TECHNICAL REPORT

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Plastics — Recycling and recovery — Necessity of standards

Plastiques — Recyclage et valorisation — Nécessité des normes

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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.

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.

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]							

Table 5 — Percentage of waste disposal and treatment by region

Region/ Treatment [%]	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
Recycling	9	6,6	4,5	33,3	5	20	9
Incineration	< 1	< 1	< 1	12	< 1	17,8	24
Landfill (controlled and unspecified)	23	24	43,3	54	4	21,4	49
Open dump	52,7	69	26,8	< 1	75	25,6	18
Other	14,3	< 1	24,4	< 1	15	15,2	< 1
Source: Geyer, Jambeck and Law[1]							

The participating cities from each region are presented in Table B.1.

5.2 Overview of the supply chain uptaking recycled plastics

The process by which waste plastics move from the place at which they are generated to the point at which they become a recycled material is complex. Heterogeneous, dispersed waste generation and infrastructure contribute to this complexity which, for plastics, is also compounded by the large range of polymers involved and mixed with a variety of end-user wastes when end products are collected when becoming waste.

Many actors are involved, ranging from informal waste collectors that collect recyclables to earn income, to governmental and municipal organisations that typically have a statutory duty to manage waste on behalf of their citizens (OECD[3]). The private sector also plays a key role in waste management, providing services to businesses and citizens to treat and dispose of waste materials. In many countries, businesses operate via government funded contracts, but also often through independent entrepreneurship. Community-based organisations and non-governmental organisations are also commonly involved in plastics recycling in many contexts (GIZ[4]).

6 Inventory of existing standards (national, regional and global)

6.1 General

Existing standards on international, European and national levels can be found in Tables 6 to 12.

6.2 ISO/TC 61, *Plastics*, SC 14, *Environmental aspects*

Table 6 — Existing standards under ISO/TC 61, SC 14

Number	Name
ISO 15270	Plastics — Guidelines for the recovery and recycling of plastics waste
ISO 17088	Specifications for compostable plastics

6.3 CEN/TC 249, *Plastics*

Table 7 — Existing standards under CEN/TC 249

Number	Name
EN 15342	Plastics — Recycled Plastics — Characterization of polystyrene (PS) recyclates
EN 15343	Plastics — Recycled Plastics — Plastics recycling traceability and assessment of conformity and recycled content
EN 15344	Plastics — Recycled Plastics — Characterization of Polyethylene (PE) recyclates
EN 15345	Plastics — Recycled Plastics — Characterization of Polypropylene (PP) recyclates
EN 15346	Plastics — Recycled plastics — Characterization of poly(vinyl chloride) (PVC) Recyclates
EN 15247	Plastics — Recycled Plastics — Characterization of plastics wastes
CEN/TR 15353	Plastics — Recycled plastics — Guidelines for the development of standards for recycled plastics
CEN/TS 16010	Plastics — Recycled plastics — Sampling procedures for testing plastics waste and recyclates
CEN/TS 16011	Plastics — Recycled plastics — Sample preparation
CEN/TS 16398	Plastics — Template for reporting and communication of bio-based carbon content and recovery options of biopolymers and bioplastics — Data sheet
EN 14995	Plastics — Evaluation of compostability — Test scheme and specifications

6.4 ISO/TC 122/SC 3, *Performance requirements and tests for means of packaging, packages and unit loads*, ISO/TC 122/SC 4, *Packaging and environment* and CEN/TC 261/SC 4, *Packaging and the environment*

Table 8 — Existing standards under CEN/TC 122/SC 3, CEN/TC 122/SC 4 and CEN/TC 261/SC 4

Number	Name
ISO/TR 16218	Packaging and the environment — Processes for chemical recovery
ISO/TR 17098	Packaging material recycling — Report on substances and materials which may impede recycling
ISO 18604	Packaging and the environment — Material recycling
ISO 18605	Packaging and the environment — Energy recovery
ISO 18606	Packaging and the environment — Organic recycling
EN 13440	Packaging — Rate of recycling — Definition and method of calculation
EN 13437	Packaging and material recycling — Criteria for recycling methods — Description of recycling processes and flow chart
CEN/TR 13688	Packaging — Material recycling — Report on requirements for substances and materials to prevent a sustained impediment to recycling
EN 13430	Packaging — Requirements for packaging recoverable by material recycling
EN 13431	Packaging — Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value
EN 13432	Packaging — Requirements for packaging recoverable through composting and biodegradation — Test scheme and evaluation criteria for the final acceptance of packaging
ISO 12418-1 (JIS K7390-1)	Plastics — Post-consumer poly(ethylene terephthalate) (PET) bottle recyclates — Part 1: Designation system and basis for specifications

Table 8 *(continued)*

Number	Name
ISO 12418-1 (JIS K7390-2)	Plastics — Post-consumer poly(ethylene terephthalate) (PET) bottle recyclates — Part 2: Preparation of test specimens and determination of properties
ISO 18263-1 (JIS K7393-1)	Plastics — Mixtures of polypropylene (PP) and polyethylene (PE) recyclate derived from PP and PE used for flexible and rigid consumer packaging — Part 1: Designation system and basis for specification
ISO 18263-2 (JIS K7393-2)	Plastics — Mixtures of polypropylene (PP) and polyethylene (PE) recyclate derived from PP and PE used for flexible and rigid consumer packaging — Part 2: Preparation of test specimens and determination of properties
ISO 13636 (JIS Z1716)	Plastics — Film and sheeting — Non-oriented poly(ethylene terephthalate) (PET) sheets
ISO 18601 (JIS Z 0130-1)	Packaging and the environment — General requirements for the use of ISO standards in the field of packaging and the environment
ISO 18602 (JIS Z 0130-2)	Packaging and the environment — Optimization of the packaging system
ISO 18603 (JIS Z 0130-3)	Packaging and the environment — Reuse
ISO 18604 (JIS Z 0130-4)	Packaging and the environment — Material recycling
ISO 18605 (JIS Z 0130-5)	Packaging and the environment — Energy recovery
ISO 18606 (JIS Z 0130-6)	Packaging and the environment — Organic recycling

6.5 ASTM Subcommittee D20.95 on Recycled Plastics (USA)

Table 9 — Existing standards under ASTM Subcommittee D20.95

Number	Name
ASTM D7209	Standard Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products *(withdrawn 2015)*
ASTM D5491	Standard Classification for Recycled Post-Consumer Polyethylene Film Sources for Molding and Extrusion Materials
ASTM D6288-17	Standard Practice for Separation and Washing of Recycled Plastics Prior to Testing
ASTM D5577-19	Standard Guide for Techniques to Separate and Identify Contaminants in Recycled Plastics
ASTM D5814-18	Standard Practice for Determination of Contamination in Recycled Poly(Ethylene Terephthalate) (PET) Flakes and Chips Using a Plaque Test
ASTM D5991-17	Standard Practice for Separation and Identification of Poly(Vinyl Chloride) (PVC) Contamination in Poly(Ethylene Terephthalate) (PET) Flake
ASTM D6265-17	Standard Practice for Separation of Contaminants in Polymers Using an Extruder Filter Test
ASTM D7611/ D7611M-19	Standard Practice for Coding Plastic Manufactured Articles for Resin Identification

6.6 UNI (Italy)

Table 10 — Existing Italian standards

Number	Name
UNI 10667-1:2017	Plastic raw-secondary materials — Part 1: Generality on plastic raw-secondary materials and plastics by-product
UNI 10667-2:2010	Plastic raw-secondary materials — Polyethylene for general purposes from the recycling of industrial residues and/or from pre and/or post consumer materials. Part 2: Requirements and test methods.
UNI 10667-3:2011	Plastic raw-secondary materials– Polypropylene for general purposes from the recycling of industrial residues and/or from pre and/or post consumer materi-als — Part 3: Requirements and test methods
UNI 10667-4:2011	Plastic raw-secondary materials — Polyvinylchloride for general purposes, from the recycling of pre and/or post consumer liquid containers — Part 4: Requirements and test methods.
UNI 10667-5:2012	Plastic raw-secondary materials — Plasticized Polyvinylchloride for general purpose, from the recycling of industrial residues and/or from pre and/or post consumer materials — Part 5: Requirements and test methods.
UNI 10667-6:2011	Plastic raw-secondary materials — Poly(vinylchloride) from unplasticized rigid not plasticized items to be used for general purposes — Part 6: Requirements and tests methods.
UNI 10667-7:2011	Plastic raw-secondary materials — Polyethylenterephtalate flakes for the production of fibres, from the recycling of post consumer liquid containers — Part 7: Requirements and test methods.
UNI 10667-8:2011	Recycled plastics materials — Polyethylenterephtalate flakes for blow moulding, from the recycling of post- consumer liquid containers — Part 8: Requirements and test methods.
UNI 10667-9:2011	Plastic raw-secondary materials — Polyethylenterephtalate flakes for the production of sheets and sheetings, from the recycling of post-consumer liquid containers — Part 9: Requirements and test methods
UNI 10667-10:2011	Plastic raw-secondary materials — Polystyrene for general purposes, from the recycling of industrial residues and/or from pre and/or post-consumer materials — Part 10: Requirements and test methods.
UNI 10667-11:2009	Recycled plastic materials — Polyethylene and ethylene copolymers from agricultural and horticultural films to be used for different purposes — Part 11: Requirements and test methods.
UNI 10667-12:2006	Recycled plastic materials — Expanded polystyrene from industrial residues and/or from post-consumer to be used for general purposes — Part 12: Requirements and test methods.
UNI 10667-13:2013	Plastic raw-secondary materials — Fillers obtained from grinding of production and/or post- consumer waste of reinforced plastics composites — Part 13: Requirements and test methods.
UNI 10667-14:2016	Recycled plastic materials — Part 14: Mixtures of polymeric recycling materials and of others materials based on cellulose to be used as aggregate into mortar of cement, bitumen and asphalt — Requirements and test methods.
UNI 10667-15:2008	Recycled plastic materials — Polyethylenterephtalate from post consumer, industrial scraps and residues from mechanical recycling to be used for chemical recycling and depolymerization — Part 15: Requirements and test methods.
UNI 10667-16:2015	Plastic raw-secondary materials — Blends of heterogeneous plastics based on polyolefins from industrial residue and/or from post consumer materials to be used for different processing technologies — Part 16: Requirements and test methods

Table 10 *(continued)*

Number	Name
UNI 10667-17:2018	Plastic raw-secondary materials — Part 17: Blends of heterogeneous plastics based on polymers from industrial residue and/or from post consumer materials to be used for reducing processes in iron and steel industries — Requirements and test methods
UNI 10667-18:2011	Plastic raw-secondary materials — Blends of heterogeneous plastics based polyolefins from industrial residue and/ or from post consumer materials to be used for conversion into liquid and/or gas fuel — Part 18: Requirements and test methods.
UNI/TR 11524:2014	Guidelines for the safety assessment of a mechanical recycling process for the production of polyethylenterephthalate (PET) recycled suitable for the use of the production of materials and items intended for contact with food, by "challenge test".
UNI 11038-1:2010	Plastics packaging from post-consumer selected as homogeneous fractions — Assessment of conformity of the batch to the specification of homogeneity — Part 1: Polyethylenterephtalate (PET) liquid container.
UNI 11038-2:2010	Plastics packaging from post-consumer selected as homogeneous fractions — Assessment of conformity of the batch to the specification of homogeneity — Part 2: Polyethylene (PE) liquid container.
UNI 11038-3:2010	Plastics packaging from post-consumer selected as homogeneous fractions — Assessment of conformity of the batch to the specification of homogeneity — Part 3: polyethylene (PE) films and sheeting.
UNI 10853-1:2000	Recycled plastic materials from recovery of durable goods to end of life — General.
UNI 10853-2:2000	Recycled plastic materials from recovery of durable goods to end of life — Polypropylene — Requirements and test methods.
UNI 10853-3:2006	Recycled plastic materials from recovery of durable goods to end of life — Part 3: Polystyrene — Requirements and test methods.
UNI 10853-4:2006	Recycled plastic materials from recovery of durable goods to end of life — Part 4: Acrylonitrile/Butadiene/ Styrene (ABS) — Requirements and test methods

6.7 BIS (India)

Table 11 — Existing Indian standards

Number	Name
BIS 14534:2016	Plastics — Guidelines for the Recovery and Recycling of Plastics

6.8 JISC (Japan)

Table 12 — Existing Japanese standards

Number	Name
JIS C 9911:2014	Calculation and display methods of recycled and reuse indicator of electric and electronic equipment
JIS K 2170:2013	Reclaimed oil
JIS K 6313:1999	Reclaimed rubbers
JIS K 6329:1997	Retreated tires
JIS K 9797:2006	Unplasticized poly (vinyl chloride) (PVC-U) three layer pipes with recycled solid core
JIS K 9798:2006	Unplasticized poly (vinyl chloride) (PVC-U) three layer pipes with recycled foamed core
JIS Z 0609:2017	Plastic flat pallets using recycled containers and packing

Table 12 *(continued)*

Number	Name
JIS Z 7120:2003	Plastics-Guideline for application of Mobius loop to plastic products

7 General description of mechanical and chemical recycling techniques

7.1 Material recovery

It is possible to increase the volume of plastic waste suitable for material recovery and the quality of the recycling process by optimising existing collection and processing systems but there are limitations for all recycling systems and therefore a combination of mechanical and chemical recycling is necessary.

7.2 Mechanical recycling

7.2.1 General

Mechanical recycling is recycling by re-melting after sorting and cleaning, unless not collected separately. This technique is suitable for thermoplastics. Mechanical recycling is most profitable for thermoplastic materials because the most resources used for manufacturing of polymer resin, approximately 80 % of the energy required to produce 1 cm^3 polypropylene is expended on the polymerization and associated processes. The limitation of mechanical recycling for thermosetting plastics and plastic composite could be a good motivation for a complementary recycling such as chemical recycling.

7.2.2 Preparatory activities for mechanical recycling

Depending on the collection technique and type, the need of following preparation could vary which affects also the quality of recyclates.

— Collecting

— Sorting and separation

— Washing

— Sterilization

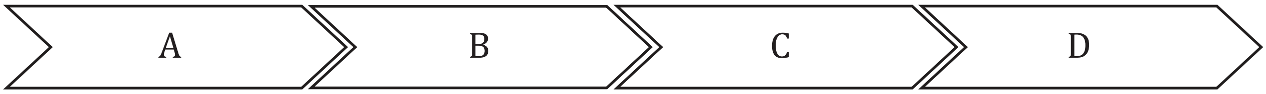
— Quality tests

— Compounding

— Granulation

7.2.3 Mechanical recycling process

In general, once collected, the post-consumer plastic waste aimed at mechanical recycling are delivered to a material recovery facility or handler for sorting into single waste streams in order to increase value. The sorted plastic waste is then baled and shipped to re-processors where the plastic waste is chopped into flakes and contaminants such as paper labels are removed (e.g. by cyclone separators) and/or the flakes are washed. Flakes may be further re-extruded into granules/pellets at the re-processor, or they can be sold as flakes to the end-users for the manufacture of new products. Some re-processors may already re-compound the recycled material with additives and/or more virgin raw material at the re-extruding phase. Figure 1 displays the stages of mechanical plastic recycling.



Key

A sorting
B shredding (flaking)
C washing and drying
D extrusion/agglomeration

Figure 1 — Mechanical plastic recycling stages

7.3 Chemical recycling feedstock recovery

Chemical recycling/feedstock recovery is a process which breaks down the polymers through cracking, gasification or depolymerization processes into their chemical constituents and converts them into products like basic chemicals, monomers or oligomers for new plastics. These are used as raw materials for production of new chemicals for plastics.

Chemical decomposition can also result in GHG emissions in regard to the need for energy to depolymerise/crack the polymers. As long as the use of renewable energy for recycling technologies are not available and the technologies have not reached a level of maturity energy recovery could be an option to substitute fossil fuel while avoiding disposal.

There is still no criterion or simple method to use for choosing a preferred recycling method (challenge) when a plastic material will go to the next life. Despite this, chemical recycling could be a good method in addition to the current mechanical recycling in some cases, such as plastic waste flows from discards of mechanical recycling, regarding difficulty to go through mechanical recycling depending on composition (multilayer or unsuitable components and additives) and mixed plastic flows. Chemical recycling can be performed by different processes depending on what end product considered from syngas to saturated fuel products and all in between. Table 6 shows a summary of different chemical recycling types.

Table 6 — Summary of chemical recycling types

Chemical processing type	Specific technology	Description of process	Technological readiness levels (TRL)
Thermolysis	Pyrolysis (thermal cracking)	Thermal degradation (400 °C to 800 °C) in the absence of oxygen (same process as charcoal making)/ inert atmosphere. Produces a carbonised char, syngas and liquid hydrocarbon oils.)	Collection and sorting technologies and plastic waste feedstock stream strongly influence pyrolysis process and therewith composition of the multicomponent product stream. Beside of some syngas producing pyrolysis plants and some Demoplants with a polyolefine feedstock pyrolysis current TRL of Pyrolysis: 3–6 with high innovation demand.

Table 6 *(continued)*

Chemical processing type	Specific technology	Description of process	Technological readiness levels (TRL)
	Gasification	Partial oxygenation at high temperatures. Dried, mechanically sorted plastics are granulated to optimum size particle and gasified in reaction chamber to produce high calorific value syngas (CO and H_2) and char (can either be combusted directly or used to synthesize products such as methanol or ammonia)	Current TRL: 4–7 Same challenge as Pyrolysis — Plastic waste stream influence process stability, yield and selectivity with high innovation demand.
	Liquid-gas hydrogenation	Addition of hydrogen via chemical reaction forming highly saturated fuel products.	Relies on supply of pure hydrogen and very high pressures; most processes thought to be at maximum TRL: 3–4. As long as hydrogen could not be produced with renewable energy not very sustainable in regard to LCA
Chemical depolymerisation	Methanolysis	Degradation of PET to dimethyl terephthalate.	High– downstream process effort, TRL: 4–6.
	Glycolysis	Uses ethylene glycol to produce bis (2-hydroxyethyl) terephthalate (in case of PET) and other PET glycolyzates; used for manufacture of copolyesters, hydrophobic dye stuffs, unsaturated resins, polyurethane foams, and acrylic coatings.	Simple process, TRL: 6–9.
	Hydrolysis	Heated with an excess of water at high temperatures.	TRL: 6–9, Products can be used to produce virgin PET, or may be converted to (expensive) chemicals like oxalic acid — slow and expensive.
	Ammonolysis	As hydrolysis with ammonia.	TRL: 3. Not commercially used.

8 Mapping of relevant challenges

8.1 General

This clause lists different challenges with plastics recycling relevant to standardization.

8.2 Lack of standards

8.2.1 Calculating recycling rate

There is no international harmonized method for calculation of recycling rates. In Europe, recycling rates are typically calculated as the proportion of materials recycled as a percentage of total waste generated. However, the method for doing so is not standardized in Europe yet; there are two broad concepts for calculation:

— weigh the material that leaves the sorting plant or enters the recycling plant;

— weigh the material that is successfully processed.

Each method will yield different results because not all the waste entering the system is recyclable. Non-recyclable residues can be a significant proportion of sorted materials in many cases. When the latter of the two methods is used, it is challenging to get accurate data for any material processed abroad, leading to an inflation of the amount of material recycled.

Further uncertainty arises because the waste hierarchy is not applied consistently across nations. This means that terms such as energy recovery and material recycling may be used interchangeably or are applied to different processes.

Other disparities result from the classification of waste from mining and agriculture which may be poorly regulated in some nations. EU members have underlying specific targets for packaging materials such as metals, plastics, paper, wood and glass. In contrast to the above method, progress to these targets is based on the proportion of material recycled as a percentage of total material placed on the market (POM).

8.2.2 Right choice of recycling method

There is a crucial need to have a list of criteria or a simple method to use for choosing a preferred recycling method when a plastic material will go to the next life.

8.2.3 Quality and properties of recyclates

There is a crucial need to have a doable and fast method for determination of the quality of the recyclate material from both mechanical and chemical recycling.

8.2.4 Renewable and recycled feedstock

During transition time from fossil to renewable sources, we should have a standard with an LCA based tool for determination of sustainability of using renewable feedstock and recycled for further life application.

8.2.5 Resource efficiency

Methodology to take into consideration both resource efficiency and recyclability performance

8.2.6 Traceability and marking in design stage

Traceability of plastic materials in the supply chain and throughout the recycling process remain an important task to fulfil safety and quality requirement on the end product level. A general concern with, for example, additives can be a lack of transparency and information about what additives are being used in different materials as well as a concentration of legacy material, such as in mechanical recycled end products.

This can reduce the appeal of recycled plastics use in products, especially those where they may be absorbed by humans such as baby products or food packaging. These uncertainties can discourage demand for recycled plastics in a number of new products with specific safety requirements. Safety requirements are also demanded for any products regardless of the source of the raw material. Product design and marking requirements can make it easier and safer to dismantle, reuse and recycle and also track the included material. Product design both on material and product level could become important. Insufficient waste management results in littering and resource inefficiency (Palm 2018[6]).

Different types of plastic materials in post-consumer waste are difficult to collect due to missing waste management regulation, to their geographically dispersed generation and the wide range of different polymers, compounds and composites in use. Commonly used packaging materials such as PET and commonly used variants of commodity plastics (PE and PP) are captured for recycling due to their widespread use which improves the economy of scale for collectors. However, less-commonly used polymers like technical plastics do not offer the same economy of scale that makes their collection viable while waste management related regulation to collect and separate different plastic materials are currently neither harmonized nor very often in place. Furthermore, where different polymers are combined within items or where plastics are combined with other materials, it is difficult and costly to separate them for recycling. Developments in product design and block-chain IT-solutions have the potential to exacerbate this problem. Post-consumer plastic waste often also may contain impurities such as food residues, non-target materials, and non-recyclable materials. Incidental contamination or lack of information about the possible presence of chemicals of concern is an additional problem for various streams of plastics waste.

9 Necessity of standards — Background for necessity based on challenges with missing standards, list up

- Design for recycling
- Quality standards
- Process parameters to control
- Characterization of recyclates
- Contamination
- Recycling guidelines
- Waste management
- Plastics waste management “Guidelines for utilization of plastics waste/recycled plastics in Bituminous/Asphalt Road construction”
- Recycling consideration of bioplastics (biobased and or biodegradable)
- Recyclability vs. recycled
- Recyclate questioner B2B
- Food contact approval
- Application of additives
- Handling of biodegradable or cross-contaminated materials in recycling
- Marking of recyclable plastics

Annex A
(informative)

Additives and functions

Table A.1 — Additives and functions

Additives	Function
Accelerator	Substance used to increase the rate at which a process occurs, usually refers to the cure process in thermosetting resins
Antiblocking agent	Substance prevents plastics from sticking together
Antifogging agent	Substance improves packaging film clarity by preventing any water condensing as droplets on the surface of the film
Antioxidant	Substance which protects a polymer against oxidation whether during processing or in-service life
Antistatic agent	Substance which reduces or eliminate surface electrical charges and hence prevents dust pick up on polymer surfaces
Biocide	Substances which protect a plastics article against attack by microorganism such as fungicides, bactericides, etc. in most cases when plasticisers present,
Blowing agent	Substance has the effect of expanding or foaming the polymer by generating gas in chemical or evaporation process
Compatibiliser	Substance usually polymeric which increases miscibility to a mixture of two dissimilar polymers
Coupling agent	Substance adds to treat a surface so that bonding occurs between it and another kind of surface, e.g. mineral and polymer
Curing agent	Reactive substances promote crosslinking in polymers, e.g. peroxides in polyesters or amines in epoxy
Diluent	A solvent which makes a solution more dilute. Substance which reduces resin viscosity and makes processing easier.
Defoaming agent	Substance which removes trapped air from liquid mixes during compounding
Exotherm modifier	Substance which reduces the maximum temperature reached during an exothermic crosslinking reaction
Fibre	Reinforcement for polymers, improves mechanical properties
Filler	Substance designed to change polymer physical properties (e.g. fire resistance, modulus, shock resistance) or to lower cost.
Flame Retardant	Substance which reduce or prevent combustion
Foam catalyst	Substance used mainly in polyurethane foam production to control foaming process and foam quality
Fragrance modifier	Substances which mask an undesirable odour
Heat stabilizer	Substance prevents polymer from degrading thermally during processing even in absence of oxygen,
Impact modifier	Substance added to absorb the mechanical energy and hence increase resistance to impact
Light stabilizer	Substance added to reduce or eliminate polymer degradation reactions caused by visible or ultra- violet light radiation
Source: Plastic additives, Geoffrey Pritchard[7].	

Table A.1 *(continued)*

Additives	Function
Low profile additive	Substance added to thermosetting moulding compounds, particularly polyesters, to counteract shrinkage during cure, and uneven surface finish
Lubricant	Substance has two functions: they prevent polymers from sticking to the mould and reduce melt viscosity. They also reduce friction between polymers particles before they melt
Microsphere/Microballoon	Spherical hollow filler particles used to reduce weight
Nucleating agent	Substance which promotes or controls the formation of spherulites in crystallizable polymers and leads to several small spherulites rather than a few large ones.
Odour modifier	Substance added to mask an undesirable odour
Optical Brightener	Special fluorescent organic substances used to correct discoloration or enhance whiteness. They absorb ultraviolet radiation and emit it as visible light.
Peroxide	Source of free radicals for crosslinking thermosetting resins or polyolefins.
Plasticiser	Substance designed to space out the polymer chains, facilitating their movements and enhancing flexibility (lower modulus) and ductility
Processing aid	Substance added to reduce the melt viscosity and improving melt homogeneity
Release agent	Substance used as an internal additive or a coating to ease the parting of a plastic object from its mould.
Slip agent	Additive reduces friction and allow ease of polymer handling and processing
Smoke suppressant	Substance which changes the nature of the polymer combustion process and reduce smoke formation.
Surfactant	Substances which reduce surface tension in liquids.
Thickening agent	Substance added to increase viscosity by reacting with carboxyl end groups.
Thixotropic agent	Substance which modifies the dependence of viscosity on shear rate, producing low viscosity at high rates and vice versa.
Ultraviolet (UV) stabilizer	Acts as light stabilizer and protect the polymer from degradation by the ultraviolet radiation.
Wetting agent	Substance wet out solid substrates, e.g. filler particle surfaces, and help their uniform dispersion in a polymer matrix without agglomeration.
Source: Plastic additives, Geoffrey Pritchard[7].	

Annex B
(informative)

Participating cities

Table B.1 — List of participating cities

Region	Cities
Middle East and North Africa	Tripoli, **Libya**
	Tehran, **Iran**
	Saida, **Lebanon**
	Kuwait City, **Kuwait**
	Jaddah, **Saudi Arabia**
	Dubai, **United Arab Emirates**
	Doha, **Qatar**
	Beirut, **Lebanon**
	Amman, **Jordan**
	Algiers, **Algeria**
	Abu Dhabi, **United Arab Emirates**
	Sousse, Tunisia
	Sanaá, **Yemen**
	Baghdad, **Iraq**
	Rabat, **Morocco**
	Cairo, **Egypt**
	Tunis, **Tunisia**
	Tangier, **Morocco**
Sub-Saharan Africa	Harare, **Zimbabwe**
	Gweru, **Zimbabwe**

Table B.1 *(continued)*

Region	Cities
East Asia and Pacific	Yokohama, **Japan**
	South Tarawa, **Kiribati**
	Tongatapu, **Tonga**
	Wellington, **New Zealand**
	Vientiane, **Lao PDR**
	Honiara, **Solomon Islands**
	Port Vila, **Vanuatu**
	Port Moresby, **Papua New Guinea**
	Majuro, **Marshall Islands**
	Funafuti, **Tuvalu**
	Jakarta, **Indonesia**
	Kuala Lumpur, **Malaysia**
	Mandalay, **Myanmar**
	Pohnpei, **Micronesia,** Fed. Sts.
	Phnom Penh, **Cambodia**
	Upolu (Apia), **Samoa**
	Ho Chi Minh City, **Vietnam**
	Bangkok, **Thailand**
	Cebu, **Philippines**
	South Tarawa, **Kiribati**
	Tongatapu, **Tonga**
	Wellington, **New Zealand**
	Vientiane, **Lao PDR**
	Honiara, **Solomon Islands**
	Port Vila, **Vanuatu**
	Port Moresby, **Papua New Guinea**
	Majuro, **Marshall Islands**
	Funafuti, **Tuvalu**
	Jakarta, **Indonesia**
	Kuala Lumpur, **Malaysia**
	Mandalay, **Myanmar**
	Pohnpei, **Micronesia, Fed. Sts.**
	Phnom Penh, **Cambodia**
	Upolu (Apia), Samoa
	Ho Chi Minh City, **Vietnam**
	Bangkok, **Thailand**
	Cebu, **Philippines**
	Kitakyushu, **Japan**
	Kobe, **Japan**
	Naha, **Japan**
	Osaka, **Japan**
	Quezon City, **Philippines**
	Suva, **Fiji**
	Toyama, **Japan**
	Ulaanbaatar, **Mongolia**