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Matters related to the implementation of the Convention: scientific and technical matters: technical guidelines

Technical guidelines on the environmentally sound management of plastic wastes

Submission by the contact group on technical matters

Note by the Secretariat

The annex to the present note contains a revised version of the annex to document UNEP/CHW.16/INF/11 on the technical guidelines on the environmentally sound management of plastic wastes as submitted by the contact group on technical matters. The present note, including its annex, has not been formally edited.

Annex

Technical guidelines on the environmentally sound management of plastic wastes

(Version of 12 May 2023)

Contents

Abbreviations

ABS	acrylonitrile butadiene styrene
AHEG	ad hoc expert group
ASTM	American Society for Testing and Materials
BAT	best available techniques
BEP	best environmental practices
BFRs	brominated flame retardants
CEN	European Committee for Standardization
CiP	Chemicals in Products Programme
c-octaBDE	commercial octabromodiphenyl ether
c-pentaBDE	commercial pentabromodiphenyl ether
decaBDE	decabromodiphenyl ether
DRS	deposit-and-return system
ELV	end of life vehicles
EN	European norm
EPR	extended producer responsibility
EPS	expandable polystyrene
ESM	environmentally sound management
EU	European Union
FEP	perfluoroethylene /propylene
GHG	greenhouse gas
HBCD	hexabromocyclododecane
HDPE	high-density polyethylene
HFCs	hydrofluorocarbons
HIPS	high impact polystyrene
IATA	International Air Transport Association
ICCM	International Conference on Chemical Management
IMO	International Maritime Organization
INC	intergovernmental negotiating committee
ISO	International Organization for Standardization
LDPE	low-density polyethylene
MF	melamine formaldehyde
MFA	tetrafluoroethylene/perfluoromethyl vinyl ether
MSW	municipal solid waste
NA	neutralisation agent
NIR	near-infrared
ODS	ozone depleting substances
OECD	Organisation for Economic Co-operation and Development
PA	polyamide
PBS	polybutylene succinate
PBT	polybutylene terephthalate
PC	polycarbonate
PCB	polychlorinated biphenyls
PCL	polycaprolactone
PE	polyethylene
PET	polyethylene terephthalate
PF	phenol formaldehyde
PFA	perfluoroalkanes
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
PLA	polylactic acid
POP	persistent organic pollutants
POP-BDE	brominated diphenyl-ethers listed in the Stockholm Convention: tetra-BDE, penta-BDE, hexa-BDE, hepta-BDE, deca-BDE
PP	polypropylene
PS	polystyrene
PTFE	polytetrafluoroethylene
PUR	polyurethane
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
PVOH	polyvinyl alcohol
PVF	polyvinyl fluoride

QA	quality assurance
QC	quality control
RDF	refuse derived fuel
SAICM	Strategic Approach to International Chemical Management
UNEA	United Nations Environmental Assembly
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
UF	urea-formaldehyde
UV	ultraviolet
VIS	visual spectrometry
WEEE	waste electrical and electronic equipment
XPS	extruded polystyrene
XRF	X-ray fluorescence
XRT	X-ray transmission

Units of measurement

kg	kilogram
mg/kg	milligram(s) per kilogram.
mg	milligram
ppm	parts per million
tonne	1000 kg

I. Introduction

A. Scope

1. The present technical guidelines provide guidance on the environmentally sound management (ESM) of plastic wastes, pursuant to decisions BC-14/13 and BC-15/10 and BC-16 [to be completed post COP16] of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal. This document supersedes the technical guidelines for the identification and environmentally sound management of plastic wastes and for their disposal of December 2002.

2. Plastic wastes, in the context of these guidelines, covers plastic wastes classified by entries Y48 in Annex II, A3210 in Annex VIII and B3011 in Annex IX to the Basel Convention. Furthermore, the guidelines cover plastic wastes extracted and/or separated from other waste streams that have plastic components or consist partially or fully of plastic (e.g., wastes collected from households (Y46), waste electrical and electronic equipment (WEEE), waste vehicles, waste cables, waste lead-acid batteries and waste textiles for which there are separate related entries in Annexes VIII and IX).

3. It should be noted that several other technical guidelines also provide guidance on plastic wastes, as follows:

(a) For specific guidance on plastic wastes containing or contaminated with persistent organic pollutants (POPs), see the Basel Convention general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (UNEP, 2022a) and the Basel Convention specific technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether or decabromodiphenyl ether (UNEP, 2019d), technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexachlorobutadiene (UNEP, 2015a), technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with short chain chlorinated paraffins (UNEP, 2019b), technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF) and perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds (UNEP, 2022b) and technical guidelines on the environmentally sound management of wastes containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, hexachlorobenzene, polychlorinated biphenyls, pentachlorobenzene, polychlorinated naphthalenes or hexachlorobutadiene (UNEP, 2019e);

(b) For specific guidance on plastic wastes containing, or contaminated with mercury or mercury compounds, see the technical guidelines on the ESM of wastes consisting of, containing, or contaminated with mercury or mercury compounds (UNEP, 2022c);

(c) For specific guidance on the co-processing of plastic wastes in cement kilns, see the Basel Convention technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP, 2011);

(d) For specific guidance on the incineration of plastic wastes, see the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022d);

(e) For specific guidance on the landfilling of plastic wastes, see the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022e).

(f) For specific guidance on plastic wastes from healthcare facilities, see the technical guidelines on environmentally sound management of biomedical and healthcare wastes (Y1, Y3) (UNEP, 2002).

B. About plastics and plastic wastes

4. Plastics started being made over 100 years ago from cellulose (Bellis, 2021). They started to come into wider use in the 1950s and within a few years production had risen to a high rate. They are currently almost exclusively made from fossil fuels such as crude oil or gas. In 2021, 90.2% of the world's plastics production was fossil-based. Post-consumer recycled plastics and bio-based] plastics

respectively accounted for 8.3% and 1.5% of world plastic production (Plastics Europe, 2022). Global production of plastic increased from 1.5 million tonnes in 1950 (Plastics Europe, 2008) to 390 million tonnes in 2021 (Plastics Europe, 2022).

5. Plastics are lightweight with varying degrees of strength and durability. They can be both thermal and electrical insulators, can be moulded in various ways, and can offer a large range of characteristics and colours achieved through additives. Plastics are most commonly used for packaging, food containers, building and construction, textiles, vehicles, electrical and electronic equipment, agricultural film and piping, healthcare equipment, sporting equipment and energy generation infrastructure.

6. However, plastic wastes and its hazardous additives can have adverse effects on human health and the environment. Such effects are for example caused by the properties of polymers, and from hazardous substances in plastic, including the use of hazardous additives and processing aids, that may render the plastic waste hazardous, difficult to recycle or not suitable for recycling. Attention to such effects has increased recently particularly, amongst other issues, due to the ubiquity of plastics and microplastics in marine, freshwater and terrestrial environments (UNEP, 2021a)(Bank, 2022). This is a consequence of the leakage of plastic into the environment at every stage of its lifecycle, particularly if plastic wastes are not managed in an environmentally sound manner.

6bis. The plastics lifecycle includes a full range of activities from extracting raw materials, production, distribution, use and disposal as waste. Environmental problems may be caused at any stage in the lifecycle of plastics, inter alia from point source emissions to air, water and soil from production processes, as well as from plastic wastes not managed in an environmentally sound manner. Such impacts are for example caused by certain additives and processing aids that may render the waste hazardous, difficult to recycle or not suitable for recycling. . The majority of plastics degrade very slowly in the environment.

7. The environmentally sound management of plastic wastes has been a constant challenge. Of the 353 million tonnes of plastic waste generated globally in 2019, 9% was recycled, 19% was incinerated, almost 50% was disposed in landfills and 22% was disposed of in dumpsites, subjected to open burning or leaked into the environment (OECD, 2022).

8. Landfilling of plastic wastes can have adverse effects on human health and the environment, in particular in non-engineered landfills or open dumpsites, such as the leaching of plastics additives, as well as leakage of microplastics and macroplastics into the wider environment. Gasification, pyrolysis and combustion, in particular open burning, of plastic wastes can also adversely affect human health and the environment due to emissions and releases of greenhouse gases and pollutants, such as unintentionally produced POPs and mercury.

9. The leakage of plastic and plastic wastes into the environment can occur from a variety of land-based and ocean-based sources in the form of macroplastics, microplastics and nano-size plastic particles. The sources include, but are not limited to, the uncontrolled dumping of waste, litter, wastewater, storm water run-off and sewers, microplastics intentionally added to products, loss of fishing gear and spillage of plastic pellets, as well as wear from the use of a variety of products containing plastics such as artificial turf, paints and synthetic textiles, unintentional releases from plastic materials in production processes and equipment, potential microplastic releases from incinerator bottom ash, and the fragmentation of oxo-degradable plastics and failed dissolution of water-soluble plastics. Leakages may notably be caused by insufficient and inefficient waste collection, transport and disposal systems, private consumer behaviour as well as business practices. Microplastic pollution is further compounded by the spreading on land of wastewater and sewage sludges that contain microplastic.

C. Types of plastics

1. What is plastic?

10. Plastic is a synthetic material or modified natural material, either a polymer or combination of polymers of high molecular mass modified or compounded with additives such as fillers, plasticizers, stabilizers, flame retardants and colourants. There are different definitions of plastic in current international or national documents. For example, according to the International Organization for Standardization (ISO) “plastic is a material which contains as an essential ingredient a high polymer

and which, at some stage in its processing into finished products, can be shaped by flow" (ISO, 2013). Other definitions are available, including from MARPOL[1].

11. Polymers are natural or synthetic substances composed of very large molecules, called macromolecules, that are multiples of simpler chemical units called monomers. There are a number of detailed definitions of the term "polymer", such as by the OECD[2].

2. Classification of polymers

12. Since polymer types are so diversified it is difficult to classify them in a comprehensive manner. One of the most common ways of classifying polymers is to separate them into thermoplastics and thermosets:

(a) Thermoplastics are polymers which soften when heated and solidify upon cooling, allowing them to be remoulded and recycled. Examples are polyethylene (PE), polypropylene (PP), and polystyrene (PS). Most common consumer plastics are thermoplastics;

(b) Thermosets are polymers that are set into a mould once, normally with a chemical reaction taking place, and cannot be re-softened or moulded again. Examples of thermosets include urea formaldehyde (UF) resins, phenol formaldehyde (PF) resins, and melamine formaldehyde (MF) resins. Thermosets are often used for high-heat applications such as electronic equipment, appliances, construction, and insulation.

13. Polymers can be produced either from materials produced from fossil fuels (fossil-based) or from biomass (bio-based). Both can be chemically identical and also have identical physical properties. Polymers can include additives to improve the base-polymer's physical properties.

14. Both fossil-based plastics and bio-based plastics can be biodegradable or non-biodegradable. Examples are shown in Figure 1.

15. Biodegradable plastics are broadly understood to refer to plastics that can be degraded under specific conditions, such as temperature, UV radiation, humidity, oxygen content and pH, by microorganisms in nature, such as bacteria, mould, and algae, and turn into carbon dioxide and other small molecules (SAPEA, 2020). When a plastic is claimed to be biodegradable, information by the producer is needed about the timeframe, the stages and level of biodegradation, and the environmental conditions required for biodegradation (European Bioplastics, 2018). Some standards exist in relation to biodegradability of plastics [3], however these standards are designed for very specific and limited conditions. These standards applicable to specific conditions will not be applicable to all natural environmental conditions. If these specific conditions are not met, the biodegradable plastic waste may not fully degrade in the environment resulting in environmental concerns. Further information on biodegradable plastics can be found in European Commission, 2022

16. Compostable plastics are a subset of biodegradable plastics designed to biodegrade under controlled conditions (European Commission, 2022). Compostable plastics are considered those plastics which have been tested and adhere to international standards for biodegradation in an industrial composting facility[4]. In addition, compostability may be certified by a third party. While compostable plastic waste does not contribute to the soil quality of the compost, it can be composted together with organic waste[5]. For compostable plastic waste to be fully composted together with organic waste, the composting must happen under specific conditions of temperature, moisture, oxygen level and microbial activity, normally found in controlled industrial composting facilities.

[1] See MARPOL Annex V. Available from: https://www.imo.org/en/OurWork/Environment/Pages/Garbage-Default.aspx

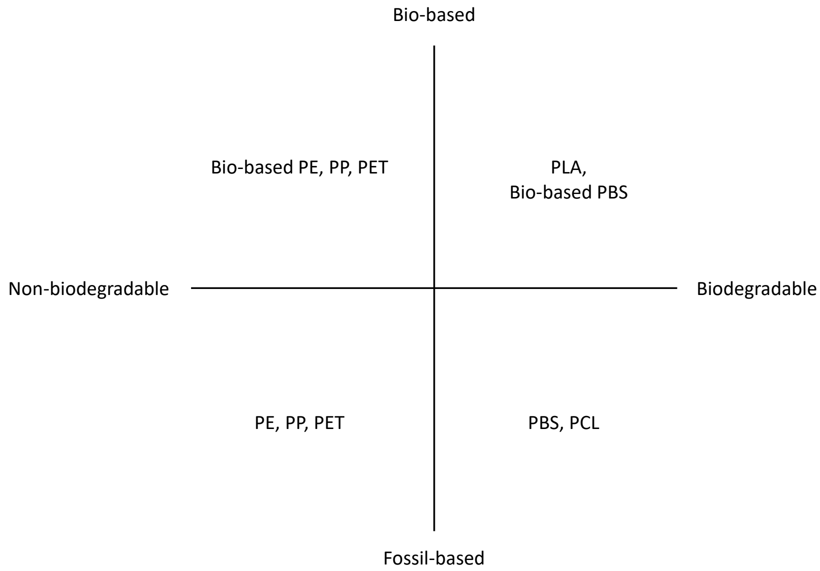
[2] https://www.oecd.org/env/ehs/oecddefinitionofpolymer.htm

[3] ISO 17556:2019 -Plastics- Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved]. [ISO22403:2020 – Plastics — Assessment of the intrinsic biodegradability of materials exposed to marine inocula under mesophilic aerobic laboratory conditions — Test methods and requirements.

[4] Examples of such standards include ISO 5413, ISO 17088, ISO 18606, American Society for Testing and Materials ASTM D6400-21 (ASTM, 2021) (in the U.S.), European Standard EN 13432:2000 (European Standard, 2000) and EN 14995:2006 (European Standard, 2006).

[5] It is noted that the term "bio-waste" is used as a synonym in some countries.

Figure 1: Examples of bio-based plastics, fossil-based plastics, biodegradable plastics and non-biodegradable plastics



Source: Adapted from European Bioplastics (2018)

17. Oxo-degradable plastic are non-biodegradable plastics. They are made by blending a pro-degradant additive into a non-biodegradable plastic during the extrusion process, which accelerates the fragmentation of plastics under specific conditions. However, unlike biodegradable and compostable plastics, once oxo-degradable plastics and their fragments are buried in the soil, out of sunlight, the degradation process stops or slows significantly and persistent small plastic particles remain intact, causing the release of microplastics. The resulting microplastics are made of oxidised non-biodegradable polymers.

18. Kept for consistency purpose only

3. Common types of polymers

19. There are a wide range of polymers used in common plastics and they each have different properties which make them appropriate for different applications. Properties and typical applications of common polymer types, including those covered by entries Y48, A3210 and B3011 in Annex II, Annex VIII and IX to the Basel Convention respectively, are shown in Table 1.

Table 1: Properties and typical applications of common polymer types including those covered by entries Y48, A3210 and B3011

Polymer Type	Labels (ASTM D7611)	Properties	Typical Applications
Polyethylene terephthalate (PET)		clear and resistant to heat, cold, and chemicals	plastic bottles (water, soft drinks etc.) food packaging film, strapping, carpets, vehicle tyre cords and fibres
High-density Polyethylene (HDPE)		durable and resistant to shock and cold	packaging film, industrial film, bottles, tubs, cups, closures, toys, tanks, drums, cable insulation, pipes, gasoline tanks, shipping containers,

Polymer Type	Labels (ASTM D7611)	Properties	Typical Applications
			seating and household goods
Polyvinyl chloride (PVC)	3 V	rigid or soft via plasticizers, resistant to water and solvents and flame retardant	piping, vinyl flooring, cabling insulation, window frames and roof sheeting
Low-density Polyethylene (LDPE)	4 LDPE	lightweight, flexible, and resistant to shock and cold	packaging film, cling-film, bags/sacks, lids, toys, coatings, flexible containers, tubing, irrigation pipes and vehicle dashboards
Polypropylene (PP)	5 PP	lightweight and resistant to heat, water and chemicals	yoghurt pots, snack wrappers, packaging films, bottles/caps, automotive battery cases, parts and body components, electrical components, carpet pile and backing, drainage goods
Polystyrene (PS)	6 PS	lightweight, structurally weak, and easily thermoformed or expanded	packaging applications, dairy product containers, cups, coat hangers and electrical appliances
Acrylonitrile butadiene styrene (ABS)	7 OTHER	durable, stiff, hard and resistant to shock	computers, televisions, kitchen appliances, toys, musical instruments, electrical products and automobile component parts
Polycarbonates (PC)	7 OTHER	clear, resistant to shock and heat and flame retardant	electronic applications, products in construction industry (e.g., for dome lights, flat or curved glazing, and sound walls), CDs, Blu-ray discs, automotive, aircraft and railway parts
Polyethers	7 OTHER	resistant to heat, chemicals,flame retardants, oils, grease and abrasion	electrical components, medical equipment, and

Polymer Type	Labels (ASTM D7611)	Properties	Typical Applications
			automobile components

Source: ASTM (2022)

4. Other types of polymers

(a) Cured resins, condensation products and fluorinated polymers

20. Entries Y48 and B3011 listed in Annexes II and IX to the Basel Convention, respectively, make special mention of plastic wastes consisting of cured resins, condensation products or fluorinated polymers. Cured resins are plastics formed by cross-linking polymer chains and include (but are not limited to) UF resins, PF resins, MF resins, epoxy resins and alkyd resins. Condensation products are plastics formed by the removal of water or alcohol during polymerization and the final molecular weight of the polymer is controlled by the equilibrium concentration of water or alcohols in the molten polymer at the end of the polymerization. Examples of such polymers are polyamides and polyester. Fluorinated polymers are polymers with multiple carbon–fluorine bonds and can come in many different forms. Properties and typical applications of cured resins and fluorinated polymers mentioned in entries Y48 and B3011 are shown in Table 2 and 3 respectively.

Table 2: Properties and typical applications of cured resins mentioned in entries Y48and B3011

Polymer type	Properties	Typical Application
Urea formaldehyde (UF) resin	stiff, hard, and resistant to heat and solvent	glue resins in particle board, medium density fibreboard, plywood used in building material and furniture and kitchen worktops
Phenol formaldehyde (PF) resin	resistant to heat, oils and chemicals and flame retardant	
Melamine formaldehyde (MF) resins	high tensile strength and resistant to water and shock	
Epoxy resins	resistant to heat, chemically stable, high mechanical strength and anti-corrosive	coating and glue resin, glass fibre resins
Alkyd resins	compatible to materials and resistant to corrosion	coating

Source: Copps Industries (2020)

Table 3: Properties and typical applications of fluorinated polymers mentioned in entries Y48 and B3011

Polymer type	Properties	Typical Application
Perfluoroethylene/propylene (FEP)	resistant to corrosion, chemicals and wear	wiring, coaxial cable, wiring for computer wires and technical gear
Tetrafluoroethylene/perfluoro alkyl vinyl ether (PFA)		extruded wire insulation, tubing, protective film, sheet linings, pump housings and non-stick materials
Tetrafluoroethylene/perfluoro methyl vinyl ether (MFA)		non-stick coatings and anticorrosion coatings
Polyvinylfluoride (PVF)	flame retardant and resistant to weather	encapsulant in PV applications, vacuum bagging, coating and lamination
Polyvinylidenefluoride (PVDF)	high tensile strength and resistant to chemicals	piping products, sheet, tubing, films, plate and an insulator for premium wire

Source: Fang Liu et al. (2013), Rodney et al. (2014)

(b) Polymers that are biodegradable under certain conditions

21. Typical applications of polymers that are biodegradable under certain conditions are listed in Table 4.

Table 4: Typical applications of polymers that are biodegradable under certain conditions

Polymer Type	Typical Application
Polyglycolic acid (PGA)	controlled drug releases, implantable composites, bone fixation parts subcutaneous sutures, and intracutaneous closures in surgeries

Polymer Type	Typical Application
Polylactic acid (PLA)	packaging and paper coatings, sustained release systems for pesticides and fertilizers, mulch films, and compost bags
Polybutylene succinate (PBS)	food packaging (e.g., cups and plates) and agricultural mulch films
Polycaprolactone (PCL)	mulch and other agricultural films, fibres containing herbicides to control aquatic weeds, seedling containers and slow-release systems for drugs
Polyhydroxybutyrate (PHB)	products like bottles, bags, wrapping film and nappies, as a material for tissue engineering scaffolds and for controlled drug release carriers
Polyhydroxyvalerate (PHBV)	films and paper coatings, biomedical applications, therapeutic delivery of worm medicine for cattle, and sustained release systems for pharmaceutical drugs and insecticides
Polyvinyl alcohol (PVOH)	packaging applications which dissolve in water to release products such as laundry detergent, pesticides, and hospital washables
Polyvinyl acetate (PVAC)	adhesives, the packaging applications include boxboard manufacture, paper bags, paper lamination, tube winding and re-moistenable labels

Source: Shah et al. (2008)

5. Plastics in composites, plastic multilayers, and polymer blends

22. Composites may be made of plastics and non-plastics materials. The plastics may be bound to other materials to create multi-material packaging such as metal (e.g., metallized wrappers and sachets) or paper-based materials (e.g., in beverage cartons). Composite materials typically have properties superior to the individual materials themselves. Alternatively, the plastics and non-plastics materials may be integrated to produce a new material such as glass-fibre filled plastics which have superior physical mechanical properties or wood-plastics composites that look like wood but do not require the maintenance associated with wood. Composites are used to improve durability and efficiency in a wide variety of applications for example in the aerospace, automotive, marine, energy, and infrastructure and defense applications. For example, wind turbine blades are typically constructed of fibreglass-reinforced plastics. Carbon-fiber reinforced thermoset and thermoplastic composite materials are used in aerospace applications. Such composite materials tend to be significantly more difficult to deconstruct and recycle.

23. Plastic multi-layered materials consist of bonded layers of different polymers that together provide superior properties to the individual polymer types used on their own. Multi-layer polymers provide certain characteristic specific functions in the use-phase (e.g., oxygen and ultraviolet (UV)-light barrier layers, sealing layers and surface finish layers). For example, food packaging films may contain 7 layers of material (e.g., metallized crisp packet). Multilayer structures are also more difficult to recycle.

24. Polymer blends, sometimes referred to as polymer alloys, combine different polymer types that each contribute desired properties in specific applications. Miscibility and compatibility increase between polymers of the same family (e.g., PE and PP belong to the polyolefin family and PS and ABS belong to the styrenics family). Furthermore, compatibility can be enhanced by the use of an additive to bring polymers together in a physical blend (compatibilizer additive technology). Tolerances will be highly dependent on the specific polymers being used.

6. Typical additives and processing aids

25. Most plastics are a blend of polymers and additives. Additives are substances that are added to plastics to bring about certain changes to the characteristics of the plastics as desired and are usually included in the polymer matrix by blending in the melt phase but are not necessarily chemically bonded. This leads to the potential for them to be released into the environment during their production, use and waste phase.

26. Processing aids refers to several different classes of materials and are used to improve the processability and handling of high-molecular-weight polymers. Processing aids are can for example be lubricants, polymerization catalysts and solvents (Wiesinger et al, 2021).

27. Functions and concentration ranges of typical additives in plastic are listed in Table 5.

Table 5: Functions and concentration ranges of typical additives.

Additives	Functions	Concentration range (%w/w)
Plasticizers (e.g., adipates, azelates, citrates, benzoates, ortho-phthalates, terephthalates, sebacates and trimellitates)	To impart plasticity (softness and flexibility) to the material into which they are incorporated. Typical polymers without	10-70[6]

[6] 70% applies to a small range of applications.

Additives	Functions	Concentration range (%w/w)
	plasticizers are too rigid for certain applications.	
Flame retardants (e.g., brominated flame retardants and organophosphate flame retardants)	To prevent ignition of the plastic material and to reduce flammability risks in products.	3–25 (for brominated flame retardants)
Stabilizers, antioxidants and UV stabilizers (e.g., Hindered Amine Light Stabilizers (HALS), benzotrialozes, benzophenones and organic nickel compounds)	To prolong the lifetime of the polymer by suppressing degradation that results from UV-light, oxidation, and other phenomena. Typical stabilizers absorb UV light or function as antioxidants.	0.05–10
Biocides (e.g., compounds based on tin, mercury, arsenic, copper and antimony)	Protecting plastics in certain applications from attack and degradation by microorganisms	0.001-1
Fillers (e.g., mica, talc, kaolin, clay, calcium carbonate, limestone and barium sulphate)	To improve performance or reduce production costs.	up to 70
Colourants (e.g., pigments, soluble azocolourants and processing oils)	To produce plastics products in various colours.	0.25–5

Sources: Hansen et al, (2013), Hahladakis et al. (2018), Xanthopoulos,P (2014)

28. The addition of hazardous additives or processing aids has the potential to render plastic waste hazardous , difficult to recycle or not suitable for recycling. A recent analysis of the global governance of plastics indicates that 128 chemicals of concern used in the plastics life cycle are currently regulated by existing multilateral environment agreements, such as additives, processing aids and monomers and non-intentionally-added substances (BRS, 2023; UNEP, 2023).[7]

Table 6 provides information on POPs listed by the Stockholm Convention that have been or are used as plastic additives or processing aids and Table 7 provides information on some substances that have been or are used as plastic additives and have been identified as substances of very high concern (SVHC) under EU REACH legislation[8].

Table 6: POPs listed in the Stockholm Convention that have been or are used as plastic additives or processing aids

Additives	Purpose	Plastics	Typical content
Hexabromobiphenyl (HBB) (UNEP, 2006a)	Flame retardant	ABS for construction machine housings, and electrical products, polyurethane foam for auto upholstery, coatings and lacquers	N/A
Hexabromocyclododecane (HBCD)	Flame retardant	Expandable polystyrene, XPS in insulation HIPS in electrical and electronic equipment	0.7–2.5% (EPS, XPS) 1–7% (HIPS) (UNEP, 2017a)
Dechlorane Plus	Flame retardant	ABS, PBT, polyester, PP, PE, epoxy resins, PUR	8 – 35% (UNEP, 2022i)
Decabromodiphenyl ether (decaBDE)	Flame retardant	HIPS, PA, PE, PP	5–16% (Buekens and Yang 2014)
Heptabromodiphenyl ether (heptaBDE)	Flame retardant		N/A

[7] This is a subset of around 3,200 chemicals of potential concern identified in plastics and includes additives, processing aids and monomers and non-intentionally-added substances. There are approximately 6,000 other chemicals used in plastics that do not have data to indicate their safety (BRS, 2023 ;UNEP, 2023).
[8] See: https://echa.europa.eu/support/authorisation/substances-of-very-high-concern-identification

Additives	Purpose	Plastics	Typical content
Hexabromodiphenyl ether (hexaBDE)	Flame retardant	as c-octaBDE in: ABS, HIPS, PBT, PA	12–18% (UNEP, 2017b)
Pentabromodiphenyl ether (pentaBDE)	Flame retardant		N/A
Tetrabromodiphenyl ether (tetraBDE)	Flame retardant	as c-pentaBDE in polyurethane (PUR), plastics in former printed circuit boards	0.5–5% (UNEP, 2017b)
Short chain chlorinated paraffins (SCCPs)	Plasticizer, flame retardant	PVC	
Perfluorooctanoic acid (PFOA), its salts and PFOA related compounds (UNEP, 2016a)	Processing aids, surfactants	Fluorinated polymers, such as polytetrafluoroethylene (PTFE), sidechain fluorinated polymers such as fluoroacrylate;	N/A
Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (UNEP, 2006b)	Processing aids, plastic coatings	Fluorinated polymers	N/A

Source: Wagner et al. (2020)

Table 7: Information on some SVHCs listed on the ECHA website[9] that have been or are used as plastic additives.

Additives	Purpose	Plastics	Typical content
Bisphenol A (Food and Drug Administration, 2014)	Antioxidant	PS, PVC, PC	
Tris phosphite (TNPP)	Antioxidant	PS, PVC	
Diethylhexylphthalate (DEHP)	Plasticizer	PVC	30% (European Chemicals Agency 2007)
Benzylbutylphthalate (BBP)	Plasticizer	PVC	5–30% (European Chemicals Agency 2007)
Dibutyl phthalate (DBP)	Plasticizer	PVC	1,5% (Danish Environmental Protection Agency, 2009)
Diisobutyl phthalate (DIBP)	Plasticizer	PVC	Comparable to DBP (Gächter and Müller 1990)
The following lead compounds • Trilead bis(carbonate) dihydroxide (Basic lead carbonate) • Tetralead trioxide sulphate (Tribasic lead sulphate) • Pentalead tetraoxide sulphate (Tetrabasic lead sulphate) • Phthalato(2-)] dioxotrilead (Dibasic lead phthalate) • Lead oxide sulfate (Basic lead sulphate) • Dioxobis(stearato)trilead • Trilead dioxide phosphonate (Dibasic lead phosphite) • Sulfurous acid, lead salt, dibasic Fatty acids, C16-18, lead salts	Stabilizer	PVC	0.6-2.5%[10]

[9] https://echa.europa.eu/candidate-list-table.

[10] Lead stabilizers are used as a proprietary blend of different stabilizers. The concentration range shown above reflects the total concentration contained in the blend.

Additives	Purpose	Plastics	Typical content
Short chain chlorinated paraffins (SCCPs)	Plasticizer, flame retardant	PVC	
Medium chain chlorinated paraffins (MCCPs) (UNEP, 2022f)	Plasticizer, flame retardant	PVC	
UV 328 2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol	UV stabilizer	ABS resin, epoxy resin, fibre resin, PVC, unsaturated polyesters, polyacrylates and polycarbonates, polyolefins, polyurethanes, PVC, polyacrylate, epoxy and elastomers	1 - 10% (UNEP, 2021b, UNEP, 2022g)
UV 327 2,4-di-tert-butyl-6-(5-chlorobenzotriazol-2-yl) phenol	UV stabilizer	Outdoor applications	Max 0.5% (De Kort, 2017)
UV 350 2-(2H-benzotriazol-2-yl)-4-(tert-butyl)-6-(sec-butyl) phenol	UV stabilizer	Outdoor applications	Max 0.5% (De Kort, 2017)
UV 320 2-benzotriazol-2-yl-4,6-di-tert-butylphenol	UV stabilizer	Outdoor applications	Max 0.5% (De Kort, 2017)

Source : Wagner et al. (2020)

II. Relevant provisions of the Basel Convention and international linkages

A. Basel Convention

1. General provisions

29. The Basel Convention, which entered into force on 5 May 1992, aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements, and disposal of hazardous and other wastes. It does this via a set of provisions on the transboundary movement of wastes and their ESM. In particular, the Basel Convention stipulates that any transboundary movement (export, import or transit) of wastes is permissible only when the movement itself and the planned disposal of the hazardous or other wastes are environmentally sound. A set of provisions of the Basel Convention lays out Parties obligations to ensure the ESM of wastes. These are listed in paragraphs 31 to 34 below.

30. Article 2 (“Definitions”), paragraph 1, of the Convention defines wastes as “substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law”. Paragraph 4 of that article defines disposal as “any operation specified in Annex IV” to the Convention. Annex IV contains two categories of operations: those leading to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative uses (R operations) and those not leading to this possibility (D operations). Paragraph 8 defines the ESM of hazardous wastes or other wastes as “taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes.”

31. Article 4 (“General obligations”), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision. Paragraph 1 (a) states: “Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13.” Paragraph 1 (b) states: “Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such wastes when notified pursuant to subparagraph (a) above.”

32. Article 4, paragraphs 2 (a)-(e) and 2 (g), and paragraph 8, contain key provisions of the Basel Convention pertaining to environmentally sound management, transboundary movement, waste minimization and waste disposal practices aimed at mitigating adverse effects on human health and the environment:

Paragraphs 2 (a) – (e) and 2 (g): "Each Party shall take the appropriate measures to:

(a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social, technological and economic aspects;

(b) Ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;

(c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;

(d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement;

(e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting;

(g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner.

Paragraph 8: "Each Party shall require that hazardous wastes or other wastes, to be exported, are managed in an environmentally sound manner in the State of import or elsewhere."

33. The Ban Amendment entered into force 5 December 2019, and it provides that Parties listed in Annex VII to the Convention (members of the European Union (EU), Organisation for Economic Cooperation and Development (OECD) and Liechtenstein) shall prohibit transboundary movements of hazardous wastes to States not listed in Annex VII of hazardous wastes which are destined for operations according to Annex IV-A and hazardous wastes under Article 1.1(a) which are destined to operations according to Annex IV-B[11].

2. Provisions relating to plastic wastes

34. According to article 1 ("Scope of the Convention"), the Basel Convention covers two types of waste subject to transboundary movement: "hazardous wastes" and "other wastes".

35. Paragraph 1 of Article 1 reads as follows:
(a) Wastes that belong to any category contained in Annex I, unless they do not possess any of the characteristics contained in Annex III; and

(b) Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit."

36. Annex I wastes are presumed to exhibit one or more Annex III hazardous characteristics, which may include H4.1"flammable solids"; H6.1 "Poisonous (Acute)"; H6.2 "Infectious substances"; H11 "Toxic (delayed or chronic)"; H12 "Ecotoxic"; or H13 (capable after disposal of yielding a material which possess a hazardous characteristic), unless, through "national tests," they can be shown not to exhibit such characteristics. National tests may be useful for identifying a particular hazardous characteristic in Annex III of the Convention until such time as the hazardous characteristic is fully defined. Guidance documents for Annex III hazardous characteristics H4.1, H11, H12 and H13 were adopted on an interim basis by the Conference of the Parties to the Basel Convention at its sixth and seventh meetings.

37. At its fourth meeting in February 1998, the Conference of the Parties added the two lists of wastes as two new annexes to the Convention, namely Annex VIII (list A) and Annex IX (list B). These were intended to provide greater certainty and clarity to the entries. List A and List B are kept under review by the Conference of the Parties; in addition, a process was established under Decision BC VIII/15 of the Conference of the Parties to the Basel Convention to facilitate the identification and agreement on new entries.,

[11] For information on the status of individual Parties in relation to the amendment/s, please see the Status of Ratifications page on the Basel Convention website.

38. List A of Annex VIII describes wastes that are "characterized as hazardous under Article 1, paragraph 1 (a) of this Convention" although "their designation on this Annex does not preclude the use of Annex III [hazard characteristics] to demonstrate that a waste is not hazardous" (Annex I, paragraph (b)). List B of Annex IX lists wastes that "will not be wastes covered by Article 1, paragraph 1 (a), of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic". However, please note that Annex I and Annex III remain the factors to characterize wastes as hazardous for the purpose of this Convention, and that List A and List B are not intended to be exhaustive[12].

39. As stated in Article 1, paragraph 2, "Wastes that belong to any category contained in Annex II that are subject to transboundary movement shall be "other wastes" for the purposes of this Convention".

40. The Basel Convention contains three main entries on plastic wastes in Annexes II, VIII and IX of the Convention[13] as follows:

(a) Annex II (categories of wastes requiring special consideration, i.e., they are subject to the control procedure): entry Y48 covering all plastic waste, including mixtures of plastic waste, except for the plastic waste covered by entries A3210 (in Annex VIII) and B3011 (in Annex IX);

Y48[14,15]	Plastic waste, including mixtures of such waste, with the exception of the following: • Plastic waste that is hazardous waste pursuant to paragraph 1 (a) of Article 1[16] • Plastic waste listed below, provided it is destined for recycling[17] in an environmentally sound manner and almost free from contamination and other types of wastes:[18] - Plastic waste almost exclusively[19] consisting of one non-halogenated polymer, including but not limited to the following polymers: o Polyethylene (PE) o Polypropylene (PP) o Polystyrene (PS) o Acrylonitrile butadiene styrene (ABS) o Polyethylene terephthalate (PET) o Polycarbonates (PC) o Polyethers - Plastic waste almost exclusively consisting of one cured resin or condensation product, including but not limited to the following resins: o Urea formaldehyde resins o Phenol formaldehyde resins o Melamine formaldehyde resins o Epoxy resins o Alkyd resins - Plastic waste almost exclusively consisting of one of the following fluorinated polymers[20]: o Perfluoroethylene/propylene (FEP) o Perfluoroalkoxy alkanes: ▪ Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) ▪ Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA) o Polyvinylfluoride (PVF) o Polyvinylidenefluoride (PVDF)

[12] PENDING to add the reference to the guidance on the control system

[13] See decision BC-14/12.

[14] This entry becomes effective as of 1 January 2021.

[15] Parties can impose stricter requirements in relation to this entry.

[16] Note the related entry on list A A3210 in Annex VIII.

[17] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B) or, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

[18] In relation to "almost free from contamination and other types of wastes", international and national specifications may offer a point of reference.

[19] In relation to "almost exclusively", international and national specifications may offer a point of reference.

[20] Post-consumer wastes are excluded.

	• Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling[21] of each material and in an environmentally sound manner and almost free from contamination and other types of wastes[14].

(b) Annex VIII (wastes presumed to be hazardous, subject to the control procedure): entry A3210 covering hazardous plastic waste;

A3210[22]	Plastic waste, including mixtures of such waste, containing or contaminated with Annex I constituents, to an extent that it exhibits an Annex III characteristic (note the related entries Y48 in Annex II and on list B B3011).

(c) Annex IX (wastes presumed to be non-hazardous, not subject to the control procedure): entry B3011, which replaced the entry B3010 from 1 January 2021.

B3011[23]	Plastic waste (note the related entries Y48 in Annex II and on list A A3210): • Plastic waste listed below, provided it is destined for recycling[24] in an environmentally sound manner and almost free from contamination and other types of wastes[25]: - Plastic waste almost exclusively[26][19] consisting of one non-halogenated polymer, including but not limited to the following polymers: o Polyethylene (PE) o Polypropylene (PP) o Polystyrene (PS) o Acrylonitrile butadiene styrene (ABS) o Polyethylene terephthalate (PET) o Polycarbonates (PC) o Polyethers - Plastic waste almost exclusively[14] consisting of one cured resin or condensation product, including but not limited to the following resins: o Urea formaldehyde resins o Phenol formaldehyde resins o Melamine formaldehyde resins o Epoxy resins o Alkyd resins - Plastic waste almost exclusively[27] consisting of one of the following fluorinated polymers[28]: o Perfluoroethylene/propylene (FEP) o Perfluoroalkoxy alkanes: ▪ Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) ▪ Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA) o Polyvinylfluoride (PVF) o Polyvinylidenefluoride (PVDF) • Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling[29] of each

[21] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B), with prior sorting and, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

[22] This entry becomes effective as of 1 January 2021.

[23] This entry becomes effective as of 1 January 2021. Entry B3010 is effective until 31 December 2020

[24] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B) or, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

[25] In relation to "almost free from contamination and other types of wastes", international and national specifications may offer a point of reference.

[26] In relation to "almost exclusively", international and national specifications may offer a point of reference.

[27] In relation to "almost exclusively", international and national specifications may offer a point of reference.

[28] Post-consumer wastes are excluded

[29] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B), with prior sorting and, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

	material and in an environmentally sound manner, and almost free from contamination and other types of wastes21.

41. The entries Y48, A3210 and B3011 became effective on 1 January 2021, except for one Party for which these entries became effective on 10 February 2022[30].

42. In addition to the plastic waste entries referred to in paragraph 41, Table 8 contains an indicative list of other entries relevant to plastic waste listed in Annexes I, II, VIII, and IX to the Convention.

Table 8: Indicative list of other entries with direct reference to plastics wastes and other entries that are relevant to plastic wastes listed in Annexes I, II, VIII and IX of the Convention[31]

Entries with direct reference to plastic wastes	
Y13	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives
A1181[32]	**Electrical and electronic waste (note the related entry Y49 in Annex II)[33]** • Waste electrical and electronic equipment (a) containing or contaminated with cadmium, lead, mercury, organohalogen compounds or other Annex I constituents to an extent that the waste exhibits an Annex III characteristic, or (b) with a component containing or contaminated with Annex I constituents to an extent that the component exhibits an Annex III characteristic, including but not limited to any of the following components: – glass from cathode-ray tubes included on list A – a battery included on list A – a switch, lamp, fluorescent tube or a display device backlight which contains mercury – a capacitor containing PCBs – a component containing asbestos – certain circuit boards – certain display devices – certain plastic components containing a brominated flame retardant • Waste components of electrical and electronic equipment containing or contaminated with Annex I constituents to an extent that the waste components exhibit an Annex III characteristic, unless covered by another entry on list A Wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment, and containing or contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic (e.g. fractions arising from shredding or dismantling), unless covered by another entry on list A
A1190	Waste metal cables coated or insulated with plastics containing or contaminated with coal tar, polychlorinated biphenyls (PCB)[34], lead, cadmium, other organohalogen compounds or other Annex I constituents to an extent that they exhibit Annex III characteristics

[30] http://www.basel.int/Countries/StatusofRatifications/PlasticWasteamendments/tabid/8377/Default.aspx.

[31] Refer to Annexes I, II, VIII and IX to the Basel Convention to see the full entries.

[32] This entry becomes effective as of 1 January 2025.

[33] PCBs or PBBs are at a concentration level of 50 mg/kg or more in equipment, in a component, or in wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment.

[34] PCBs are at a concentration level of 50mg/kg or more.

A3050	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives excluding such wastes specified on list B (note the related entry on list B B4020
B1115	Waste metal cables coated or insulated with plastics, not included in list A A1190, excluding those destined for Annex IVA operations or any other disposal operations involving, at any stage, uncontrolled thermal processes, such as open burning.
B3026	The following waste from the pre-treatment of composite packaging for liquids, not containing Annex I materials in concentrations sufficient to exhibit Annex III characteristics: • Non-separable plastic fraction • Non-separable plastic-aluminium fraction
B4020	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives, not listed on list A, free of solvents and other contaminants to an extent that they do not exhibit Annex III characteristics, e.g., water-based, or glues based on casein starch, dextrin, cellulose ethers, polyvinyl alcohols (note the related entry on list A A3050)
Other entries relevant to plastic waste	
Y1	Clinical wastes from medical care in hospitals, medical centres and clinics
Y3	Waste pharmaceuticals, drugs and medicines
Y4	Wastes from the production, formulation and use of biocides and phytopharmaceuticals
Y10	Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)
Y12	Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish
Y18	Residues arising from industrial waste disposal operations
Y24	Arsenic; arsenic compounds
Y26	Cadmium; cadmium compounds
Y27	Antimony, antimony compounds
Y29	Mercury; mercury compounds
Y31	Lead; lead compounds
Y41	Halogenated organic solvents
Y42	Organic solvents excluding halogenated solvents
Y45	Organohalogen compounds other than substances referred to in this Annex (e.g., Y39, Y41, Y42, Y43, Y44)
Y46	Wastes collected from households
Y49[35,36]	**Electrical and electronic waste** • Waste electrical and electronic equipment (a) not containing and not contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic, and (b) in which none of the components (e.g., certain circuit boards, certain display devices) contain or are contaminated with Annex I constituents to an extent that the component exhibits an Annex III characteristic

[35] This entry becomes effective as of 1 January 2025.

[36] Note the related entry on list A A1181 in Annex VIII.

	• Waste components of electrical and electronic equipment (e.g., certain circuit boards, certain display devices) not containing and not contaminated with Annex I constituents to an extent that the waste components exhibit an Annex III characteristic, unless covered by another entry in Annex II or by an entry in Annex IX Wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment (e.g. fractions arising from shredding or dismantling), and not containing and not contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic, unless covered by another entry in Annex II or by an entry in Annex IX
A1160	Waste lead-acid batteries, whole or crushed
A1170	Unsorted waste batteries excluding mixtures of only list B batteries. Waste batteries not specified on list B containing Annex I constituents to an extent to render them hazardous
A1180[37]	Waste electrical and electronic assemblies or scrap[38] containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110)[39].
A3120	Fluff - light fraction from shredding
A3140	Waste non-halogenated organic solvents but excluding such wastes specified on list B
A3150	Waste halogenated organic solvents
A3180	Wastes, substances and articles containing, consisting of or contaminated with polychlorinated biphenyl (PCB) polychlorinated terphenyl (PCT), polychlorinated naphthalene (PCN) or polybrominated biphenyl (PBB), or any other polybrominated analogues of these compounds, at a concentration level of 50 mg/kg or more[40]
A4020	Clinical and related wastes; that is wastes arising from medical, nursing, dental, veterinary, or similar practices, and wastes generated in hospitals or other facilities during the investigation or treatment of patients, or research projects
A4030	(PENDING description – Secretariat)
A4070	Wastes from the production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish excluding any such waste specified on list B (note the related entry on list B B4010)
A4110	Wastes that contain, consist of or are contaminated with any of the following: • Any congenor of polychlorinated dibenzo-furan • Any congenor of polychlorinated dibenzo-p-dioxin
A4130	Waste packages and containers containing Annex I substances in concentrations sufficient to exhibit Annex III hazard characteristics
B1090	Waste batteries conforming to a specification, excluding those made with lead, cadmium or mercury

[37] Entry A1180 is effective until 31 December 2024.

[36] This entry does not include scrap assemblies from electric power generation.

[37] PCBs are at concentration level of 50 mg/kg or more.

[40] The 50 mg/kg level is considered to be an internationally practical level for all wastes. However, many individual countries have established lower regulatory levels (e.g., 20 mg/kg) for specific wastes.

B1110[41]	Electrical and electronic assemblies: • Electronic assemblies consisting only of metals or alloys • Waste electrical and electronic assemblies or scrap[42] (including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A A1180) • Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse[43], and not for recycling or final disposal[44]
B1250	Waste end-of-life motor vehicles, containing neither liquids nor other hazardous components
B3030	Textile wastes[45]
B3035	Waste textile floor coverings, carpets
B4010	Wastes consisting mainly of water-based/latex paints, inks and hardened varnishes not containing organic solvents, heavy metals or biocides to an extent to render them hazardous (note the related entry on list A A4070)
B4030[46]	Used single-use cameras, with batteries not included on list A

B. International linkages

1. Stockholm Convention

43. The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty aimed at protecting human health and the environment from POPs.

44. The objective of the Stockholm Convention, which entered into force on 17 May 2004, is set forth in Article 1 (“Objective”): “Mindful of the precautionary approach as set forth in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Convention is to protect human health and the environment from persistent organic pollutants.”

45. The POPs listed in Annexes A, B, or C of the Stockholm Convention that are relevant in relation to plastic waste, inter alia as additives or processing aids, are:

(a) Hexabromobiphenyl (HBB);

(b) Hexabromocyclododecane (HBCD);

(c) The following polybromodiphenyl ethers: decabromodiphenyl ether (decaBDE), heptabromodiphenyl ether (heptaBDE), hexabromodiphenyl ether (hexaBDE), pentabromodiphenyl ether (pentaBDE) and tetrabromodiphenyl ether (tetraBDE);

(d) Short-chain chlorinated paraffins (SCCPs);

(e) Perfluorooctanoic acid (PFOA), its salts and PFOA related compounds;

(f) Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride;

(g) Unintentionally produced POPs.

[41] Entry B1110 is effective until 31 December 2024.
[42] This entry does not include scrap from electrical power generation.
[43] Reuse can include repair, refurbishment or upgrading, but not major reassembly
[44] In some countries these materials destined for direct re-use are not considered wastes.
[45] Refer to Annex IX to the Basel Convention to see the full entry
[46] Entry B4030 is effective until 31 December 2024.

46. For further information on the general provisions and the waste-related provisions of the Stockholm Convention, refer to section II.B of the General technical guidelines on POPs.

47. For further information on the specific provisions related to these POPs, it is referred to the specific technical guidelines on POP-BDEs (UNEP, 2019d), HBCD (UNEP, 2015a), SCCPs (UNEP, 2019c), PFOS and PFOA (UNEP, 2022a) and unintentionally produced POPs (UNEP, 2019e).

2. Minamata Convention

48. The Minamata Convention on Mercury, which entered into force on 16 August 2017, is a global treaty with the objective according to Article 1, "to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. For further information on the general provisions and the waste-related provisions of the Minamata Convention, refer to section II.B of the technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds (UNEP, 2022c).

49. Some plastics contain mercury, including residual mercury from the manufacturing process of PVC, and pigments containing mercury sulphide. Mercury and methylmercury also adsorb onto marine plastics.

3. Montreal Protocol

50. The Montreal Protocol on Substances that Deplete the Ozone Layer is a global treaty aimed at protecting the Earth's ozone layer by phasing out the chemicals that deplete it. The agreement entered into force in 1989. Under the Montreal Protocol), Parties are obligated to phase out the production and consumption of ozone-depleting substances (ODS) according to specified controls schedules, as well as to phase down the production and consumption of hydrofluorocarbons (HFCs). HFCs do not deplete the ozone layer but are greenhouse gases that were introduced to replace some uses of ODS.

51. Several of the substances controlled by the Montreal Protocol are used or have been used as blowing agents in the manufacture of rigid plastic foams. In foams used mainly for insulation purposes, in particular rigid polyurethane foam, trichlorofluoromethane (CFC-11), 1,1-dichloro-1-fluoroethane (HCFC-141b) and 1,1,1,3,3-pentafluoropropane (HFC-245fa) have been used, among other substances controlled by the Protocol. While there are no obligations pertaining to the destruction of these substances under the Protocol, the Parties agreed through Decision IV/24 to urge "all parties to take all practicable measures to prevent releases of controlled substances into the atmosphere", including "to destroy unneeded ozone-depleting substances where economically feasible and environmentally appropriate to do so". Furthermore, Parties to the Montreal Protocol have approved a list of destruction technologies and related minimum destruction removal efficiencies applicable to controlled substances[47], and a Code of Good Housekeeping Procedures[48], which outlines measures that should be considered to ensure that releases to the environment of controlled substances are minimized during the disposal of plastic wastes containing substances controlled by the Protocol.

4. Work under the United Nations Environment Assembly (UNEA) on marine plastic litter and microplastics

52. Concerns about global marine litter including plastic pollution and microplastics and the related risks to the environment and potentially human health are increasing. The negative effects on ecosystems, biota, societies and economies have been globally recognised and governments are committing to reducing plastic pollution. Four resolutions on marine plastic litter and microplastics have been adopted by UNEA at its sessions in 2014, 2016, 2017 and 2019 to address this global challenge. The issue has also been addressed in separate resolutions, detailed below, on sustainable consumption and production, waste management and single-use plastics in 2019.

53. UNEA-1 resolution 6 on "Marine plastic debris and microplastics" (UNEP/UNEA, 2014) formally brought the issue within the scope of UNEA's agenda and emphasized the challenges of marine debris, particularly plastic and microplastic pollution, the need for urgent action, further information and research and encouraged multi-stakeholder engagement.

54. UNEA-2 resolution 11 on "Marine plastic litter and microplastics" (UNEP/UNEA 2016) addressed the challenges related to marine litter, the issues of microplastic and nano-size particles,

[47] https://ozone.unep.org/treaties/montreal-protocol/meetings/thirtieth-meeting-parties/decisions/annex-ii-destruction-technologies-and-status-their-approval.

[48] https://ozone.unep.org/meetings/fifteenth-meeting-parties-montreal-protocol/decisions/annex-iii-code-good-housekeeping.

transport of plastic through freshwater systems, slow degradation processes and the release and adsorption of chemicals such as POPs.

55. In 2017, UNEA-3 resolution 7 on "Marine litter and microplastics" (UNEP/UNEA, 2017) addressed the importance of preventive actions through waste minimization, environmentally sound waste management, actions in areas with large sources of marine plastic litter and recognized that measures exist to provide cost-effective solutions. UNEA members also recognized the importance of long-term elimination of discharges of litter and microplastics to the oceans and avoiding detriment to marine ecosystems, and the human activities dependent on them, from marine litter and microplastics.

56. The resolution also established an open-ended ad hoc expert group (AHEG) to further examine barriers to and options for combating marine plastic litter and microplastics. The AHEG discussed the adequacy of existing global governance frameworks (UNEP/AHEG, 2018a), and addressed issues related to information, monitoring and governance and possibilities for enhancing existing efforts or identifying new governance structures for marine plastic litter (UNEP/AHEG, 2018b).

57. UNEA-4 resolution 6 on "Marine plastic litter and microplastics" (UNEP/UNEA 2019) extended the mandate of the AHEG to address development of indicators to harmonize monitoring, the need for effective monitoring of sources, the quantities and impacts of marine litter, and invited member states to promote environmentally sound waste management and marine plastic litter recovery; a multi-stakeholder platform was also established to strengthen coordination and cooperation. UNEA-4 resolution 9 on "Addressing single-use plastic products pollution" encourages member states to develop and implement actions to address the environmental impacts of single-use plastic products, identify environmentally friendly alternatives to single-use plastics, promote improved waste management and more resource-efficient design, production, use and sound management of plastics across their life cycle. At its third and fourth AHEG meetings in November 2019 and November 2020, AHEG discussed stocktaking of existing activities and the effectiveness of existing and potential responses to address marine litter issues (UNEP/AHEG 2019 and UNEP/AHEG 2020). In 2020, AHEG completed its mandate, however, potential options for continued work on the global level will be considered at UNEA-5.

58. At UNEA 5.2, a resolution 5/14 titled, 'End plastic pollution: Towards an international legally binding instrument' was adopted. By this resolution, the Assembly agreed to convene an Intergovernmental Negotiating Committee (INC) to develop an international legally binding instrument on plastic pollution, including in the marine environment, with the ambition to complete its work by the end of 2024[49].

59bis. Microplastics and chemicals in plastic products are issues with emerging evidence of environment and human health risks identified in the Global Chemicals Outlook II (UNEP, 2019f).

5. Strategic Approach to International Chemicals Management (SAICM)

59. SAICM was developed to support the achievement of the global goal of sound chemicals and waste management by 2020, agreed at the 2002 Johannesburg World Summit on Sustainable Development. It is a multi-stakeholder, multi-sector voluntary international policy instrument focussed on the achievement of the Sustainable Development Goals relating to sound chemical and waste management. Its work is governed by the following documents: Dubai Declaration; Overarching Policy Strategy; Global Plan of Action and Overall Orientation and Guidance.

60. The International Conference on Chemical Management (ICCM) under SAICM assesses and calls for appropriate action on emerging policy issues and issues of concern. Chemicals in Products (CiP) was identified as an issue of concern at the ICCM2 in 2009 "with a view of taking appropriate cooperation actions, to consider the need to improve the availability of and access to information on chemicals in products in the supply chain and throughout their life cycle." The CiP Programme, a voluntary framework activity, was welcomed by the fourth session of the ICCM4. The Programme's activities are focussed on greater access to the information on chemicals in products that actors need for the sound management of chemicals, and the products that contain them, throughout their life cycle. One of the potential outcomes of the Programme is "enhancing the safe recycling and reuse of materials and products". The CiP Programme focuses specifically on four sectors: textiles, toys, electronics, and building materials.

61. Other emerging issues under SAICM relevant to plastics include hazardous substances within the life cycle of electrical and electronic products, perfluorinated chemicals and the transition to safer alternatives, and endocrine disrupting chemicals. In addition, it is recognized that actions have been

[49] PENDING – to add link to where the resolution is made available.

taken to address microplastic use in cosmetics and personal care products, but actions addressing other major sources of microplastics are limited (UNEP, 2020a).

62. SAICM shares common goals with multilateral environmental agreements such as the Basel, Rotterdam and Stockholm Conventions. In 2019 the Conference of the Parties to the Basel, Rotterdam and Stockholm Conventions requested the Secretariat (decisions BC-14/21; SC-9/19; RC-9/9) to continue to enhance cooperation and coordination with relevant initiatives including SAICM.

III. Guidance on environmentally sound management (ESM) of plastic wastes

A. General considerations

63. Environmentally sound management (ESM)[50] is a broad policy concept that is understood and implemented in various ways by different countries, organizations and stakeholders. The provisions and guidance documents pertaining to the ESM of hazardous wastes and other wastes under the Basel Convention provide for a common understanding and international guidance to support and implement the ESM of hazardous wastes and other wastes. OECD has also produced core performance elements related to ESM.

64. The 2013 Framework for the environmentally sound management of hazardous wastes and other wastes, adopted by decision BC-11/1 ("ESM framework") (UNEP, 2013) establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM. In addition, a set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c and UNEP,2019h) has been developed. The ESM framework and the practical manuals are intended as practical guides for governments and other stakeholders participating in the management of hazardous wastes and other wastes and complement the Basel Technical guidelines. Moreover, guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP, 2019a) and a practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements (UNEP, 2022f) have been developed.

65. As presented in paragraph 33 of this document, Article 4 of the Basel Convention contains provisions related to the ESM of hazardous wastes and other wastes. ESM is also the subject of the following declarations:

(a) The 1999 Basel Declaration on Environmentally Sound Management, which was adopted at the fifth meeting of the Conference of the Parties to the Basel Convention, calls on the Parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention. This takes into account social, technological and economic concerns, and through further reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention;

(b) The 2011 Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes was adopted at the tenth meeting of the Conference of the Parties to the Basel Convention. The Declaration reaffirms that the Basel Convention is the primary global legal instrument for guiding the ESM of hazardous wastes and other wastes and their disposal, including efforts to prevent and minimize their generation, and efficiently and safely manage that which cannot be avoided.

66. The waste management hierarchy is a guiding principle for the ESM of waste and covers prevention, minimization, reuse, recycling, other recovery including energy recovery, and final disposal. The hierarchy encourages treatment options that deliver the best overall environmental outcome, taking into account lifecycle thinking[51].The waste management hierarchy has also been recognised by the Strategic Framework (adopted by decision BC-10/2), the ESM framework (see its paras. 11, 14, 18, 26 and 43) and in the Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous and other wastes and their disposal (UNEP, 2017d). UNEA-2 resolution 11 on marine plastic litter and microplastics also called on countries to establish and implement necessary policies, regulatory frameworks and measures

[50] See paragraph 31 for the definition of ESM in the Basel Convention.

[51] Decision BC-10/2: Strategic framework for the implementation of the Basel Convention for 2012-2021.

consistent with the waste hierarchy.[52] The waste hierarchy was also defined and described in UNEP's Global Waste Management Outlook (UNEP, 2015b).

67. Parties should consider a systemic approach to harmonizing and developing policy frameworks related to plastic wastes. Such an approach may address the root causes of the problem and take a long-term perspective that considers the long-lasting consequences of plastic in the environment, including the marine environment.

68. In addition, Parties should develop a range of measures (strategies, legislation, regulations and programmes) and monitor their implementation to support the meeting of ESM objectives. The implementation of national strategies, policies and programmes are effective methods to ensure a structured approach to the implementation of legislation and regulations; monitoring and enforcement; incentives and penalties; technologies; and other tools in which all key stakeholders participate and cooperate (UNEP, 2013). The following sections should be taken into account when establishing, implementing or evaluating ESM.

B. Legislative and regulatory framework

69bis. Legislative and regulatory frameworks should be implemented in accordance with the administrative systems of the countries.

69. Parties to the Basel Convention should examine their national and subnational strategies, policies, controls, standards and procedures to ensure that they are in agreement with the Convention and with their obligations under it, including those that pertain to the transboundary movement and ESM of plastic wastes.

70. Most countries already have in place some form of legislation that outlines broad environmental protection principles, powers and rights. Such legislation should make ESM operational and include requirements for protection of both human health and the environment. Such enabling legislation can give governments the power to enact and enforce specific rules and regulations on the ESM of plastic wastes, including provisions for inspections and for establishing penalties for violations (e.g., on illegal traffic).

71. Such legislation should enable relevant authorities to monitor whether facilities where plastic wastes are disposed of, for example plastic waste recycling facilities, have obtained all the necessary approvals and can demonstrate due diligence in compliance to ensure such facilities are fully protective of human health and the environment. In addition, any legislation should establish whether actors involved in plastic waste management (e.g., collectors, transporters, and recyclers) ensure that the collection, transportation, storage and disposal of wastes are environmentally sound.

72. The legislation should require adherence to ESM principles, ensuring that countries provide ESM of plastic wastes, including environmentally sound disposal as described in the present guidelines. Specific components or features of a regulatory framework that would meet the requirements of the Basel and Stockholm Conventions and other international agreements are addressed in relevant guidance documents developed under these conventions.[53]

73. The legislation should cover plastic product policies to increase the recycling rates of plastic wastes or stimulate sustainable use of plastic products.

1. Extended producer responsibility

74. Extended Producer Responsibility (EPR) systems for products containing plastic have been introduced in many countries. EPR is an approach that promotes reduction in the environmental impact of products, throughout their lifespan, from production to the waste stage. EPR assigns the responsibility of the whole lifecycle of a product to the producer, including environmentally sound waste disposal. There is no "one-size-fits-all" solution. The EPR instrument(s) that is/are the most appropriate to a specific region/country, taking into consideration market conditions, national capabilities and circumstances should be selected. A country has full control of what is covered in EPR and how it will be implemented including how to define the producer. EPR systems could be mandatory or voluntary and be applied at a national level or at a sub-national level (e.g., regional, local or community level) in order to develop participatory initiatives and solutions to address plastic

[52] http://web.unep.org/unea/list-resolutions-adopted-unea-2.

[53] Further guidance on Basel Convention regulatory frameworks can be found in the following documents: *Manual for the Implementation of the Basel Convention* (UNEP, 2015d) and *Basel Convention: Guide to the Control* (UNEP, 2015e). Parties to the Stockholm Convention should also consult the *Guidance for Developing a National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants* (UNEP, 2017e).

pollution.[54]

75. In addition to plastic packaging, products partly consisting of plastic such as electrical and electronic equipment and vehicles are, in some developed and emerging economies, under relevant EPR schemes. For example, in Canada, EPR schemes are in place in many provinces and territories and cover a range of plastic products including plastic film, bags, containers, and products partially consisting of plastic, such as electronics (Environmental and Climate Change Canada, 2021 and Electronic Products Recycling Association, 2020). In the European Union (EU) for example, Member States must establish EPR schemes for certain single use plastic products to ensure that producers contribute to the cost of waste collection, transportation and treatment of the waste, of awareness raising measures and of cleaning up litter (European Union, 2019). In a few countries, such as China, France, Italy, Spain and Sweden, EPR has, for example, been introduced for agricultural plastic film, and Argentina has introduced EPR for agrochemical plastic containers. Other products such as toys, housewares, furniture, mattresses, fishing gear and textiles (such as carpets) may also be covered by EPR schemes. Saudi Arabia local authorities assign local producers and recyclers to have a collaborative initiative on cleaning of plastic waste on shorelines with an external non-profit environment organization. This assignment has extended to make end user awareness, sortation and conversions of waste to useful plastics applications.

76. Kept for consistency purpose only

77. Kept for consistency purpose only

2. End-of-waste status

78. The text of the Basel Convention does not clarify when a waste ceases to be a waste. The Glossary of Terms of the Basel Convention provides explanatory notes in this regard (UNEP, 2017f). Possibilities for waste to cease to be waste referenced in the Glossary of terms include when:

(a) It has been prepared for reuse;

(b) It has undergone a recycling operation and that operation is completed;

(c) It has otherwise gained end-of-waste status as a result of a recovery operation.

79. Some Parties have adopted conditions in their national legislation that can determine the point at which a material need no longer be classified as waste, such as the European Union (European Union, 2008) and the UK (English Environment Agency, 2016).

3. Transboundary movement requirements

80. Transboundary movements of hazardous wastes and other wastes must be kept to a minimum consistent with their environmentally sound and efficient management and conducted in a manner that protects human health and the environment from any adverse effects that may result from such movements. Y48 in Annex II and A3210 in Annex VIII are categorized as other wastes and hazardous wastes respectively and should, as far as is compatible with their ESM, be disposed of in the country where they were generated. Transboundary movements of such wastes are permitted only under the following conditions:

(a) If the country of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner;

(b) If the wastes in question are required as a raw material for recycling or recovery industries in the country of import;

(c) If the transboundary movements in question are in accordance with other criteria decided by the Parties.

81. Any transboundary movements of hazardous wastes and other wastes considered under the Basel Convention are subject to prior written notification from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Parties shall not permit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes in accordance with the Basel Convention.

[54] Further information on EPR is available in the practical manual on extended producer responsibility adopted by decision BC-14/3

82. Parties listed in Annex VII to the Convention (members of the EU, OECD and Liechtenstein), that are bound by the Ban Amendment, shall prohibit transboundary movements to states not listed in Annex VII of hazardous wastes which are destined for operations according to Annex IVA and hazardous wastes under Article 1.1(a) which are destined to operations according to Annex IVB[55].

83. The Basel Convention also requires that information regarding any proposed transboundary movement of hazardous wastes and other wastes be provided using the accepted notification form and that the approved consignment be accompanied by a movement document from the point where the transboundary movement commences to the point of disposal. Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards[56].

84. When a transboundary movement of hazardous wastes and other wastes to which consent of the countries concerned has been given cannot be completed, the country of export shall ensure that the waste in question is taken back into the country of export for their disposal if alternative arrangements cannot be made. In the case of illegal traffic (as defined in Article 9, paragraph 1), as the result of conduct on the part of the exporter or the generator, the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal or otherwise disposed of in accordance with the provisions of the Basel Convention (as per Article 9, paragraph 2). For further information, see the Guidance on the implementation of the Basel Convention provisions dealing with illegal traffic, adopted by COP13 in 2017 (UNEP, 2017g).

85. No transboundary movements of hazardous wastes and other wastes are permitted between a Party and a non-Party to the Basel Convention unless a bilateral, multilateral or regional agreement or arrangement exists as required under Article 11 of the Convention.

4. Considerations on terms contained in the entries Y48 and B3011

86. In the entries Y48 and B3011 the terms “almost free from contamination and other types of wastes” and “almost exclusively consisting of” appear. These terms assist in distinguishing between entries Y48 and B3011.

87. When implementing the entries B3011 and Y48 at the domestic level, Parties may interpret the terms “almost free from contamination and other types of wastes” and “almost exclusively consisting of” used in these entries in different ways. Examples of approaches to interpreting these terms are the following:

(a) A quantitative approach using quantitative criteria. Guidance following this approach has for example been issued in the European Union (European Commission, 2021). Such guidance, inter alia, contains that, for the first indent of entry B3011, the content of contamination, other types of wastes or non-halogenated polymers, cured resins or condensation products, or fluorinated polymers other than the one non-halogenated polymer, cured resin or condensation product, or fluorinated polymer that makes up the bulk of the plastic waste should not exceed a total maximum percentage of the weight of the consignment of 2%;

(b) An approach drawing on an assessment of quantitative elements and qualitative criteria. Guidance following this approach has for example been issued by the Scottish Environment Protection Agency (Scottish EPA, 2020). This guidance says that to be classified under entry B3011, a consignment of a certain type of plastic waste must contain only minimal amounts of other plastic wastes and only minimal amounts of contamination or other wastes. The assessment of the minimal amounts is based on the quantity, type and quality of contaminants in the waste and on the specific type of waste.

88. Parties and their competent authorities should share information on the national legislation and relevant guidance they have issued in a transparent and efficient manner.

89. It is the responsibility of persons involved in shipments of plastic wastes, such as exporters, importers, and carriers, to ensure they comply with the national legislation and apply the relevant guidance issued by the States of export, import and transit.

[55] For information on the status of individual Parties in relation to the amendment, please see the Status of Ratifications page on the Basel Convention website http://www.basel.int/Countries/StatusofRatifications/BanAmendment/tabid/1344/Default.aspx.

[56] In this connection, the United Nations Recommendations on the Transport of Dangerous Goods (Model Regulations) of 2019 (UNECE, 2019) or later versions should be used.

5. Specifications for containers and storage sites

90. To meet the requirements of ESM and specific clauses in the Basel and Stockholm Conventions (for example, Basel Convention Article 4, paragraph 7, and Stockholm Convention Article 6, paragraph 1), Parties may need to enact specific legislation that describes the types of containers and storage areas that are acceptable for particular plastic waste streams.

91. Parties should ensure that containers that may be subject to transboundary movement meet international standards such as those established by the International Air Transport Association (IATA), the International Maritime Organization (IMO) and the ISO.

6. Requirements for plastic waste treatment and disposal facilities

92. Most countries have legislation in place that requires the operators of waste treatment and disposal facilities to obtain approval to operate. Approvals may contain specific conditions that must be adhered to for these approvals to remain valid. A permitting or approval process based on established and transparent criteria on, inter alia, how to operate facilities, emission levels, monitoring, as well as an inspection regime may be an appropriate approach. It may prove necessary to add requirements specific to plastic wastes to meet the requirements of ESM, and to comply with the specific requirements of the Basel and Stockholm Conventions.

7. Other legislative controls

93. Examples of other aspects of the life-cycle management of plastic wastes that could be regulated through legislation and or a permitting/approval process may include:

(a) Environmental impact assessment of facilities disposing of plastic wastes, if appropriate;

(b) Citing provisions and requirements relative to the storage, handling, collection and transportation of plastic wastes;

(c) Public participation in the permitting or approval process for plastic waste disposal facilities as referred to in section III, J;

(d) Requirements for health and safety of workers;

(e) Decommissioning requirements for plastic recycling facilities, including:

- (i) Inspection prior to and during decommissioning;
- (ii) Procedures to be followed to protect worker and community health and the environment during decommissioning;
- (iii) Post-decommissioning site requirements;

(f) Emergency contingency planning, spill and accident response, including:

- (i) Clean-up procedures and post-clean-up concentrations to be achieved;
- (ii) Worker training and safety requirements;
- (iii) Waste prevention, minimization and management plans;
- (iv) Obligations to ensure best-practice management systems, including requirements for annual reporting and regular third-party auditing and verification after the accident;

(g) Restrictions on greenhouse gas (GHG) emissions across the life cycle of plastics including their management as wastes, including such restrictions as are required to meet nationally determined contributions for parties to the Paris Agreement.

C. Waste prevention and minimization

1. General considerations

94. The Basel Convention affirms that reducing the generation of hazardous wastes and other wastes to a minimum in terms of quantity and/or hazard potential is the most effective way of protecting human health and the environment from the dangers posed by such wastes.

95. In Article 4, paragraph 2, the Basel Convention calls on Parties to “ensure that the generation of hazardous wastes and other wastes is reduced to a minimum”. Waste prevention should be the preferred option in any waste management policy, so that the need for waste management is reduced, enabling resources to be used more efficiently.

96. At the tenth meeting of the Conference of the Parties to the Basel Convention, the Parties, in adopting the Cartagena Declaration committed "to enhancing the active promotion and implementation of more efficient strategies to achieve prevention and minimization of the generation of hazardous waste and other wastes and their disposal".

97. One of the multiple benefits of plastic waste prevention and minimization is the reduction in the release of plastic waste into the terrestrial and marine environments. The Conference of the Parties to the Convention addressed the prevention and minimization of the generation of plastic waste in its decision BC-14/13: Further actions to address plastic waste under the Basel Convention, in particular in part II of the decision.

98. According to the ESM framework, the need to manage wastes and/or the risks and costs associated with waste management can be reduced by not generating wastes and by ensuring that generated wastes are less hazardous (UNEP, 2013).

99. The ESM framework states that "companies that generate wastes (waste generators) are responsible for ensuring the implementation of best available techniques (BAT) and best environmental practices (BEP) when undertaking activities that generate wastes". In doing so, they act to minimize the wastes generated by ensuring research, investment in design, innovation and development of new products and processes that use less resources and energy and that reduce, substitute or eliminate the use of hazardous materials (UNEP, 2013).

100. Waste management efforts require multi-stakeholder involvement in the development of waste management plans with a strong emphasis on prevention and minimization, in partnership with waste generators, industrial users and civil society.

101. A practical manual on waste prevention, as part of the set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c), provides stakeholders with general guidance on waste prevention principles, strategies and possible measures and tools. The Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous wastes and other wastes and their disposal (UNEP 2017d) identifies elements of a waste prevention and minimization programme that apply also to plastic wastes.

2. Policy instruments and measures on waste prevention and minimization

102. .

103 .Waste prevention and minimization are essential elements in the transition from a linear to a circular economy[57]. Table 9 provides a non-exhaustive list of examples of measures that have been adopted in some countries to support plastic waste prevention and minimization. The examples, which are expanded upon in paragraphs 104 to 120, may not be suitable for adoption in all countries. Consequently Parties, and where appropriate local authorities, businesses, and community groups, should consider which measures are most appropriate for their needs at the national level. This should ensure that the selection of waste prevention and minimization measures takes into account national resources, capability, circumstances, and priorities, including participatory initiatives and solutions. A country has full control of what measures are covered in waste prevention and minimization and how it will be implemented in their countries.

Table 9: Examples of both voluntary and mandatory policy instruments and measures on waste prevention and minimization,[58,59,60]

Policy instruments	Waste prevention and minimization measures
Regulatory	- Design requirements - Ban on certain single-use plastic products , such as single-use plastic bags or cutlery[61] - Ban on oxo-degradable plastics

[57] For information, examples of policy instruments and measures on waste prevention and minimization can be found in (OECD, 2019).

[58] Some measures are relevant to more than one policy instrument.

[59] [These are non-exhaustive list of policy instruments and measures on waste prevention and minimization without any judgment on their effectiveness]

[60] These measures may and may not be applicable for all countries

[61] For example, see European Union, 2019.

	- Restrictions on hazardous substances in plastics and of microplastics in products - Consumption reduction measures[62] - Targets on recovery/recycling - Targets on recycled content - Deposit return schemes to increase reuse and recycling - Labelling and identification of products - Extended Producer Responsibility (EPR), - Green procurement criteria - Landfill ban/incineration ban - Measures to Reduce the use of hard-to-recycle plastics - Measures for other materials mixed or coated with plastic. e.g., wood, paper, glass, cotton, etc
Market-based	Taxes on products (e.g. packaging, plastic bags, virgin plastic) - Tax exemptions and other positive economic incentives (e.g. for reuse and repair) - Pay-as-you-throw schemes (PAYT) - Deposit return schemes - Extended producer responsibility (EPR) - Landfill tax/incineration tax - Economic incentives for reusable and repairable products and packaging, packaging-free businesses
Information-based	- Awareness campaigns/school education - Labelling and identification of products - Procurement guidelines - Providing practical information, e.g., via information exchange platforms, to businesses and consumers - Environmental certification schemes
Voluntary	- Product standards (e.g., eco design) and specifications - Stakeholder recognition and incentive programs - Labelling and identification of products - Extended producer responsibility (EPR) - Green procurement criteria - Sustainable procurement

(a) Regulatory instruments and measures

103bis. The instruments and measures below should take into account national resources, capability, circumstances, and priorities, including participatory initiatives and solutions.
A country has full control of what measures are covered in waste prevention and minimization and how it will be implemented in their countries.

103. Design requirements for products are a central feature in successful waste prevention and minimization policy. It has been shown that eco-design, for all products, determines almost 80 percent of a product's environmental impact (European Commission, 2012).

104. Design requirements can reduce the amount of plastic waste generated by limiting the use of plastics in new products. This can be achieved either by using alternative materials with less environmental impact or by reducing the size of the products. In addition, the volume of plastic packaging could be reduced, e.g., in order to prevent excessive use of packaging that is not necessary.

105. For some plastic products, the most relevant design feature would be to focus on an extended lifespan, thereby postponing and reducing waste generation. This can be achieved through integrating aspects of durability, reusability, repairability and upgradability in the design process.

106. 106 bis Design requirements could be tailored to ensure the use of certain hazardous substances in plastics are avoided or minimized. Restrictions on the use of intentionally added microplastics in products, such as in certain cosmetics and paints, could also be considered at the design stage. Choices made at the design stage can have impacts on how products are managed in an environmentally sound manner when they become waste. For example, the use of carbon black in consumer packaging could be avoided as these black plastics may be difficult to detect by automatic sensor sorting thereby impeding recycling. Any selection of materials or additives that contribute to difficult-to-recycle plastic waste should also be carefully considered to determine whether their use is necessary for the specific application. Typical examples include composite products, plastic multilayers or other

[62] For example, see European Union, 1994, and European Union, 2019.

products where the individual parts or layers are difficult to separate as they consist of a combination of plastics and other material types or of different plastic polymers (see paragraphs 23-25).

107. Selective waste prevention and minimization measures, such as bans or consumption reduction measures, have been applied in some countries to specific single-use plastic products and/or other plastic products that are frequently found in litter, such as cutlery, plastic bags and other packaging products. For example, in certain countries measures have been adopted to address food packaging made from EPS as this has been identified as a particular problem in litter because it can be easily dispersed by wind and is easily broken up. In addition, measures to reduce the consumption of these products could also be relevant and may lead to a reversal of increasing consumption.

108. Other selective waste prevention and minimization, measures may focus on the use of certain plastics that are known to cause problems. For example, oxo-degradable plastics, which are designed to degrade quickly into smaller pieces, contributing to litter problems and the release of microplastics (see paragraph 18) could be considered.

109. [Left for consistency of paragraph number.]

110. Setting targets for the use of recycled content in plastic products and/or targets for recovery/recycling could increase the demand for secondary raw materials and strengthen their market position, thereby stimulating plastic waste collection and recycling activities. This may also increase general public awareness of the importance of separate waste collection and environmentally sound waste management. In addition, the implementation of deposit return schemes for plastic products, such as PET beverage bottles, typically leads to improved levels of plastic waste segregation, collection and recycling.

111. Businesses, including manufactures, suppliers and retailers should disseminate product design information through the use of standards, claims, labels and identification schemes regarding plastic products, e.g., for clear and well-designed recyclability labels. This will enable consumers to make informed choices when buying products, thereby contributing to the prevention and minimization of waste. Such claims and labels could also enable plastic waste disposal facilities to access information about additives or processing aids present in the plastic waste which may render it hazardous or problematic, for example POPs or SVHC (see tables 6 and 7 and paragraph 218). Information contained in claims and labels may therefore assist measures to avoid contamination of subsequent recycling and manufacturing processes.

112. Principles such as reliability, relevance, clarity, transparency and accessibility should serve as the main guiding principles of standards, claims, labels and identification schemes related to plastic packaging (UNEP, 2020b).

113. Kept for consistency purpose only

114. Green public procurement criteria may be developed to facilitate the inclusion of green requirements in tender documents, including specific requirements on the use of products that meet certain design requirements (e.g., setting requirement for minimum recycled content). Since the public sector's purchasing accounts for a large proportion of the economic activity in society, such criteria could have an important influence on the marketplace.

115. Other measures may be employed to divert the management of plastic waste higher up the waste hierarchy. For example, a ban on sending recyclable plastic waste to energy recovery activities, except in cases where the plastic waste contains hazardous substances which represent a particular health risk or environmental hazard and require destruction could be considered. Countries could also implement a ban on the landfilling or incineration (without energy recovery) of plastic waste. These measures could increase recycling and stimulate waste prevention; but may require careful consideration to ensure any risk of improper disposal of plastic waste, (e.g., open dumping or open burning) is minimised.

(b)Market-based instruments and measures

116bis. The instruments and measures below should take into account national resources, capability, circumstances, and priorities, including participatory initiatives and solutions.
A country has full control of what measures are covered in waste prevention and minimization and how it will be implemented in their countries.

117. Market-based measures may be used to incentivize the prevention and minimization of plastic waste. For example, tax exemptions, subsidies, or grants/loans could be used to support businesses that sell products without plastic packaging or to support enterprises that engage in the re-use or repair

of plastic products or the recycling of plastic waste. Pay-as-you throw (PAYT) schemes with variable pricing for waste collection by weight or volume, could be used to encourage businesses and/or residents to generate less plastic waste and to incentivize separation of plastic waste at source. Conversely, market-based measures may be used to discourage activities that either increase the generation of plastic waste or impact negatively on the reuse or recycling of plastic waste. These may take the form of increased taxation of the use of virgin raw materials in plastic products or selective taxes or surcharges on single-use plastic products or plastic products that do not comply with specified criteria, such as recycled content. Increased taxation could also be applied to non-hazardous recyclable plastic waste sent to energy recovery activities or to incineration without energy recovery or any plastic waste sent to landfill with the intention of encouraging the diversion of plastic waste to reuse or recycling activities. These types of instruments could, since they are linked to the economy, be more sensitive to national circumstances, needs and priorities than regulatory instruments.

(c) Information-based instruments and measures

116. Raising awareness of plastic waste prevention and minimization measures amongst the public and businesses may support the increased adoption of these activities. Furthermore, this can lead to a change of public awareness relating to production and consumption. Examples of awareness raising include targeted public campaigns and education initiatives which may involve sharing practical information and tools on how individuals and businesses can reduce the amount of plastic waste they generate. Raising awareness amongst school pupils may also help to change the behaviour of parents.

117. Additionally, local authorities should consider the promotion of community-based waste prevention initiatives by working with local businesses and residents. For further information, see section III.J.

(d) Voluntary instruments and measures

118. Local authorities, businesses, schools and communities could also voluntarily adopt a range of the waste prevention and minimization measures outlined above. Measures can also be adapted to fit specific national and local circumstances. For example, some regulatory measures could be applied voluntarily by various actors, such as product standards and specifications, labelling and identification of products, EPR and green procurement criteria.

120.bis Governments can also foster voluntary waste prevention and minimisation initiatives as an alternative or an addition to regulatory measures. For example, through government recognition or certification programs that publicise positive actions taken by local authorities, businesses, schools or communities that go beyond mandated requirements.

3. Reduction of plastic leakage through waste prevention and minimization

119. Waste prevention and minimization measures described above should reduce the leakage of plastics from the waste phase. In addition, special care should be taken to reduce the release of plastics to the environment from the unintended loss of plastic products, such as fishing gear, plastic pellets and artificial turf. Most of these losses occur in the use phase of products, the loss of pellets may also occur in the production, transport, and storage phases (Karlsson et al, 2018)[63].

120. The leakage of plastics from the production, transport and use phase can be addressed through various regulatory, voluntary and information-based measures. In general, procedures and best practices for handling of the products should be applied to minimize the risk of their loss to the environment. For some product types, notably plastic pellets, this should be done for several handling steps along the value chain, since losses can occur from any of the steps. Leakages of plastics and the relevant sources may differ from country to country, so measures to prevent leakages should be tailored to national circumstances.

121. For further information on measures taken to prevent and reduce single-use plastic waste and packaging waste, consult the "Compilation of information, best practices and lessons learned on measures taken by key stakeholders to prevent and reduce single-use plastic waste and packaging waste" (UNEP/CHW.16/INF/55).

[63] See also the Operation Clean Sweep® voluntary program: https://www.opcleansweep.eu/

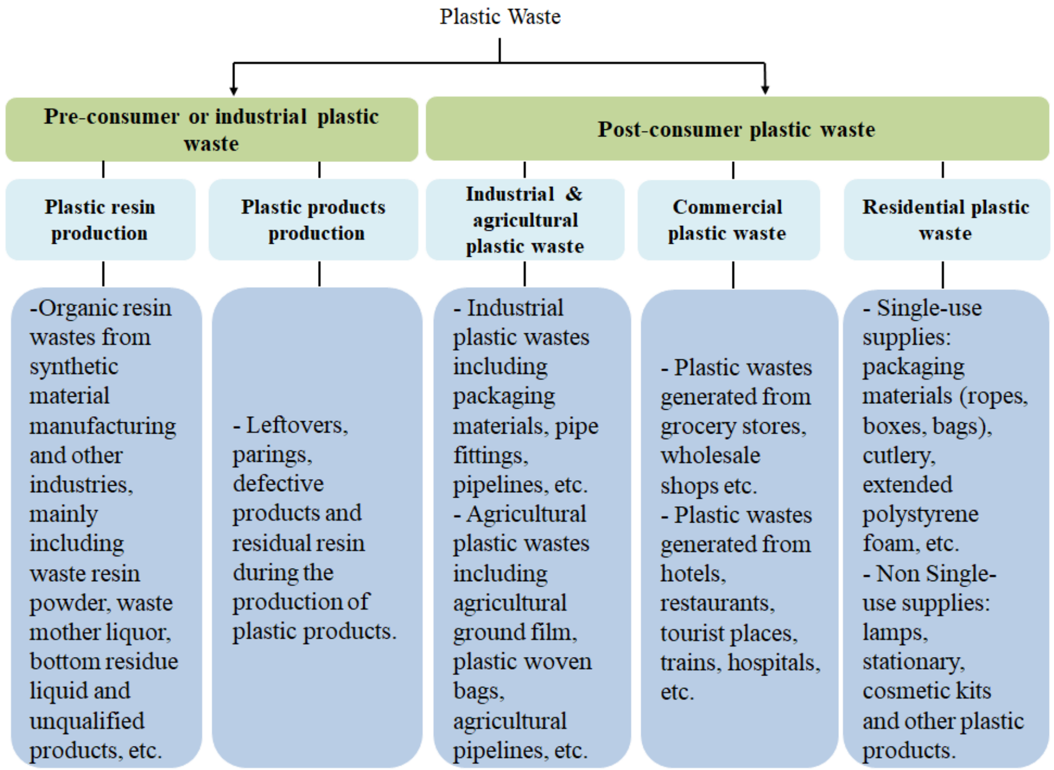
D.Identification and inventories

1. Identification of plastic wastes sources

122. The identification of plastic waste is the starting point for their effective ESM. To enable effective action to prevent, minimize and manage plastic wastes, it is important that Parties identify the sources of plastic waste generation and quantify the amount of plastic wastes generated.

123. Plastic wastes can be categorised into two main categories: pre-consumer and post-consumer wastes (see Figure 2). Post-consumer plastic wastes are found mainly in municipal solid waste (MSW) and in the following economic sectors: industry, agriculture, building, construction and demolition, commercial, institutional, automotive, electrical and electronic equipment, and textiles (see Table 10 for main sources and examples of plastic wastes).

Figure 2: Classification of plastic wastes



Source: Based on Yang et al., 2018.

Table 10: Main sources and examples of plastic wastes:

Source	Examples of waste types generated	Detailed examples
Pre-consumer plastic wastes		
Polymer production and compounding	Wastes from: · Industrial packaging · Pre-production offcuts · Sweepings · Off-specification plastic	Off-specification colour pellets, compounder purge, clean-down waste, pellet conveying systems line-purge waste, handling and bulk loading spillages.
Plastic conversion	Wastes from moulding and extrusion	Sheet edge trimmings and mould flow sprues.
Plastic assembly or installation	Wastes from plastic assembly and installation processes	Damaged assemblies, intentional ‘press-out’ blanks, component handling tabs, screw thread covers, body panel covers, failed trial polymer applications
Post-consumer plastic wastes		
Municipal solid waste	Consumer plastic packaging	Plastic bottles, pots, tubs, trays, films and wrappers.
	Garden plastics	Outdoor seats and tables, toys, buckets, flowerpots, paddling pools.
	Household products	Crates, filing boxes, washing baskets, kitchenware.
	Furnishings	Seating foams, upholstery textiles, legs, feet, mouldings, and mattresses.
	Sports and leisure equipment	Rackets, balls, cushion mats, protective headwear and footwear.

Commercial and large industrial plastic wastes	Packaging and containers	Waste of bags, drums and containers from the food and chemical industries, packaging films, industrial equipment, crates.
Agriculture plastic wastes	Flexible films, fibres, string and nets Tanks, drums, containers and pipes	Greenhouses covers, fertilizer sacks, mulch and fumigation films, silage bale-wraps, bird protection nets and baling twine. Water tanks, chemical drums, fertilizer bottles, irrigation pipes and valves.
Plastic wastes from hospitals, health and safety, and laboratories	Single-use plastic packaging, medical and laboratory supplies and personal protective equipment	Infusion bottle (bag), dialysis bucket, plastic packaging, packing box, packing barrel, masks, protective clothing.
Plastic wastes from WEEE	Refrigerators, computers, vacuum cleaners, small domestic appliances, mobile phones and office equipment.	Printed circuit board, fans, shells, PUR foams, pipes, inner tank, coil, plastic capacitor, and resistance
Plastic wastes from end-of-life vehicles waste (ELV)	-	Car bumpers, body mouldings, interior trim panels, seat foams, flexible cooling pipes, battery shell.
Plastic wastes from Fishing/aquaculture	Nets and other fishing gear	Fishing nets, trawls, ropes, strapping bands, floats, buoys
Wastes from construction and demolition		Plastic from window frames and doors, construction off-cuts, roofing sheets, insulation panels, textiles, drainage pipes.
Plastic wastes from textiles	Textile wastes	Clothing and textiles such as towels, curtains, bedding, and carpets.
Plastic wastes from cables		Cable jackets

2. Identification of plastic products/wastes according to the resin type

124. The ASTM D7611—Standard Practice for Coding Plastic Manufactured Articles for Resin Identification provides a set of symbols appearing on plastic products that identify the plastic resin out of which the product is made (See Table 1).

3. Identification of hazardous and non-hazardous plastic wastes

125. According to Article 1 paragraph 1(a) of the Convention, plastic waste that belongs to any category contained in Annex I is to be considered hazardous waste, unless it does not possess any of the hazardous characteristics contained in Annex III. For example, the following plastic wastes should therefore be presumed to be hazardous waste[64]:

(a) Plastic wastes covered under the category Y13 (wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives) and entry A3050. For example, wastes of formaldehyde resins, epoxy resins and alkyd resins, in particular when uncured, may possess the hazardous characteristics H6.1, H8, H11 and H12 and H13:

(b) Plastic wastes containing or contaminated with heavy metals covered under the categories Y24 (arsenic; arsenic compounds), Y26 (cadmium; cadmium compounds), Y29 (Mercury; mercury compounds) and Y31 (lead; lead compounds). For example, waste of rigid PVC, in particular of legacy rigid PVC, that contains cadmium and lead stabilizers, and plastic components separated from waste lead-acid batteries (A1160), such as battery casings, may possess the hazardous characteristics H6.1, H11, H12 and H13, in which case they would fall under entry A3210:

(c) Plastic wastes containing or contaminated with brominated flame retardants (BFRs), in particular BFRs that are POPs according to the Stockholm Convention, covered under category Y45 (organohalogen compounds other than substances referred to elsewhere in Annex I) and entry A3210. In addition, plastic waste containing BFRs may, if antimony compounds are used as synergists of the BFRs, fall under category Y27 (Antimony, antimony compounds). Depending on the concentration and the chemical properties of the BFRs and their synergists, plastic wastes containing or contaminated with BFRs, for example plastic components separated from waste electrical and

[64] It should be noted that some of the entries in Annex VIII have references to entries in Annex IX. See also Table 8.

electronic equipment (A1180[65], A1181[66]), may possess the hazardous characteristics H6.1, H11, H12 and H13.

(d) Textile wastes made of plastic containing or contaminated with PFAS compounds after treatment for waterproofing covered under category Y45 (organohalogen compounds other than substances referred to elsewhere in Annex I). PFAS compounds such as PFOS and PFOA that are listed as POPs under the Stockholm Convention, may possess the hazardous characteristics H6.1, H11, H12 and H13, in which case they would fall under entry A3210;

(e) Plastic wastes contaminated with hazardous materials such as solvents covered under the categories Y41 (halogenated organic solvents) and Y42 (organic solvents excluding halogenated solvents), and entry A3140 and A3150. For example, a waste solvent plastic tank may possess the hazardous characteristics H11 and H12;

(f) Plastic wastes from medical care in hospitals, medical centres and clinics covered under the category Y1(clinical wastes from medical care in hospitals, medical centers and clinics) and entry A4020, plastic wastes contaminated with waste pharmaceuticals, drugs and medicines under the category Y3 (Waste pharmaceuticals, drugs and medicines). For example, waste plastic articles from medical care such as waste syringes may possess the hazardous characteristics H6.1, H6.2, H11 and H12.

(g) Plastic wastes containing certain additives such as MCCPs covered under Annex I category Y45 (organohalogen compounds other than substances referred to elsewhere in Annex I) and entry A 3210 may possess the hazardous characteristics H11 and H12.

(h) Plastic wastes from metal cables containing or contaminated with organohalogen compounds covered under category Y45 (organohalogen compounds other than substances referred to elsewhere in Annex I) and entry A1190. Such plastic waste may possess the hazardous characteristics H6.1, H11, H12 and H13;

(i) Plastic wastes from waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs) covered under category Y10 (waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)) and entry A3180, and possibly under entries A1160, A1170, A1180[67], A1181,[68]A3120 and A4130. PCBs and HBB, a PBB, are listed as POPs under the Stockholm Convention. Waste containing PCBs, PCTs and PBBs may possess the hazardous characteristics H6.1, H11, H12 and H13, depending on their concentration levels in a waste;

(j) Plastic wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish covered under the category Y12 (wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish) and entry A4070. For example, wastes of azo dyes may possess the hazardous characteristics H11, H12 and H13;

(k) Plastic wastes that contain or are contaminated with any congenor of polychlorinated dibenzo-furan and/or any congenor of polychlorinated dibenzo-p-dioxin covered under the category Y43 (any congenor of polychlorinated dibenzo-furan) and Y44 (any congenor of polychlorinated dibenzo-p-dioxin) and entry A4110 . These plastic wastes may possess the hazardous characteristics H6.1, H11 and H12;

(l) Plastic wastes covered under category Y4 (Wastes from the production, formulation and use of biocides and phytopharmaceuticals) and entry A4030, and possibly under entries A3210 and A4130. For example, an empty plastic container for biocides may possess the hazardous characteristics H6.1, H11, H12 and/or H13;

(m) Plastic wastes covered under category Y18 (Residues arising from industrial waste disposal operations. For example, residues from the processing of hazardous plastic wastes, such as from sorting or shredding, may possess the hazardous characteristics H6.1, H11, H12 and H13, in which case they would fall under entry A3210;

[65] This entry is effective until 31 December 2024
[66] This entry becomes effectives as of 1 January 2025
[67] This entry is effective until 31 December 2024
[68] This entry becomes effectives as of 1 January 2025

(n) Plastic waste packages and empty containers from waste streams (Y1 – Y18) or contaminated with constituents (Y19-Y45) covered under entry A4130 may possess hazardous characteristic H13 and the specific hazard of the substance contained;

(o) Plastic wastes having as constituent organohalogenated compounds covered under category Y45 (organohalogen compounds other than substances referred to elsewhere in Annex I) and entry A3210, may possess hazardous characteristics H11, H12 and H13.

127bis All non-hazardous fluorinated polymers fall under Y48, unless they are pre-consumer plastic waste consisting almost exclusively of one of FEP, PFA, MFA, PVF, PVDF, destined for recycling in an environmentally sound manner and almost free from contamination and other types of waste. In such a case, they would fall under B3011.

126. Annex II to the Basel Convention lists category Y46 (Wastes collected from households) which may contain or be contaminated with certain plastic wastes referred to in paragraph 127 and 127bis.

4. Identification of non-hazardous contaminants

127. Contaminants are unwanted materials present in plastic wastes., including non-hazardous contaminants. The composition of plastic wastes depend not only on the intrinsic composition of the different plastics but may also contain certain non-hazardous contaminants which derive from the production, use or waste phases of the plastic lifecycle.

128. Plastic wastes from industrial processes often arise in large volumes of clean material consisting of a single polymer type with low levels of contamination. However, it can have a higher contamination than virgin plastics (Huysveld et al. 2019) and be non-homogenous when it is generated in the manufacture of composite materials. The majority of residential post-consumer plastic wastes is a much wider range of mixed items and material types, where the contamination levels may be significant.

129. Mixed polymer waste streams may be more difficult to recycle. For instance, small amounts of PVC mixed with other polymers (PE, PP or PET) can prevent effective recycling. Clear PET and PVC (i.e., from packaging) have a particular problem with cross-contamination as their visual appearance is very similar. The density ranges of PET and PVC also overlap making it more challenging to separate the polymers using float-sink technology. Film types such as PP, PET and multi-layer laminates are considered contaminants in a mixed LDPE stream (Mepex Consult AS, 2017).

130. Paper labels can contaminate recyclable plastic wastes (e.g., stock identification labels on pallet wraps). Inks, that are used to print information directly on the surface of the packaging material, can bleed during the recycling washing process and discolour the recyclate and waste liquid effluent.

131. Plastic wastes can be contaminated with either non-ferrous or ferrous metals. Plastic wastes from cables may contain residual metals. Post-consumer plastic packaging wastes may contain aluminium which may be difficult to remove.

132. Contamination can also appear at the use phase of plastic. Plastic waste can also be contaminated with food or beverage residues. Many packaging items contain a residual level of the original contents and require washing during recycling, leaving a clean plastic material for onward processing.

133. Plastic film wastes from agriculture may contain high percentages of soil and traces of pesticides, and emptied plastic containers may still contain and be impregnated with agrochemicals, that could render the waste hazardous under Art. 1, paragraph. 1 (a) and (b) of Basel Convention.

5. Specifications

134. Specifications (see the footnotes related to “almost free from contamination and other types of waste” and “plastic waste almost exclusively consisting of” in entries B3011 and Y48 that refer to international and national specifications that may offer a point of reference) can be sourced from industry-wide standards, regional and national quality standards linked to the plastic waste trade.

135. For further information on specifications, consult the “Compilation of national and international specifications related to “almost free from contamination and other types of wastes” and “almost exclusively” for shipments of plastic waste destined for recycling” (UNEP/CHW.16/INF/56).

6. Inventories

136. Inventories can be an important tool for identifying, quantifying and characterizing wastes. When developing an inventory for plastic wastes, priority should be given to the identification of important waste streams (e.g., hazardous plastic wastes).

137. National inventories may be used to:

(a) Establish a baseline quantity of plastic products, articles and plastic wastes and products with a relevant content of plastic and related wastes;

(b) Establish an information registry to assist with safety and regulatory inspections;

(c) Assist with the preparation of emergency response plans;

(d) Track progress towards minimizing and phasing out specific plastic waste streams (e.g., single-use plastics).

138. For further information on the development of national inventories Parties may consult the methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention. (UNEP, 2015c). The guide focuses on the actions recommended to develop the national information systems that produce the information needed to assist countries in fulfilling their reporting obligations under the Basel Convention. In addition, Practical guidance on the development of an inventory of plastic wastes has been developed (UNEP, 2022f).

139. [Kept for consistency of paragraphs numbers]

E. Sampling, analysis and monitoring

140. Sampling, analysis and monitoring are important activities in the management of plastic wastes enabling the manager of the wastes and those who regulate its management to identify the composition of plastic types in some waste streams, the degree of contamination of the plastic wastes, as well as the presence and concentration of hazardous substances within plastic wastes.

141. Monitoring and surveillance serve as elements for identifying and tracking environmental concerns and human health risks.

142. The information obtained from the monitoring should be used:

(a) To detect any releases which cause any change to the quality of the surrounding environment;

(b) To ensure that different types of plastic wastes are managed in an environmentally sound manner;

(c) To identify potential issues relating to possible exposure to humans and determine whether adjustments to the management approach might be appropriate.

143. Sampling, analysis and monitoring should be conducted by trained professionals in accordance with a well-designed programme and using internationally accepted or nationally approved methods, carried out using the same method each time over the duration of the programme. They should also be subjected to rigorous quality assurance (QA) and quality control (QC) measures. Mistakes in sampling or analysis, or deviation from standard operational procedures, can result in meaningless data or even programme-damaging data.

144. Each Party should identify its sampling, analysis and monitoring needs and ensure it has laboratory and equipment capacity that will meet the required operating standards. Training and protocols should be in place to ensure that standards can be met, and that quality data and meaningful results can be obtained.

145. As there are different reasons for sampling, analysis, and monitoring, and because wastes come in so many different physical forms, many different sampling, analysis, and monitoring methods are available. For information on good laboratory practices the OECD series (OECD, various years) and the Handbook on Good Laboratory Practices (WHO, 2009) may be consulted. The next three sections consider key elements that should be included in sampling, analysis, and monitoring.

1. Sampling

(a) General considerations

146. The overall objective of any sampling activity is to obtain a sample that can be used for the targeted purpose, e.g., waste characterization, compliance with regulatory standards or specifications

or suitability of proposed treatment or disposal methods, and environmental monitoring. This objective should be identified before sampling is started. It is essential that quality requirements for equipment, transportation and traceability are met.

147. Standardised sampling procedures should be established and agreed before the start of a sampling campaign. Elements of these procedures include the following:

(a) The number of samples to be taken, the sampling frequency, the duration of the sampling project and a description of the sampling method (including QA procedures put in place, e.g., field blanks and chain-of-custody);

(b) Selection of location or sites and time or stage of sample-taking (including description and geographic localization);

(c) Identity of the person who took the sample and conditions during sampling.

(d) Full description of sample characteristics – labelling;

(e) Preservation of the integrity of samples during transportation and storage (before analysis);

(f) Close cooperation between the sampler and the analytical laboratory;

(g) Appropriately trained sampling personnel.

148. Sampling should comply with specific national legislation, where it exists, or with international regulations and standards. Sampling procedures include the following:

(a) Development of a standard operational procedure for sampling plastic wastes;

(b) Application of well-established sampling procedures;[69]

(c) Establishment of QA and QC procedures.

149. All these steps should be followed for sampling programmes to be successful. Similarly, documentation should be thorough and rigorous.

(b) Sampling of plastic wastes

150. Sampling of plastic wastes may be carried out to identify the composition of plastic types in some waste streams and the degree of non-hazardous contamination of the plastic wastes, as well as the presence and concentration of hazardous substances within plastic wastes. This information may be used to determine the suitability of disposal methods.

151. Microplastics samples can be sorted according to characteristics such as location, shape, polymer type, amount, size, colour or surface condition. The sampling methods for microplastics will differ depending on the compartment being sampled (sea surface or water column) and the size range of litter being monitored. A common challenge in any sampling effort is for the information collected to be as representative as possible. The abundance and distribution of plastic in the water surface and water column compartments are highly variable due to seasonal changes in river outputs, ocean currents or mechanisms of degradation and fragmentation. Some of the methods used for sampling microplastics include using ship intake water for sampling, bulk water sampling, pump sampling, Continuous Plankton Recorder (CPR), etc. Although standardized methods for sampling microplastics have not been established, some countries have developed specific methods for sampling microplastics in seabed and biota. (UNEP/GESAMP, 2019)

152. When carrying out sampling of plastic wastes, locations should be determined based on the objective of the sampling being undertaken. These could include:

(a) Points of collection of plastic wastes, including collection of marine litter;

[69] Such as procedures developed by ISO, ASTM, the EU, the United States Environmental Protection Agency (EPA), the Global Environment Monitoring System (GEMS), and the European Committee for Electrotechnical Standardization (CENELEC) (See Standard on Collection, logistics and treatment requirements for WEEE (Waste Electrical and Electronic Equipment) – Part 1: General Treatment Requirements, in particular specifications for de-pollution), and the European Committee for Standardization (CEN) (see EN 14899:2005 Characterization of waste - Sampling of waste materials - Framework for the preparation and application of a sampling plan and the series of CEN/TR 15310 1-5: 2006 Characterization of waste - Sampling of waste materials).

(b) Input and output of disposal facilities (e.g., material recovery and re-processing facilities);

(c) Points of reception of imported plastic wastes, e.g., ports.

(c) Sampling for environmental monitoring and biomonitoring

153. Pollutant emissions related to disposal and treatment of plastic wastes at respective facilities can include liquids, solids, gases, and others, which can be determined following the specific national legislation or international regulations and standards. Waste matrices typically sampled for monitoring emissions include:

(a) Liquids:

(i) Wastewater from plastic waste treatment/disposal facilities as well from the sewage treatment facilities (inlet and outlet);

(ii) Leachate from dumpsites and landfills;

(iii) Water (surface water, drinking water and industrial and municipal effluents);

(b) Solids:

(i) Consumer products;

(ii) Solids from industrial sources and treatment or disposal processes (e.g., fly ash, bottom ash, filter and scrubber residues, sludge and wastewater treatment sludge still bottoms, other residues, clothing, ash from dumpsite and landfill fires;

(iii) Soil, sediment (including in drains and water bodies near plastic waste disposal facilities), rubble and compost;

(c) Gases:

(i) Air (indoor);

(ii) Air (emissions);

(d) Biota and human biological samples (for the purpose of biomonitoring):

(i) Trout and other fatty fish in water bodies as well as soil living organisms, chicken and other biota feeding from the ground in the vicinity of plastic waste disposal facilities;

(ii) Bodily fluid and hair samples from workers in plastic waste-management and communities located near facilities.

154. Sampling for the purpose of monitoring should prioritize the investigation of pollutants specifically associated with the disposal of plastic wastes including, but not limited to, the following:

(a) Bisphenols and phthalates;

(b) Short chain chlorinated paraffins;

(c) Medium chain chlorinates paraffins;

(d) Per- and polyfluoroalkayl substances;

(e) Brominated flame-retardants;

(f) Relevant UV stabilizers such as UV 320, UV 327, UV 328 and UV 350;

(g) Relevant aldehydes such as formaldehyde;

(h) Heavy metals, in particular antimony, cadmium, lead and mercury;

(i) Polychlorinated dibenzodioxins (PCDDs)/ polychlorinated dibenzofurans (PCDFs);

(j) Polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/PBDFs).

2. Analysis

155. Normally, plastic waste analysis is performed in a dedicated laboratory. However, rapid developments in process instrumentation and real-time online detection equipment have enabled very sophisticated high-speed sensors to be used in-situ on sorting equipment and in the field (e.g., hand-

held X-ray fluorescence (XRF) detection of metals in plastics; online X-ray transmission sorting systems).

156. For analysis in laboratories, there are several analytical methods available. Therefore, Parties should verify the availability and costs of methods of chemicals, including POPs, relevant to plastics before developing a monitoring and sampling programme.

157. The main steps in the analysis are:

(a) To scope the sample group(s) e.g., source separated plastic, plastic from residual household waste, reprocessed plastic;

(b) To proceed with pre-treatment of samples;

(c) To select target analytes;

(d) To prepare samples (e.g., microwave assisted digestion with magnetic stirring);

(e) To select chemical analysis method (e.g., Inductively coupled plasma mass spectrometry);

(f) To proceed with statistical analysis of samples.

158. The analysis of microplastics is related to their particle size, shape, concentration, and chemical composition. For microplastics, it is often difficult to describe the sizes, shapes and polymer types fully and reliably, from complex environmental matrices, using a single analytical method. In general, microplastic analysis consists of two steps: physical characterization of potential plastics (e.g., microscopy) followed by chemical characterization (e.g., vibration spectroscopy) for confirmation of plastics. In special cases, co-contaminant chemical analysis is performed on extracted chemicals. Through physical characterization (done by visual observation with the naked eye, or by using microscopy), size (maximum dimension or particle image), shape and colour can be observed and recorded. Chemical characterization is a final step to identify microplastics from the other natural materials, when visual and microscopic observation is not enough to confirm the particle nature. The most common method used in chemical characterization of microplastic particles is spectroscopy (e.g., Fourier-Transform Infra-Red and Raman) (UNEP/GESAMP, 2019).

3. Monitoring

159. Article 10 (“International Cooperation”) paragraph 2 (b) of the Basel Convention requires Parties to “cooperate in monitoring the effects of the management of hazardous wastes on human health and the environment”.

160. Monitoring programmes should be implemented for facilities managing plastic wastes if appropriate, as they provide an indication of whether a plastic waste management operation is functioning in accordance with its design and complying with environmental regulations and serve as elements for identifying and tracking environmental concerns and human health risks.

161. Information collected from monitoring programmes can feed into science-based decision-making processes and can be used for the evaluation of the effectiveness of risk management measures, including regulations. Monitoring of plastic litter, both in the marine environment and on land, can provide information on the nature, extent and impact of plastic pollution, notably on which products are prone to be discarded outside the waste management system. Monitoring can also give information on the effectiveness of policy measures related to plastic waste management.

162. To measure the effectiveness of ESM practices at a facility, accurate and up-to date data are required on the precise effects of the activities of the facility on the environment as well as on individuals. Therefore, a planned, regular sampling and monitoring programme should be conducted.

163. Monitoring is not restricted to analytical measuring, it also includes regular maintenance, visual and safety checks.

F. Handling, separation, collection, packaging, compaction, transportation and storage

164. Handling, separation, collection, packaging, compaction, transportation and storage are important elements in the management of plastic wastes, including in relation to the prevention of plastic leakage. Procedures and processes for managing wastes should be considered for these activities, both for hazardous and non-hazardous plastic wastes, to prevent spills and leaks, e.g., through wind, resulting in worker exposure, releases to the environment or exposure of the community.

1. Handling

165. Plastic wastes should be handled appropriately to minimize risk to human health and the environment. It should be taken into account that wastes from polymer manufacturing and blending processes are often in the form of powders or granulates contained in bulk bags or containers. Post-consumer wastes are likely to be in bulky form and may require baling or bagging for transportation to waste processors. Employees should be supplied with appropriate protective clothing, trained in the safe handling of large/heavy containers and equipped with equipment such as sack-barrows, pallet trucks and fork-lift trucks.

2. Separation

166. Separation at source of generated plastic wastes increases efficiency and reduces costs related to segregating mixed waste and can improve the quality of the outputs from downstream pre-treatment, sorting and recovery operations. Source separation entails the sorting of plastic waste from other types of waste before collection as opposed to separation from other waste after collection. In order for source separation to be an effective approach, plastic waste generators should be given clear instructions and information about the required separation method prior to collection (e.g., by means of on-pack recycling labels or other simple separation instructions such as ‘clear drink bottles only’).

167. Source separation can be described as a form of multi-stream collection system in which the waste generator is responsible for manually sorting plastic wastes and placing them into designated bins or bags, to keep them separate by type or according to certain established criteria.

168. Source separation of post-consumer plastic packaging wastes may be performed in:

(a) Mono-material separation systems, where plastic wastes are segregated at source as one material fraction including more than one type of plastic together (as mixed plastics) or targeting specific plastic types (e.g., PET bottles, or rigid plastic such as pots, tubs and trays);

(b) Co-mingled separation systems, where several types of source separated dry wastes (e.g., metal and plastic wastes) are collected together.

169. The collection of clean plastic wastes that have been separated at source should be a priority as this will facilitate a simpler recycling process system and will generally produce recyclate polymers with a higher quality, with lower waste fractions and improved environmental performance (i.e., lower energy cost per tonne, reduced washing effluent flows).

3. Collection

170. Care should be taken in establishing and operating collection programmes for plastic wastes in order to increase the efficiency of the waste collection system.

(a) Household plastic wastes collection schemes

171. The three main recognized household plastic wastes collection schemes are:

(a) Source-separated or multiple-stream collection scheme;

(b) Co-mingled fractions or single-stream collection scheme;

(c) Residual waste or mixed waste collection scheme.

172. These schemes utilise the following collection systems for the collection of plastic wastes:

(a) Kerbside collection system: The system includes containers at ground level for collection from the street. Packaging plastic wastes are collected as a single stream or together (co-mingled) with a different waste fraction i.e., plastic and metal wastes are collected in the same bin;

(b) Door-to-door collection system: Door-to-door collection schemes involve a system whereby plastic waste streams in bags, bins, and/or containers are collected directly at households with regular frequency. Packaging plastic wastes are collected as a single stream or together (co-mingled) with different dry waste fractions i.e., plastic and metal wastes are collected in the same bin;

(c) Bring system (Drop-off) system: Consumers bring their plastic wastes such as plastic bottles and plastic bags to a certain collection site. While this is generally used for enhancing collection of plastic bottles, it could also be used for plastic bags and wraps, like grocery bags, zipper sandwich bags and some cereal bags, to be dropped off at depots and stores. Collection sites may include municipal staffed collection sites where several types of wastes (e.g., WEEE and bulky waste from households) can be brought by residents (civic amenity sites).

173. Deposit-and-return system (DRS): DRS is a system whereby consumers buying a product pay an additional amount of money (a deposit) that will be reimbursed upon the return of the packaging or product to a collection point. The system is based on offering an economic incentive for consumers to return empty containers to any shop to ensure that they will be reused or recycled. For beverage containers, these systems are already operating in many countries. The DRS could be expanded to other types of plastic packaging.

174. The highest quality plastic wastes are typically from separate collection via DRS, followed by kerbside separated/door-to-door collection. The quality will, however, also depend on the type and quality of further pre-treatment before recycling, such as washing.

175. The possibility of organizing selective collection schemes depends mainly on the volume of plastic waste collected separately and the frequency of collection. Collection schemes may be much more difficult for drop-off systems than for kerbside systems and in rural areas compared to urban or semi-urban areas. When selective collection is organized with compartmentalized trucks, both plastic wastes and residual household wastes can be collected simultaneously.

176. The informal sector, including individuals and small enterprises, is involved in the collection of plastic wastes. This is a common practice in geographies where the formal sector provides insufficient waste management (Wilson et al., 2006; Kumar et al., 2018; Hande, 2019). Collection of recyclables takes place from all possible places where access is possible, for example, open dumpsites, the streets, and door-to-door collection. For further information on these types of situations, see the guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP, 2019a).

177. Communities in mountainous and remote regions face challenges, due to the terrain, isolation, and remoteness, for the collection of plastic waste that may not be experienced in other regions. Such communities may rely heavily on the informal sector for plastic waste collection (see paragraph 178). Challenges in collection of plastic waste in these communities can stem from transportation, influx of plastic waste from those outside the community, e.g., tourists, or lower volumes of recyclable waste that makes separate collection difficult. Community-based solutions for the collection of plastic waste should be explored, such as raising community awareness of the value of plastics, incentivizing the return of plastic wastes, e.g., through a deposit program, and targeting tourist lodge owners to collect plastic waste for environmentally sound disposal (Alfthan *et al.,* 2016).

(b) Industrial, commercial, institutional, and agricultural plastic and other waste collection schemes

178. Collection of industrial and institutional plastic wastes, commercial packaging plastic wastes and agricultural plastic wastes could be organized by waste generators themselves, or with large drop-off containers rented by the generators and collected regularly by private operators. The collection systems should be designed in such a manner that the plastic wastes are transported to specialized treatment facilities. In the European agriculture sector, many countries have implemented collection schemes, funded by producers, which allow farmers to bring collected farm plastic wastes to organised hubs on specific dates and times during the year. This facilitates efficient manual sorting and baling of the various plastic types at those hubs using mobile baling equipment, prior to transportation to reprocessing facilities. Plastic packaging waste from hazardous pesticides, herbicides and other bio-active substances should be separately collected.

179. Plastic wastes originating from maritime activities such as aquaculture and fisheries, both as their own waste and marine litter that gets caught in the fishing gear of commercial fishing vessels (e.g., nets, trawls and ropes), should be brought back on land and delivered to port reception facilities.

180. Waste leakages from marine activities, e.g., loss of fishing gear, should also be collected and delivered to a municipally or privately operated waste management system, as should plastic wastes from clean-ups along beaches, rivers and waterways and other water bodies. This also applies to the unintended leakage of other plastics, such as plastic pellets. Special collection schemes may be applied to retrieve unintentionally lost plastic products. For instance, lost fishing gear can be located, e.g., by equipping the gear with GPS thereby ensuring targeted retrieval of lost gear. Plastic wastes from marine litter, collected by clean-ups or by fishing vessels, typically contain significant amounts of ropes and nets. Extra separation operations will therefore be needed to untangle the materials in order to facilitate recycling of the waste.

4. Separating and extracting plastic wastes from other waste streams

181. Efforts should be made to separate and extract plastic waste from other waste streams which contain a considerable volume of plastics such as WEEE, waste vehicles, construction and demolition

waste, waste cables and waste textiles. Source separation is the most desirable option. When this is not possible, effort should be made to separate plastics from the respective waste stream post collection to the extent that is feasible. Some of these wastes are large, and it should be ensured that collection and treatment infrastructure is in place that is capable of handling them. The method of separation of plastics from the waste stream will depend on factors like characteristics of the waste stream in consideration, availability of sorting technology, possibility of automation and associated cost. A 'one size fits all' approach may not be possible, and the appropriate method used for separation should be chosen based on the factors mentioned above.

182. For example, in very dense urban environments, source separation of plastic wastes can be difficult. In these cases, plastic wastes can be sorted out of mixed MSW. By using advanced sensor sorting technology and avoiding contamination with organic and paper waste in the mixed MSW, the quality of the resulting plastic wastes can be similar to the quality of plastic wastes from source separation systems. Other simpler techniques may result in plastic wastes of an inferior quality, in terms of physical/mechanical and other properties, to plastic wastes collected from source separation systems. For example, recyclate produced from plastic wastes from simple post-sorting operations can have a strong odour, particularly when the original mixed MSW contained organic waste. This can limit the possibility, or potentially make it impossible, to use the material in consumer applications.

5. Packaging

183. Packaging of plastic wastes falls into two categories: packaging for transportation and packaging for storage.

184. Packaging for transportation of hazardous plastic wastes is often controlled by national dangerous goods transportation legislation. For packaging specifications for transportation, reference materials published by IATA, IMO, United Nations Economic Commission for Europe (UNECE), and national governments should be consulted.

185. Plastic wastes, whether hazardous or not, should be properly packed for both ease of transportation and as a safety measure to reduce the risk of leaks and spills. For certain plastic wastes, baling might be appropriate. However, if this is an inappropriate size, transportation in big bags or closed bulk containers can be a reasonable measure.

186. Packaging of plastic wastes for storage should be conducted as follows:

(a) Plastic wastes should be properly packaged;

(b) In most cases packaging that is acceptable for transportation is suitable for storage, unless more stringent storage requirements are specified. Plastic wastes in the original containers of plastic products before becoming plastic wastes are generally safe for storage if the packaging is in good condition;

(c) Plastic wastes should not be stored in containers that were not intended to contain such wastes, that have labels on them that incorrectly identify their contents, or which may be contaminated;

(d) Containers that are deteriorating or deemed unsafe should be emptied or placed inside a sound outer package (overpack). When unsafe containers are emptied, the contents should be placed in appropriate new or refurbished containers. All new or refurbished containers should be clearly labelled as to their contents;

(e) Smaller containers can be packaged together in bulk by placing them in appropriate or approved larger containers containing absorbent material.

6. Compaction, shredding, compressing and baling

187. Plastic wastes from semi-finished product conversion, packaging wastes and other plastic wastes may be bulky and may contain more than one type of plastic waste. For economical transportation and storage some compaction may be necessary. The most common compaction processes are shredding, compressing and baling. Some plastics, such as EPS, should not be shredded but can be compacted. Compaction may destroy the plastic corpus which may contain important labels or markings from which technical information can be derived for the recycler. As such, compaction may not be appropriate if such technical information needs to be retained. With complete plastic items, it can be determined what the material it is and what additives it contains.

188. Shredding, compressing and baling should take place spatially separated from other technical equipment / process steps and a fire-prevention system should be installed. This is because explosive

substances may be contained in the waste (e.g., lithium-ion batteries in electrical appliances or spray cans with residual contents) due to incorrect disposal or sorting.

189. Shredding may be either a dry or a wet process. Wet shredding is used not only to achieve compaction but also to begin the process of cleansing the plastic residues of paper labels, glue and dirt. Both baling and shredding require properly trained and equipped personnel, including occupational exposure protection strategies for the processes, as well as processes for handling wastewater and other wastes from the shredding.

190. Wherever possible, sorting into single material streams should be undertaken before the compaction process. However, shredded material may not be accepted in certain cases because quality standards beyond common sorting processes are required.

191. Mixed plastic wastes should only be shredded if there is an assured application for the mixed output or if a post-shredding sorting system is available to produce single material streams of acceptable quality.

192. Shredding should be conducted as follows:

(a) Shredders should be constructed and installed so as to protect the operator from flying fragments, hazardous substances, entangling film waste and noise, in addition to protection from other types of health hazards during the process;

(b) Shredders should be protected from metallic contamination by metal detector/removal systems, if a shredder is not able to handle metal contamination;

(c) Before shredded material is re-processed it should be dried and/or conditioned to the specification used by downstream industry/waste processors.

193. Baling is suitable for component, film and bottle wastes. Baling should be conducted as follows:

(a) The size and form of the bale should be optimized for its transportation and further processing;

(b) Over-compaction of baled plastic waste may weld the waste together producing a solid mass that can be difficult to separate;

(c) It should be considered that compacted bales contain considerable mechanical energy. The rust-resistant steel or polyester strapping should be strong enough to contain the long-term load of the compacted material;

(d) Care should be taken when opening bales to avoid injury caused by the sudden release of compacted materials;

(e) It should be taken into account that under-compacted bales may be unstable;

(f) Bales should only be handled by means of a pallet truck or fork-lift truck due to the potential large weights involved.

194. The compressing of plastic waste may be carried out to facilitate storage and transportation, depending on the nature of the wastes and the method of subsequent treatment. For example, wastes with high moisture content may not be suitable for compression.

7. Transportation

195. The transportation of shredded or baled plastic waste requires considerable attention to the stability and protection of the load. Bags and bales should be stacked no more than 2.5 meters high, and the load should be secured either with strong ropes or tarpaulins. Loads should be protected from weather and vandalism. When loading and unloading plastic wastes, particular care should be taken to ensure the safety of workers. Plastic wastes should be prevented from entering the environment during transportation.

8. Storage (D15 or R13)

196. Plastic wastes in shredded or baled form should be stored on clean concrete floors. If plastic wastes are stored indoors, a fire-prevention system should be available to prevent fires and ease firefighting. If plastic wastes are stored outdoors, it should be protected from contamination and weather damage by means of tarpaulins or other suitable weatherproof covering. This will also help prevent plastic leakage, e.g., through wind drift. Protection against fire should also be in place. Contamination of plastic wastes from dust and dirt can be avoided by the use of pallets.

197. Plastic wastes stored outside should be covered with a UV-protective material as polymers degrade with prolonged exposure to UV light, resulting in the deterioration of the physicochemical properties of the plastic.

198. Storage space should not be completely occupied by plastic wastes. There should be access to all areas for handling equipment and for emergency services vehicles. There should be sufficient exit paths from the storage area for employees and they should be well marked and easy to find. The storage area should be secured against unauthorised entry. Fire-fighting equipment should also be readily available (see section H below).

G. Environmentally sound disposal

1. General considerations

199. According to the waste management hierarchy, prevention, minimization, reuse and recycling should be prioritized over other recovery operations and final disposal operations. For pursuing recycling and recovery of plastic wastes, the guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous wastes and other wastes (UNEP, 2019c) may be useful.

200. Disposal operations relevant to plastic waste and provided in Annex IV, part A and B of the Basel Convention are the following, ordered according to the waste management hierarchy, whereby operations that take place prior to the submission to the following operations are addressed in paragraph 214:

(a) R3 Recycling / reclamation of organic substances which are not used as solvent;

(b) R1 Use as a fuel (other than in direct incineration) or other means to generate energy;

(c) D5 Specially engineered landfill and D10 Incineration on land.

201. Some disposal operations that occur prior to the submission to any operations referred to in paragraph 202 above are applicable to plastic wastes. These operations are addressed in sections F.5, F.6, F.8 and G.2 and include the following operations:

R12 Exchange of wastes for submission to operations R1, R3, or R13;
R13 Accumulation of material intended for operations R1, R3, or R12;
D9 Physico-chemical treatment prior to submission to operations D5, D10, D14 or D15;
D13 Blending or mixing prior to submission to operations D5, D9, D10, D14 or D15;
D14 Repackaging prior to submission to operations D5, D9, D13 or D15;
D15 Storage pending operations D5, D9, D10, D13 or D14.

202. It should be noted that some applicable disposal operations for plastic wastes containing or contaminated with mercury or POPs are different than those identified in paragraph 205 and 206. Specific guidance on the environmentally sound disposal operations applicable to plastic wastes containing or contaminated with mercury or mercury compounds or POPs is provided in the technical guidelines on the ESM of wastes consisting of, containing, or contaminated with mercury or mercury compounds (UNEP, 2022c) and the general technical guidelines on the ESM of wastes consisting of, containing or contaminated with POPs (UNEP, 2022), respectively.

203. Plastic waste recycling (operation R3) can be categorized as follows:

(a) Mechanical recycling, whereby plastic waste is processed by sorting, size reduction, cleaning and drying, thermal melt-extrusion and pelletizing, and compounding;

(b) Solvent-based recycling whereby plastic waste is dissolved in a solvent and the polymer is separated from constituents (e.g., flame-retardants) from plastic waste using solvents while keeping the plastic polymer molecules chain largely intact (solvent-based purification);

(c) Chemical recycling is an emerging technology, whereby plastic polymer molecules are broken down into smaller component parts (monomers or oligomers), subjected to further processing and used as base chemicals, including feedstock for plastic manufacture (feedstock recycling). Chemical Recycling, an evolving field, may be a complementary technology to mechanical recycling for certain plastic waste types. More evidence is needed on the applicability of the ESM concept to chemical recycling.

204. Plastic waste recycling can be hindered by other methods of plastic waste disposal. For example, energy recovery of plastic wastes may become competitive in financial terms and reduce

plastic waste recycling. Parties may consider introducing policy, regulatory and financial instruments to prioritise plastic waste recycling over other recovery and final disposal.

205. The recycling of plastic wastes can be challenging because of the wide variety of uses, additives, and blends that are used in a multitude of products. Recycling can be either reprocessing into the original product application with equivalent properties (closed-loop recycling) or a different plastic application with similar material properties (open-loop recycling).

206. As noted above, closed-loop recycling refers to a recycling method in which recycled plastic wastes are processed and returned to their original use. A well-established example of closed-loop recycling is bottle-to-bottle recycling. Open-loop recycling refers to the recycling process whereby plastics wastes are converted into new use. An example of open-loop recycling is the recycling of waste PET bottles into polyester staple fibre, polyester filament, film, etc. When choosing closed-loop recycling or open-loop recycling, inter alia the physical properties, and the environmental benefits should be considered. Improving the quality of the recycled materials, as well as supporting and improving markets for secondary materials, should be promoted.

208bis. Regarding recycling of plastic applications with direct human exposure, national legislation for the use of recycled plastics in such applications should be in place to protect human health. For example, for recycled plastic used for food contact materials, national legislation is in place in the European Union to prevent or minimize migration of substances into food (FOOTNOTE: See regulation EC 1935/2014 on materials and ….).

2. Mechanical recycling (covered by R3)

207. Mechanical recycling is commonly used to treat thermoplastic polymers such as PP, PE and PET. Thermoplastics polymers are better suited for mechanical recycling compared to thermosetting polymers because thermoplastics can be re-melted and reprocessed into new products with relative ease.

208. Mechanical recycling can be divided into the following main process stages:

(a) Physical sorting, size reduction, cleaning and drying to make purified, polymer flakes (see subsections (i) to (iv) below);

(b) Thermal melt-extrusion and pelletizing to make shaped profiles or wide sheets, or homogenous polymer pellets (see subsection (v) below); and/or compounding to make recyclate pellets with improved mechanical properties to meet the quality specifications for end-use product applications (see subsection (vi) below).

209. There are multiple configurations of equipment and individual unit operations to create a complete mechanical recycling process. Various designs, methods and approaches having been developed for the very wide range of different plastic waste streams. Some of such methods are ‘mature technologies’ (e.g., PET bottle recycling), while others are new and still evolving (e.g., robotic artificial intelligence (AI) sorting machines, or combined laser light, X-ray and induction sensor sorters).

210. Direct recycling of plastic wastes refers to the direct thermal plasticization of plastic wastes, followed by profile or shaped product forming. Normally this simplified ‘direct’ process can only be applied to clean, single-polymer industrial waste streams (e.g., the waste mould-flow sprues ejected from an injection forming process being immediately granulated and re-moulded). However, when this practice is conducted within an existing industrial process facility, the material may not become ‘waste’.

211. Table 14 describes some of the generic processing unit operations employed for mechanical recycling of plastic wastes. However, it should be noted that every individual design of a facility will utilize its own set of equipment items, machinery layout and sequence of techniques needed for obtaining high-quality output recyclates from the particular mix, type and format of the incoming plastic waste streams.

Table 14: Mechanical recycling operations (not necessarily sequential)

Process	Description
Sorting: 1. To remove non-plastic materials including contaminants	Sorting methods are used to separate plastic wastes, remove non-target materials including contaminants and purify to a single polymer type. The main separation methods are manual separation, size & shape sorting, induction sorting, magnetic ferrous removal,

Process	Description
2. To separate individual polymers or similar plastic types 3. To separate plastic wastes that are difficult to recycle or not suitable for recycling, 4. To separate hazardous plastic waste 5. To sort by colour	eddy current metal separation, air-flow separation, automatic sensor sorting of materials, float-sink density separation and hydro-cyclone density separation. Other novel techniques are employed based upon any detectable physical differences in materials.
Size Reduction: Granulation / grinding Shredding / chopping Milling / comminution Crushing / impaction	Size reduction is used to chop plastic wastes into small flakes or chips, liberating joined materials & enables downstream separation (e.g., metals, glass, paper) and separating different plastic types (e.g., PET bottles from PP lids).
Cleaning / Washing	Manual or machine cleaning methods are used to remove various non-target materials or contaminants , such as oils, dust, dirt, biodegradable waste, labels, adhesives and printing inks from the surface of waste plastics. Can be wet or dry-friction methods.
Drying	Drying is used to remove surface moisture after wet washing.
Melt-Extrusion	Melt-extrusion consists of gradually heating plastic flakes by heated barrel and its friction with a rotating screw to form a melt that is shaped through a rod die-head to prepare the extrudate for pelletizing.
Pelletizing	Pelletizing creates recyclate pellets for further application by chopping of water-cooled strands or by direct die-face cutting to make small pellets with uniform flow characteristics.
Compounding	Compounding may be conducted through physical modification (by mixing of additive components before extrusion) or chemical modification (by adding active ingredients before extrusion).

212. Some examples of mechanical recycling steps for specific types of post-consumer plastic wastes are the following , not necessarily taking place in the same facility:

(a) PET bottles: Sorting (including colour sorting) → grinding → washing → separating → drying → processing into PET bottles, polyester fibres, sheets or containers;

(b) LDPE films used in agriculture and industrial packaging: Pre-washing → grinding → washing → separating → drying → melt-filtration → processing for example into refuse bags or agricultural films;

(c) PVC pipes: Grinding → washing → separating → drying → reprocessing into similar or other applications;

(d) EPS fish boxes: Sorting → washing and drying → grinding → regranulation and melt filtration → reprocessing into PS or EPS pellets or product;

(e) Mixed WEEE and/or ELV plastic waste: Sorting and separation → shredding and separating of plastic from metal fractions → screening and size reduction → air-separation of fluff and dust removal → density separation in modified liquid media → spin-drying → sensor sorting → colour sorting rubber and elastomer removal → bulk-mixing in silo → extrusion compounding → de-gassing → melt-filtration → pelletisation.

213. Operators of mechanical recycling facilities should ensure that they take such steps as are necessary to prevent consequences to human health and the environment and, if such consequences occur, to minimize them, such as the following:

(a) Air emissions in the form of dust and volatile organic compounds (VOCs) (He et al., 2015);

(b) Wastewater releases for example from the washing of plastics flakes;

(c) Indirect air emissions associated with heat production (e.g., for flake washing), if the heat is generated on-site by gas, oil, etc;

(d) Site littering;

(e) Unsound residuals management such as dumping and open burning of unrecycled fractions;

(f) Unnecessary water use , e.g., for washing, sink float separation, and pellet cooling;

(g) Retention of hazardous substances into recyclates e.g., from additives or contaminants, unless otherwise regulated under final product specifications;

(h) Contamination of the recycling site and surrounding areas with POPs as well as other hazardous substances (Tang et al., 2015);

(i) Pellet loss (Karlsson et al., 2018).

214. In most cases, well managed material handling, process safety procedures and good housekeeping can minimize the risk of these adverse impacts taking place, when carried out under professional supervision and within a waste management regulatory control system.

215. Certain types of plastic wastes are not suitable for mechanical recycling. This can for example be due to the complexity of the physical structure of the wastes and the way different polymer types and other materials have been combined within the original product design. Examples include thermosetting plastic composites, where the plastic resin cannot be thermally re-formed and the fibres are very difficult to remove, and thin-walled, multi-layer packaging films made with various plastic and metallic layers bonded together.

216. It is important to remove plastics that contain or are contaminated with additives, processing aids or other substances, notably POPs or SVHC (see Tables 6 and 7), to an extent to render the waste hazardous
, difficult to recycle or not suitable for recycling, in order to avoid contamination of subsequent recycling and manufacturing processes. Where such removal is not possible or difficult, it is important to manage the subsequent recycling and manufacturing processes accordingly.

217. With the currently applied pre-treatment technologies, such as sorting, washing, float-sink and grinding, there may still be contaminants present in the post-consumer plastic waste, as these techniques are not able to thoroughly clean the polymers and remove the impurities embedded in the polymer structure. Solvent-based extraction methods can be applied to remove target additives from the polymer matrix without dissolving (Kol et al 2021).[70]

218. Kept for consistency purpose only

(a) Sorting

219. Sorting can be classified into manual sorting, automated/mechanical sorting, float-sink separation, liquid density separation, electrostatic separation and sorting by hydro-cyclones and centrifugal sorting. Automated/mechanical sorting technologies can be broadly classified into screen separators, air separators, ballistic separators and film grabbers based on their ability to sort items based on particle shape, size and density (see table 15). Furthermore, based on their ability to remove different types of metals from the waste stream, they can be classified into overband/conveyer head-roller magnets, eddy current separators, and induction sensors. Sensor based sorting and robotic sorting are examples of advanced forms of automated sorting.

220. Since plastic wastes may be mixed with impurities and other types of plastic wastes, which may not only cause difficulty in recycling plastic wastes but may also greatly affect the quality of the products produced, plastic wastes should be separated from non-plastic wastes (e.g., metals, rubber, sand, fabrics) through sorting and, where appropriate and feasible, sorted into single polymer types.

221. Manual sorting involves identification by shape, colour, appearance of the plastic that distinguishes it for visual identification by the operators (Ruj et al., 2015). Manual sorting operations may be a pre-sorting stage before or after mechanical sorting in order to remove unwanted or contaminated input materials and improve the efficiency of a downstream-automated process. Manual sorting may also be used in final quality checks at the end of a sorting process to ensure that sorted plastics meet technical specifications.

222. Manual sorting may be suitable when larger plastic items are present in large amounts in mixed waste and have not yet been size reduced to small flakes, or when separating different polymer types from mixed plastic wastes. In most cases, when plastic items or particles to be sorted are below circa 75 to 100mm in size, then manual sorting will become overly laborious and not be practicable.

[70] Solvent-based extraction techniques such as the dissolution-precipitation technique have shown to be able to remove target additives from the polymer matrix as well as to selectively recover different polymers.

223. Manual separation of plastic wastes into single plastic material streams could be performed directly from piles of plastic wastes or from the surface of sorting conveyors. In both cases manual sorting requires experience, knowledge, dexterity and concentration for long time periods. In many cases, the use of polymer-type labels (see Table 1) on individual items or components is not practical.

224. Manual sorting can be augmented by the use of hand-held analytical instruments and sensors to rapidly test individual polymer pieces in the field or sorting yard. However, sample test times above circa 30 seconds per item can make this impracticable for all but the largest items (e.g., whole car bumper assemblies).

225. For workers involved in manual sorting, there should be appropriate working conditions (e.g., provision of personal protective equipment, adequate safety training, proper ergonomics to reduce worker strain (see for example Illinois Recycling Association, 2010)).

226. Automated/mechanical sorting should be used where appropriate to increase the separation efficiency and is most effective at industrial scale (i.e., 5,000 to >50,000 tonne per annum input waste volume). The exact method of identification, separation and sorting can depend upon a wide range of physical and chemical properties of the plastic and the contaminant materials, as well as the size, shape and format in which it is presented to the sorting equipment. Automated mechanical sorting systems for plastic wastes can include a very wide range of technologies and separation methods.

227. Screen separators, air classifiers and ballistic separators are used for the removal of small, light, 2D pieces such as film and paper and for removal of heavy pieces such as glass and stone. The separation method depends upon the physical size, shape (i.e., 2 or 3 dimensions), density and mass of the sorted items. The creation of a waste stream which has a uniform range of particles or items within a controlled size and shape format is important for the successful application of downstream sorting methods. Table 15 below provides an overview of size, shape and density sorting technologies.

Table 15: Overview of size, shape and density sorting technologies (automated/mechanical sorting)

Technology	Sub- Type	Description
Screen separators	Trommel screen	An angled rotating cylinder with holes that allows wastes of a given size to fall through.
	Disk Screen	A bed of vertical-spaced discs that transports large waste items but allows smaller items to drop through the gaps.
	Oscillating screen	A vibrating/oscillating declined bed that allows smaller waste to pass through holes in the mesh deck while transporting larger wastes to the end.
	Flip-flop screens	A flexible, oscillating screen deck is used to transport material down an inclined belt. The resulting motion allows smaller items to pass through the set size of hole in the screen deck. Particularly useful for sticky or wet materials which have a tendency to clog screen holes.
Air separators	Zigzag air classifier	Waste is dropped through an upward air current in a zig-zag shaped flue. Light wastes are blown to the top, while heavier wastes fall to the bottom.
	Rotary air classifier	A trommel screen separator with an air current that captures the lightweight fraction.
	Cross-current air classifier	Wastes are fed on a conveyor and dropped through an air stream. The light components are blown horizontally to a collection point and the heavy components drop through.
	Suction hood	Sucks light weight wastes directly from the conveyor belt.
Ballistic Separator	N/A	A steeply inclined bed with a perforated plate screen deck, with alternate vibrating elements. Light fractions are lifted by cams to the top of the bed, heavy fractions fall to the bottom.
Film grabber	N/A	Wastes are accelerated onto a rotating drum with spikes. These hook plastic film and let other waste drop.

Source: International Solid Waste Association (ISWA) 2017

228. In most cases it is sensible to remove unwanted metallic contaminant prior to any size reduction or further material-type separation. Normally this follows a logical three-step approach to metal removal:

(a) First – Ferrous and magnetic metals (cast iron, mild-steel);

(b) Second – Non-ferrous metals (aluminium, copper, brass, zinc etc.);

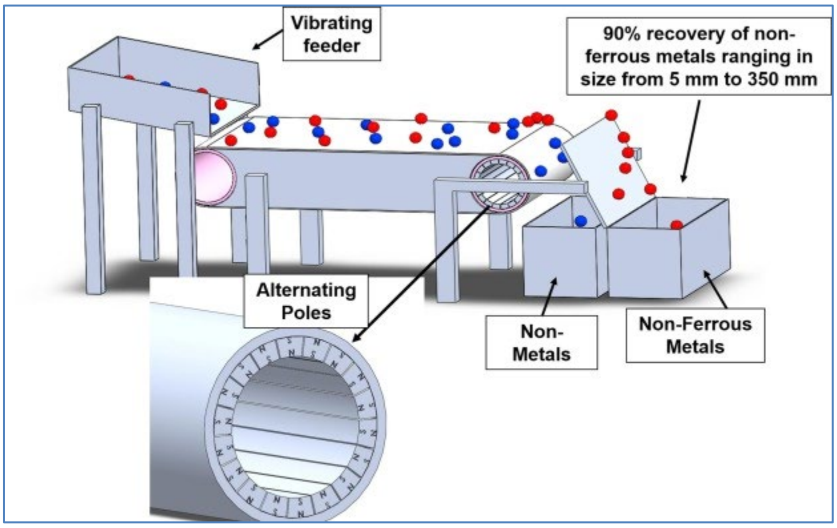
(c) Third – Stainless-steels and metal composites (304 / 316– stainless grades).

229. Based on their ability to remove different types of metals from the waste stream, automated sorting technologies can be classified into overband/conveyer head-roller magnets (removal of magnetic/ferrous metals), eddy current separators (sorting of non-ferrous metals), and induction sensors (sorting of stainless steel and composites).

230. Overband magnets can be used to lift ferrous metal from the moving waste stream, and often move the trapped metal items away to a side-located metal waste bin. Belt-conveyor head-roller magnets attract and hold ferrous metal items onto the conveyor belt as it passes over and back under the cylindrical top-roller, while other non-magnetic waste drops down its natural ballistic path under gravity. A splitting plate is normally positioned just below the roller, between the two different falling paths, to ensure a good separation and capture of the recovered metal parts.

231. Eddy current separators (see Figure 3) are used to separate non-ferrous metal contaminant items, e.g., copper, aluminium, brass, zinc with pieces at 5 to 30 mm nominal size. The plastic waste stream is passed over a very high-speed rotating magnetic roller that induces a rapidly changing magnetic flux field up through the transfer conveying belt and this causes an induced electric current inside each moving conductive metal particle. The resulting repulsive force causes the metal item to 'jump up' and away from the belt, so that it follows a higher trajectory ballistic path, enabling a separation plate to divert most metals away from the bulk plastic stream.

Figure 3: Eddy Current Separator – generic operating principle



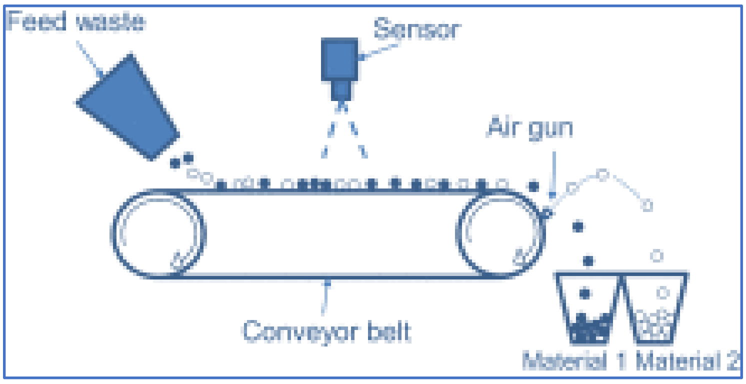
Source: York et al (2019)

232. Sensor-based sorting machines, with induction loops positioned immediately below the sorting conveyor belt, can be used to detect and then eject stainless steel and/or composite conductive items as they pass through the electro-magnetic field generated by the induction sensor loop. The exact position and approximate size of the metallic item are detected by the electric signal induced in the loop and this information is rapidly analysed to trigger an air-jet pulse that blows the unwanted contaminant particle away from the bulk flow of plastics as it leaves the end of the belt. In many cases, this type of detection technology is combined with over-belt optical and X-ray sensor methods to provide additional identification and characterization information during a single pass along a multi-material sorting (e.g., Near Infrared (NIR) / XRF / Induction combined).

233. Automatic sensor-based technology can be used to sort materials according to its type. Sensor-based sorting technology (see Figure 4) including, but not limited to, near infrared (NIR), mid infrared (MIR), laser-induced breakdown spectroscopy (LIBS), visual spectrometry (VIS), XRF and, (X-ray transmission (XRT) enables separation of plastics by polymer type, plastic density or colour, as well

as removing other materials (e.g., paper/cardboard, glass and metals) thus optimizing the plastic waste recycling process and ensuring a higher final quality. In most applications, mixed plastic wastes are transported on a fast-moving conveyor under strong light or X-ray source where high-speed sensing cameras record the position, shape and reflected light or wave signals and make instant analysis of the received spectrum. This allows the polymer type and certain additive chemicals to be identified. Immediately post-detection precisely controlled compressed air-jets are used to eject the sorted items away from the bulk material flow at the end of the transport cover, with splitting plates positioned to affect the final separation process.

Figure 4: Generic layout for most over-belt, sensor-based sorting detect-and-eject methods



Source: Serranti et al (2019)

234. Advanced, automated sensor sorting can also be used to separate plastic wastes from mixed, residual MSW. In addition, these technologies can be used to sort plastic wastes separated and extracted from bulk flow streams of other waste streams, such as mixed WEEE, ELV and mixed construction waste, as described in section F.4. Table 16 provides an overview of available sensor sorting technologies. Constant and rapid technology developments are continually adding new and novel sorting methods to this family of sorting methods. Modern flake sorting designs of sensor equipment can operate on particles as small as 3 to 10mm, but for whole packaging items the normal size of sorted items is in the 40 to 300mm range.

Table 16: Overview of sensor sorting technologies

Near infrared (NIR)	Used to differentiate between plastic types (PET, HDPE, PVC, PP and PS) and to differentiate plastic waste from mixed, residual MSW and other materials such as paper and metals.
Visual spectrometry (VIS)	Used to identify materials based on colour
X-ray Fluorescence (XRF)	Used to differentiate between metals / alloys (for example, copper from steel). Also used for potential POPs or SVHC screening of brominated, chlorinated and fluorinated plastic additives
X-ray Transmission (XRT)	Identifies materials based on atomic density – for example, halogens and organic components, mineral fillers, hidden metal particles inside plastic parts etc.

Source: Cuauhtémoc et al (2021)

235. Robotic sorting is an advanced form of automated sorting. Robots can identify specific products using cameras and analyse images against an internal database of products identified by shape, size, colour, and texture. Typically, rapid speed mechanical arms and grabbers are used to pick and deflect the selected items from the bulk material flow. These systems can also utilize a wide range of detection sensors and camera types, in a similar approach to the over-belt sorting equipment described above.

236. In certain cases, float sink separation and liquid density separation can be used to separate various types of polymers. For float-sink separation, small flakes or particles of mixed plastic are fed into a vessel or tank filled with liquid of a known and controlled density. Plastics in the mix which have a solid density lower than the liquid separation medium will float; those plastics heavier than the liquid density will sink.

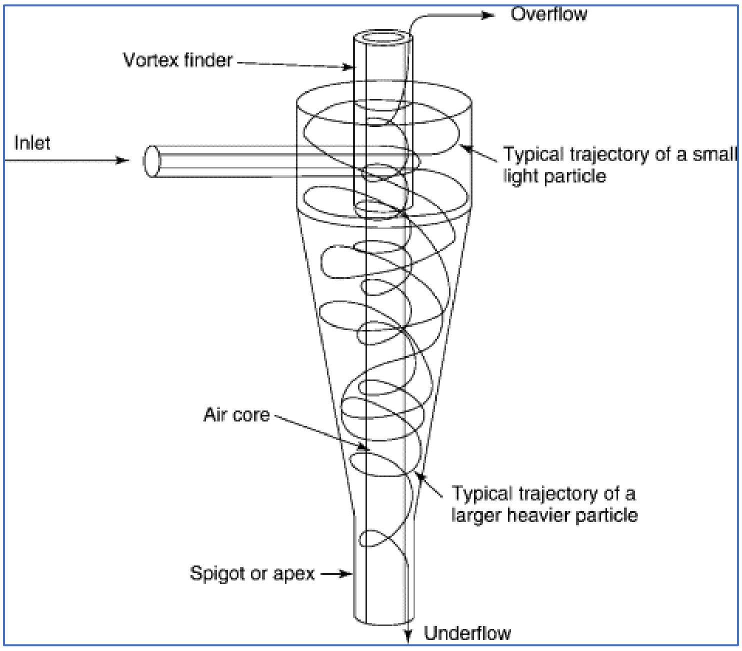
237. Water is most commonly used as the separation liquid, to create a density separation at a specific gravity of 1.00. Other fluid densities can be achieved by making controlled salt solutions or adding suspended solids as fine powders to create density split points at up to a specific gravity of 1.40 (Ragaert et al, 2017).

238. Float-sink separation in water can effectively separate polyolefins (PP, HDPE, LDPE) from PVC, PET and PS, with higher liquid salinity, for sink-float sorting of PS and ABS (in the range of a specific gravity of 1.08 to 1.20). Use of different media can allow separation of PS from PET, but PVC cannot be removed from PET in this manner as their density ranges overlap. In fact, a density gap of 0.1 to 0.2 g/cm³ is recommended to enable a successful float-sink separation with reasonable purity of fractions.

239. Float-sink separation is not effective for separating plastics with similar density. Electrostatic separation can be used to separate polymeric materials of the same or very similar density (e.g., ABS and PS). The principle of electrostatic separation is based on differences in electrostatic forces acting on particles of the mixture exposed to the electric field. The effectiveness of electrostatic separation depends, among others, on the size and shape of particles in the mixture (which has a stochastic character), environmental conditions like humidity, pressure and temperature, the moisture content of the mixture as well as its voltage level, the configuration of the electrode system, and the position of the feeding unit. (Rybarczyk et al, 2020) A plastic containing BFR additives has a higher density (circa +10% higher) than the same plastic without BFR. This density technology can be used to sort plastic waste separated and extracted from WEEE and ELV, as the polyolefin and styrenics floated fraction obtained are almost free of BFRs. BFRs (minor impurities in the ppm range) can persist, but the vast majority of BFRs should be separated into the denser plastic residuals.

240. Hydro-cyclones are based on the principle of centrifugal acceleration to separate plastic waste mixtures by density. A hydro-cyclone transfers fluid pressure energy into high-speed rotational fluid motion (see Figure 5). This rotational motion creates a strong centripetal force within the spinning liquid chamber (i.e., a G-force of multiple times gravity) causing a rapid and strong relative movement of solid particles suspended in the fluid in relation to the particle and fluid density, thus permitting rapid density separation of materials from one another. Hydro-cyclones have a very high throughput rate and result in highly accurate density separation if plastic particle size is small (<6mm nominal size) and of a regular shape.

Figure 5: General configuration liquid hydro-cyclones



Source: Makenji (2009)

241. A similar sorting process for shredded plastics is centrifugal sorting. A cylindrical water-filled centrifuge is used for this purpose and the whole body of the chamber is rotated at very high speed to induce a centrifugal force within the liquid suspension (with up to ~300 G-force). The technique can selectively separate plastic flakes from a mixture of polymer waste materials (Karaman et al., 2015). Various designs of industrial scale continuous power-driven centrifuges are available to provide very accurate density separations of plastics.

(b) Size reduction

242. Shredding, granulation, crushing, cutting, chopping, milling and grinding are mechanical methods for the size reduction of plastic waste items. Selection of the appropriate machinery and method will depend upon the input size of the waste stream, the size and thickness of the items and the toughness of the plastic type as well as the plastic waste format (e.g., solid mouldings, flexible films, woven textiles etc). Size reduction is a necessary process for plastic waste recycling, which delivers a controlled particle size range to the downstream sorting process while also enabling separation of different material types from complex waste components (e.g., HDPE screwcaps from PET beverage bottles; brass screw inserts from electronics casings). Size reduction methods for plastic wastes can be divided into dry and wet systems, but the dry method is most commonly used for cleaner plastic waste streams.

243. When using a dry method to shred or grind plastic wastes, dust prevention and noise reduction equipment is recommended. When using a wet method to crush plastic wastes, the use of a liquid effluent filtration system is recommended to prevent small particles from entering the wastewater.

244. Regardless of which size reduction method is used it is advisable to acquire efficient, energy-saving technology, equipped with effective safety protection measures. Cutting blade wear rates and replacement parts also contribute significantly to operating costs.

(c) Cleaning

245. Plastic wastes may be contaminated with dirt, dust, oils and greases and other wastes. Effective surface cleaning of plastic wastes is vital to reduce impurities before entering a thermal extrusion or granulation process and to reduce consumption of polymer-melt waste in particle filtration screens.

246. Many designs and configurations of cleaning machinery using liquids, in particular water, exist, as well as complete multi-stage plastic washing processes. Mixing, stirring, scrubbing, surface friction, abrasion and high-pressure liquid jets are all employed to remove surface dirt, dust, oils, paints, adhesives and paper-labels etc. The addition of chemical detergents and other cleaning agents (e.g., caustic soda) is common, as is the use of hot-water to provide more effective cleaning (e.g., for label-glue removal from bottles)

247. A circulating liquid system can be used for cleaning plastic wastes and fresh liquid should only be used to supplement the system losses. Phosphorus free cleaning agents or other green cleaning agents are preferable.

248. The cleaning liquid should be collected, assessed for contamination and treated before release to the environment or recycled within the recycling unit.

249. Dry cleaning recycling systems, where water is not required, may be used to pre-clean plastics from sand, stones, glass, paper, etc.

(d) Drying

250. Drying of plastic wastes is carried out to remove excess moisture.

251. Commonly used plastic waste drying technologies include centrifugal spin-drying, air-blast drying, fluidized bed drying, infra-red drying and these often include heated airflow to increase the drying rate.

252. Most common plastic types (e.g., PE, PP and PS) need to be dried to below circa 0.5% water prior to feeding into thermal melt processing equipment. Certain polymer types require much longer drying times to remove all traces of absorbed moisture from within the plastic granules (e.g., PET, ABS, PC, Nylon), otherwise cosmetic and structural problems will result post-extrusion and during moulding.

253. The gas produced by drying of plastic wastes should be treated appropriately before being released to the atmosphere in particular if it is odorous or it contains harmful volatile contaminants.

(e) Thermal melt-extrusion and pelletizing

254. Plastic extrusion processing equipment is the most commonly used method for the final stages of mechanical recycling. Electrical power is used to rotate mechanical screw elements within a heated metal barrel. The combined effects of the physical screw mass-transfer forces and the applied barrel heaters melts the waste polymer flakes and mixes and blends the input raw material components to make a homogenous polymer compound with consistent material properties.

(a) Melt-Filtration - Metal wire-mesh melt-filter screens are often used to remove the final traces (to reach below ~0.5% of plastic mass) of solid particulate contaminants during high-pressure polymer melt flow through a heated extruder screw-and-barrel machine. Used filters should be collected and re-processed;

(b) Pelletizing - The molten output flow leaving the extruder is normally shaped into the form of filament strands by a multi-port die-head, and then cutting or ‘chipping’ is applied to create small (circa 2 to 3 mm) solid plastic pellets. Cooling water baths plus strand-chippers or die-face cutters with pumped water-rings are frequently used to solidify the plastic pellets ready for bagging or bulk storage in silo;

(c) Profile Extrusion - Alternatively, thermal extrusion equipment can be fitted with direct shape-forming die heads to make continuous shaped profiles (e.g., PVC window frames) or wide sheets to create rolls of thin plastic suitable for onward shape forming (e.g., vacuum forming of flowerpots and trays).

(f) Compounding

255. The main purpose of compounding is to make recyclate pellets with improved mechanical properties to meet the quality specifications for end-use product applications. Cosmetic improvements to colour, odour and surface finish can also take place during extrusion compounding of plastic. All of these improvements increase the quality of the recyclate. Compounding may be conducted through physical or chemical modifications, as follows:

(a) Physical Modification - The most common methods for compounding involve the physical mixing of additive components at an accurately controlled mass-ratio to the main recycled plastic waste infeed at the extruder barrel inlet-port. Typical additives that effect physical changes to the output recyclate properties are fillers, impact- and flow-modifiers, fibre re-enforcements, plasticizers, antioxidants, UV-stabilizers etc. Pigments and dyes are commonly added to meet a defined output plastic colour specification. In all cases, a thorough and complete blending, dispersion and mixing of the additive components is important to create a consistent and homogenous output recyclate quality (as described in Table 5 – Additives);

(b) Chemical Modification – during compounding it is possible to effect chemical changes to the recycled plastic waste input by the addition of active ingredients to the input mixture and by control of the physical conditions within the extrusion barrel (e.g., temperature-time profile, degree of shear-mixing and barrel pressure). Typically, chemical improvements to the polymer molecular structure are the desired outcome, with re-building of chain-length, cross-linking bonds, modified crystallinity and improved phase-mixing being examples of this technique. Increasing the polymer viscosity of PET bottle flakes by polycondensation during the extrusion recycling phase is a well-known example of this approach.

3. Solvent-based recycling (covered by R3)

256. Solvent-based recycling refers to solvent-based purification which dissolves the solid plastic’s physical macro-structure but preserves the original molecular structure of the individual polymer chains. This method can be used to separate and remove additive chemicals and fillers bound within the waste polymer compound. The resulting cleaned polymer molecules can then be recovered (e.g., by precipitation), dried and re-formed into the original plastic material at close to 100% product purity and mass yield.

257. Based on the similar compatibility between solvent and solute molecules, solvent-based recycling separates the plastic resin from various additives and fillers. Solvent-based recycling is a novel technology allowing the recycling of, among others, complex polymer compounds like multilayer packaging or contaminated polystyrene using selective dissolution.

4. [Chemical recycling (covered by R3)

259bis. More information is required on the ESM of plastic wastes through chemical recycling, see also Appendix A

258. The term ‘chemical recycling’ describes a broad range of methods, which have significantly different outputs arising from the applied process techniques. The various methods can be classified into, but not limited to, three categories:

(a) Solvolysis (monomer recycling);

(b) Pyrolysis (falls under chemical recycling in case the output of the facility is used as material for base chemicals and is not used as fuel or for energy production);

(c) Gasification (falls under chemical recycling in case the output of the facility is used as material for base chemicals and is not used as fuel or for energy production).

259. Solvolysis is the collective term used for various types of solvent-specific methods, including ‘glycolysis’, ‘methanolysis’ etc. Solid plastic is dissolved into a liquid phase solvent and the polymer molecules then further break-down into smaller component parts (mainly monomer or oligomers). This technique can be used for polymers with specific targetable bonds. This approach preserves the useful chemical components of the waste polymer molecules, and these can be re-used back into full-scale industrial reactors, as direct replacement for primary feedstock raw materials. In the process of purification, hazardous wastes may be generated which should be treated appropriately. The mass of output polymer material recovered by this method could be used as the basis for ‘recycled plastic’.

260. In the context of chemical recycling, pyrolysis is a method that refers to a thermal process without oxygen. Plastic wastes are subjected to intense heat and chemical break-down during a thermal reaction process which results in output streams that are a mixture of gases, liquids and waxes, plus a residual carbonaceous char. In this process, hazardous wastes may be generated which should be treated appropriately. Often the lightest gaseous output fractions are incinerated within the process to generate some of the heat energy for the chemical break-down. In most cases this is carried out in the absence of oxygen or moisture. Pyrolysis may be used for polymers consisting exclusively of hydrocarbons such as polyethylene, polypropylene and polystyrene.

261. Some of the resulting output mass fractions from pyrolysis can be used as chemical feedstock to replace prime (e.g., oil-derived) naphtha materials, as part of the cracking and polymerization reaction stages that make-up large-scale petrochemical process plants. However, the tracking and tracing of the exact end-destination for the waste-derived monomer and short-chain fractions is usually not possible. Mass-balance approaches (a type of chain of custody model) are a means to estimate the actual mass-flow from input plastic waste into the polymer end-products.

262. Within the mass-balance approaches, there can be significant variation used for this type of chemical recycling with respect to allocation of inputs to outputs. There are various measurement schemes to certify mass-balance processes, which vary in their definitions of recycling and recycled content (Edwards, 2021). ISO 22095 (Chain of custody — General terminology and models) can be used as the basis for the definition and description of chain of custody models. Out of the Chain of Custody models according to the terminology described in ISO 22095, book and claim removes all physical links between inputs and outputs and therefore is not considered a valid approach for chemical recycling of plastic wastes.

263. [In the context of chemical recycling, gasification involves plastic wastes being subjected to high-temperatures in the presence of an oxidizing agent to break down the polymer to a ‘syngas’ containing carbon dioxide, monoxide, water and hydrogen (Solis, 2020). This can, in some cases, be converted into ethanol and then used to make new hydrocarbons (e.g., polyethylene).] Chemical recycling, [is complementary to] mechanical recycling, [and] is generally an energy-intensive process. and Additionally, hazardous substances can be found in liquid and solid residues and in air emissions from chemical recycling (European Chemicals Agency, 2021).

266. Operators of chemical recycling facilities should ensure that they take such steps as are necessary to prevent consequences to human health and the environment and, if such consequences occur, to minimize them, such as the following:

(a) Emissions of greenhouse gases;

(b) Disposal or releases of unrecycled fractions and other wastes generated from chemical recycling, notably any impacts from their unsound management such as dumping and open burning;

(c) Reintroduction of hazardous substances into the output, including recycled fractions from the process e.g., from additives or contaminants;

(d) Wastewater releases into any environmental media such as water bodies and land prior to treatment;

(e) Site littering;

(f) Effects from hazardous solvents in solvolysis (Ügdüler, 2020)

264. Chemical recycling, an evolving field, may be a complementary technology to mechanical recycling for certain plastic waste types[71]. Various examples of chemical recycling methods for plastic wastes are available at the pilot-plant stage and also at close to full-scale operating throughput. There is a lack of evidence to generate conclusions around the viability of many technologies, and a lack of understanding of the life-cycle impacts (Hann et al., 2020). Therefore, more evidence is needed on the applicability of the ESM concept to chemical recycling.

265. For further information refer to the report "Chemical Recycling of Polymeric Materials from Waste in the Circular Economy" (European Chemicals Agency, 2021), "Chemical recycling: A critical assessment of potential process approaches (Quicker et al, 2022)", "Chemical Recycling of Plastic Waste: Comparative Evaluation of Environmental and Economic Performances of Gasification- and Incineration-based Treatment for Lightweight Packaging Waste" (Voss et al, 2022) and "Chemical Recycling: State of Play" (Hann et al, 2020).**]**

5. Energy recovery (R1)

266. Kept for consistency purpose only

267. Plastic wastes suitable for energy recovery may, for example, be non-recyclable or hard-to-recycle plastic wastes, plastic wastes consisting of small items dispersed among other waste materials, plastic wastes with a POP content at or above the low POP content limit values and residues from the recycling process containing plastic wastes which cannot themselves be recycled. In line with the waste hierarchy, recycling of plastic wastes should be prioritized over energy recovery, except in the case where certain plastic types or additives represent a particular health risk or environmental hazard and require destruction in a controlled system.

268. For energy recovery, plastic wastes can inter alia be thermally treated through incineration with energy recovery with other kinds of waste, e.g., MSW and industrial wastes, through co-incineration in blast furnaces and power plants, through gasification or through pyrolysis and through co-processing in cement kilns.

269. Most plastics are hydrocarbon polymer compounds that can burn and have a high calorific value (see Table 17). Due to its high calorific value, plastic waste should be mixed with other compatible waste fractions with a low calorific value in order to achieve a preferably constant calorific value of the mixture.

Table 17: Energy values of plastic wastes, including mixed plastic wastes, in comparison with other waste and fuels.

Single polymers / *Fuels or wastes*	**Lower calorific value[72](MJ/kg)**
LDPE / HDPE	45
PP	45
PS	41
ABS, *Oil*	40
Coal	25
PET	23
PVC	22
Packaging Derived Fuels (PDF)	20
Refuse Derived Fuel (RDF)	15-17
MSW, Wood	8-10
Mixed polymers (Plastic Fuels)	
LDPE/PP/ HDPE (food packaging)	45
PP/ABS/HDPE (computers)	43
LDPE/PP/PVC (mixed packaging) PP/ LDPE/PVC (non-food packaging)	37 37
PU/PP/PVC/ABS (bumpers/fuel tanks)	33

[71] Paragraph 217 considers certain types of plastic wastes that are not suitable for mechanical recycling.

[72] Other terms meaning the same as "lower calorific value" are "lower heating value", "net heating value", and "net calorific value". It is noted there are different methods for calculating it.

270. Plastic wastes can be part of fuels derived from waste such as Solid Recovered Fuel (SRF) in accordance with the European standard (EN 15359) and RDF. SRF usually has a higher calorific value than RDF. RDF is produced by removing non-combustible components such as metals, glass and putrescible materials from MSW and then pelletizing the combustible material. As this is processed MSW, RDF has a higher concentration of plastic waste than MSW and consequently a higher energy value.

271. For further information on incineration with energy recovery of plastic wastes containing or contaminated with POPs, refer to the General technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with persistent organic pollutants (UNEP, 2022a). For further information on incineration with energy recovery of plastic wastes other than plastic wastes containing or contaminated with POPs, refer to the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022d). For information on the reduction of mercury releases from the energy recovery of plastic waste containing or contaminated with mercury, refer to the technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds (UNEP, 2022c).

272. For further information on the co-processing of plastic wastes in cement kilns, refer to the technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns (UNEP, 2011).

273. For further information on the disposal of incineration residues, refer to the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022d), and the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022e). For further information on the disposal of incineration residues containing or contaminated with POPs, refer to the General technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with persistent organic pollutants (UNEP, 2022).

6. Final disposal operations (D5, D10)

274. According to the waste management hierarchy, final disposal of plastic wastes is the least preferred option. Final disposal operations that may be relevant to plastic wastes include specially engineered landfill (D5), and incineration on land (D10).

275. Since plastics can be very light, special care should be taken to ensure plastic wastes are not blown off-site by wind.

276. Some additives such as phthalates, decaBDE, HBCD, PFOS and PFOA contained in plastics could enter the leachate of landfills (Teuten et al., 2009; Wowkonowicz & Kijenska, 2017; Stuart et al., 2019).

277. When carrying out incineration on land (D10) of plastic waste, a preferably constant calorific value of the mixture should be achieved (see paragraph 272 and Table 17).

278. For further information on landfilling of plastic wastes, refer to the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022e). For further information on landfilling of plastic wastes containing or contaminated with POPs, refer to the General technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with persistent organic pollutants (UNEP, 2022). For information on the reduction of mercury releases from plastic wastes containing or contaminated with mercury from specially engineered landfill (D5), refer to the technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with mercury or mercury compounds (UNEP, 2022c).

279. For further information on incineration on land (D10) of plastic wastes containing or contaminated with POPs, refer to the General technical guidelines on the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (POPs) (UNEP, 2022a). For further information on incineration on land (D10) of plastic waste other than plastic wastes containing or contaminated with POPs, refer to the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022d). For information on the reduction of mercury releases from incineration on land (D10) of plastic wastes containing or contaminated with mercury, refer to the technical guidelines on the environmentally sound management of wastes consisting of, containing, or contaminated with mercury or mercury compounds (UNEP, 2022c).

7. Specific aspects related to recycling of certain types of plastic wastes

(a) Specific aspects related to recycling of common types of plastic wastes

280. Specific aspects of recycling of common types of plastic waste (PE, PP, PS, ABS, PET, PC, PVC) are provided below.

(i) Recycling of waste PE

281. LDPE can be mechanically recycled and this involves initial removal of contaminants followed by washing, drying and melt re-processing. Post-extrusion, the LDPE melted paste can be re-formed into thin plastic sheets which can be used for manufacturing plastic products. Good quality LDPE is used for household items like plastic wrap, grocery bags, and non-food containers. Recycled LDPE can be made into garbage cans, garbage bags, construction panelling, furniture, flooring and bubble wrap.

282. Bales of LDPE film can provide a high yield depending on the waste source, with clean distribution film performing best. The recyclate can be reintroduced into many primarily film related applications (e.g., non-food contact packaging, grocery bags, refuse bags, drip irrigation systems).

283. HDPE is normally treated through mechanical recycling. At first, the plastic waste is sorted and cleaned in order for any unwanted non-plastic debris to be removed. Then it needs to be segregated and purified, so that only HDPE items will be re-processed together. If other, non-compatible plastic polymers were to remain in the batch, the recycled end-product will be poor quality. HDPE can be separated by NIR sensor sorting techniques. However, if the plastic is too dark in colour, which means it absorbs the infrared waves, it is difficult to use this technique. Sorted HDPE is then shredded, washed melted and filtered to further purify the polymer. Finally, the plastic is cooled into pellets which can be used in product manufacturing. Recycled HDPE is used, for example, in pens, plastic lumber, plastic fencing, picnic tables and non-food bottles.

284. HDPE obtained from MSW (e.g., milk containers), distribution (e.g., crates and pallets), and construction (e.g., pipes) can be sorted at the article level into relatively pure HDPE streams.

285. HDPE obtained from waste vehicles and WEEE is often sorted by density separation. Preferably, this stream should be further separated (e.g., through electrostatic sorting). Alternatively, HDPE from waste vehicles and WEEE can be co-processed into a compounded blend, although the properties of the final plastic may be of a lower quality than individual 100% pure polymers.

286. Plastic wastes consisting of PE are usually mixed with PP and, occasionally, PVC. HDPE and LDPE may also be mixed together. PE has a degree of compatibility with PP, but has poor compatibility with PVC, so even if the amount of PVC is small, it must be removed before melt processing.

287. The PE/PP compatibility can be enhanced through the use of compatibilization additives. The presence of a small amount of PP in PE will not greatly reduce the performance of the recycled material, but if the amount of PP is large, then, for example, EPDM (ethylene propylene diene monomer rubber) can be considered as a possible compatibilizer for improved melt-blending.

288. Kept for consistency purpose only

(ii) Recycling of waste PP

289. PP obtained from MSW (e.g., margarine tubs), bulky waste (e.g., garden furniture), distribution (e.g., crates and pallets), ELV and WEEE mixed-plastics and construction wastes can be sorted into relatively homogeneous single-polymer waste streams. Good segregation of these different waste streams helps to deliver well-characterised mixed plastic waste items into recycling sorting facilities and aids higher recycling yields and recyclate quality.

290. Regarding the mechanical recycling of PP, like other plastics, good sorting, washing, purification and melt re-processing are all critical steps to delivering high yield and quality of recyclate output. In the melt reprocessing phase, high purity PP flake is fed into an extruder where it is melted at 180 to 220 °C then homogenized, de-gassed, melt-filtered and die-formed into strands before cooling to be chipped into pellet granules. This is the common format for secondary PP raw-material polymer product.

291. Recycled PP can be mixed with virgin PP in any ratio for the production of new products such as clothes hangers, playground equipment, compost bins and kerbside recycling crates. However, there are many recent examples of high-quality PP recyclates being used at 100% levels for the production of car-parts, pipes, drainage goods and electrical product casings, as well as for non-food contact packaging items.

(iii) Recycling of waste PS

292. PS can be recycled physically and/or mechanically. HIPS is easier to recycle since its properties are not greatly affected even after multiple re-processing. The recycling rate of PS packaging waste is low due to the difficulty in removing food residues and odours from used packages.

293. PS foams can be troublesome for most rigid plastic recycling facilities. If oily molecules, water, and other contaminants make it into recycled materials, the substances can disrupt and weaken the polymers. PS clamshell containers and coffee cups are especially likely to be dirty, adding to the effort of processing them for recycling (Lemonick. S, 2019).

294. Solvent-based dissolution of foamed PS and rigid-PS waste materials can be used to remove unwanted contaminants, odours, and additives (e.g., BFR) to create high-purity PS recyclates[73].

(iv) Recycling of waste ABS

295. ABS can be successfully recycled mechanically from mixed waste streams. Similar to the recycling of PS from these waste fractions, NIR sorting is difficult due to the extensive use of black plastics. However, density separation can be employed to create a mixed-styrenics fraction (PS+ABS) that is almost free from BFR additives. The presence of mineral filled-PP in the plastic waste infeed mixture will result in some PP contamination in the PS+ABS density sorted fraction, which is incompatible for melt-blending even at low levels. Further separation may not always be necessary, because ABS and PS polymers display a level of compatibility in extrusion, although further purification is possible using electrostatic sorting, to remove filled-PP and PS, to make near-pure ABS for higher-end applications. The ABS recyclates can be reintroduced into their original applications (e.g., vacuum cleaners) or other used for other applications (e.g., non-food containers; automotive parts; furniture feet).

296. ABS regenerated material can sometimes be blended with other similar types of compatible plastic waste (e.g., HIPS), and, by adding various functional additives, modified ABS blended materials with good toughness, corrosion resistance, oil resistance, cold resistance, weatherability and anti-aging properties can be produced. When recycled, ABS from plastic wastes can be used either in a mixture with virgin material, or as 100% recyclate, to produce products.

(v) Recycling of waste PET

297. PET makes up a large percentage of rigid, household packaging items in the form of blow-moulded bottles and thermoformed trays, often in clear, natural colour. The collection of rigid packaging from municipal sources means that PET recycling rates are some of the highest for any plastic, especially in countries where DRS are well-established (e.g., Norway has over 90% bottle collection rates)[74]. Polyester fibre recycling from clothing, household fabrics and bedding (e.g., duvet fillings) remains at very much lower rates, due to less prevalence of collection systems for these products.

298. Blow-moulded PET from bottles is one of the plastic wastes that are easiest to recycle and have the highest recycling rate of any common plastic. Closed loop recycling (e.g., bottle to bottle) is possible. This is because it is relatively easy to wash, separate out coloured flakes and then upgrade the intrinsic viscosity (polymer chain length) during the recycling process to near-virgin quality using polycondensation reactions. Food-contact approval certification has been given to advanced recycling processes that can demonstrate very high purity and tight quality control of the closed-loop recycled PET (r-PET), with usage levels of up to 100% r-PET to make new consumer drinks bottles.

299. The process of recycling PET bottles (or other rigid PET packaging wastes) for use in fibres is generally to sort, granulate, float sink, wash and dry. The fibres are made by adding colouring (as required), extrusion melting, filtering, and spinning into fibres. The output quality of the fibres depends upon the input quality of the PET flakes and the capability of the recycling process. The most demanding woven applications with very fine denier yarns can be successfully made from 100% recycled PET.

300. PET textiles and fibres can be recycled by thorough washing and re-melting. Recycled PET can be used for carpets, garments and non-woven applications.

301. Kept for consistency purpose only

[73] See https://www.ivv.fraunhofer.de/en/recycling-environment/recycling-plastics.html#creasolv.

[74] See https://www.bpf.co.uk/suppliers/packaging/deposit-return-schemes.aspx.

(vi) Recycling of waste PC

302. Waste PC can be recycled by mechanical recycling. PC is difficult to separate from mixed WEEE and ELV waste plastic streams due to the difficulty in reaching a high enough purity of the individual PC sorted flakes. Most PC recycling happens where source segregated PC-rich waste streams exist, such as used CD and DVD discs. After repeated recycling and reprocessing PC is prone to degradation and its mechanical properties, especially notched impact strength, will be significantly reduced. Therefore, PC recycled material can be reinforced by adding a toughening agent.

(vii) Recycling of waste PVC

303. PVC can be recycled by mechanical recycling, which involves mechanically treating the waste (e.g., grinding) to reduce it into much smaller particles (i.e., powder or 'pulver'). The resulting granules can be melted and re-moulded into different products, usually the same product from which it came, such as window frame profiles.

304. Certain PVC wastes may contain high concentrations of lead compounds, phthalates, or other additives to an extent to render the waste hazardous , difficult to recycle or not suitable for recycling.. In such cases, the future use of the recycled PVC should be carefully assessed in order to ensure its adequacy with the permitted uses in case of restrictions due to the presence of such additives in products.

(b) Specific aspects related to recycling of other types of plastic wastes

305. Specific aspects related to recycling of other types of plastic wastes (cured resins, fluorinated polymers, biodegradable plastic wastes, textile plastic wastes) are provided below.

(i) Recycling of waste cured resins

306. Cured resins are thermoset polymers which cannot be remelted or dissolved in a solvent. This makes such polymers difficult to recycle.

(ii) Recycling of waste fluorinated polymers

307. The recycling of waste fluorinated polymers is not well established inter alia as they may contain additives (e.g., glass fibres, glass beads, graphite, and soot) to an extent to render the waste hazardous or problematic (Schlipf et al., 2014). In addition, fluorinated polymers applied to metal articles (e.g., non-stick frying pans) may not be recycled as it is difficult to separate them from metal wastes during metal recycling.

308. In addition to the fluorinated polymers referred to in table 3, polytetrafluoroethylene (PTFE) is of practical relevance and the main material used. Currently, recycling of fluorinated polymers is mainly applied to certain PTFE wastes. Some of the fluorinated polymers are thermosets, such as PTFE, which cannot undergo thermal melt-extrusion or compounding, but can be recycled after size reduction. The recyclates obtained in this process can be used as additives e.g., in plastics other than PTFE. It is not possible to use such recyclates in their original applications. Some other fluorinated polymers, such as FEP and PFA, are thermoplastics and can undergo thermal melt-extrusion or compounding. It is noted that the fluoride content of fluorinated polymers may lead to corrosion during recycling.

(iii) Recycling of biodegradable plastic wastes

309. Biodegradable plastic wastes, including compostable wastes, are not suitable for mechanical recycling together with non-biodegradable plastic wastes. To avoid contaminating or otherwise reducing the quality of plastic recyclate, biodegradable plastics should not be mixed with non-biodegradable plastics in the recycling stream. If collected in a separate stream, some types of biodegradable plastic wastes may be recycled e.g., with mechanical recycling. Research and development in this area is still ongoing. While mechanical recycling of some types of biodegradable plastic wastes is possible, it may be difficult to convert them into useful products, especially due to thermomechanical degradation during extrusion. Therefore, after each cycle the product quality is lower compared with the starting material.

310. As an example of biodegradable plastic wastes, PLA may be effectively sorted out during a mechanical recycling process using spectroscopy. However it is not possible to separate it using mechanical sorting techniques such as density separation. Therefore biodegradable plastics can contaminate the recycled fraction and degrade the quality of recyclate. PLA is denser than water so in the flotation tank any PLA fragments may eventually follow the PET stream towards mechanical recycling. This mixing of PLA with PET materials may cause problems in the reprocessing stage since PLA and PET have different melting points (Luc et al., 2018).

311. Kept for consistency purpose only

(iv) Recycling of textile plastic wastes

312. Textiles with fabrics that contain more than one fibre are inherently difficult to recycle mechanically because the fibres cannot be easily separated. (e.g., cotton and polyester blends).

313. Recycling of Nylon-6 (polyamides type) has been widely used in the carpet industry, through combining mechanical and chemical (depolymerization) processes (Hann et al., 2020). Nylon 6.6 (polyamides type) is commonly recycled mechanically from pre-consumer fibres (Le, 2018).

314. PP carpet fibres can be recycled, but the process is simplified when the complete carpet structure (i.e., pile fibres; adhesives; foam underlay) has been designed and constructed for ease-of-recycling by using fully compatible polymer types in the product composition. This approach works well for short-life carpets used, e.g., for large area exhibition halls and sports arenas.

8. Specific aspects related to the disposal of compostable plastic wastes

315. Composting of compostable plastic wastes together with organic waste can be applied in certain controlled industrial composting facilities e.g., PLA- and starch-based plastics used for waste collection bags (Spierlinga, 2017). However, not all industrial composting facilities can treat compostable plastic waste within the operating timeframe, as each facility operates with varying conditions of time, temperature, moisture, oxygen, and microbial activity.

317bis While international standards on compostable plastic have requirements in relation to plant toxicity[75], research is ongoing about whether compostable plastic contains hazardous substances. Zimmerman et al (2020) found that certain biodegradable plastic, which included some compostable plastic, for example PLA, can contain hazardous substances in a similar way to fossil-based plastics and may therefore not be suitable for composting.

316. When collecting compostable plastic for treatment in a controlled industrial composting facility, clear guidance should be provided to residents and other waste generators about which type of compostable plastic waste can be collected together with the waste streams destined for composting in controlled industrial composting facilities.

318bis. Collecting non-compostable plastics together with compostable plastic and organic waste should be avoided. Sorting should be undertaken to ensure that non-compostable plastic wastes are removed from the waste stream destined for composting to the industrial composting facility, in accordance with the relevant acceptance criteria for the facility.

319bis. The time it takes for compostable plastic waste to be composted in a controlled industrial composting facility can vary significantly for example depending on the chosen composting process, and the conditions and the properties of the compostable plastic wastes (such as the material thickness). This should be done in accordance with the relevant standard the compostable plastic waste was certified with (e.g., decomposition occurs at a rate similar to the other elements of the material being composted). The outputs of composting compostable plastics are CO2, water, biomass, and inorganic compounds. In cases where the compostable plastic wastes are disposed of in controlled industrial composting facilities that are not able to treat them, this may result in residual plastic remaining in the compost and could subsequently lead to plastic leakage and the release of microplastics.

319quat. As compostable plastics are designed to break down in specific conditions of a controlled industrial composting facility, it should be noted that compostable plastic waste will not completely break down in a landfill in accordance with its certification criteria, and may result in increased

[75] For example, under ASTM D6400-21 compostable plastic is not permitted to leave toxic residue that would adversely impact the ability of the finished compost to support plant growth.

methane releases. Therefore, compostable plastics should be composted in a controlled industrial composting facility rather than landfilled, where such facilities exist.

H. Health and safety

317. Both the supplier and/or operator of the facility should ensure that the following information is available and safety measures are in place, when required:

(a) The identity, quality and form of the plastic waste, especially the content of chemicals of concern such as POPs;

(b) The safe handling instructions appropriate to the plastic wastes;

(c) The protective clothing that should be worn by employees, including eye and ear protection, gloves, protective footwear, filter masks and hard hats, depending on the processing to which the plastic waste is subjected;

(d) The safe storage of the compacted plastic wastes, including mechanical handling equipment, stack heights/stability and stack spacing;

(e) Fire prevention, firefighting, fire extinguishers, emissions from burning plastic wastes, advice to fire fighters, means of dealing with fire residues.

318. To improve knowledge regarding possible risk due to contamination, the origin of the waste and information on how the waste is generated will help improve recycling and reduce risk to employees. Waste operators should have access to sufficient information on relevant hazardous substances (additives etc.) used at the production step of the plastic.

319. Contaminated plastic wastes, such as packaging of pesticides or other hazardous chemicals, should be handled with specific care, in particular if it constitutes a hazardous waste dependant on the type and amount of contamination.

320. When plastic waste is contaminated with larger quantities of food residues problems with micro-organisms, odour and attraction of pests may occur. Measures should be taken to reduce odour and pests around the workplace.

321. Plastic containers used to supply hospitals with sterile water and other aqueous solutions may safely be recycled provided they have been kept separated from medical/clinical wastes (e.g., VCA[76]). These clean plastic wastes may be subject to traceability requirements when recycled (e.g., ISO11607[77]), or they may be recycled for non-healthcare applications.

324bis. Care should be taken to protect plastic wastes from contamination with water, insect pests or dirt during transport and storage.

322. . Kept for consistency of para numbers

323. The following rules should apply in the workplace:

(a) Smoking should be forbidden in the plastic waste storage and disposal areas and such areas should be protected by secure fencing;

(b) Ready access to all parts of storage areas should be maintained by well-organised and supervised stacking patterns in order to ensure efficient working conditions, easy emergency escape routes for workers and ready access for emergency services vehicles;

(c) Suitable extinguishers should be readily available in storage areas and staff should attempt to extinguish fires in their very earliest stages.

324. Working conditions for employee health and safety should include, as applicable (Illinois Recycling Association, 2010):

[76] VCA Vinyl Council of Australia https://www.vinyl.org.au/images/vinyl/Sustainability/PVCRecoveryInHospitals.pdf

[77] ISO11607- Packaging for terminally sterilized medical devices (available from: https://www.iso.org/standard/70799.html)

(a) An environmentally comfortable and safe working environment. This includes:

(i) Space that is heated in the winter, cooled in the summer, and has good air exchange (ventilation);

(ii) Anti-fatigue mats to reduce the physical discomfort of standing in one place for long periods of time;

(iii) Sufficient lighting to reduce eye strain;

(iv) Gloves, safety glasses, hearing protection, steel-toed boots, and, if applicable, hardhats, facemasks and respirators;

(b) All stations and conveyors should be ergonomically designed. For instance, sorting conveyors should be of a comfortable reach across width, if sorting from one side of the conveyor.

1. Fire and safety

325. In the event of a fire (at any industrial operation):

(a) All staff should evacuate the premises immediately and assemble at recognised points and be counted;

(b) The emergency services should be summoned immediately and should be reminded:

(i) Of the speed at which fire can spread in burning plastics;

(ii) That burning plastics may form a mobile stream of burning material which can rapidly transfer the fire to other areas and can also block drains;

(iii) Of the need for self-contained breathing apparatus when entering a building in which any material is burning.

326. Good practice guidance for managing fire safety during the reception, treatment and storage of solid combustible wastes is provided by the Waste Industry Safety and Health (WISH) forum on reducing fire risks at waste management sites (WISH, 2020).

2. Smoke and toxic gases

327. The major cause of deaths in accidental fires is through the inhalation of carbon monoxide and smoke which should be prevented (Fardell, 1993). Fire brigades usually regard the smoke and fumes from any accidental fire as toxic and employ self-contained breathing apparatus when entering a burning building regardless of the materials present.

328. It should be taken into account that combusting PVC and fluorinated polymers may emit acidic gases. The high chlorine content of PVC reduces its ignitability and also generates less heat compared with other types of plastics[78]. It should also be noted that combusting fluorinated polymers can produce hydrogen fluoride which is acutely toxic and ecotoxic.

329. Toxic gases emitted during thermal degradation are harmful on their own, but those harms can be multiplied when they are emitted in combination. For example, when carbon monoxide and hydrogen cyanide are emitted together from polyurethane insulation foam (a thermoset plastic) this can significantly increase the risk of cardiac arrest and cancer, hazards well-known to firefighters (Drager Safety AG & Co).

330. Soot from combusting materials, natural and man-made, contain small concentrations of more toxic materials and so should be handled with care using appropriate protective clothing.

I. Emergency response

331. Emergency response plans should be in place for plastic wastes in production, use, storage and transport or at disposal sites. The principal elements of an emergency response include:

(a) Identifying all potential hazards, risks and accidents;

(b) Identifying relevant local and national legislation governing emergency response plans;

(c) Planning for anticipated emergency situations and possible responses to them;

(d) Maintaining a complete up-to-date inventory of the plastic wastes on site;

[78] See https://envorinex.com/web_assets/docs/products/PVC%20and%20Fire.pdf

(e) Training personnel in response activities, including simulated response exercises, and first aid;

(f) Maintaining mobile spill response capabilities or retaining the services of a specialized firm for spill response;

(g) Installing mitigation measures such as fire suppression systems, spill containment equipment, fire-fighting water containment, spill and fire alarms, and firewalls;

(h) Installing emergency communication systems, including signs indicating emergency exits, telephone numbers, alarm locations and response instructions;

(i) Installing and maintaining emergency response kits containing sorbents, personal protective equipment, portable fire extinguishers and first aid supplies;

(j) Integrating facility plans with local, regional, national and global emergency plans, if appropriate;

(k) Regularly testing emergency response equipment and reviewing emergency response plans.

332. Emergency response plans should be prepared jointly by interdisciplinary teams that include emergency response, medical, chemical and technical personnel and labour and management representatives. When applicable, representatives of potentially impacted communities should also be included.

J. Awareness and participation

333. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. It is essential that the public and all stakeholder groups have a chance to participate in the development of policy related to plastic wastes, the planning of programmes, the development of legislation, the review of documents and data and decision making on local issues related to plastic wastes. Paragraphs 6 (g) and (h) of the Basel Declaration reflect an agreement to enhance and strengthen efforts and cooperation to achieve ESM with regard to the enhancement of information exchange, education, and awareness-raising in all sectors of society, along with cooperation and partnership at all levels between countries, public authorities, international organizations, industry, non-governmental organizations and academic institutions.

334. Articles 6, 7, 8, and 9 of the UNECE 1998 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention), along with the Escazú Convention, require the parties to conduct fairly specific types of activities regarding public participation in specific government activities, the development of plans, policies and programmes and the development of legislation and call for access to justice for the public with regard to the environment.

335. Public awareness and attitudes to plastic wastes can affect the population's willingness to cooperate and participate in adequate plastic waste management practices. General environmental awareness and information on health risks due to deficient plastic waste management are important factors which need to be continuously communicated to all sectors of the population.

336. Raising public awareness and promoting public participation is especially critical for separation and collection as important steps for environmentally sound management of plastic wastes.

337. Local authorities should organize awareness raising campaigns/events addressed to business (commercial, beach users, fishermen, etc.) and the public (tourists, households, etc.) to make people aware of the importance of ESM of waste plastics in tackling environmental problems such as marine litter and in improving people's lives. There exists a variety of communication techniques that can be used, such as door to door information, leaflets, community meetings, media etc. Communication objectives could (Climate and Clean Coalition, 2013):

(a) Address cultural practices and beliefs;

(b) Emphasize health benefits;

(c) Use simple messages and multiple media types;

(d) Build on existing neighbourhood networks;

(e) Emphasize the economic benefits of proper plastic waste management;

(f) Frame plastic waste management activities as a topic of great interest for voters, particularly on important issues (e.g., marine plastic litter);

(g) Increase visibility and credibility of plastic waste management activities (e.g., by issuing uniforms to workers);

(h) Identify instances where city activities support national goals;

(i) Communicate about the national benefits of proper local plastic waste management (e.g., to attract investments);

(j) Tailor communication to the intended audience;

(k) Emphasize the economic benefits to businesses (e.g., better conditions for attracting investment);

(l) Target groups with broad influence (e.g., tourism boards).

Appendix A

[Emerging technologies/techniques

Chemical recycling (covered by R3)

More information is required on the ESM of plastic wastes through chemical recycling.

1. The term ‘chemical recycling’ describes a broad range of methods, which have significantly different outputs arising from the applied process techniques. The various methods can be classified into, but not limited to, three categories:

(a) Solvolysis (monomer recycling);

(b) Pyrolysis (falls under chemical recycling in case the output of the facility is used as material for base chemicals and is not used as fuel or for energy production);

(c) Gasification (falls under chemical recycling in case the output of the facility is used as material for base chemicals and is not used as fuel or for energy production).

2. Solvolysis is the collective term used for various types of solvent-specific methods, including ‘glycolysis’, ‘methanolysis’ etc. Solid plastic is dissolved into a liquid phase solvent and the polymer molecules then further break-down into smaller component parts (mainly monomer or oligomers). This technique can be used for polymers with specific targetable bonds. This approach preserves the useful chemical components of the waste polymer molecules, and these can be re-used back into full-scale industrial reactors, as direct replacement for primary feedstock raw materials. In the process of purification, hazardous wastes may be generated which should be treated appropriately. The mass of output polymer material recovered by this method could be used as the basis for ‘recycled plastic’.

3. In the context of chemical recycling, pyrolysis is a method that refers to a thermal process without oxygen. Plastic wastes are subjected to intense heat and chemical break-down during a thermal reaction process which results in output streams that are a mixture of gases, liquids and waxes, plus a residual carbonaceous char. In this process, hazardous wastes may be generated which should be treated appropriately. Often the lightest gaseous output fractions are incinerated within the process to generate some of the heat energy for the chemical break-down. In most cases this is carried out in the absence of oxygen or moisture. Pyrolysis may be used for polymers consisting exclusively of hydrocarbons such as polyethylene, polypropylene and polystyrene.

4. Some of the resulting output mass fractions from pyrolysis can be used as chemical feedstock to replace prime (e.g., oil-derived) naphtha materials, as part of the cracking and polymerization reaction stages that make-up large-scale petrochemical process plants. However, the tracking and tracing of the exact end-destination for the waste-derived monomer and short-chain fractions is usually not possible. Mass-balance approaches (a type of chain of custody model) are a means to estimate the actual mass-flow from input plastic waste into the polymer end-products.

5. Within the mass-balance approaches, there can be significant variation used for this type of chemical recycling with respect to allocation of inputs to outputs. There are various measurement schemes to certify mass-balance processes, which vary in their definitions of recycling and recycled content (Edwards, 2021). ISO 22095 (Chain of custody — General terminology and models) can be used as the basis for the definition and description of chain of custody models. Out of the Chain of Custody models according to the terminology described in ISO 22095, book and claim removes all physical links between inputs and outputs and therefore is not considered a valid approach for chemical recycling of plastic wastes.

6. [In the context of chemical recycling, gasification involves plastic wastes being subjected to high-temperatures in the presence of an oxidizing agent to break down the polymer to a ‘syngas’ containing carbon dioxide, monoxide, water and hydrogen (Solis, 2020). This can, in some cases, be converted into ethanol and then used to make new hydrocarbons (e.g., polyethylene).] Chemical recycling, [is complementary to] mechanical recycling, [and] is generally an energy-intensive process. and Additionally, hazardous substances can be found in liquid and solid residues and in air emissions from chemical recycling (European Chemicals Agency, 2021).

7. Operators of chemical recycling facilities should ensure that they take such steps as are necessary to prevent consequences to human health and the environment and, if such consequences occur, to minimize them, such as the following:

(b) Disposal or releases of unrecycled fractions and other wastes generated from chemical recycling, notably any impacts from their unsound management such as dumping and open burning;

(c) Reintroduction of hazardous substances into the output, including recycled fractions from the process e.g., from additives or contaminants;

(d) Wastewater releases into any environmental media such as water bodies and land prior to treatment;

(e) Site littering;

(f) Effects from hazardous solvents in solvolysis (Ügdüler, 2020)

8. Chemical recycling, an evolving field, may be a complementary technology to mechanical recycling for certain plastic waste types[79]. Various examples of chemical recycling methods for plastic wastes are available at the pilot-plant stage and also at close to full-scale operating throughput. There is a lack of evidence to generate conclusions around the viability of many technologies, and a lack of understanding of the life-cycle impacts (Hann et al., 2020). Therefore, more evidence is needed on the applicability of the ESM concept to chemical recycling.

9. For further information refer to the report "Chemical Recycling of Polymeric Materials from Waste in the Circular Economy" (European Chemicals Agency, 2021), "Chemical recycling: A critical assessment of potential process approaches (Quicker et al, 2022)", "Chemical Recycling of Plastic Waste: Comparative Evaluation of Environmental and Economic Performances of Gasification- and Incineration-based Treatment for Lightweight Packaging Waste" (Voss et al, 2022) and "Chemical Recycling: State of Play" (Hann et al, 2020).]
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[79] Paragraph 217 considers certain types of plastic wastes that are not suitable for mechanical recycling.

Bibliography

American Society for Testing and Materials, 2021. ASTM D6400-21 Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities. Available from: https://www.astm.org/d6400-21.html

(Bellis, 2021)

[Bank, M.S. 2022. Microplastic in the Environment: Pattern and Process. Springer. Available from: https://link.springer.com/book/10.1007/978-3-030-78627-4]

Buekens, A. Yang, J. ,2014. Recycling of WEEE plastics. A review. Journal of Material Cycles and Waste Management volume 16, pages 415–434. Available from: https://link.springer.com/article/10.1007%2Fs10163-014-0241-2

Copps Industries, 2020. Selecting the right epoxy resin for your application Available from: https://www.coppsindustries.com/blog/selecting-the-right-epoxy-resin-for-your-application/

Cuauhtémoc Araujo-Andrade, Elodie Bugnicourt, Laurent Philippet, 2021 Review on the photonic techniques suitable for automatic monitoring of the composition of multi-materials wastes in view of their posterior recycling. Available from: https://pubmed.ncbi.nlm.nih.gov/33749390/

Dräger Safety AG & Co, "Understanding the Toxic Twins: HCN and CO" Available from: https://www.draeger.com/Library/Content/toxic-twin-lt-8177-en-gb.pdf

De Kort, 2017. Use maps for masterbatching, compounding and converting processes: by EuPC and EuMBC. Available from: https://echa.europa.eu/csr-es-roadmap/use-maps/use-maps-library

Edwards, S. 2021. A comparative Assessment of Standards and Certification Schemes for Verifying Recycled Content in Plastic Products. Eunomia Research & Consulting with support from Circular Innovation Council.

English Environment Agency, 2016. Guidance: Non-packaging plastics: quality protocol. Available from: https://www.gov.uk/government/publications/non-packaging-plastics-quality-protocol/non-packaging-plastics-quality-protocol

European Bioplastics, 2018. What are bioplastics: Material types, terminology, and labels – an introduction. Available from: https://docs.european-bioplastics.org/publications/fs/EuBP_FS_What_are_bioplastics.pdf

European Chemicals Agency (ECHA), 2021. Chemical recycling of polymeric materials from waste in the circular economy. Available from: https://echa.europa.eu/documents/10162/1459379/chem_recycling_final_report_en.pdf/887c4182-8327-e197-0bc4-17a5d608de6e?t=1636708465520)

[European Commission, 2012. Eco-design your future –How ecodesign can help the environment by making products smarter. Available from: https://publications.europa.eu/en/publication-detail/-/publication/4d42d597-4f92-4498-8e1d-857cc157e6db/language-en.]

European Commission, 2014. Development of Guidance on Extended Producer Responsibility (EPR). Final Report. Available from: https://ec.europa.eu/environment/archives/waste/eu_guidance/pdf/Guidance%20on%20EPR%20-%20Final%20Report.pdf

[European Commission, 2022. Communication from the Commission. EU policy framework on biobased, biodegradable and compostable plastics. Available from: https://environment.ec.europa.eu/system/files/2022-12/COM_2022_682_1_EN_ACT_part1_v4.pdf]

European Standard, 2000. EN 13432:2000 Requirements for packaging recoverable through composting and biodegradation. test scheme and evaluation criteria for the final acceptance of packaging. Available from: https://www.en-standard.eu/din-en-13432-requirements-for-packaging-recoverable-through-composting-and-biodegradation-test-scheme-and-evaluation-criteria-for-the-final-acceptance-of-packaging-english-version-of-din-en-13432/

European Standard, 2001. EN 13432:2001 Requirements for packaging recoverable through composting and biodegradation. test scheme and evaluation criteria for the final acceptance of packaging. Available from: https://www.en-standard.eu/une-en-13432-2001-requirements-for-packaging-recoverable-through-composting-and-biodegradation-test-scheme-and-evaluation-criteria-for-the-final-acceptance-of-packaging/

European Standard, 2006. EN 14995:2006 Plastics. Evaluation of compostability. Test scheme and specifications Available from: https://www.en-standard.eu/bs-en-14995-2006-plastics-evaluation-of-compostability-test-scheme-and-specifications/

European Union, 1994. Directive 94/62/EC of the European Parliament and of the Council of 20 December 1994 on packaging and packaging waste. Available from: https://eur-lex.europa.eu/eli/dir/1994/62/2018-07-04

European Union, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. Available from http://data.europa.eu/eli/dir/2008/98/2018-07-05

European Union, 2019. Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. Available from: http://data.europa.eu/eli/dir/2019/904/oj

Fardell, P., (1993). Toxicity of plastics and rubber in fire. RAPRA Review Reports - No. 69.

Fang Liu, David W. Grainger, 2013. C - Fluorinated Biomaterials. Biomaterials Science (Third Edition). Academic Press, 92-103. Available from: https://doi.org/10.1016/B978-0-08-087780-8.00011-5.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., Purnell, P., 2018. An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. Journal of hazardous materials, 344, 179-199. Available from: https://www.sciencedirect.com/science/article/pii/S030438941730763X, downloaded on 08/01/20.

Hande, S., 2019. The informal waste sector: a solution to the recycling problem in developing countries. Field Actions Science Report. Special Issue 19 | 2019 Available from: https://journals.openedition.org/factsreports/5143

Hann, S. & Connock, T. (2020). Chemical Recycling: State of Play. Eunomia Research & Consulting for CHEM Trust.

Hansen, E., Nilsson, N. H., Lithner, D., Lassen, C., 2013. Hazardous substances in plastic materials. Available from: http://www.byggemiljo.no/wp-content/uploads/2014/10/72_ta3017.pdf.

He, Z., Li, G., Chen, J., Huang, Y., An, T., & Zhang, C., 2015. Pollution characteristics and health risk assessment of volatile organic compounds emitted from different plastic solid waste recycling workshops. Environment International, 77, 85–94. Available from: https://doi.org/10.1016/j.envint.2015.01.004

Hong Kong Environmental Protection Department, 2020. Guidelines on import and export control of waste plastic. Available from: https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/waste/guide_ref/files/WastePlastics_Guidelines_eng.pdf

Illinois Recycling Association, 2010.
Best Operational Practices Manual for Materials Recovery Facilities and Recycling Drop-Off Facilities. Available from: https://illinoisrecycles.org/wp-content/uploads/2014/10/IRA_BOPM_2010.pdf.

Institute of Scrap Recycling Industries (ISRI), 2020. Institute of Scrap Recycling Industries: Scrap specifications circular 2020. Available from: https://www.isri.org/recycling-commodities/scrap-specifications-circular.

International Standards Organisation (ISO), 2013. ISO 18606:2013 Packaging and the environment — Organic recycling. Available from: https://www.iso.org/standard/55874.html

International Standards Organisation (ISO), 2013. ISO 472:2013 Plastics – vocabulary. Available from: https://www.iso.org/standard/44102.html

International Standards Organisation (ISO), 2021. ISO 17088:2021 Plastics — Organic recycling — Specifications for compostable plastics. Available from: https://www.iso.org/standard/74994.html

International Standards Organisation (ISO), 2022. ISO 5412:2022 Plastics — Industrial compostable plastic shopping bags. Available from: https://www.iso.org/standard/81236.html

Karaman, E., Kurt, M., 2015. Sorting of plastic waste for effective recycling, Int. Journal of Applied Sciences and Engineering Research, Vol. 4, No. 4.

Karlsson, T. M., Arneborg, L., Broström, G., Almroth, B. C., Gipperth, L., & Hassellöv, M. ,2018. The unaccountability case of plastic pellet pollution. Marine Pollution Bulletin, 129(1), 52–60. Available from: https://doi.org/10.1016/j.marpolbul.2018.01.041

Kumar, A., Samadder, S.R., Kumar, N., Singh, C., 2018. Estimation of the generation rate of different types of plastic wastes and possible revenue recovery from informal recycling, Waste Management, Volume 79(2018), Pages 781-790

Lemonick, S., 2019. Chemistry may have solutions to our plastic trash problem. Available from: https://cen.acs.org/environment/pollution/Chemistry-solutions-plastic-trash-problem/96/i25.

Makenji, K, 2009. Mechanical methods tor recycling waste composites Management, Recycling and Reuse of Waste Composites, Woodhead Publishing in materials. Cambridge, Boca Raton, FL, U.S.A.: Woodhead Publishing Ltd.; CRC Press. ISBN 9781845694623. Available from: http://www.gbv.de/dms/weimar/toc/603367380_toc.pdf

Organisation for Economic Co-operation and Development (OECD), 2016. Extended Producer Responsibility - Guidance for efficient waste management. Available from: https://www.oecd.org/environment/waste/Extended-producer-responsibility-Policy-Highlights-2016-web.pdf

Organisation for Economic Co-operation and Development (OECD), 2019. Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews. Available from: https://www.oecd-ilibrary.org/environment/waste-management-and-the-circular-economy-in-selected-oecd-countries_9789264309395-en

[Organisation for Economic Co-operation and Development (OECD), 2022. Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. Available from: https://www.oecd.org/environment/plastics/]

Plastics Europe, 2008. The Compelling Facts About Plastics: An analysis of plastics production, demand and recovery for 2006 in Europe. Available from: https://plasticseurope.org

[Plastics Europe, 2022. Plastics – the Facts 2022. Available from: https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/]Quicker, P., Seitz, M. Vogel, J. 2022. Chemical recycling: A critical assessment of potential process approaches. Waste Management & Research: The Journal for a Sustainable Circular Economy. Available from: https://journals.sagepub.com/doi/abs/10.1177/0734242X221084044

Ragaert, K., Delva, L. and Van Geem, K, 2017. Mechanical and chemical recycling of solid plastic waste. Waste Management, 69, pp.24-58 Available from: https://www.sciencedirect.com/science/article/abs/pii/S0956053X17305354

Ruj, B., Pandey, V., Jash, P., Srivastava, V. K., 2015. Sorting of plastic waste for effective recycling. International Journal of Applied Science and Engineering Research, 4(4), 564-571.

Rybarczyk, D. Jędryczka, C., Regulski, R. Sędziak, D, Netter, K., Czarnecka-Komorowska,D. Barczewski, M. and Barański. M 2020, Assessment of the Electrostatic Separation Effectiveness of Plastic Waste Using a Vision System Sensors (Basel). 2020 Dec; 20(24): 7201. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7765917/

[SAPEA, Science Advice for Policy by European Academies. (2020). Biodegradability of plastics in the open environment. Berlin: SAPEA. Available from: https://www.sapea.info/wp-content/uploads/bop-report.pdf]

Scottish Environment Protection Agency, 2020. International waste shipments guidance on the Basel Convention amendments on plastic waste. Available from https://www.sepa.org.uk/media/539014/basel_convention_amends_plastic_waste.pdf.

Serranti. S, Bonifazi, B, 2019. Techniques for separation of plastic wastes, Use of Recycled Plastics in Eco-efficient Concrete, Woodhead Publishing Series in Civil and Structural Engineering. Available from: https://www.sciencedirect.com/science/article/pii/B9780081026762000025

Schlipf, M. Schwalm, T. ,2014. Closing the Recycling Loop. Kunststoffe Int. 2014, 6, 58– 60. Available from: https://multimedia.3m.com/mws/media/973095O/publication-in-magazine-kunststoffe-international-closing-the-recycling-loop.pdf?fn=2014%2006%20KUint%20P58f%20-%20Closing%20the

Shah, A.A., Hasan, F., Hameed, A., Ahmed, S. ,2008. Biological degradation of plastics: A comprehensive review. Biotechnology Advances 26 (2008) 246–265, Available from: https://www.sciencedirect.com/science/article/abs/pii/S0734975008000141?via%3Dihub

Spierlinga, S., et al. ,2017. Bio-based plastics – A building block for the circular economy? Procedia CIRP. Vol. 69 pp. 573-578. Available from: https://www.sciencedirect.com/science/article/pii/S2212827117307849

Tang, Z., Huang, Q., Yang, Y. et al., 2015. Polybrominated diphenyl ethers (PBDEs) and heavy metals in road dusts from a plastic waste recycling area in north China: implications for human health. Environ Sci Pollut Res 23, 625–637 (2015). Avalable from : https://doi.org/10.1007/s11356-015-5296-7

Teuten et al., 2009. Transport and release of chemicals from plastic to the environment and to wildlife. Philosophical Transactions of the Royal Society B: Biological Sciences. 2009 Jul 27; 364. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873017/#

Sibel Ügdüler, Kevin M. Van Geem, Martijn Roosen, Elisabeth I.P. Delbeke, Steven De Meester, Challenges and opportunities of solvent-based additive extraction methods for plastic recycling, Waste Management, Volume 104,2020, Pages 148-182, Available from: https://doi.org/10.1016/j.wasman.2020.01.003.

United Nations Environment Programme (UNEP), 2006a. Risk profile on hexabromobiphenyl, Report of the Persistent Organic Pollutants Review Committee on the work of its second meeting. Available from: http://chm.pops.int/TheConvention/POPsReviewCommittee/ReportsandDecisions/tabid/3309/Default.aspx

UNEP, 2006b Risk profile on perfluorooctane sulfonate. Report of the Persistent Organic Pollutants Review Committee on the work of its second meeting. Available from: http://chm.pops.int/DNNADMIN/DataEntry/MandeepsHiddenModules/POPsChemicalsMandeeps/tabid/754/Default.aspx

UNEP, 2011. Basel Convention: Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns. Available from: http://www.basel.int/Implementation/Publications/TechnicalGuidelines/tabid/2362/Default.aspx

UNEP, 2013. Framework for the environmentally sound management of hazardous wastes and other wastes. Available from: http://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMFramework/tabid/3616/Default.aspx

UNEP, 2015a. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromocyclododecane. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2015b. Global Waste Management Outlook. Available from: https://www.unep.org/resources/report/global-waste-management-outlook

UNEP, 2015c. Methodological Guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention. UNEP/BRS/SBC/2015/5.

UNEP, 2015d. Manual for the implementation of the Basel Convention. Available from: http://www.basel.int/Implementation/LegalMatters/Compliance/GeneralIssuesActivities/Activities201415/Manualfortheimplementation/tabid/4160/Default.aspx

UNEP, 2015e. Guide to the control system. Available from: http://www.basel.int/Implementation/LegalMatters/Compliance/GeneralIssuesActivities/Activities201415/Guidetothecontrolsystem/tabid/3561/Default.aspx

UNEP, 2016. Risk profile on pentadecafluorooctanoic acid (PFOA, Perfluorooctanoic acid), its salts and PFOA-related compounds. Available from: http://chm.pops.int/DNNADMIN/DataEntry/MandeepsHiddenModules/POPsChemicalsMandeeps/tabid/754/Default.aspx

UNEP, 2017a. Guidance for the inventory of Hexabromocyclododecane (HBCD). Available from: http://www.pops.int/Implementation/NationalImplementationPlans/GuidanceArchive/GuidanceforHBCD/tabid/5332/Default.aspx

UNEP, 2017b Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. Available from: http://chm.pops.int/Implementation/NationalImplementationPlans/GuidanceArchive/Guidancefortheinventoryof PBDEs/tabid/3171/Default.aspx

UNEP, 2017c. Set of practical manuals for the promotion of the environmentally sound management of wastes. Available from: http://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMToolkit/Overview/tabid/5839/Default.aspx

UNEP, 2017d. Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous and other wastes and their disposal. Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP13/tabid/5310/Default.aspx

UNEP, 2017e. Guidance for developing a national implementation plan for the Stockholm Convention on persistent Organic pollutants. Available from: http://chm.pops.int/Implementation/NationalImplementationPlans/GuidanceArchive/GuidanceforDevelopingNIP/tabid/3166/Default.aspx

UNEP, 2017f. Basel Convention Glossary of Terms. Available from: http://www.basel.int/Implementation/LegalMatters/LegalClarity/Glossaryofterms/SmallIntersessionalWorkingGroup/tabid/3622/Default.aspx

UNEP, 2017g. Guidance on the implementation of the Basel Convention provisions dealing with illegal traffic (paragraphs 2, 3 and 4 of Article 9)

UNEP, 2019a. Guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP/CHW.14/INF/8).

UNEP, 2019b. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with short chain chlorinated paraffins. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2019c. Guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous and other wastes (UNEP/CHW.14/INF/7). Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP14/tabid/7520/Default.aspx

UNEP, 2019d. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether or decabromodiphenyl ether. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2019e. Technical guidelines on the environmentally sound management of wastes containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, hexachlorobenzene, polychlorinated biphenyls, pentachlorobenzene, polychlorinated naphthalenes or hexachlorobutadiene. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2019f. Global Chemicals Outlook II: From Legacies to Innovative Solutions: Implementing the 2030 Agenda for Sustainable Development. Available from: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/policy-and-governance/global-chemicals-outlook

UNEP, 2020a. An assessment report on issues of concern: chemicals and waste issues posing risks to human health and the environment. Available from: https://wedocs.unep.org/handle/20.500.11822/33809.

UNEP 2020b. Can I Recycle This? A Global mapping and assessment of standards, labels and claims on plastic packaging. Available from: https://www.oneplanetnetwork.org/sites/default/files/from-crm/unep_ci_2020_can_i_recycle_this_0.pdf

UNEP, 2021a From Pollution to Solution: A global assessment of marine litter and plastic pollution. Available from: https://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution

UNEP, 2021b Decision POPRC-16/3: UV 328. Available from: http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC16/Overview/tabid/8472/Default.aspx

UNEP, 2022a. General technical guidelines for the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022b. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride and perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds. (under revision) Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022c. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022d. Technical guidelines on the environmentally sound disposal incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022e Technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5). Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022f. Practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements. Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP15/tabid/8392/Default.aspx

[UNEP, 2022g. Draft risk management evaluation: UV-328, Addendum 1. Available from: http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC18/Overview/tabid/9165/Default.aspx]

[UNEP, 2022h. Placeholder for Practical guidance on the development of inventories of plastic waste]

UNEP/AHEG, 2018a. Report of the first meeting of the ad hoc open-ended expert group on marine litter and microplastics, Available from: https://www.unep.org/environmentassembly/expert-group-on-marine-litter

UNEP/AHEG 2018b. Report of the second meeting of the ad hoc open-ended expert group on marine litter and microplastic, Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/31115/K1905085%20-%20UNEP-AHEG-2019-3-6%20-%20SECOND%20ADVANCE%20FOR%20CLIENT%20ONLY.pdf?sequence=1&isAllowed=y

UNEP/AHEG, 2019. Report of the third meeting of the ad hoc open-ended expert group on marine litter and microplastics. Available from: https://www.unep.org/events/un-environment-event/third-meeting-ad-hoc-open-ended-expert-group-marine-litter-and?_ga=2.43260837.1693339031.1643573604-151971570.1635859733

UNEP/AHEG, 2020. Report on the work of the ad hoc open-ended expert group on marine litter and microplastics at its fourth meeting. Available from https://wedocs.unep.org/bitstream/handle/20.500.11822/34632/UNEP%20AHEG%204%207.pdf?sequence=4&isAllowed=y

UNEP/GESAMP, 2019 Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean. Available from: http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean

UNEP/UNEA, 2014. Resolution. 6 “Marine plastic debris and microplastics” Available from: https://www.unep.org/environmentassembly/proceedings-and-report-resolutions-and-decisions-unea-1?%2Fproceedings-report-ministerial-dialogue-resolutions-and-decisions-unea-1=

UNEP/UNEA, 2016. Resolution 11 “Marine plastic litter and microplastics”. Available from: https://www.unep.org/environmentassembly/proceedings-report-resolutions-and-decisions-unea-2

UNEP/UNEA, 2017. Resolution 3 “Marine litter and microplastics”. Available from: https://www.unep.org/environmentassembly/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-3

UNEP/UNEA, 2019. Resolution 6 “Marine plastic litter and microplastics”. Available from: https://www.unep.org/environmentassembly/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-4

Voss, R., Lee, R.P. & Fröhling, M. Chemical Recycling of Plastic Waste: Comparative Evaluation of Environmental and Economic Performances of Gasification- and Incineration-based Treatment for Lightweight Packaging Waste. Circ.Econ.Sust. (2022). Available from: https://link.springer.com/article/10.1007/s43615-021-00145-7

Wagner, S., Schlummer, M. (2020). Legacy additives in a circular economy of plastics: Current dilemma, policy analysis, and emerging countermeasures. Resources, Conservation and Recycling. Volume 158, July 2020, 104800 Available from: https://www.sciencedirect.com/science/article/pii/S092134492030121X

Wiesinger, H., Wang, Z., Helweg, S. ,2021. Deep dive into plastic monomers, additives, and processing aids. Environ. Sci. Technol. 2021, 55, 13, 9339–9351. Available from: https://pubs.acs.org/doi/abs/10.1021/acs.est.1c00976

Wilson, D., Velis, C., Cheeseman, C.R., 2006. Role of informal Sector Recycling in Waste Management in Developing Countries. Available from: https://doi.org/10.1016/j.habitatint.2005.09.005

Waste Industry Safety and Health (WISH), 2020. Reducing fire risk at waste management sites. Available from: https://www.wishforum.org.uk/wish-guidance/

Wowkonowicz & Kijenska, 2017. Phthalate release in leachate from municipal landfills of central Poland.Available from: https://doi.org/10.1371/journal.pone.0174986

Xanthopoulos. P ,2014. Need for light stabilizers & UV absorbers in polymers. Available from: https://polymer-additives.specialchem.com/selection-guide/light-uv-stabilizers-selection-for-polymers

Yang, S.S. ,2018. Progresses in Polystyrene Biodegradation and Prospects for Solutions to Plastic Waste Pollution, IOP Conference Series: Earth and Environmental Science, Volume 150, Issue 1, pp. 012005. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/150/1/012005/pdf.

York R. Smith, James R. Nagel, Raj K. Rajamani, 2019. Eddy current separation for recovery of non-ferrous metallic particles: A comprehensive review. Minerals Engineering, Volume 133, 15 March 2019, Pages 149-159. Available from: https://www.sciencedirect.com/science/article/abs/pii/S089268751830582X

Zimmerman L, Dombrowski A, Volker C, Wagner M, 2020. Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition.Environment International, Volume 145, December 2020. Available from: https://www.sciencedirect.com/science/article/pii/S0160412020320213