TECHNICAL REPORT

ISO/TR 23891

First edition

Plastics — Recycling and recovery — Necessity of standards

Plastiques — Recyclage et valorisation — Nécessité des normes

PROOF/ÉPREUVE

Reference number
ISO/TR 23891:2020(E)

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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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.

Introduction

Facing resource consumption beyond the capacity of the global ecosystem, the complex challenges connected to the plastics recycling must be overcome globally. It is more efficient that processes and a better management of waste indicate the most obvious potential to increase resource efficiency. This management can be achieved by reducing waste or by reusing, or recycling of the waste. Plastics waste entering a formal waste management system, are usually recycled, incinerated or disposed of in landfill. However, in communities where a formal waste management system does not exist, a substantial proportion of plastics waste is disposed of in uncontrolled dumps, watercourses, or burned openly (UNEP, 2016). Different kinds of plastics included in plastic waste, must be reused, collected and recycled to a much higher degree than today. Therefore, an agreement for this work and identification of the necessity of standards in the plastics recycling system and giving direction for the adoption of regional standards and/or the developing of new and existing standards took place at ISO/TC 61 Plastics-meeting in Japan 2018 and gave the reason for the work on this document.

This document has been developed to assist all plastics industry stakeholders in the development of new and improved standards for plastic recycling.

It gives a short general introduction to plastic recycling and describes the process from feedstock to plastics, the different types of recycling technologies and highlights common problems in relation to recycling of plastic materials and products. Both fossil and non-fossil feedstock are discussed.

In Clause 6, existing standards are mapped. In Clause 8, challenges in the transition to a sustainable plastic system are discussed. The necessity of standards is identified in Clause 9.

The overall structure of this document is as follows:

— brief overview of the current situation;

— general description of recycling techniques;

— inventory of existing standards (national, regional and global);

— mapping of relevant challenges;

— necessity of standards.

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Plastics — Recycling and recovery — Necessity of standards

1 Scope

This document gives a brief overview of the current (2019) situation in plastic recycling systems, relevant existing standards and short description of different recycling techniques. It aims to identify the necessity of standards in the plastics recycling system and give direction for the adoption of regional standards and/or the development of new and existing standards.

This document addresses various recycling options, with focus on, but not limited to, mechanical recycling, chemical and/or feedstock recycling and the corresponding preparatory activities.

This document excludes organic recycling (also designated as biological recycling) and energy recovery.

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 472, *Plastics — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 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/

4 Overview prerecycling plastic technologies

4.1 General considerations related to recycling

4.1.1 Process into the polymer resins

Polymer resins in a bulk state which go through a thermal or chemical process (whether it is the moulding of thermosetting plastics, extrusion, injection moulding or film blowing of thermoplastics or spinning of a fibre from the melt) undergo deformation by applied forces. It means that the finished article is subjected to stress. Since plastics are a large group of similarly based but significantly different materials, the process has various effects on their short- and long -term behaviours. These effects should be considered during design and recycling of a plastic component or product before and after each lifecycle.

4.1.2 Design for sustainability

Design for sustainability includes selecting a proper material composition for a particular application. It is essential to define the properties not only to the performance of the component or product during usage phase, but also to its recycling and the next lifecycle. Design of a particular application should also cover recycling process. Plastics and products containing plastics should be designed for reuse, durability beyond their usage period, and recyclability. Design for an application should consider the whole life cycle including end-of-life with dismantling, chemical composition of plastics and their suitability to be reused in order to minimize barriers in recycling and for the next lifecycle.

4.1.3 Additives

Additives are essential ingredients in plastics which can make a difference between the success and failure for all plastics value chain and, of course, on the recycling's part. Additives can help or destroy the recycling of plastics depending on synergic or antagonistic effects. A general concern with additives is the lack of transparency and information about what additives are being used in different materials. This may reduce the appeal of recycled plastics use in products. Added to the issues of the additives, there is local legislation limiting the plastic recycling and in some cases with amendment to legislation.

Table 1 shows the proportion of additives by type used in global plastics resin (non-fibre) waste based on estimated additives used between 2000 and 2014 (See Reference [1]).

Table 1 — Proportion of additives by type used in global plastics resin (non-fibre) waste based on estimated additives used between 2000 and 2014, and waste in 2015

Additive type	**Proportion of additives in global plastics production 2000–2014** (%)	**Mass of additives that became waste in 2015** (tonnes)
Plasticisers	34	7,2
Fillers	28	5,9
Flame retardants	13	2,7
Antioxidants	6	1,3
Heat Stabilizers	5	1,1
Impact modifiers	5	1,1
Other	4	0,8
Colourants	2	0,4
Lubricants	2	0,4
Light stabilizer	1	0,2
Totals	**100**	**21,1**

Some common additives are presented in Annex A, Table A.1.

4.2 Plastics processing and conversion

4.2.1 Blow moulding

Blow moulding is used when the plastic item to be created needs to be hollow. A molten tube is created with blow moulding by using compressed air, which blows up the tube and forces it to conform to the chilled mould. Variations of blow moulding include injection, injection-stretch, and extrusion blow moulding.

Injection blow moulding uses a preform, which is taken to a blow mould, heated and filled with compressed air. As a result, it conforms to the interior design of the blow mould. With injection-stretch blow moulding, the plastic is stretched prior to being formed. Otherwise, it is essentially the same as the injection process.

With continuous extrusion, a molten plastic tube is continuously created. At the appropriate times, the tube is pinched between two mould halves. Then, a needle or a blow pin is inserted into the tube and blows compressed air up the part to force it to conform to the mould interior. With accumulator extrusion, the molten plastic material is gathered in the chamber before it is forced through a die to form a tube.

4.2.2 Compression moulding

Compression moulding is the most common process used with thermosetting materials and is usually not used for thermoplastics. With this process, the material is squeezed into its desired shape with the help of pressure and heat. Plastic moulding powder and other materials are added to the mix in order to create special qualities or to strengthen the final product. When the mould is closed and heated, the material goes through a chemical change that causes it to harden into its desired shape. The temperature, amount of pressure, and length of time utilized during the process depends on the desired outcome.

4.2.3 Extrusion

The process of extrusion is usually used to make products such as film, continuous sheeting, tubes, profile shapes, rods, coat wire, filaments, cords, cables, flat tapes, yarn, monofilament and multifilament, etc. In general, any extrusion machinery consists of mainline equipment (rotating screw of specific design and configuration fitted inside a cylindrical barrel, attached with die specific to the product being extruded) and downstream equipment as required for the type and specification of end product. As with injection moulding, dry plastic material is placed into a hopper and fed into a long heating chamber. At the end of the chamber, however, the material is forced out of a small opening or a die in the shape of the desired finished product. As the plastic exits the die, it is placed on a conveyor belt where it is allowed to cool. Blowers are sometimes used to aid in this process, or the product may be immersed in water to help it cool.

4.2.4 Injection moulding

The main method used for processing plastic is injection moulding. With this process, the thermoplastic is placed into a hopper. The hopper then feeds the plastic into a heated injection unit, where it is pushed through a long chamber with a reciprocating screw. Here, it is softened and melted to a fluid state.

A nozzle is located at the end of the chamber. The fluid plastic is forced through the nozzle into a cold, closed mould. The halves of the mould are held shut with a system of clamps. When the plastic is cooled, they harden/polymerize to an infusible state, the halves open, and the finished product is ejected from the press.

In the case of thermosets, the feeding unit is cooled and the mould is heated to achieve the requested crosslinking.

Thermosetting materials usually are not processed with injection moulding because before they will soften, they harden to an infusible state. If they are processed with injection moulding, they need to be moved through the heating chamber quickly, so they do not set.

4.2.5 Reaction injection moulding (RIM)

Reaction injection moulding, or RIM, is one of the newer processes used in the plastics industry. It differs from liquid casting in that the liquid components are mixed together in a chamber at a lower temperature of only about room temperature to 60 °C before it is injected into a closed mould. Here, an exothermic reaction occurs. As a result, RIM requires less energy than other injection moulding systems. Reinforced RIM, or R-RIM, involves adding materials such as milled or chopped glass fibre in the mixture in order to increase the stiffness.

4.2.6 Thermoforming

Thermoforming uses a plastic sheet, which is formed with the mould by applying heat and then air or through mechanical assistance. By evacuating air in the space between the mould and the sheet the method is called vacuum forming.

4.2.7 Transfer moulding

Transfer moulding is generally used only for forming thermosetting plastics. It is similar to compression moulding because the plastic is cured into an infusible state through pressure and heat. Unlike compression moulding, however, transfer moulding involves heating the plastic to a point of plasticity prior to being placed into the mould. The mould is then forced closed with a hydraulically operated plunger.

Transfer moulding was initially developed as a method for moulding intricate products, such as those with many metal inserts or with small, deep holes. This is because compression moulding sometimes disturbed the position of the metal inserts and the holes of these types of products. With transfer moulding, on the other hand, the liquefied plastic easily flows around the metal parts without causing them to change position.

5 Brief overview of plastic waste management

5.1 Waste management

The solid waste management is a global issue affecting our environment and living organisms. The global picture of solid waste management is very different in different parts of the world. It depends on many factors and trends and behaviours, predominantly on the economic welfare of those responsible to establish and organize a solid waste management system locally, but also on consumption, waste generation, composition, collection and handling, and has direct effect on recycling and recovery of plastic waste. Every decision from individuals and government about consumption and waste management affects the daily life and cleanliness of communities. Reference [2] shows that, as countries develop from low-income to middle-and high -income levels, their waste management situations also evolve. Urban waste management costs more for local administration budget in low-income countries (20 %) compare to middle-income (10 %) and high-income countries (4 %). At the same time, funding is more difficult for low-income countries when they have to compete for funding with other priorities such as clean water, health care and education.

This document is a product of studying different aspects from waste management, generation, composition, collection, treatment, and disposal to include information on financing and costs, institutional arrangements and policies, administrative and operational models, citizen engagement, special waste and informal sector. It included 217 countries and 367 cities. The cities that participated in the survey are listed in Annex B (see Table B.1). The countries are divided in 7 regions East Asia and Pacific, Europa and Central Asia, Latin America and the Caribbean, the Middle East and North Africa, South Asia, Sub-Saharan Africa and North America. Based on the volume of waste generated, its composition and how it is managed, it is estimated that 1,6 billion tonnes of carbon dioxide equivalent GHG were generated from solid waste treatment and disposal 2016 which is about 5 % of the global emissions (see Reference [3]). Plastic waste is 12 % of global waste composition. Waste composition various by income level and percentage of organic matter in waste decreases as income level rises as shown in Table 2.

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Table 2 — Plastic waste percentage varies depending on countries income

Income level	Food and green (%)	Glass (%)	Metal (%)	Paper and cardboard (%)	Plastic (%)	Wood (%)	Rubber and leather (%)	Other (%)
Low income	56	1	2	7	6,4	< 1	< 1	27
Lower-middle income	53	3	2	12,5	11	< 1	< 1	17
Upper-middle income	54	4	2	12	11	1	< 1	15
High income	32	5	6	25	13	4	4	11
Source: Geyer, Jambeck and Law[1]								

There are differences in composition of waste and changes in this composition with time for countries with different in-come, e.g. the share of organic waste which reflects changes in consumption depending on enhancement of in-come for the countries. Tables 3, 4 and 5 show the waste generation, plastics waste generation, and treatment of solid waste by region.

Table 3 — Share of waste generation by region

Region	Middle East and North Africa	Sub-Saharan Africa	Latin America and the Caribbean	North America	South Asia	Europe and Central Asia	East Asia and Pacific
Percentage of waste generated [%]	6	9	11	14	17	20	23
Source: Geyer, Jambeck and Law[1]							

Table 4 — Share of plastic waste generation by region

Region	Middle East and North Africa	Sub-Saharan Africa	Latin America and the Caribbean	North America	South Asia	Europe and Central Asia	East Asia and Pacific
Percentage of plastics waste [%]	12	8,6	12	12	8	11,5	12
Source: Geyer, Jambeck and Law[1]							

