attempt towards a globally harmonized terminology.

— Test methods: Methods for the detection, analysis and assessment of plastic particles present in the environment, such as aquatic litter, are neither harmonized nor standardized. Simple visual tests, in particular, have proved to be insufficient. This document will describe the sampling, its preparation of samples and further analytics, especially in waters as the main task of this document, since reproducible and verifiable procedures are indispensable to derive valid data for the environmental assessment and on this basis concluding appropriate measures to improve the environmental situation.

Not only has the plastics economy recognized the importance of this topic and started diverse action programmes, which are, for example, compiled through the Global Plastics Declaration Initiative,

also political groups (e.g. G 7 and G 20), international organisations such as OECD, administrations of regions and individual countries are increasingly taking care about the serious issue of littered plastic waste and microparticles in the environment. In addition, numerous research activities have also been initiated. All these key stakeholders will highly benefit from a globally harmonized procedure.

This document includes references to studies and investigations in relation with plastics in the environmental matrix and biota, including microplastics. Important is the chapter terms and definitions. It presents the basis for future work in ISO. The description of the size classes is particularly relevant. Reference is made to other classifications of other organizations, for example in the area of Nanoparticles (see also OECD). The references selected within this document reflect the current knowledge without claiming to be complete or fully up-to-date. The content and conclusions of the different studies referenced in the bibliography are under the responsibility of their authors.

NOTE The document was developed under the scope of ISO/TC 61 *Plastics* and follows resulting requirements. Independent from these, terms are used in the text, which are in the scope of other ISO/TCs, such as:

— ISO/TC 38, *Textiles;*

— ISO/TC 45, *Rubber and rubber products;*

— ISO/TC 217, *Cosmetics*

Plastics — Environmental aspects — State of knowledge and methodologies

1 Scope

This document summarizes current scientific literature on the occurrence of macroplastics and microplastics, in the environment and biota. It gives an overview of testing methods, including sampling from various environmental matrix, sample preparation and analysis. Further, chemical and physical testing methods for the identification and quantification of plastics are described.

This document gives recommendations for three steps necessary for the standardization of methods towards harmonized procedures for sampling, sample preparation and analysis.

This document does not apply indoor and health related aspects.

NOTE The collection of plastics or microplastics in the environment by citizen social monitoring projects is not in the scope of this document. Although such projects can help sensitize the society to environmental problems and can even reduce the entry and presence of plastics in the environment, this monitoring concept is not considered suitable for a robustly representative and scientific analysis of microplastics in the environment via standardization.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

— IEC Electropedia: available at http://www.electropedia.org/

3.1
polymer
chemical compound or mixture of compounds consisting of repeating structural units created through polymerization

Note 1 to entry: In practice above 10 000 Dalton.

Note 2 to entry: Polymers comprise both plastics and elastomers. The latter is excluded from the scope of ISO/TC 61.

3.2
plastic
material which contains as an essential ingredient a high *polymer* (3.1) and which, at some stage in its processing into finished products, can be shaped by flow

Note 1 to entry: Plastics consists mainly polymers and minor contents of *additives* (3.7).

Note 2 to entry: Supplementary to the term “plastic”, “plastic product” is also used. According to ISO 472, a plastic product represents “any material or combination of materials, semi-finished or finished product that is within the scope of ISO/TC 61, Plastics”.

Note 3 to entry: Plastics comprise both *thermoplastic* (3.3) and *thermoset* (3.4) materials.

[SOURCE: ISO 472:2013, 2.702, modified — Notes to entry have been replaced.]

3.3
thermoplastic
plastic (3.1) that has thermoplastic properties

[SOURCE: ISO 472:2013, 2.1178]

3.4
thermoset
plastic (3.1) which, when cured by heat or other means, changes into a substantially infusible and insoluble product

[SOURCE: ISO 472:2013, 2.1181]

3.5
elastomer
macromolecular material which returns rapidly to its initial dimensions and shape after substantial deformation by a weak stress and release of the stress

Note 1 to entry: The definition applies under room temperature test conditions.

[SOURCE: ISO 472:2013, 2.327]

3.6
composite
solid product consisting of two or more layers (often in a symmetrical assembly) of, for instance, plastic film or sheet, normal or syntactic cellular plastic, metal, wood or a composite with or without adhesive interlayers

[SOURCE: ISO 472:2013, 2.182.2, modified — The example has been omitted.]

3.7
additives
chemicals added to *polymers* (3.1) to improve/change the individual properties of the specific plastic material

Note 1 to entry: Important additives such as fillers/reinforced materials, softeners and flame retardants are referenced according to ISO 1043-2 to ISO 1043-4.

3.8
macroplastic
any solid plastic particle or object insoluble in water with any dimension above 5 mm

Note 1 to entry: Typically, a macroplastic object represents an article consisting of plastic or a part of an end-user product or a fragment of the respective article, such as cups, cup covers.

Note 2 to entry: The defined dimension is related to the longest distance of the particle.

3.9
microplastic
any solid plastic particle insoluble in water with any dimension between 1 µm and 1 000 µm (=1 mm)

Note 1 to entry: This term relates to plastic materials within the scope of ISO/TC 61. Rubber, fibres, cosmetic means, etc. are not within the scope.

Note 2 to entry: Typically, a microplastic object represents a particle intentionally added to end-user products, such as cosmetic means, coatings, paints, etc. A microplastic object can also result as a fragment of the respective article.

Note 3 to entry: Microplastics may show various shapes.

Note 4 to entry: The defined dimension is related to the longest distance of the particle.

3.10
large microplastic
any solid plastic particle insoluble in water with any dimension between 1 mm and 5 mm

Note 1 to entry: *Microplastics* (3.9) may show various shapes.

Note 2 to entry: Typically, a large microplastic object represents an article consisting of plastic or a part of an end-user product or a fragment of the respective article.

Note 3 to entry: Microplastics in this size range are, for example, plastic pellets as intermediates for further down-stream processing such as moulding, extrusion, etc. resulting to semi-finished products which are not final end-user products.

3.11
microparticle
solid particle insoluble in water in the dimension between 1 µm and 1 000 µm (=1 mm)

Note 1 to entry: There is currently no specific distinction between nanoparticles and microparticles.

3.12
macroparticle
solid particle not soluble in water in the dimension above 5 mm

3.13
nanoplastic
plastic particles smaller than 1 µm

Note 1 to entry: According to OECD nanoparticles are up to 100 nm.

3.14
litter
solid object disposed of or abandoned in the *environment* (3.17)

3.15
marine litter
litter (3.14) found in the marine or coastal *environment* (3.17)

3.16
waste
any material or object which the holder discards, or intends to discard, or is required to discard

[SOURCE: ISO 15270, 3.34]

3.17
environment
conditions and surroundings that might influence the behaviour of an item or biotic life

Note 1 to entry: Environmental matrices are: water, air and soil.

Note 2 to entry: The relation to the environment within this document does not refer to environmental aspects such as resource efficiency, energy consumption, climate protection, etc. rather this document focuses on the relevance with respect to potential releases into the environment on land or sea.

[SOURCE: ISO 472:2013, 2.1310, modified — The definition has been edited to specify biotic life and Notes to entry have been added.]

3.18
ageing
entirety of all irreversible chemical and physical processes occurring in a material in the course of time

Note 1 to entry: For testing purposes, ageing is often applied artificially.

3.19
biota
living organisms in the *environment* (3.17)

4 End-use applications of plastic materials and its relevance to the environment

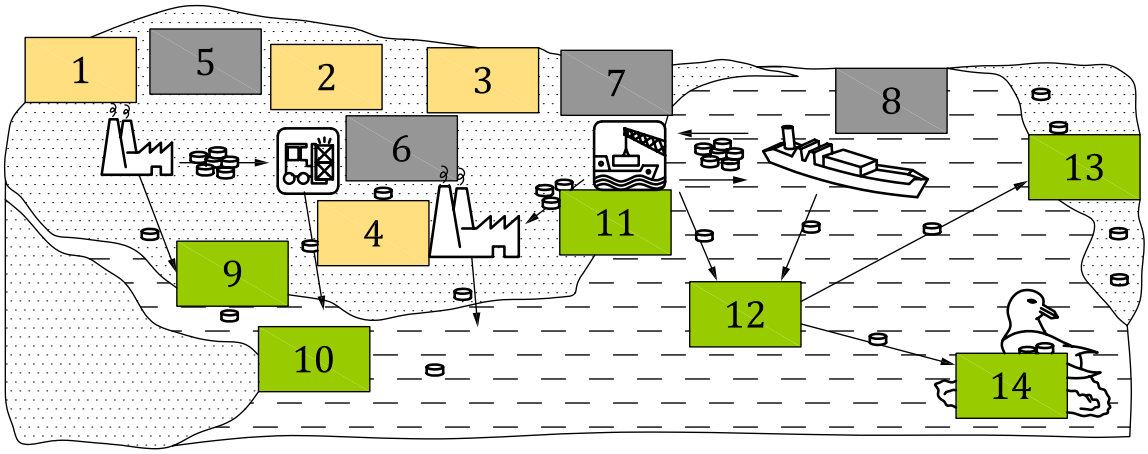
4.1 General

Plastics are important materials in today's modern life and play an integral role in both households and industries. Over recent years, the consumption of plastic materials has significantly increased and today they find diverse fields of areas of application such as packaging, building and construction, automotive, electrical and electronic equipment, etc. Depending on the performance requirements of the final end application, an article can contain plastics and/or composites.

The production of plastic materials is strictly regulated by legislative rules that translate into permit requirements for materials production by the chemical and plastics industry according to the Industry Emission Directive in Europe. In this way, emissions into air, water and soil can be well managed by applying the best available technologies for polymer production according to legislative rules and technical guidance.

The plastics value chain can be described as follows. Plastic materials are mostly manufactured from fossil raw materials like oil or gas and are mainly produced in the form of powders, flakes and pellets (a preformed moulding material). This material may further be compounded before its use in moulding and extrusion processes for its subsequent conversion into intermediate semi-finished products like sheets, profiles, films, etc. These will be shaped into a variety of final articles in the household, buildings, mobility sectors, etc. For the market relevant plastic materials used by the diverse application sectors, see 4.2 to 4.5, the term "plastics" comprises thermoplastic materials and thermosets.

Figure 1 shows how in the industrial value chain the various steps of production, logistics and distributions as well as entry pathways of plastics are distinguished.



Key

Yellow boxes:	steps of the value chain
Grey boxes:	logistics, distribution, trade, transfer
Green boxes:	entry pathways
1	raw material producer
2	compounder/converter
3	OEM
4	supplier/tier
5	logistics on land
6	distribution/trade
7	transfer/shipment
8	logistics on sea
9	drain from municipality
10	river
11	port
12	ocean
13	beach/coast
14	biota

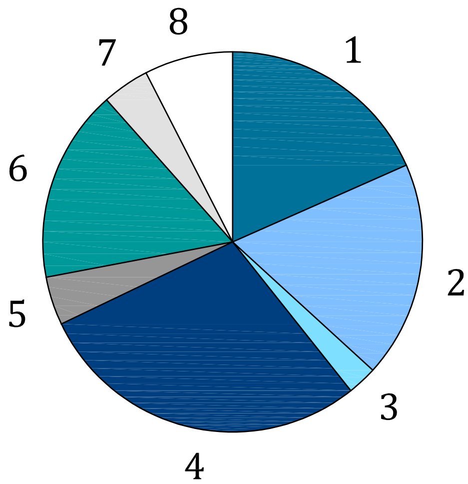
NOTE This figure is based on a graph of International Pellet Watch: www.tuat.ac.jp/-gaia/ipw/en/what.html

Figure 1 — Schematic illustration of the plastics value chain in the context within the environment after a graph of international pellet watch

NOTE Figure 1 represents a highly simplified illustration of the industrial value chain, the logistics and distribution as well as possible entry pathways into the environment. The reality is much more complex, thereby, with further interim steps, interlinkages, dependences or possible further aspects.

Both legislation as well as standardization, especially quality and environmental management like ISO 9000 group of standards and ISO 14000 group of standards, are in place and may be in principle considered as appropriate means to minimize eventual losses for each production step as well as logistics and distribution.

According to the European Market and Research Group of the European plastics manufacturers[2], the total global production of plastic materials amounted to approx. 280 Mio tons in 2016 without other plastics i.e. thermosets, elastomers, adhesives, coatings, sealants and fibres. Asia accounts for about 50 % of the world-wide production with China leading with 29 % of global production. European production is less with 19 % and similar to NAFTA states (Canada, Mexico and the US) who have a share of 18 %. It is assumed that the strong growth in Asia will also continue over the next years reinforcing their leading role in worldwide plastics production.



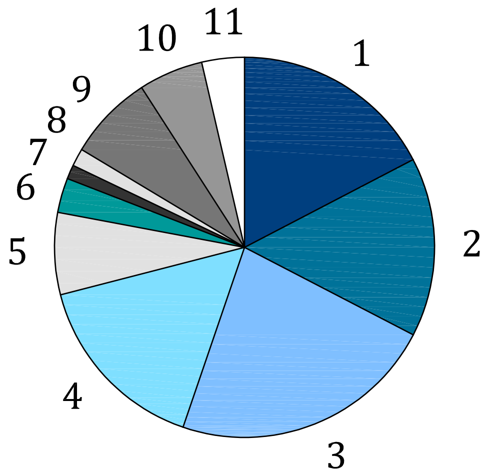
Key

1 NAFTA 18 %
2 Europe (WE +CEE) 19 %
3 CIS 2 %
4 China 29 %
5 Japan 4 %
6 Rest of Asia 17 %
7 Latin America 4 %
8 Middle East, Africa 7 %

NOTE Graph according to Plastics Europe[2].

Figure 2 — World Plastics Material Production in 2016 by country/region

Globally, the most important types of plastic materials are standard plastics. More than three quarters of the global plastics production consist of polyethylene, polypropylene, polyvinylchloride and polystyrene including expanded polystyrene, see Figure 3. Less than 10 % are considered as engineering plastics.



Key

1 LDPE, LLDPE, 17 %
2 HDPE 15 %
3 PP 23 %
4 PVC 16 %
5 PS, EPS 7 %
6 ABS, ASA, SAN 3 %
7 PA 1 %
8 PC 1 %
9 PET 7 %
10 PUR 6 %
11 other thermopl. 4 %

NOTE Graph according to Plastics Europe[2].

Figure 3 — World Plastics Material Production in 2016 by type of polymer

When an article that contains plastic materials is placed on the market, it is used by a variety of end-users such as the industrial/commercial sector as well as the private and household sector. Finally, after an article has fulfilled its valuable intended purpose to the end-user, it comes to its end-of-life stage and, thus, it becomes waste. It is important at this stage that such a discarded product should enter a well-managed waste collection system, operated by either municipalities or by privately organized enterprises for the further waste treatment, so that the embedded material or energy resources will be recovered effectively and efficiently.

However, such effective waste management schemes are not available in all countries of the world which may result in significant amounts of wasted products, including those made of plastics, being improperly treated or thoughtlessly discarded into the environment, on land or at sea. Leakage of plastics into the environment is caused mainly through uncontrolled or improper handling of goods and waste and it is important that measures are taken to prevent this.

The subsequent Clause 5 gives an overview of reports and studies on the occurrence of plastics and plastics containing waste in the environment. Nevertheless, no validated data exist until today in order to accurately report the amount of waste entering the environment. Also, the mechanism on the sources and sinks are not yet sufficiently analysed and understood. Therefore, internationally standardised procedures are a prerequisite in order to set-up facts and derive appropriate measures.

Though environmental, product and waste management legislation (including logistics, shipment and treatment of waste, waste water and sewage), is well-established in several countries, the release of plastic products and other waste materials into the environment by littering through improper management is expected to increase in countries with little or no waste and service infrastructure. A